Doug Cocks

Global Overshoot

Contemplating the World's Converging Problems

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The picture is Jean-Francois Millet's 'Man with a Hoe,' painted in oil on canvas (80 x 99 cm) in 1860–1862. It is reproduced with the permission of the J. Paul Getty Museum, Los Angeles.

Preface

We shall not cease from exploration
And the end of all our exploring
Will be to arrive where we started
And know the place for the first time.
(TS Eliot[1])

Myself when young did eagerly frequent
Doctor and Saint, and heard great Argument
About it and about: but evermore
Came out by the same Door as in I went.
(Omar the Tentmaker[2])

This book has its origins in a handful of questions and perceptions which has been niggling me since the publication in 2003 of *Deep Futures*,[3] my attempt to equip myself with an evidence-informed set of beliefs—working hypotheses—about humanity's prospects for surviving, and surviving well, through the centuries and millennia ahead.

Writing *Deep Futures* cheered me up no end. While present knowledge condemns our species to eventual extinction in one way or another, I concluded that we could well have a long Indian summer before us, provided that we keep learning,

[1] From his *Little Gidding* (Number Four of the 'Four Quartets'.) http://www.tristan.icom43.net/quartets/gidding.html (Accessed 19 Jan 2011).

[2] Edward FitzGerald, Rubáiyát of Omar Khayyám, 1859, http://ebooks.adelaide.edu.au/o/omar_khayyam/o54r/ (Accessed 19 Jan 2011).

[3] Cocks, D., 2003, *Deep Futures: Our Prospects for Survival*, University of New South Wales Press and McGill University Press, Sydney.

stay lucky and don't turn what is promising to be a particularly difficult century into a full-blown catastrophe.

I was seeing the twenty-first century as one where the people of the world might, through hard work, shrink the overarching problems of war, poverty, injustice, environmental degradation and sociopathy; or, more positively, creep up on the goals of peace, material well-being, social justice, environmental protection and sociality (goodwill). The challenge, as I saw it then, could be expressed in terms of how to most effectively improve quality of life for most people. However, the perspective I have come to hold as I write the present book is, not quite that humanity is fighting for survival, but, plausibly, *we are threatened with a large and rapid drop in quality of life* (*e.g. fear and hunger*) *across the world*; *and that humanity's primary task for the foreseeable future should be cast in terms of defending the status quo*, *not improving on it*. More colloquially, our challenge is one of sandbagging the levees, not irrigating the desert.

There is nothing particularly novel about my updated perspective; perhaps I am just catching up. The world is awash with premonitions that global society is on the brink of being massively disrupted by global-scale processes associated with, for example, global warming and the depletion of fossil fuel deposits. There is probably general agreement on the need for international cooperation to address such global-scale problems, and recognition that achieving such cooperation is always difficult. Working from within this mainstream world view—call it *Interventionism*—there are thousands of policy analysts and scientists, mostly from first world countries, documenting and modelling global change—economic, social and environmental—and developing social and material technologies for responding to the threats and opportunities it presents.

My own response to global-scale problems is somewhat different. As when writing *Deep Futures*, my humanistic (humanitarian) starting point is a wish to contribute to the *achievement of high quality of life for most people into the indefinite future*, the goal I call *quality survival*. But I do not want to write yet another treatise on how to set up a carbon trading scheme or recycle water or, indeed, any aspect of the mechanics of tackling the world's many problems; I want to produce a philosophy, a way of looking at things, not a recipe book. My plan is to understand what is happening, not to suggest solutions.

My starting point is to build up an historical and prehistorical understanding of how humanity and the human ecosystem came to be as they are (Chaps. 1, 2, 3, and 4) and, from there, in Chap. 5, explore how people of different temperaments might respond to a suggestion, a diagnosis rather than an assertion, that a global-scale *Overshoot Crisis* has already begun. A system is in *crisis* when it is moving quickly towards a highly uncertain future. It is in *overshoot* when one or more processes of cumulative change appear to be approaching limits (sometimes called tipping points) where a major reorganisation could well be triggered. My scenario of an *Overshoot Crisis* rests on the perception that the converging effects of four momentous human-made trends—towards overpopulation, global overheating, overextraction (of resources) and over-connectedness[4] between nodes of activity, e.g. an increasingly

[4] Connectivity is the ability of one element in a network to influence another.

interdependent world economy—will, unless actively averted, impact pervasively on quality of life via destructuring processes such as deurbanisation (abandoned cities), deindustrialisation (shattered economies), depopulation (megadeaths), and deglobalisation (e.g. currency wipe-outs, declining trade, declining internationalism). That is, an Overshoot Crisis could turn into an *Overshoot Catastrophe*.

In addition to the conventional wisdom of Interventionism in some form or other, Chap. 5 discusses tough-minded *Empiricism* and tender-minded *Reconstructionism* as other legitimate ways of responding to the diagnosis of an Overshoot Crisis. Empiricists have a 'wait-and-see' perspective while Reconstructionists have, metaphorically, a 'Noah's Ark' perspective. More directly, *Reconstructionism* is the belief that it is already too late to stop a massive disorganisation and simplification of the human ecosystem. As of now, we are committed to passing through a dystopic bottleneck and the Reconstructionist suggestion is that we should be concentrating on how we might best help our great-grandchildren (or beyond?) regain some quality of life as they emerge on the other side where, if they are lucky, they will toil their days away in agricultural villages. Because Reconstructionism is all too easily labelled as defeatist and sanctimoniously dismissed, I have felt it useful to explore the puzzles it throws up. As for the Empiricists' perspective, it suffers from being too easily hijacked by vested interests wanting to use caution as an excuse for inaction.

Assuming that a global-scale Overshoot Crisis is indeed coming into view, how realistic is it to believe, as many mainstream Interventionists do, that global society can and will, rationally and comprehensively, intervene to forestall a large and rapid drop, a plunge, in quality of life across the world? My answer is 'quite unrealistic'. All that can be hoped for is a collation of uncoordinated interventions by various protagonists—from international organisations to individuals—each acting within their own sphere of influence to 'fix' some facet of the total problematic as they see it.

There are two elephantine reasons why the Interventionist perspective has to be judged naïve, both so fundamentally at odds with the way problem-solving is conceptualised in 'enlightened' societies that neither can be readily admitted to the public consciousness. First, in no sense is there a collective 'We', united around achieving or defending quality survival as a primary task. Next, even if there were, the Overshoot Crisis has been generated from within the human ecosystem, this being what scientists call a *complex dynamic system*. That label means, first, that the speed, size and duration of the Overshoot Crisis cannot be predicted and, second, that humanity's knowledge of how such systems work is insufficient to allow them to be confidently steered in some preferred direction, such as defending global quality of life. I will return to these two difficulties presently.

Chapter 5 concludes that while humans will survive their self-made Overshoot Crisis, it won't be because of any remarkable capacity to adapt to major challenges in ways that protect quality of life. It will be because the Crisis wasn't as bad as some thought it might have been; that is, the species had not been really tested. Or, it will be that while the Crisis was highly destructive of quality of life for most, it spat out a post-bottleneck population which, scattered and much-reduced, retained sufficient social and material technologies to begin rebuilding stable sedentary societies and improving quality of life once again.

This conclusion will be unwelcome to many people, particularly those with an exaggerated view of humanity's ability to know its goals and to manage itself and the world to achieve them. It has not been done deliberately, but we need to acknowledge that humanity has brought a crisis on itself, one which it is not yet ready to deal with. We are confronted with a knot of spillover problems of a type which we have not yet learned how to avoid, much less solve. This is despite the fact that our material and mental capabilities have increased sharply in the last 3,000 years. While every generation has its world view(s), recent generations have acquired a dramatically improved understanding—plausible, coherent, and naturalistic—of most (?) of the world's physical, biological, social and psychological processes. Each year we know a little more. Strange as it sounds, it is an enormous achievement of consciousness to recognise that, as a species, we face great problems which are of our own making and which, for the moment, we are unable to solve.

It is not judgmental to recognise that, metaphorically, *H. sapiens* is an adolescent species whose emotional development has been slower than its cognitive development, e.g. not yet having learned to empathise and collaborate with others, and being, on occasions, thoughtlessly cruel or abusive; impulsive; still unduly bewitched by material technology; unconcerned about the species' life expectancy, or even with planning life a few generations into the future. Indeed, likening the life story of the human species to the life of a human individual is a rich enough metaphor (an allegory perhaps) to not only suggest ways of understanding where we have arrived, but also alternative directions we might take in search of enhanced quality of life. For example, taking a whole-of-life perspective might lead the species to conclude that what is now happening, namely an Overshoot Crisis, is no more and no less than the next challenge to be survived, as best we can, so that we might return to constructing quality lives for the lineage.

Conversely, thinking of the species as living out a life story offers the individual an insight into his/her own identity, namely, as someone playing a role in their species' Overshoot Crisis, e.g. as an Empiricist, an Interventionist, a Reconstructionist, a pawn, an opportunist; and so on.

Just as any individual's life story takes shape within the 'life story' of its species, so is the species' life story embedded in the successively larger and longer 'life stories' of the ecosphere (Earth's surface film of plants and animals and their environments), the planet and the cosmos. Chapters 1, 2, 3, and 4 attempt to build up a basic awareness—I term it *Eco-awareness*—of how well-recognised evolutionary and ecological processes (physical, biological and cultural) have given rise to a temporal sequence of increasingly complex energy-degrading systems, from the early universe to today's worldwide human ecosystem.

In Chap. 6, 'Ecohumanism and Other Stories', I argue that an Eco-awareness of the processes underlying the *Story of Global Overshoot* provides an initial framework and a succinct language for formulating and debating what-to-do responses to the perception of Overshoot. Building on this conclusion, I proffer the philosophy of *Ecohumanism*—a bundling of Eco-awareness and the Quality Survival goal—as a useful *tool* for thinking about the Global Overshoot Crisis. Definitionally, humanism is a philosophy which puts human progress at its centre, and Ecohumanism is a humanism which is informed by an extended awareness of ecosphere processes, both ecological and evolutionary. Metaphorically, Ecohumanism views global society as being like an evolving ecosystem in which a plethora of human interest groups are the 'virtual species' and the social and material technologies these groups repeatedly create are the 'mutations' which selectively change the quality-survival prospects of the adapting groups.

The value of Ecohumanism to those confronting Global Overshoot cannot be 'proved', but it can be demonstrated in various ways, and this is what Chap. 6 essays. It shows how Eco-awareness can be helpful, for example, in shaping attitudes towards threatening trends (like population growth); or in the identification of issues which need to be widely debated, e.g. choice of an overarching societal goal.

Further, the chapter's section on 'Practical Ecohumanism', presents a sample of indicative guidelines to bear in mind when addressing, not the proximate causes (overpopulation, overheating, overconnectedness, overextraction) of the Overshoot Crisis, but several of its underlying causes (root causes) as these emerge from the Story. One of these is the aforementioned difficulty which human groups have in cooperating for their common good, what I call the *virtual-species problem*. The other is the *complexity problem*, a recognition that complex situations, those characterised by networks of causes rather than simple sequential causes, can only be steered adaptively, i.e. by some strategy of incremental and continuously monitored trial-and-adjust operations.

The question of what-to-do in the face of complexity is not going to be answered by simply subscribing to some abductively plausible 'origin' story leading up to Global Overshoot. Nevertheless, the choice of what strategies to trial and, equally, to avoid trialling, does depend on the way in which the past is understood—an understanding which recognises the role of luck, the role of natural events, the role of morality, the limits of reason, the arbitrary nature of emotions, what worked, what failed….The list goes on. There is a presumption here that while no strategic choice can ever be more than intuitive, that intuition can only be improved by a conscious elaboration of the principles and insights one would like to see influencing that choice. For the moment this is the pragmatic best we can do about complexity.

I close my case for Ecohumanism by recapitulating some of the qualities which I believe are likely, on balance, to make people *emotionally* inclined to accept it as a platform from which to contemplate the possibility of global overshoot. These include: an understanding of cultural differences; naturalism; a nonreligious spirituality; inclusiveness; an opportunity for personal responsibility; a flexible and evolving narrative; an acceptance of the species' strengths and weaknesses; and an understanding of death. Ecohumanism is proclaiming an origin story, which, not being exclusive to any national or religious group, and which, because it does include all people at all times, has the emotional pull to bind people everywhere into an empathising global family or tribe. It is a story which, of itself, can help individuals meet three of their fundamental quality-of-life needs simultaneously—for belonging, for meaning and for identity.

Ecohumanism is an invitation to outgrow belief in such shackles as 'the iron laws of history' or 'the fixity of human nature'. Or, more generally, it is an invitation to question adherence to 'truths' and authoritarian behavioural rules inherited from earlier times, sometimes from earlier origin myths. The old stories do not have to be abandoned, simply recognised as having had a function at a particular moment in cultural history.

Freed from the dogmatism and fixedness of traditional origin stories and world views, the Ecohumanist doctrine being developed in this book, based as it is on an appreciation of scientific method, is always open to both extension and reinterpretation. Thus, each generation has to reinterpret history, or, more generally, the knowledge stock, in terms and concepts that are relevant to the time; and as each generation continues to learn in its own way, its new knowledge will become part of the story its descendants will live by and learn from.

So, have I, as Omar Khayyam put it, come out by the same door as in I went? Or, have I, as TS Eliot put it, returned from my exploring with a clearer view of where I started? I certainly have not found practicable cause and effect mechanisms which will protect or enhance global quality of life. Some will judge this unfortunate in a milieu where most people feel they are unable to discuss a problem publicly unless they have a solution to offer. There is every prospect that the people of the world are going to struggle and suffer enormously over coming decades. Perhaps that can and will be avoided, or perhaps it just won't happen. For those of us who are aware of these 'scenario' futures, several questions arise. Do I care? Which scenario will I adopt as my working assumption? Do I want to help protect global quality of life? How can I best help?

I find the prospect of plunging quality of life, worldwide, very plausible and very distressing but doubt if there is anything practical I can do. What I do know is that writing this book has increased my understanding of and empathy with my own species and sharpened my sense of the joy and pain of living. I very much want this species to seek and find quality survival. We may be about to endure a great setback but, if so, we will surely rise like the phoenix. And I realise that we will rise that much more easily if we can protect the knowledge stock that has been accumulating, with ups and downs, for several hundred thousand years. Nor do we want to have to struggle for centuries or millennia to regain the heights of joy and pain that a great poetic consciousness can express[5]:

Once and once only for
each thing-then no more.

For us as well. Once.
Then no more… ever.

But to have been as one,
though but the once,
with this world,
never can be undone.

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[5] Rainer Maria Rilke (from his Ninth Duino Elegy) http://www.hunterarchive.com/files/Poetry/Elegies/Duino_Elegies.html (Accessed 19 Jan 2011).

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One pleasure of writing any book is the sparse flashes of insight that come as, mostly, one struggles to say things well enough, a somewhat grittier pleasure. Some of those insights come from within but more are triggered by arguments, or even phrases, in the books one reads. Once discovered, ideas tend to keep reappearing but there is something special about those who first open doors for you. I want to acknowledge, with particular affection, nine books and authors who have sharply expanded my understanding of the world:

Julian Jaynes (1976), *The Origins of Consciousness in the Breakdown of the Bicameral Mind.*[6]

Walter Ong (1982), *Orality and Literacy*: *The Technologizing of the Word*.[7]

Gordon Childe (1936/1981), *Man Makes Himself.*[8]

Eric Fromm (1942), *Fear of Freedom*.[9]

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[6] Jaynes, J., 1976, *The Origin of Consciousness in the Breakdown of the Bicameral Mind*, Houghton Mifflin, Boston.

[7] Ong, W., 1982, *Orality and Literacy*: *The Technologizing of the Word*, Methuen, London.

[8] Childe, G., 1936/1981, *Man Makes Himself*, Moonraker Press, Bradford-on-Avon, England.

[9] Fromm, E., 1942, *Fear of Freedom*, Routledge & Kegan Paul, London.

Eric Chaisson (2001), *Cosmic Evolution*: *The Rise of Complexity in Nature*.[10]

Karl Polanyi (1944/2001), *The Great Transformation*: *The Political and Economic Origins of our Time*.[11]

Zoltan Torey (1999), *The Crucible of Consciousness*: *A Personal Exploration of the Conscious Mind*.[12]

Peter Berger and Thomas Luckmann (1966), *The Social Construction of Reality*: *A Treatise in the Sociology of Knowledge*.[13]

George Gaylord Simpson (1949), *The Meaning of Evolution*.[14]

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[10] Chaisson, E., 2001, C*osmic Evolution*: *The Rise of Complexity in Nature*, Harvard UP, Cambridge, Mass.

[11] Polanyi, K., 1944/2001, The Great Transformation: The Political and Economic Origins of our Time, Beacon Press, Boston.

[12] Torey, Z., 1999, *The Crucible of Consciousness*: *A Personal Exploration of the Conscious Mind*, Oxford University Press, Melbourne.

[13] Berger, P., and Luckmann, T., 1966, *The Social Construction of Reality*: *A Treatise in the Sociology of Knowledge*, Doubleday New York.

[14] Simpson, G.G., 1949, *The Meaning of Evolution,* Yale University Press, New Haven.

Contents

Chapter 1
The Deep Past: A Story of Ceaseless Change

> The fate of individual human beings may not now be connected in a deep way with the rest of the universe, but the matter out of which each of us is made is intimately tied to the processes that occurred immense intervals of time and enormous distances in space away from us. Our Sun is a second- or third-generation star. All of the rocky and metallic materials we stand on, the iron in our blood, the calcium in our teeth, the carbon in our genes were produced billions of years ago in the interiors of a red giant star. We are made of star-stuff (Carl Sagan *The Cosmic Connection*, 1973, pp. 189–190).

This is a book about the plausible possibility that world society is entering an Overshoot Crisis which, within the next few decades of this twenty-first century, *could* produce widespread social disorganisation and plunging quality of life for a majority of the world's people. My chosen task in this opening chapter is to argue and demonstrate that a knowledge and causal understanding of what happened in the *Deep Past*—between the beginning of the universe and the advent of primates and mammals on Earth—is a valuable resource for those looking to respond, practically and attitudinally, to such a dystopic scenario. In the next several chapters I will extend the same approach to the more recent past.

As told by science, the step-by-step narrative of what happened in the Deep Past gets better by the year as researchers collect and interpret more and more data about the natural world and the universe, using ever-better measurement and experimental methods and organising frameworks. *Consilience* is making an important contribution here, i.e. insights from different scientific disciplines are, more than ever, being brought to bear on common puzzles; ecology, for example, is as important as genetics for understanding biological evolution. So, while there is much debate over the 'best' interpretation of particular events, concepts and sequences (dates of past events are particularly subject to revision), there are no glaring contradictions in the

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story in its outline form; it is eminently plausible. Many excellent books tell parts of this story,[1] and some further attempt to tell the larger story of both the distant and the more recent past.[2]

In this chapter I propose to make (selective) use of the story of the Deep Past in two ways. One, more general, is to use it as a vehicle for explaining what science has asserted about change processes per se. The other, more specific, is to use it to identify particular material changes in the Deep Past which might inform the way in which 'what-to-do' questions and 'what's happening?' questions are answered in the contemporary world.

With respect to these specifics, the story of the Deep Past is a source of provisional but rational information about how the Earth system has behaved over geological time and *might* hence behave into the future; in terms of, e.g. volcanism, temperatures, sea levels and biological extinctions. For example, over geological time, the globe has been largely ice-free when atmospheric CO_2 levels have been above 500 parts per million.[3] The story brings an awareness of how the universe and the solar system are passing through their life cycles and what this means for the future of the Earth, including humans. Thus, it gives contemporary humans an initial 'fix' on the extent to which the bio-physical world's behaviour might be susceptible to human intervention versus the extent to which its various behaviours might have to be accepted and adapted to (or happily ignored).

On *change* as such, the story of the Deep Past, when it is listened to carefully, has the potential to bring home to people that it is often more productive to think of reality as a process of ongoing, ubiquitous change, punctuated by periods of relative stability, rather than the other way round.[4] Change is normal. Under this *world view*, 'things' are simply standing waves (attractors) in a continuous dynamical process and have no inherent absolute properties—like eddies on a river. As Heraclitus said, 500 years before the Common Era (500 BCE), 'You can not step twice into the same river.' Even a stone is a slow-moving dynamic process! For present purposes, a good reason for preferring *process thinking*[5] as a perspective to one which focuses on the behaviour of 'things' is that it is change, not stability, which brings threats and opportunities to human societies. Thus, the Global Overshoot Crisis is important because it embodies a threat of destructive change.

The more general insight that I am seeking to take advantage of is that abstract concepts that have been developed by generations of scientists for understanding the emergence and persistence of stars, planets, organisms and ecosystems can be

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[1] Chaisson, E., 2001, *Cosmic Evolution: The Rise of Complexity in Nature*, Harvard UP, Cambridge, Mass.; Rees, M.J., 2003, *Our Final Century*, Heinemann, London.

[2] Lloyd, C., 2008, *What on Earth Happened?* Bloomsbury, London; Southwood, R., 2003, *The Story of Life*, Oxford University Press, Oxford; Christian, D., c.2004, *Maps of Time: An Introduction to Big History*, University of California Press, Berkeley, London.

[3] Glikson, A., 2010, Good Planets are Hard to Come By, Online Opinion, http://www.onlineopinion.com.au/view.asp?article=10033 (Accessed 29 Dec 2010).

[4] Whitehead, A.N., 1933, *Adventures of Ideas,* Free Press, New York.

[5] http://plato.stanford.edu/entries/process-philosophy/ (Accessed 30 Dec 2010).

remarkably useful for understanding, or just priming speculation about, change in today's global society, including the role of the human mind.

Consider the concept of *evolution,* the cornerstone of process thinking. At its simplest, evolution is any process of piecewise or bit-by-bit change over time. Understood at this level, evolutionary change pervades nature in all its forms. Charles Darwin and Alfred Wallace are rightly famous, not just for documenting evolutionary change in various animal and plant forms, i.e. change in their inherited characteristics, but for arguing convincingly that it has been a slow process of *natural selection* that has produced the unity and the diversity we can see in the tree of life. As Theodore Dobzhansky observed, nothing makes sense in biology except in the light of this process.[6]

Subsequently, since Darwin's time, the basic idea behind natural selection, namely, the *selective (non-random) retention of variation*, has been co-opted to explain evolutionary change in all manner of *systems*. Under the banner of *Universal Darwinism* or, to be less biological, *Universal selection*,[7] change-sequences in various physical, chemical, psychological, cultural (including economic and technological) and other types of systems have been 'explained' using one or another version of this powerful idea. For example, solving problems by 'trial-and-error' involves generating a variety of potential solutions until one which works is found and adopted (retained).

Another powerful and related idea for understanding change, one which I will show to be well represented in the story of the Deep Past, is that reality is made up of nested layers of *dissipative* or *energy-degrading* systems[8]—smaller, faster-running systems nestling inside larger, slower-running systems. The fundamental property of dissipative systems is that they continuously take in energy, physical materials and information (a patterned form of energy with special properties) from their environment and continuously excrete (dissipate) materials, information and degraded energy—energy of a lowered quality in terms of its capacity to do work—back into the environment. For example, the multi-species assemblages which ecologists refer to as *communities* or *ecosystems* can, in some sense, be considered as energy-processing systems which are transforming high-quality solar energy into chemical energy and then distributing this to all of the community members to be dispelled, eventually, as heat, a low-quality (useless) form of energy. The link here to evolution is that evolution is a process which creates, maintains and destroys dissipative systems.

Apart from its value for exemplifying the generic nature of change and for indicating something of the future world's behavioural possibilities, I have a third reason for presenting some extracts from the story of the Deep Past: It is my belief that

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[6] Dobzhansky, T., 1967, *The Biology of Ultimate Concern*, Rapp and Whiting, London.

[7] Hull, D. L., 1988, Science as a Process: An Evolutionary Account of the Social and Conceptual Development of Science, University of Chicago Press, Chicago; Nelson R.R. and Winter, S.G., 1982, An Evolutionary Theory of Economic Change, Belknap Press, Cambridge, MA.

[8] Salthe, S.N., 1985, *Evolving Hierarchical Systems: Their Structure and Representation,* Columbia University Press, New York.

some (enhanced) version of this narrative will have to be an important part of the emotional capital, the system of beliefs and attitudes, that humans will need to call on to encourage and guide them, if and when they conclude they are facing a massive crisis which perhaps can be averted but, otherwise, has to be endured.[9] While I cannot expand that rationale here, I do return to it in my final chapter. Hinting at the flavour here, the quote from Carl Sagan at the head of this chapter not only introduces the material story of the Deep Past, but captures something of its evocative and energising power. 'Fancy that!' I say. It is wonderful and amazing that the breath I am now drawing probably contains gas molecules once breathed by Charles Darwin, to pick an historical figure whose spirit permeates this book. Equally wonderful is Sagan's pithy reminder that the hydrogen and helium which condensed out of the rapidly cooling pulse of photons (packets of energy) produced in the first second of the life of the universe soon coalesced, gravitated, into 'furnace' stars where, for the first and last time, molecules of all the heavier elements would be 'forged'. Some of these, billions of years later, would end up in Darwin, long after being dispersed around the universe as their parent furnace-stars first imploded and then exploded, i.e. as they became *supernovae*. Planets, life and human intelligence can all be regarded as by-products of the stellar epoch. As a 'memory' which we all share, we are truly children of the stars.

Evolution Before Life

Formation of Matter

The best available non-supernatural story of the evolution of the universe begins 13.7 billion years ago (Bya or Ga), soon after a postulated explosion (the 'big bang') projected incomprehensibly large quantities of super-hot high-quality radiant electro-magnetic energy outwards, taking the 'envelope of space' with it. According to the standard theory, the universe inflated from being a 'bubble' of space smaller than an atom, and a container for all the energy in the universe, to something larger than our solar system in less than a second—and has been expanding and (therefore) cooling down ever since.

Everything that has happened in the universe since that 'local density fluctuation' (and everything that will happen in the future) has been an instantiation, an expression of just one pervasive conversion process or equilibration process, namely, the ongoing conversion of that original high-grade (also called low-entropy) locally concentrated energy into low-grade (high-entropy) locally dispersed or spread-out energy. Call it the *cosmic equilibration process.* And *everything* means just that. It includes the formation, persistence and destruction of matter, galaxies,

[9] Salthe, S.N. and Furhman, G., 2005, The Cosmic Bellows: The Big Bang and the Second Law, *Cosmos and History,* **1**(2), pp. 295–318.

stars, planets, plants, animals, brains, ideas (minds??) and societies. Nature abhors disequilibrium! The cosmic equilibration process is spontaneous in the sense that whenever conditions allow (and such are many) the conversion process proceeds at the maximum speed compatible with those conditions. Or, putting this another way, for every set of conditions under which conversion is possible, conversion proceeds at a characteristic speed. It is a necessary condition for the occurrence of a spontaneous process that *entropy*, low-quality energy, should be produced.

Before going on, a word about energy, in particular about its quantity and quality. Like many abstract things, we have, to quote the great physicist Richard Feynman, ‘no knowledge of what energy is’. A standard definition such as ‘energy is the capacity to do work’ is seen to be tautological when it is realised that ‘doing work’ means that the amount of energy in one part of a system of interacting entities is increased (we then say that *work* has been done on that part of the system) at the expense of the amount of energy stored in some other part of that system. For example, when Galileo supposedly carried his weights up the Leaning Tower, the weights acquired gravitational potential energy and Galileo lost chemical (metabolic) energy. What we most importantly do know about energy is that it exists in various forms (e.g. heat, light, gravitation, invisible radiation, kinetic, mechanical work, chemical, potential, nuclear, electrical) and that it can be converted (within limits) from one form to another without any loss in quantity—but with an inescapable loss in quality.

That last sentence is an informal statement of both the first and second laws of thermodynamics, this being the science of energy (a much better name would be energetics). The first law of thermodynamics says that energy can be neither created nor destroyed, only changed from one form to another. So the total quantity of energy in the universe is the same now as it ever was. The second law says that each time a quantity of energy of a particular quality changes from one form to other forms, there is a loss in the amount of energy subsequently available for and capable of participating in similar kinds of energy conversions in the future. A system’s *entropy* is simply the amount of energy in it which is unavailable to do further work.

This pervasive process of converting or dissipating (useful word) low-entropy energy into high-entropy energy is equivalently called entropy production or ‘loss of free energy’. From a human perspective, a common example is the conversion of high-quality chemical energy in the form of petroleum plus oxygen into low-quality ‘waste’ thermal (heat) energy and simple ‘tailpipe’ chemicals which have few high-energy bonds, e.g. water and CO_2. After being converted into the kinetic energy of a moving vehicle, the chemical energy of petroleum is unavailable for further ‘useful’ tasks. The second law is simply saying that the cosmic equilibration process clicks over another notch whenever (and only when) energy is converted from one form to another. In this context, the cosmic equilibration process is the tendency for higher quality locally concentrated energy to spontaneously dissipate into lower quality less-concentrated energy, i.e. it does so if it is not blocked (as it commonly is) by chemical, physical or psychological barriers/constraints.[10] The reason that the

[10]http://entropysite.oxy.edu/students_approach.html (Accessed 30 Dec 2010) has a good simple discussion.

evolution of the universe as a whole is irreversible is that its energy mix contains ever more entropy, never less. Thus, it can never return to last week's energy mix! The universe would be in equilibrium if it contained no pockets of relatively high-grade energy.

The famous Einstein equation reminds us that matter (that which has mass and occupies space) and energy are interconvertible under the right conditions. As the early super-hot universe cooled, conditions became suitable for matter in the form of, first, heavy particles (e.g. neutrons, protons and antiprotons), then successively lighter particles (e.g. electrons and positrons) to 'condense' from colliding photons (packets) of radiant energy. High-quality high-temperature photons were being converted into particles of matter plus lower-quality lower-temperature photons, an entropy-increasing process consistent with the cosmic equilibration principle and the second law of thermodynamics. As cooling continued, temperature conditions necessary for the formation of matter came to an end and the amount of matter in the universe has remained approximately constant since that time.

The gradient or 'difference between locations' which is being increasingly eliminated by the cosmic equilibration process was originally created when, shortly after time zero, the universe was expanding and cooling so rapidly that the equilibrium proportions being successfully maintained between matter particles and energy particles (photons) during the first 100 s was destroyed. How? There is a different equilibrium ratio between numbers of matter particles and energy particles for each combination of mass density (grams of matter per cubic centimetre (cc) of universe) and temperature in the cosmic medium. But, after 100 s, density-temperature conditions were changing too fast for such equilibrium to be maintained. In an expanding universe, radiant energy was cooling faster than matter was cooling. Putting this another way, the reason that the amount of matter in the universe has stayed approximately constant is that since conditions cooled well below the temperature of matter formation, there has not been any energy source sufficiently concentrated to energise particles to the point where they would 'evaporate' back into radiation.

Formation of Atoms and Molecules from Elementary Particles

Between 10,000 and a million years after time zero, and with further cooling to 4,000°K (4,000° above absolute zero), elementary positive and negative particles could begin assembling into neutral atoms without being constantly broken up again by high-energy photons.[11] Hydrogen (90%) and helium (10%) accounted for most of the atoms formed.

Radiation does not interact with neutral atoms as it does with a gas of charged particles. It simply passes through. So, as the neutral atoms formed, and with no free

[11]Chaisson, E., 2004, Complexity: An Energetics Agenda, *Complexity*: (Journal of Santa Fe Institute), **9** (3), pp.14–21.

electrons left to scatter the photons of light, the universe steadily became transparent to radiation. It was as though, after 300 k years from time zero, a great fog blanket had lifted. Once the radiation born in the Big Bang stopped interacting with (decoupled from) the matter it had given birth to, it became the cosmic background (microwave) radiation which can be observed today and which constitutes over 99% of the universe's total energy complement.

Without charged particles to maintain thermal equilibrium (i.e. matter and radiation being at the same temperature and behaving as a single fluid) the temperatures of the matter and the photons went their separate ways. The rate of photon cooling was inversely proportional to the size of the universe, while matter cooled at a faster rate, inversely proportional to the square of the size of the universe. So, for the first time in the history of the universe, two temperatures were needed to describe things. As the temperature of the universe's hydrogen atoms (and hence their thermal energy) dropped below the dissociation energy of molecular hydrogen, they paired to form the first molecules.[12]

Formation of Galaxies and Stars from Molecules

After the end of the molecule formation epoch, matter began clustering into galaxies, with the initial locations of embryo 'protogalaxies' corresponding to locations where a few molecules had strayed together by chance and stayed together long enough to begin collecting other molecules through gravitational attraction. Once started, such a process is self-reinforcing. It is also an entropy-producing process. Gravity is a weak force and only starts to have this gathering-in effect when molecules have insufficient thermal energy to keep them apart, i.e. after cooling below 100°K. The phrase *thermal determinism* captures the powerful generalisation that there are a number of major transitions which can be readily explained as the result of the universe's decreasing temperature.[13]

As such emerging clouds of gas became ever denser, after 180 million years say, stars began igniting inside them, and clusters of stars began to form the large-scale structures now known as galactic regions. While still continuing, galaxy formation (500 billion of them) was largely over after a billion years, by which time the cosmic temperature had plummeted to 100°K or −173°C. An idea is now growing that the gross structure of the universe is that of a more-or-less flat 'mesh', with long 'filaments' of galaxies criss-crossing each other. Particularly dense clusters of galaxies are found where filaments intersect. Despite the enormous size of this mesh, galaxies have been calculated to contain only 2–3% of the matter in the universe. The rest, called *dark matter*, has not been explained. Taken together, dark matter

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[12] Lineweaver, C.H., and Schwartzman, D., 2004, Cosmic Thermobiology: Thermal Constraints on the Origin and Evolution of Life. In J. Seckbach, (Ed.) *Origins: Genesis, Evolution and Biodiversity of Microbial Life in the Universe* Kluwer Academic Press, Dordrecht, pp.233–248.

[13] Lineweaver, C.H., and Schwartzman, D., 2004, ibid.

and an equally mysterious *dark energy* are thought to make up most of the universe.[14] Dark energy appears to oppose the self-attraction of matter and to cause the expansion rate of the universe to accelerate.

While few new galaxies have formed in, perhaps, the last ten billion years, star formation (and destruction) has been a commonplace within galaxies, right up till the present. A typical star forms as ever-more hydrogen (mostly) atoms come together under the influence of gravity, eventually packing together at a density at which nuclear fusion begins, creating a hydrogen-burning 'stellar furnace' in which, as described by Sagan, conditions are suitable for the nuclei of all the heavier elements to be synthesised from hydrogen and helium. So stars are dissipative systems which extract nuclear energy at high core temperature (~10^7 K) and discard it at low surface temperature (~10^3–104 K). As an example of the contingent (but for…) nature of evolutionary processes, it can be noted that if the nuclear force that holds protons and neutrons together was any stronger, fusion of hydrogen to helium in the Sun would have finished long ago and if any weaker would not be delivering solar radiation at a level sufficient to sustain life.

Eventual Demise of Galaxies, Stars and Matter

Cosmological theory suggests that, in the fullness of time, galaxies and matter, as well as stars, will disappear from the universe. Massive 'black holes' dwell in most galaxies. These super-massive collapsed stars are called 'black' because gravity is so strong inside them that not even light rays can escape from them. Over time they capture more and more of a galaxy's matter. Viewed from the right position, Earth's galaxy, the Milky Way, looks like a Catherine wheel with trailing arms of stars spinning around a central 'black hole' every 250 million years or so. The star called the Sun is well out towards the edge of this galaxy and hence relatively safe from various nasty fates, such as being sucked into this black hole.

Long after the Sun has exhausted its fuel supplies and died down to a dim *white dwarf* star, and then a *black dwarf* (a non-radiant star), the Milky Way and other galaxies will move into what has been called the *Degenerate Era*. The only stellar objects remaining by then will be white-black dwarfs, brown dwarfs, neutron stars and black holes.

White dwarfs are the dying embers of standard hydrogen-burning stars. Their lives may be prolonged, somewhat but not indefinitely, by capturing and consuming 'dark matter'—particles of several types that have so far eluded detection but which astronomers and high-energy physicists calculate must be present in the universe in enormous quantities. *Brown dwarfs* are failed stars, having insufficient mass to initiate thermonuclear, hydrogen fusion. Stars with a mass of about eight solar masses

[14]Bahcall, N.A., Ostriker, J.P., et al., 1999, The Cosmic Triangle: Revealing the State of the Universe, *Science,* **284**, pp.1481–1488.

will complete their life cycle in a cataclysmic flare we know as a supernova. All that remains from such an event is a rapidly spinning *neutron star*, an object about the size of the Earth, composed exclusively of neutrons, with a density so great that a teaspoon of its matter is about the weight of the Earth. A star with a mass greater than eight solar masses may end up as a black hole rather than a neutron star.

Also during the Degenerate Era, galaxies will begin to unravel with some star remnants moving out to the edge of their galaxies and others falling to the centres. Most remnants, including planets, will be adrift in intergalactic space, having been ejected from their galaxies.

What could possibly happen next? One suggestion is that the mass of remnant stars will begin to dissipate through a process called *proton decay*. For a long time, protons were believed to last 'forever', like electrons. It is now believed that even they have a finite lifetime, theorised to be between 10^{30} and 10^{40} years. Since protons are a fundamental component of all matter, their decay into photons and positrons would mean the disappearance of all material structures.

That is, all material structures except black holes which, being made of neutrons, would be unaffected by proton decay, and would linger on. This is where the Degenerate Era ends and the *Black Hole Era* begins. But even black holes will not last forever. As long as they are being fed by captured stars, they will grow larger. But even these enormous masses must eventually dissipate into thermal radiation, photons and other decay products. Neutrons decay into protons, electrons and neutrinos. A black hole of one Solar mass may last for 10^{65} years. A black hole with the mass of a typical galaxy may finally evaporate after 10^{98} years. The era closes when all the black holes have radiated away and all that remains is a diffuse sea of electrons, positrons, neutrinos and radiation suspended in nearly complete and total blackness. The cosmic temperature will be a minute fraction above absolute zero. We will leave this plausible bur highly speculative story there, with the universe effectively dead.

The particulate, galactic and stellar epochs of cosmic history are all examples of the cosmic equilibration process. All involve processes in which some form of high-grade freely available energy is partly converted into other and different forms of high-grade energy (e.g. matter, material structures, kinetic structures) and partly dissipated (dispersed, degraded) into lower-grade energy, including thermal energy, the lowest grade of all in terms of its availability for conversion to other forms of energy. For example, the clustering of matter under the attractive influence of gravity is a process of converting gravitational energy to potential energy and, as with all energy conversion processes, some of the energy involved is changed from a lower-entropy state to a higher-entropy state, e.g. changed to heat and light. In particle and atom formation, radiant energy is converted into the energy which holds those entities together. In fact, particle formation, atom formation, galaxy formation and star formation are all examples of dissipative processes taking place in dissipative or energy-degrading cum energy-transforming systems.

There is a degree of evidence to suggest that within the realm of what becomes possible (with cooling, for example), dissipative systems *self-organise* or spontaneously reorganise their networks of internal energy conversion paths in such a way that the rate at which cosmic equilibration proceeds is maximised. This is called the *maximum entropy production or MEP hypothesis*.[15] It is an illuminating idea which is further discussed in an Appendix to this chapter.

Formation of the Earth and Moon

Having summarised a plausible life story of the universe into a few pages, let us return to more local matters. The Earth's Sun was born as a typical star some 4.6 billion years ago (Ga), i.e. 4,600 million years ago (Mya). It sustains itself by burning 150,000 tonnes of hydrogen a second, a rate of energy conversion which the Sun can sustain for perhaps another 5–7 billion years before swelling up 50-fold to become a 'red giant' star, incinerating the inner planets and then collapsing into a 'white dwarf' star and, ultimately, into a burnt out 'black dwarf'. Degrading free energy at such a rate sounds enormous but, on a per gram basis, the Sun's free energy rate density is 1/10,000 that of a human being.[16]

The Sun and all its planets, i.e. the solar system, formed around the same time, i.e. 4–5 Ga. Beginning with a very hot, relatively homogeneous, rotating disc of matter, gravity and temperature differences caused materials with different masses and melting points to be pulled to different distances from the Sun where they eventually cooled enough to condense and accumulate. Dense materials with high melting points condensed and accumulated nearer the Sun, e.g. Earth, Mars. Less dense materials with low melting points condensed and, pushed outwards by particles ejected from the Sun (solar wind), cumulated further from the Sun, e.g. the gas planets.

Starting 4,550 Mya as a relatively small pile of cosmic rubble drawn together by gravitational energy, the Earth grew steadily via accretion from a bombardment of various bodies including meteorites and comets, large and small. It is believed that much of Earth's water and carbon, both prerequisites for life to arise, arrived as cometary debris. There are no rocks surviving from that Hadean time because, under the heating effects of constant bombardment and radioactive decay, the Earth was molten. Indeed, the surface of the Earth was periodically vaporised and covered with an 'atmosphere' of rock vapour.[17]

High-density elements like iron and nickel sank to the centre of this liquid globe to form an inner core of solid iron and an outer core of molten iron, both of which will probably remain so for billions of years. Calcium, sodium, potassium and aluminium silicates (feldspars) melt at temperatures as low as 700–1,000°C and when molten are relatively light. Early on, they would have risen to the surface by convection

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[15] Swenson, R., and Turvey, M., 1991, Thermodynamic Reasons for Perception-Action Cycles, *Ecological Psychology*, **3** (4), pp.317–348.

[16] Chaisson, E., 2001, ibid., p.139.

[17] Hartmann, W.K., Ryder, G., et al., 2000, The Time-Dependent Intense Bombardment of the Primordial Earth/Moon System. In Canup, R.M., and Righter, K. (Eds), *Origin of Earth and Moon*, University of Arizona Press, Tucson, pp.493–512.

to become the most common minerals in the Earth's crust. This differentiation (separation) probably also initiated the escape of gases from the interior and led to the formation of the primitive atmosphere and the oceans. Flow of heat to the Earth's surface became more efficient (created more entropy) with the development of convection cells in the Earth's mantle (the layer between the core and the crust).

When a body we can call the *proto-Moon* struck Earth a glancing blow about 4.5 Bya and skidded back into space, it set the Earth spinning once every 17 h or so.[18] Day and night were created but it took another 3.5 billion years for rotation time to slow to 20 h. Currently the Earth's day length is increasing by a second every 62,500 years, an hour every 360 megayears (million years). As the Earth rotates more and more slowly the Moon is spiralling away from the Earth at a rate of about 2.5 mm per lunar month. Eventually, under the influence of the Moon's gravity and the loss of rotational energy in the form of heat generated by the friction of tidal movements, the Earth's rate of rotation will fall below one revolution per 1,100 h.

As the Earth's rotation rate slows, its shape becomes more nearly spherical (less flattened), an ongoing process which creates tremendous dynamic pressures and stresses (stored energy) within the Earth's brittle crust as it endeavours to conform to the ever changing mantle upon which its constituent tectonic plates (see below) float. Think of a wrinkling orange. Stresses from this and other internal processes such as shifts in the Earth's axis, and including convection currents in the mantle, are relieved (dissipated) by the triggering of volcanoes, earthquakes and mountain uplift.

Evolution of the Pre-life Earth

For perhaps 500 myrs after its formation, the Earth was a cooling but still molten sphere, too hot for life to emerge and survive—more thermal determinism. However, a few hundred million years later, with ocean temperatures still near-boiling, the first simple bacterial life forms had emerged.

Meanwhile, here is a brief description of how the Earth evolved and functioned as an integrated energy-processing, energy-degrading system in the pre-life era when conditions were becoming suitable for the emergence of the first organisms. My aim is to provide some background for later discussion of the processes by which life forms and their physical environments (together called the *ecosphere*) subsequently evolved and coevolved (i.e. evolved in tandem). A second aim is to discuss change and variability in the physical conditions of the pre-life Earth in a way which will inform later discussion of the conditions that life might have to adapt to in the future if it is to persist.

The main idea to be established and reinforced is that life emerged in a dynamic world where conditions were (and still are) always changing, slowly in some cases, rapidly but smoothly in others and, irregularly, there can be high-energy disturbance

[18] Denis, C., Schreider, A.A., et al., 2002, Despinning of the Earth Rotation in the Geological Past and Geomagnetic Paleointensities, *Journal of Geodynamics*, **34** (5), pp.667–685.

events emanating from space or from within the Earth. The latter have sometimes dramatically reconfigured (re-organised) the global pattern of energy dissipation associated with the cyclical movement of materials around the planet. Just as the universe as a whole can be viewed as a self-organising dissipative system spontaneously degrading energy at the maximum available rate by using that energy (plus materials) to form kinetic and static structures, so can the (pre-biotic) Earth. In Earth's case the kinetic structures are the networks of pathways along which various materials are cycled through the lithosphere, the hydrosphere and the atmosphere.

How Does the Planet Dissipate Energy?

The Earth has long been an interwoven network of coevolving (jointly changing) energy-dissipating sub-systems, drawing the energy which these sub-systems collectively degrade from two main sources, namely, the Sun and the planet's hot core.

Solar energy. Step by step, incoming solar energy is degraded from high-grade (high energy per photon) short-wave radiation to outgoing low-grade (low energy per photon) long-wave radiation as it drives many of the planet's surface processes such as wind patterns, precipitation, erosion, ocean currents, electrical storms, etc. This applies in the biotic as well as the pre-biotic world, the difference being, as we will discuss, that there are many more pathways in the biotic world.

Remember that energy cannot be converted from one form to another without simultaneously converting part of that same energy to a low-grade form (e.g. waste heat in the form of enhanced molecular kinetic energy) which cannot be subject to further conversions. Thus, a portion of all incoming solar energy is irretrievably lost back into space with each successive conversion of that incoming energy to other forms. However, while all incoming solar energy is ultimately degraded, this does not happen instantaneously. It takes time, called *residence time*, for energy to move via various processes along pathways between different planetary 'reservoirs' where it is temporarily stored. For example, solar energy which produces clouds by evaporating water has a much longer residence time on Earth than energy which strikes polar ice and is immediately re-radiated back into space.

Geosphere energy. In addition to the solar energy which drives surface processes, many of the planet's geological processes continue to be driven by the original conversion of gravitational potential energy to, first, kinetic energy and then to heat during the coming together of proto-planetary raw materials.[19] Ongoing nuclear reactions in the planet's lower mantle further boost temperatures there to something like that of the Sun's surface, more than 5,000°K. This internal energy store creates and drives processes such as continental uplift, drift and collision, sub-surface magma (hot semi-fluid) flows, volcanism, magnetic-field formation, seismic activity and polar shifts. For instance, it is core heat which drives convection currents in

[19]Chaisson, E., 2001, ibid., p.162.

the viscous mantle on which the more rigid crustal surface is 'floating'. Convection currents are probably the mechanism by which rigid plates of crustal rock (tectonic plates) are separated, pushed together or rotated, causing great rifts in the crust where the plates separate, or high mountain chains where they collide. Plate motions also give rise to earthquakes and a high heat flow towards the surface, especially along the plate boundaries where volcanoes tend to be formed, e.g. the Pacific Ocean's 'rim of fire'.

All of these processes can be regarded as alternative pathways in a large *heat engine* which is simultaneously transferring heat energy from inner Earth to outer space and converting heat energy into the kinetic energy of various material flows and mass movements. A heat engine is a device which converts heat energy to the kinetic energy of mechanical work. Notwithstanding, the amount of internal heat reaching the Earth's surface to be eventually radiated into space is very small compared with the amount of solar energy re-radiated into space.

Not all outgoing geothermal energy is converted to mechanical work; some geothermal energy is also re-stored in static structures, e.g. the kinetic energy of a moving tectonic plate is converted to and stored as gravitational potential energy when used to push up mountain ranges.

Other energy inputs. As noted, the Earth's rotational energy is gradually being dissipated by tidal friction and its angular momentum transferred to the Moon—which means sending the Moon into a more-distant orbit. Earth-Moon and Earth-Sun gravitational forces are expressed as bulges in the Earth's land and sea surfaces. Tidal flows in the oceans are what happen as the Earth rotates beneath these bulges; the resulting 'braking' friction in both crust and oceans is Earth-warming.

Finally, there are several types of small (usually) but concentrated and localised energy inputs to be processed and dissipated by various Earth systems. Lightning is not one; it is an important high-energy driver of atmospheric processes (e.g. 'fixing' nitrogen) but is generated within the Earth system. Asteroids and other occasional bodies from space have to be included here. For example, the asteroid which exploded above Siberia in 1908 had the energy of a thousand Hiroshima bombs. Simulation models suggest that an asteroid 5 km in diameter, if it landed in the Atlantic Ocean, would produce a tsunami high enough to inundate most of the world's coastal landscapes.

Overall, while still high today, the specific rate (i.e. rate per gram) at which the planet is processing incoming energy to other forms and radiating away the low-grade thermal energy this produces has fallen considerably over time, particularly in comparison with Earth's first half billion years. This observation is not incompatible with the idea that, in any time interval, the quantity of entropy (energy that has been degraded to heat) being produced by the Earth system is higher than it would be if no global material-energy cycles had emerged after the planet's initial cooling, i.e. whenever physically feasible, such cycles come into existence (spontaneously self-organise) as a way of better satisfying the *cosmic imperative* to degrade high-quality energy into low-quality energy as rapidly as possible. While energy-in must still equal energy-out if the Earth's temperature is not to change, the outgoing energy is of lower quality than it would have been in the absence of material cycling.

Box 1.1 Some Important Global Material-Energy Cycles

Hydrologic cycle
Climatic and meteorological cycles
Oceanic cycle
Ice cycle and sea level cycles
Biological cycle
Elemental (geochemical) and nutrient (biogeochemical) cycles
Supercontinent cycle
Rock-soil cycle

The Mechanics of Global Material-Energy Cycles

The restless Earth is only able to continue dissipating solar and core energy as fast as it does because the sequences of global-scale energy conversion and transfer processes which produce dissipated energy are largely based on a ‘circulatory system’ of more-or-less closed material cycles. These include (see Box 1.1) climate-weather cycles, geological, geophysical and geochemical cycles and, more recently, the biological cycle. Let me explain.

A typical global material-energy cycle has three sorts of components:

1. Reservoirs for storage of materials.
2. Transport paths which denote how material moves between reservoirs.
3. Fluxes (flow rates) which describe how much material moves along particular transport paths.

During any movement of matter between reservoirs, energy is used to convert materials (air, water, chemicals, rock, soil…) from one form to another (e.g. gas to liquid) and/or to do the work required to transport materials from reservoir to reservoir. And, in accordance with the cosmic equilibration process, the ‘thermodynamic imperative’, some of the available energy is converted at each stage into unavailable thermal energy which is then radiated out into the heat sink of space. Labelling such an energy conversion processes as cyclical simply means that most of the materials which are transformed or transported at each stage eventually return to where, and in much the same form as, they started out. This means that these materials are being recycled, that, in some sense, they are being renewed and the system is *self-maintaining*. Self-evidently, if something like this does not happen, the chain of processes in a multi-stage energy conversion cycle will stop when the available stock of input materials is exhausted.

Examples

In the *hydrologic cycle* for example, solar energy is used to evaporate liquid water, from the oceans say, into vapour and, simultaneously, to increase its (latent) energy content by 2.4×10^6 J/kg. This water vapour is carried upwards by atmospheric convection currents till it condenses at high altitudes where the air cools (due to its volume expanding as the air pressure falls) and, in condensing, releases, as heat, the energy it absorbed when first vaporised. The released heat is eventually radiated back into space and the liquid water is recycled back into the oceans as rain. So, as crudely described here, there are two stages in the hydrologic cycle. In the first stage, water is converted into 'high-energy' vapour and lifted skyward. In the second stage vapour is converted back to liquid water, low-quality thermal energy is released and the water falls to the oceans as rain. Thus, the cycling of water is completed and the stock of water available for evaporation is renewed. If most water vapour drifted into space on reaching high altitude, the hydrologic cycle would soon stop.

The *characteristic time* of a material-energy cycle is the time normally taken for materials to pass through every stage or reservoir of the cycle. One of Earth's longest cycles is the supercontinent (or Wilson) cycle, which has an average duration of about 500 myrs. Beginning about 3,000 Mya there have been five or six cycles of breakup and reformation of one or more supercontinents. A supercontinent (the most recent ones, formed when Pangaea broke into two, were Laurasia and Gondwana) breaks up into smaller continents when *radiogenic heat* from relatively shallow internal radioactivity is trapped underneath it and builds up to the point where the 'lid blows' and the supercontinent ruptures into pieces. After being broken up in this way heat no longer accumulates and the smaller continents eventually drift back together again. It might be noted that if the planet's sources of radiogenic heat were any deeper in the core, the planet would periodically revert to a totally molten state.[20] As it is, the bulk of the geosphere has been comparatively stable for the past three billion years with unrest largely confined to the 'rind-like' crust and uppermost mantle. It is the boundaries of continental plates which are the sites of most earthquakes, volcanic activity, and exchanges of heat and volatiles between the interior and the oceans and atmosphere. Plate tectonics is one of the great unifying theories in geology. Virtually every part of the Earth's crust, and every kind of rock and every kind of geology can be related to the plate tectonic conditions which existed at the time they formed. It has been said that 'Nothing in geology makes sense except in terms of plate tectonic theory'.[21]

More generally, the way in which the supercontinent process spews out new oceanic crust at mid-ocean ridges and destroys it beneath ocean trenches represents a major cycling of crustal material, water and chemical constituents between the Earth's surface and its interior. This fundamental tectonic (rock-forming) process plays a major role in controlling the chemistry (behaviour of matter at the molecular and atomic scales) of the ocean and atmosphere.

The *rock cycle* (see Box 1.2) is an example of a shorter, more localised material-energy cycle superimposed on the supercontinent cycle.[22] It involves the solidification, erosion, sedimentation, recompaction and re-melting of the mineral constituents of Earth's rocks.

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[20] Strahler, A., and Strahler, A., 1997, *Physical Geography: Science and Systems of the Human Environment,* 4th ed, Wiley, New York, p.169.

[21] http://csmres.jmu.edu/geollab/fichter/Wilson/Wilson.html (Accessed 27 July 2009).

[22] Strahler, A.N. and Strahler, A.H., 1973, Environmental Geoscience: Interaction between Natural Systems and Man, Hamilton, CA.

Box 1.2 New Rocks from Old: An Example of a Global Material-Energy Cycle

Simplifying, the rock cycle can be described as follows:

1. Magma cools and solidifies (crystallises) forming igneous rock.
2. Igneous rock weathers, gets transported and is deposited as sediments.
3. Sediments, through cementation and compaction, lithify to form sedimentary rock.
4. Sedimentary rocks, through pressure and temperature, largely at margins of continental plates, become metamorphosed forming metamorphic rocks (igneous rock can also be metamorphosed without first becoming sediments).
5. Metamorphic rock gets melted, forming magma once again (alternatively, metamorphic and sedimentary rock can be weathered, transported and deposited to form new sediments).

Geochemical cycles are those planetary-scale material-energy cycles in which individual elements such as phosphorus, carbon, nitrogen and oxygen pass through a recursive sequence of chemical forms, each embodying a different level of chemical energy. However, because these cycles have been so dramatically influenced by processes associated with the emergence of life (e.g. nutrient cycles in ecosystems), making them *biogeochemical* rather than geochemical, we will delay their discussion until we discuss the evolution of biological cycles.

Interacting Cycles

While it is convenient to describe Earth's pre-life global cycles as separate dissipative processes, there has always been a network of strong interdependencies, relationships of mutual influences and interdependent evolution (coevolution), among the main cycles.

The supercontinent cycle provides several illustrations of such interconnections. Each time a supercontinent is pulled apart, huge quantities of greenhouse gases are released and warm, wet greenhouse conditions come to prevail. When smaller continents recombine, mountain ranges and continental platforms are pushed up, soils form and assimilate CO_2 from the atmosphere as they erode; eventually this CO_2 is incorporated back into marine deposits, e.g. limestones. CO_2 levels in the atmosphere then fall, the significance of this being that glaciations and ice ages occur when atmospheric CO_2 is low. It seems then that supercontinent cycles create conditions that also produce very long climatic cycles. Various climatic cycles with much shorter characteristic times are then superimposed on these very long climatic cycles. Some of these shorter cycles, driven by various periodic changes in solar energy, are very regular (e.g. recent ice ages) and others (e.g. volcanic winters) are quite irregular.

Crustal landscapes provide another example. Under the influence of four interacting energy sources—geothermal heat, solar radiation, Earth's rotational energy and gravitational attraction—the evolution of Earth's physiography (landscapes) began with the formation of the primitive continents, oceans and atmosphere. For example, the momentum of the Earth's rotation and the gravitational attraction of the Sun, Moon and Earth led to the occurrence of tidal forces which are most noticeable in water bodies and which especially affect coastal landscapes. Gravitational forces provide energy less directly, but by attracting all Earth materials towards the Earth's centre, impart a potential energy to rocks and soil.

Geothermal heat initiates the injection of new material into the crust and the spilling of molten magma onto the surface to form volcanoes and lava flows; and also the Earth movements which produce large scale uplift, warping and folding. These processes are generally constructional in that they lead to an increase in elevation and relief. Subsequently, erosional and depositional sculpting, driven by gravity and the energies of the solar-powered wind and water cycles, reduces the elevation of these primary landforms.

Lurking here we have a particularly clear example of the coevolution of dissipative landscape processes. The geological cycle produces mountain ranges which increase the rainfall they intercept by lifting rain-bearing winds to heights where they more readily precipitate their moisture as rain. Increased rainfall increases the rate at which the mountains erode and deliver sediments to the ocean where it will again be converted to rock. So, despite large differences in characteristic times, changes in the meteorological and geological material-energy cycles are mutually influencing each other in terms of how and where they are processing material and energy, i.e. they are coevolving.

It was the long-term interplay between these internally generated constructive and externally generated deconstructive processes which guided the history of Earth's pre-biotic landscapes for a billion or so years. Then, as will be discussed presently, with the emergence and proliferation of life, a biological cycle began to interact with the physical cycles of the atmosphere, the hydrosphere and the lithosphere and, thereafter, strongly modify the history of landscape evolution. For example, we will reflect on a remarkable correlation between the supercontinent cycle, the long-term rise in atmospheric oxygen level and the increasing complexity of plant and animal life forms.[23]

[23]Campbell, I.H. and Allen, C.M., 2008, Formation of Supercontinents Linked to Increases in Atmospheric Oxygen, *Nature Geoscience*, **1**, pp. 554–558.

Kinetic and Static Structures

This is a moment to recapitulate, in quite general terms, the basic behaviours of dissipative systems (and their component dissipative structures) of the type represented by global material-energy cycles.

It bears repeating: dissipative systems are the processes through which the universe's spontaneous tendency to smooth out (eliminate) all potential energy gradients (differences in energy density between locations) works itself out. How do they do this? In their *closed form*, they are bordered collections of matter which receive energy of a particular spectral quality from the environment and return energy of a lower quality than that received. This is what *dissipation* means—the conversion of *exergy*, i.e. energy capable of doing work, into *entropy,* i.e. energy not capable of doing work. In their *open form*, they receive both matter and energy and give out both matter and energy. The Earth, our present example, is a dissipative system which has been effectively closed since the pre-biotic Earth stopped accumulating materials from space.

Delving a little deeper, the relatively high-quality energy entering a dissipative system is not dissipated until it does work on the materials residing in the system, either by moving those materials around or by changing their chemical or physical structure. When the energy which is moving materials around the system and imparting kinetic (motional) energy to them forms those materials into persistent observable forms it is creating *kinetic structures*. When the incoming energy is used to transform the system's materials, either chemically or physically, into forms with higher potential energy it is creating *static structures.* Both kinetic and static structures function as energy stores, with bigger structures storing more energy.

The important difference between kinetic structures (e.g. the global system of ocean currents) and static structures (e.g. landforms, mineral deposits) is that kinetic structures spontaneously collapse, i.e. lose their organised form and stored energy, when energy flow into the system stops whereas static structures do not. Kinetic structures are constantly being regenerated from materials being imported from the environment (open systems) or, in the case of global material-energy cycles, from recycled materials (closed systems).

Static structures are usually formed by *associative processes* in which clumps of matter are brought together and held by molecular-bonding energies. This is why they do not break down and lose that stored potential energy (gravitational, chemical, etc.) until an appropriate external pulse of bond-breaking *activation energy* is applied, e.g. heat energy, mechanical energy and chemical energy. Once a static structure has had its energy content raised to a critical level by a pulse of activation energy of some sort, it will spontaneously change its structure to one with less exergy (a state of 'minimum free energy') and dissipate the 'lost' exergy. Static structures, because they have no tendency to spontaneously change, are sometimes called equilibrium structures but this can lead to a confusion with thermodynamic equilibrium, meaning a system in which all exergy has been converted to entropy.

The Natural Variability of Global Cycles

Like all dissipative processes, the planet's main energy-degrading cycles in the atmosphere, hydrosphere, solid crust and core-mantle (and, as we shall discuss presently, the biosphere) all had a beginning and, one day, either before or when the Sun dies down, all will end. First, the Earth had to cool sufficiently for its atmosphere to outgas, its oceans to condense and its crust to solidify. Only then could these novel material structures respond to the solar and core energy loads on them by self-organising from what might be called disordered dissipation into the sorts of material-circulating, energy-dissipating systems described above. Looked at over the timescale of geological eons, the rate at which energy has been and will be dissipated by Earth's material-energy cycles will increase from zero, peak, and then decline back to zero.

But, looked at on shorter timescales, including the timescale of human affairs, the rate at which energy is dissipated in any of these cycles fluctuates around an effectively constant trend value. Like true love, the course of Earth's cycles does not run smooth. Even if there were no variability in the solar and geothermal inputs driving global cycles, there would still be a degree of intrinsic variability in cycle behaviour, i.e. in fluxes along the transport paths between reservoirs, droughts for example. For much of the time, each cycle will be similar to but not quite the same as the cycles preceding and following it. In the language of dynamic systems theory, as we shall see below, such 'self-similar' cycling is characteristic of the behaviour of a system which is being spontaneously drawn towards a *strange attractor*, also known as a *chaotic attractor*.

At other times, under the influence of somewhat larger disturbances in a cycle's material-energy sources it will temporarily move away from this 'normal' dynamic-equilibrium behaviour. And, less frequently, under the influence of even larger disturbances, the cycle will breach its *homeostatic limits* and *self-organise* into a distinctly different network of fluxes between reservoirs, e.g. setting up new paths and new reservoirs (see below). As a general rule then, Earth's dissipative systems are stable in the sense that when environmental conditions change, and stay changed, they transit to and then tend to remain in a new dynamic equilibrium, more or less different from their previous state.[24]

All Sorts of Disturbances

Both solar and geothermal inputs into global cycles exhibit random and periodic (oscillatory) variability. Oscillations in flow rates through global cycles caused by (entrained by) oscillations in insolation (radiation intensity) range from daily (e.g. sea breezes) and yearly (e.g. seasonal rainfall) to multi-millennial (e.g. ice ages). Indeed, linked to the rotation of the galaxy, there might be at least one 250 million

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[24] Strahler, A.N., and Strahler, A.H., 1997, ibid.

year insolation cycle. At the other extreme, while sunspot cycles are periodic, solar flares (storms on the Sun's surface) appear to be randomly variable.

Variations in circulation rates can also be due to interactions between cycles, for example, their coevolution as described above. Throughput and circulation rates also vary when energy and materials leak from or are diverted from one cycle into another. For example, much water is removed from the hydrologic cycle when tectonic plates slide over each other.

Conversely, materials can temporarily accumulate in one or more reservoirs of a cycle, e.g. rising sea level. In a *strongly buffered cycle* the rate at which material-energy is moving through the cycle is small relative to the storage capacities of the cycle's reservoirs. This usually means that changes in throughput in one part of the cycle take a long time to affect other parts of the cycle; the system is insensitive in the sense of being slow to respond to a given change in input rates.[25] For example, the oceans have a massive capacity to store thermal energy (heat) and, under contemporary global warming, are taking a long time to heat up to the point where their circulation patterns will change. Similarly, the planet's ice caps are buffers which can expand and contract enormously with variations in heat flow from the tropics. Or, another example, variations in river flow due to varying rainfall are smoothed out when large falls are temporarily intercepted and stored in the landscape's soils and waterbodies. Ultimately, a cycle can only proceed at the processing rate of its slowest link.

Importance of Self-Reinforcing and Self-Correcting Feedback Processes

Feedback processes have underlain much of the historical variation in processing rates exhibited by global cycles. They are processes which, at higher or lower rates than is 'normal', either deplete or augment stocks of materials stored in particular reservoirs. Alternatively, they are processes which act to reverse some initial change. In a feedback process some initial causal disturbance (change) in a stock level is, subsequently, either amplified (positive or self-reinforcing feedback) or dampened (negative or self-correcting feedback) by the very effect that it produces. Positive feedback processes are also called *autocatalytic* or self-catalysing processes. In some cases of positive feedback the rate of change may keep increasing until it encounters a 'limit' of some sort. Negative feedback processes are also called *homeostatic* processes if they result in the system being returned to a previous steady state or *homeorhetic* when they return the system to a prior trend or developmental path, e.g. long-term increases (decreases) in sea level, atmospheric carbon dioxide and atmospheric oxygen. *Complex* is a useful term for describing systems containing multiple feedback processes.

All feedback processes are examples of *circular causation*, i.e. process A affects process B affects process C…affects process A. For example, in the positive feedback

[25] Strahler, A.N. and Strahler, A.H., 1973, p. 16.

process which produces 'runaway' global warming, a small increase in greenhouse gases (e.g. from volcanic eruptions) allows the Earth to warm to the 'threshold' point where greenhouse gases trapped in ocean sediments, permafrost beds, etc. are released into the atmosphere.

A contrasting example of circular causation is the process which has occasionally led to an 'icehouse Earth': an initial disturbance which cools the Earth enough to increase its area of surface ice can trigger 'runaway' cooling when the newly formed ice reflects rather than absorbs solar energy, and that of course leads to further cooling and more surface ice. Over the life of the Earth, the most spectacular examples of positive feedback in global mass-energy cycles have perhaps been three occasions (600, 750 Mya and 2.3 Ga) when the Earth, including the oceans to a depth of at least a kilometre, has been largely frozen. It is thought that, following an initial period of cooling triggered by declining CO_2 levels or increasing oxygen levels, glaciers and sea ice, which reflect solar energy back into space, expanded to the point where further cooling followed. Every movement of the ice front towards the equator reduced, at an increasing rate, the amount of solar energy absorbed by the Earth's surface and so induced more glaciation. Each time this 'runaway' process had led to a 'Snowball Earth' the planet has remained frozen for 7–10 myrs until, plausibly, the steady release of CO_2 from volcanoes restored the atmosphere's capacity to trap heat from the Sun and allowed the Earth to warm again—another good example of the coevolution of Earth's material-energy cycles.

All positive feedback processes have a common mechanism in that they use the energy they are processing to create stable structures and kinetic processes which increase the likelihood that they will capture even more energy (or, in some cases, such as 'snowball Earth' scenarios, even less). A plant which uses light energy to make light-capturing leaves is a clear-cut example.

Another shared property of positive feedback processes is that they always come to an end. This might be because of energy or feedstock shortages or because cumulative change in the system experiencing positive feedback triggers 'corrective' feedback processes which halt or reverse the cumulating change, perhaps by diverting materials elsewhere.

In the runaway-warming example, the supply of trapped CO_2 could either be exhausted directly or the accumulation of atmospheric CO_2 might, in raising temperatures, speed up negative feedback processes which remove CO_2 from the atmosphere. Specifically, as temperatures rise, much CO_2 is removed from the atmosphere because $CO_{2,}$ as carbonic acid, is an agent in rock weathering and rock weathering takes place more rapidly at higher temperatures. So, under negative feedback, stock-accumulation processes trigger or enhance countervailing depletion processes. Or, conversely, depletion processes trigger countervailing accumulation processes. In either case, negative feedback processes decline as the system returns towards its pre-disturbance steady state.

Succinctly then, global cycles respond in different ways to small and large, temporary and ongoing, additions to and withdrawals from their material-energy supplies. Small pulses, whether internally or externally generated, are accommodated by variations in flow rates within the existing structure of paths and reservoirs, perhaps transmitting the pulse through a hierarchy of cycles superimposed on cycles. When the pulse is over, the cycles' behaviours tend to revert to the self-similar dynamic equilibria in place prior to disturbance.

Large, but not disruptively large, pulses of additional material-energy which cannot be accommodated within existing structures tend to initiate the budding off of new dissipative structures which grow through positive feedback till all the additional inputs are being processed. If the flow of additional inputs persists however, the new structures tend to persist too. Conversely, if large quantities of energy and materials are withdrawn, then parts of the system's structure and organisation will necessarily close down, e.g. plant growth ceases during 'volcanic winters'.

Perhaps the more general point here is that while feedback processes within any global cycle always come to an end, they can open and close (activate) all sorts of dissipative paths on the way to that end. This is because whenever there is a change in the material-energy entering or leaving one cycle there must be a corresponding change in another cycle (or in another part of the same cycle). It is this reciprocal relationship which ultimately underlies interaction between and coevolution among global cycles. The metaphor that comes to mind is that of a great river cutting new channels while abandoning and silting up existing channels as it ineluctably descends to the sea.

Early Earth Was a Self-Organising Dissipative System

Let us now expand on the single most powerful idea available for explaining year-to-year and place-to-place variations in the circulation rates and kinetic (material flow) pathways of global materials (water, rock, magma, minerals, gases, etc.) in the pre-biotic world, namely, *self-organisation.* It is a concept which has much in common with, indeed subsumes, the idea of *emergence*, introduced above to describe how the pathways available for dissipating the universe's energy changed dramatically over the universe's first few billion years. Thus, we talked of the sequential emergence of matter, galaxies, stars and planets. While the term 'emergence' is sometimes restricted to describing only these sorts of major changes in system organisation, notably the rate of processing energy, it will be convenient for present purposes to regard any system which is the result of a dissipative system having spontaneously re-organised, wholly or partly, as being emergent, i.e. as having emerged from its previous configuration.

Think of the Earth as a single large (by our standards) energy-dissipating system. Like most, dissipative systems, the Earth has a capacity to cycle and dissipate the matter and energy passing through it in a variety of ways, depending on its current structure and organisation and on the form and delivery rate of the system's energy inputs. In practice, the Earth's material inputs from, and outputs to, space have been minimal since it was first formed and can be ignored, i.e. the Earth system is effectively closed to material flows but open to energy flows.

Any dissipative (energy degrading) system is said to *self-organise* when it spontaneously (i.e. without being obviously triggered or, more accurately, triggered by an extremely small fluctuation (noise) in energy flow) changes, wholly or partly, from using one set of paths and reservoirs for cycling energy and materials to using a somewhat different set of paths. That is, the system re-organises itself from one form of organisation to another. As its temperature fell below its melting point, the early Earth self-organised or, as I prefer, self-re-organised in a major way; it changed from being a homogeneous molten sphere losing thermal energy by conduction to being a hierarchical set of interwoven material-energy cycles, ranging from the 500 million year supercontinent cycle to daily weather cycles. Once the planet cooled enough to allow atmosphere and ocean to form, thermal energy could thereafter be transported by coherent (organised) convection currents as well as incoherent conduction to the planet's surface. In accordance with the principle of maximum entropy production (see Appendix to this chapter), the cyclic mode, being the better entropy producer, was spontaneously selected as the planet's main mechanism for dissipating energy via the hydrosphere, lithosphere and atmosphere.

Very approximately, the self-organising Earth, taken as a whole, is, like a pan of gently simmering water, a *steady-state system*. The two main ways of dissipating solar and core energy are the transfer of heat energy from the Earth's surface to the upper atmosphere and from tropical to polar oceans. Despite a history of fluctuating flows through these and the other global material-energy cycles of the lithosphere, hydrosphere and atmosphere, the Earth has stayed in approximate energy balance for four billion years. That is, despite variations in solar and core energy inputs, global surface temperature—the most important characteristic of the climate—has almost always remained in the comparatively narrow range of 10–20°C; the present average is 15°C.[26] For example, the Sun was less bright in the distant past and has since intensified by about 25%.

There will always be some imbalance between energy being absorbed and energy being dissipated. Since 1850, for example, additional incoming energy (e.g. from fossil fuel use) has exceeded additional outgoing energy by 1–2 W/m^2 of the Earth's surface, with a large fraction of this excess going into heating the oceans. Another example: some 250 Mya the Earth warmed to the point where the temperature difference between equator and poles was insufficient to create convection currents in the single global ocean surrounding the then supercontinent (Pangea) and, as this unstirred ocean stagnated, its oxygen level fell to the point where 95% of all marine species died out. Many fear that this could happen again under contemporary global warming.

Whether or not the Earth would have stayed in such tight energy balance, maintained such a constant entropy content, if life had not evolved is an open question which will be explored presently. We will see that the global biological cycle has incorporated a number of powerful positive and negative feedback processes which did not exist in the period when all the planet's dissipative processes were purely physical, a period which started to end about four Bya. One modelling exercise

[26] Gorshkov, V.V., Gorshkov, V.G., et al., 1999, Biotic Control of the Environment, *Russian Journal of Ecology,* **30** (2) pp.87–96.

suggests that, without its biosphere, the global dissipative system would bifurcate, unpredictably, to one of two stable states with surface temperatures of −100°C or +400°C respectively.[27]

An Appendix to this chapter (More on Self-organising Systems) discusses how the quirky behaviours of self-organising systems can be better understood by using concepts from the theory of *non-linear dynamic systems*. It also expands on the relatively new idea that dissipative systems which are not confined to one steady state will tend to evolve to a state which maximises the rate at which they produce entropy.

Evolution of Life and the Ecosphere

The story of the evolution of the physical universe up to the time when it became possible for Earth-style life to evolve has been cast in terms of flows of energy and matter through an evolving hierarchy of open systems. It is a perspective we will continue to draw on as we extend the evolutionary story to life and the ecosphere. It is a beautiful illustration of the concept of *path dependency* (where you can go depends on where you have been) that Earth-life as we know it could not have evolved in the absence of any of the following necessary physical conditions[28]:

A stable parent star (the Sun), not too close to the centre of the galaxy where radiation is high and not too far out where metals are not present in sufficient quantity for planet formation.

A 'right size' parent star (if the Sun had been 30% larger, it would have burnt out in four billion years).

Earth being formed in a 'goldilocks' orbit around the Sun (neither too close and too hot nor too distant and too cold for carbon-based life).

Earth's moon being of the right size to stabilise its angle of tilt (and hence stabilise its seasons and ocean basins).

More debatably, Earth's location near a large planet (Jupiter) has provided it with a protective gravitational shield.

While physical conditions in the atmosphere, the hydrosphere (oceans and other bodies of water) and the lithosphere (solid outer surface of the planet) have changed continuously, markedly and variously since those times, and the conditions under which life can persist have also changed as life has evolved, it has, self-evidently, never become impossible for life to survive. The question we are not asking here is whether another form of life, different from the carbon-based, water-based, and DNA-based form that we know, would have evolved if the above 'necessary' conditions had not been met.

[27] Gorshkov, V.V., Gorshkov, V.G., et al., 1999, ibid.

[28] Ward, P., and Brownlee, D., 2000, *Rare Earth: Why Complex Life Is Uncommon in the Universe*, Copernicus Press, New York.

By c.4400–4100 Mya the Earth had cooled sufficiently for the continental plates to form and for the oceans to condense from water vapour in the atmosphere. That is, conditions had become such that the evolution of carbon-based life was no longer impossible. And, in the event, life did evolve, presumably some time before the dates attributed to the oldest microfossils, namely c.3800 Mya. These newly emergent types of dissipative systems, the first unambiguous life forms, were the *prokaryotes* (for simplicity, I will include the related group *Archaea* under this heading). These simple single-celled bacteria captured energy either (a) by fermenting[29] the ocean's stock of energy-rich organic compounds which had been accumulating naturally on an anaerobic (oxygen-free) Earth or (b) by a process of *anaerobic photosynthesis*, i.e. sunlight energy triggers the release of chemical energy locked up in hydrogen sulphide (H_2S) and then, by combining hydrogen and atmospheric carbon dioxide, storing that energy 'in-house' as carbohydrate (c.3200 Mya). Molecular-scale waste products (metabolites) from fermentation and photosynthesis processes would have accumulated in the environment until lines of cells evolved that were able to use these wastes for their own metabolism.

With this plausible-enough development, the first fermentation-based trophic chains (food chains) emerged, bringing with them the cycling of various chemical elements.[30] These were the first *ecosystems*, i.e. dissipative systems characterised by the re-cycling of matter between genetically different groups of organisms. While there is some evidence of an additional process of aerobic (oxygen producing) photosynthesis (by *Cyanobacteria*) having evolved by, say, c.2700 Mya,[31] it was not until c.2200 Mya that oxygen levels in the atmosphere began to rise. The advent of aerobic photosynthesis, the process which uses light energy to split hydrogen dioxide (water) rather than hydrogen sulphide, allowed prokaryote populations to expand dramatically insofar as they were now independent of the ocean's relatively small feedstocks of hydrogen sulphide and fermentable organic molecules.

Just Another Global Cycle?

From the perspective of seeing the globe as a single dissipative system, the emergence and proliferation of life can be viewed as an elaboration of the geochemical pathways by which various sorts of molecules were already being cycled through the pre-biotic global system. In particular, since organisms are largely made of molecules containing atoms of carbon, hydrogen, oxygen and nitrogen, it is the dissipation of

[29] Fermentation is the energy-yielding anaerobic (i.e. no net oxidation) breakdown of a nutrient molecule, such as glucose.

[30] Guerrero, R, 1998, Crucial Crises in Biology: Life in the Deep Biosphere, *Internl. Microbiol.*, **1**, pp.285–294.

[31] Knoll, A., 2003, *Life on a Young Planet: The First Three Billion Years of Evolution on Earth*, Princeton University Press, New Jersey.

energy during the cycling of these, plus phosphorus, sulphur, iron and some 'trace' elements, which is of interest.

Since life has been described as 'just carbon chemistry', let us take the example of carbon. The main pre-biotic carbon cycle involved the movement of CO_2 from atmosphere to lithosphere (captured during rock weathering) and hydrosphere (by dissolution and precipitation) and then to the upper mantle (via subduction) from whence it was eventually returned to the atmosphere during volcanic activity. But, as suggested above, it can also be plausibly argued, from simple chemistry principles, that as the time of life's emergence approached, a wide range of carbon-containing (i.e. organic) molecules (e.g. polycyclic aromatic hydrocarbons, amino acids) could have been repeatedly synthesised and destroyed in the high-energy conditions of the then atmosphere and oceans, including perhaps the environs of undersea hydrothermal (hot water) vents. That is, carbon was being cycled on a molecular scale as well as a 'macro' scale. From a planetary perspective, fermentation of such compounds by prokaryotes is just a further way of dissipating the energy locked up in this stock of organic molecules.

Most sorts of complex molecules contain less free energy than is collectively contained in their components and so, in accord with the cosmic imperative (or the second law of thermodynamics if you prefer), they tend to form spontaneously when their components are all present and, once formed, tend to be stable. Any such molecule is said to be in a potential well or free-energy well, meaning that a pulse of externally applied *activation energy* is required to dissociate or break it up again. Such associative (coming together) reactions are called *exothermic* (heat producing, energy-releasing) and produce entropy in the form of heat. The stable products formed are building blocks for the static (cf. kinetic) structures produced, to some extent, by most of Earth's dissipative systems. Crustal minerals are a good example.

Other complex molecules contain more free energy than is collectively contained in their components and so do not form spontaneously. Their formation requires an *endothermic* (energy-absorbing) reaction, one in which the components are forced to bond together under the influence of an outside energy source. This can happen in various ways, none of which violate the second law—as would happen if there were no *net* production of entropy. For example, they can be formed directly in high-temperature high-energy environments. Thus, in the absence of an atmospheric ozone layer, ultraviolet radiation would have been intense in pre-biotic times. Or they can be formed with the help of catalyst molecules which allow the required energy to be provided in several small pulses rather than one large pulse. Or they can be formed in environments where the outside energy required to force the components together is drawn from a 'coupled' exothermic reaction proceeding in parallel with the 'thermodynamically forbidden' endothermic reaction. Here, entropy lost during the endothermic reaction has to be less than entropy gained during the exothermic reaction if the coupled reaction is to proceed. *Coupling* is the way CO_2 is converted into organic compounds in plants. It should be noted that knowing a reaction to be thermodynamically favoured says nothing about the rate at which that reaction will proceed; that is the province of *chemical kinetics*.

Once formed, such molecules tend to dissociate spontaneously or, alternatively, when energised sufficiently by a pulse of activation energy, can react with certain other molecules (commonly oxygen), to form low-energy products (commonly oxides). Most reactions which proceed spontaneously after being 'kick-started' do so because the reaction itself generates the very conditions which allow the reaction to continue, e.g. a burning candle produces sufficient heat to vaporise more wax and raise its temperature to ignition point.

To the extent that complex high-energy molecules were being formed and broken down into component atoms or smaller molecules, these components were being cycled and were as much part, a small part though, of pre-biotic (pre-life) global cycling as other physico-chemical processes. Most importantly, to the extent that complex and high-energy molecules were being formed faster than they were being destroyed, the sort of rich molecular 'soup' from which, it is argued, life could have emerged was being accumulated. Remember that the pre-biotic Earth had a reducing atmosphere—hydrogen-rich and oxygen-poor. The Earth had evolved to contain an environment in which a new sort of self-organising system could emerge. The evolutionary stage was being set for a self-organised transition from chemistry to biochemistry and from geochemistry to biogeochemistry.

Biogeochemical Cycles

Biogeochemistry is the study of how biological and geochemical processes affect the global-scale cycling of chemical elements. We are learning that there are few large-scale chemical reactions on Earth that are not somehow affected, promoted or catalysed by living organisms. And that the physical, chemical and biological processes responsible for the composition of the atmosphere, oceans, soils and sediments are intricately linked. The overall reason for this, as we shall see, is that living organisms capture and store energy—the basic process in the biological cycle—in ways that allow it to be subsequently used to overcome thermodynamic energy barriers and to activate reactions. After life appeared, the Earth's geochemical cycles could begin to diversify into new pathways, including more rapid weathering,[32] and did so to the extent that this increased global entropy production.

Biogeochemists can reconstruct the history of the great carbon reservoirs in the crust of the Earth, the limestones and the coal deposits, as well as the distribution of nitrate and phosphate in the ocean. They find explanation for the composition of the atmosphere (nitrogen, oxygen, trace gases, etc.) in bacterial action and photosynthesis. And they record the changes over evolutionary time in the fluxes of materials between the biosphere (meaning all of life), lithosphere, atmosphere and hydrosphere, e.g. the decay of organic matter in soils and the resulting release of

[32] Minik T., Rosing, D., et al., 2006, The Rise of Continents—An Essay on the Geologic Consequences of Photosynthesis, *Palaeogeography, Palaeoclimatology, Palaeoecology*, **232**, pp.99–113.

gases into the air; the uptake of oxygen by the ocean and its utilisation at depth; and the leaching of nutrients from the soil and their transport into the sea.

The increase in atmospheric oxygen since life began suggests a corresponding increase in Earth's rate of entropy production and a progressive reduction in the planet's entropy content. Insofar as a more ordered system means one processing more energy, the latter two go together. Chemically speaking, atmospheric and oceanic conditions have changed from reducing (3.8 Ga) to mildly oxidative (2 Ga) to strongly oxidative today.

More broadly, biogeochemistry views the mix of dynamic systems near the surface of Earth as collectively self-maintaining—the outputs ('waste' products) from one sphere become the inputs for another. For example, as the ocean takes up oxygen (the waste product of plants) it releases an equivalent amount of carbon dioxide (the waste product of decay but the stuff of growth for plants). Overall, it seems clear that, for a long time, the Earth has been a dissipative self-organising system in a (slowly changing) dynamic equilibrium. Its behaviour suggests a system following the trajectory of a chaotic attractor or, very approximately, and depending on one's time frame, a system in a steady state where, plausibly, entropy is being produced at a maximum rate. As well as its roughly constant surface temperature, the Earth is stable with respect to atmospheric and oceanic composition and crustal acidity and chemical composition. On the other hand, while still small in energy processing terms, relative to Earth's other global dissipative systems, life has experienced great changes in energy throughput and standing biomass—the mass of Earth's biota (all its organisms) has increased perhaps 20-fold in the 600 myrs since the Cambrian period.[33]

While many of the feedback processes which maintain this stability are biological, this does not make the Earth a homeostatic living organism as posited by the 'strong' version of James Lovelock's 'Gaia hypothesis'.[34] For example, living organisms have a tendency to replicate. It suffices to say that life contributes massively to creating and maintaining environmental conditions under which it can and has evolved to survive.

Coevolution of the Earth and Its Ecosystems

Just as it is useful to expand the use of the term *evolution* beyond its familiar biological context, to encompass temporal changes in the atmosphere, the lithosphere and the sociosphere, it is useful to use the term *coevolution* to describe, not just the way in which biological species evolve in response to changing *selection pressures* from other species, but to encompass the variety of ways in which evolution in one dissipative system triggers evolutionary change in (a) another part of the same

[33] Wesley, J.P., 1989, Life and Thermodynamic Ordering of the Earth's Surface, *Evolutionary Theory*, **9**, pp.45–56.

[34] Lovelock, J.,1995, *The Ages of Gaia: A Biography of Our Living Earth*, Norton, New York.

system or (b) in another dissipative system. Thus, coevolution also includes behavioural and genetic responses to changes in the abiotic (non-biological) environment. For example, animals adapting to a cooling climate also, through their adaptive behaviour (e.g. digging shelters), reorganise the abiotic environment, at least locally—a process called *niche construction*.[35] From this perspective, there are two causal processes in evolution—natural selection of the organism by the niche and ongoing construction of the niche by the organism. From their parents, organisms receive both a genetic inheritance and an environmental inheritance. And, as earlier noted, coevolution also includes physical interdependencies such as the interaction of the geological and meteorological cycles.

On early Earth, life and the physical environment coevolved in several ways which led, first, to accelerated global cooling and, second, towards an equilibrium global temperature which was also optimal for the rate of production of entropy by the biosphere.[36] One of these was the way in which marine plankton (drifting microorganisms) trigger extensive cloud formation which leads the Earth to cool by reflecting sunlight more effectively than the ocean's surface. This surprising effect is caused by the release of *dimethyl sulphide* molecules to the atmosphere by plankton populations. Derivatives of these molecules become nuclei around which water vapour condenses to form clouds. The coevolutionary feedback thereafter would have been an increased selection pressure on subsequent generations of plankton to adapt to the cooler temperatures, leading to higher levels of plankton, and even cooler temperatures!

A second form of large-scale coevolution, once continents had formed to a significant extent, might have been an amplification of rock weathering by bacterial action, leading to cooling associated with the removal of heat-trapping CO_2 from the atmosphere. At a later date, the biosphere-atmosphere cycle became connected to the rock cycle by the roots of plants. Roots deliver CO_2 deep into soil where it combines with water to make carbonic acid which attacks calcium silicate in rock to yield calcium carbonate and clay. The calcium carbonate can then be transported in solution to the oceans where it can be dumped out as limestone. Thus the rate and density at which plant roots penetrate soil is a major control of weathering rates and of the rate of CO_2 removal from the atmosphere.[37]

The ideas of coevolution and evolution are important tools for imposing meaning (connections, generalisations, synopses) on the bewildering kaleidoscope of ceaseless change in the physical Earth and its ecosystems once the Earth cooled to the point where life could emerge. For the remainder of this chapter, my task is to provide a plausible-enough, albeit drastically condensed, version of this story to serve as a foundation for appreciating the evolution of modern humans and their societies (Chaps. 2–4).

[35] Sterelny, K., 2005, Made by Each Other: Organisms and their Environment, *Biology and Philosophy,* **20,** pp.20–36.

[36] Staley, M, 2002, Darwinian Selection Leads to Gaia, *J. Theor. Biol.*, **218**, pp.35–46.

[37] Falkowski, P.G., Fenchel, T.F., and Delong, F., 2008, The Microbial Engines that Drive Earth's Biogeochemical Cycles, *Science*, **320**, No. 5879, pp.1034–1039.

Archean Eon (3.8–2.5 Ga) Emergence of Life and Genes

There is no standard model for the emergence of life as there is for cosmology**.** The chain(s) of spontaneous causes and effects and staging points which resulted in the appearance and proliferation of free-floating single-cell prokaryotic organisms of various 'species' in Earth's hot (90°C) and organically rich Archean seas remains a matter for speculation and scientific debate. Notwithstanding, because of the presence of the same core biochemical pathways in all life forms, the idea that all life forms had a single common ancestor is accepted. For present purposes, we can also accept as a working hypothesis that the first recognisable prokaryotic cells were 'self-assembled' from various pre-existing components, including bacteria-sized *protocells*—vesicles with an aqueous core enclosed by a semi-permeable membrane—and self-replicating macromolecules of (plausibly) RNA (ribonucleic acid).

This is not the place to dissect either this or alternative hypotheses,[38] but it is worth noting that some version of RNA is found in all living and fossil cells, from the earliest bacteria to the human brain. The supposition is that once RNA had emerged, it was extraordinarily successful in assisting in the survival and replication of any protocell it occupied. In particular, it can be argued that the RNA molecule eventually catalysed the formation of the self-replicating DNA (deoxyribonucleic acid) molecule, this being the polymer (chain of molecules) which, in most forms of life, carries the templates, the *genes*, which guide the assembly of all the structural and enzyme proteins that cells have come to need to survive reasonably well.[39] Certainly it has been shown that some RNA sequences have catalytic capabilities and can act as *polymerases*, these being enzymes that can assemble a strand of RNA from its component nucleotides (monomers). Which is what self-replication means. Conceptually, any part of a self-replicating molecule which also catalyses the production of any sort of survival-enhancing molecule is, in effect, a gene.

Based on available evidence, a reasonable conjecture is that *liposomes*, bacteria-sized vesicles enclosed by phospholipid membranes, were naturally present in the pre-biotic seas and that cyclical systems of replicating and catalytic macromolecules[40] could have become encapsulated in such vesicles. Membranes constructed from the 'right' lipids allow ions from the external environment to permeate into the protocell at a sufficient rate to provide a supply of monomers for the vesicle's enzymes, the result being that nucleic acids accumulate in the vesicles, safe from dispersion. The physical chemistry of liposome membranes is also such as to control the ingestion of various nutrient molecules from the environment.

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[38] Segré, D., and Lancet, D., 2000, Composing Life, *EMBO Reports* **1** (3), pp.217–222.

[39] RNA would have been replaced by DNA because the latter is more stable, i.e. able to support longer genomes and, with that, more versatile organisms. It is possible that there was a phase, early in biological evolution, when the prokaryote genome (its pool of genes) consisted of unlinked RNA genes, each separately replicated.

[40] In such systems, called *autocatalytic sets*, every molecule is either 'feedstock' from the environment or synthesised by reactions catalysed by species within the system.

Then and now, prokaryotes reproduced through *asexual reproduction*, usually by splitting in two when they had grown to a critical size at which they became unstable.[41] Initially, each daughter cell contained a random share of the parent cell's genetic material, a share which would not necessarily be adequate to ensure the daughter cell's viability. Genetic recombination and exchange between organisms probably occurred, but in the form of *'horizontal' gene transfer*, e.g. when two small prokaryotes collide and merge. Indeed, this may have been the principal form of evolution before the 'invention' of *'vertical' gene transfer* in which a copy of the parent's DNA or RNA goes to each daughter cell. There may even have been a common global gene pool and a core global gene set[42] before vertical gene transfer allowed the early prokaryotes to evolve into different genetic strains, some of which reproduced more abundantly than others, depending on the characteristics of the ocean niche or habitat being occupied, e.g. its temperature, salinity, light regime, prevailing currents and available nutrients.[43] That is, natural selection, as first postulated by Darwin and Wallace, had begun.

Mutations were, presumably, a further source of genetic variability in the early prokaryotes. Sometimes, when self-replicating, a molecule can experience a copying mistake or mutation which, without destroying the molecule's tendency to self-replicate, does give it a capacity to catalyse the production of a new type of enzyme or protein which, in the right environment, improves the survival prospects of that type of prokaryote. Populations of cells that have successfully incorporated a new mutation will tend to expand relative to other populations.

Respiration is the process by which cells convert the energy in the chemical bonds of ingested and/or photosynthesised food molecules (e.g. glucose, stored starch) into ATP (adenosine triphosphate), a multi-purpose energy-storing molecule that prokaryote cells use to grow and maintain themselves. For example, the phosphorylation by ATP of amino acids and nucleotides primes (energises) them for polymerization (chaining) into polypeptides (short proteins) and polynucleotides.[44]

At some stage, around the end of the Archean perhaps, the respiration process in prokaryotes underwent a giant evolutionary leap—from being anaerobic to being aerobic: It may have been in the cyanobacteria, the group which first (?) evolved aerobic photosynthesis, that a capacity emerged for incorporating oxygen (the by-product of aerobic photosynthesis) into a complex series of reactions which

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[41] Swenson, R., and Turvey, M, 1991, ibid.

[42] Although there is enormous genetic diversity in nature, there remains a relatively stable set of core genes coding for the major redox reactions essential for life and biogeochemical cycles. Falkowski, Fenchel and Delong (ibid., 2008) argue that this set is so widespread in microorganisms that if all higher life forms were to disappear, life would simply 'reboot' from the core microbial gene set.

[43] Woese, C.R., 2002, On the Evolution of Cells, *PNAS,* **99** (13), pp.8742–8747.

[44] Weber, B.H., 1998, Emergence of Life and Biological Selection from the Perspective of Complex Systems Dynamics, In G. Van de Vijver, S.N. Salthe and M. Delpos (Eds.), Evolutionary Systems: Biological and Epistemological Perspectives on Selection and Self-Organization, Dordrecht: Kluwer, 1998, pp.59–66.

produced far more ATP per food molecule than anaerobic respiration (each molecule of oxygen also produced a molecule of CO_2). It was the acquisition of aerobic respiration and aerobic photosynthesis which ultimately provided prokaryote populations with the abundant supplies of food and energy that would support the eventual evolution of *eukaryotes*, the larger and more complex unicellular (single cell) organisms from which all multicellular plants and animals would eventually evolve.

The end of the Archean was also the time when cumulative photosynthetic activity was beginning to lift free-oxygen levels in the oceans and the atmosphere and, in the process, destroying essential enzyme systems in many types of anaerobic organisms. In oceans and freshwater lakes, until about 2.5 Ga, dissolved oxygen was triggering the precipitation of abundantly available iron as the oxides which today constitute the world's iron ore deposits. In the atmosphere, until about 2.4 Ga, most free oxygen went towards oxidising volcanic hydrogen sulphide and methane. Thereafter, over about 100 million years, atmospheric oxygen levels rose to about 2%, the beginning of a massive shift to the highly oxidising conditions (21%) that prevail today.[45]

Proterozoic Eon (2500–542 Mya) Eukaryotes, Colonies, Sex, Multicellularity

The rise in atmospheric oxygen around the beginning of the Proterozoic can be further explained, perhaps, by the 'supercontinent effect'. An elegant paper by Ian Campbell and Charlotte Allen in 2008 shows that, since the Archean, atmospheric oxygen has risen in steps or jumps and that these co-occur with amalgamations of Earth's land masses into supercontinents.[46] They suggest that the continent–continent collisions required to form supercontinents produced supermountains (sic) which eroded particularly quickly, flushing CO_2 from the atmosphere and releasing large quantities of growth-limiting nutrients such as iron and phosphorus into the oceans. This led, each time, to a proliferation of algae and cyanobacteria, and a marked increase in photosynthesis, and photosynthetically produced oxygen. Conversely, enhanced sedimentation during these periods promoted the burial of a high fraction of iron sulphide and organically produced carbon, thus blocking their reaction with free oxygen, and leading to sustained increases in atmospheric oxygen and decreases in atmospheric CO_2.

Snowball Earth is a vivid metaphor for a world where the oceans are deep-frozen and glaciation extends to the equator. It is also a canonical example of coevolution of the biosphere, the atmosphere and the hydrosphere. As noted earlier, the three occasions when this has happened in Earth's history have been attributed to a

[45] Des Marais, D.J., 1997, Long-term Evolution of the Biogeochemical Carbon Cycle, In J. F. Banfield and K. H. Nielsen, (Eds.), *Geomicrobiology: Interaction between Microbes and Minerals,* Mineralogical Society of America, Washington, D.C., pp.429–448.

[46] Campbell, I.H. and Allen, C.M., 2008, ibid.

positive feedback process powerful enough to flip the global dissipative system from one 'basin of attraction' to another, a process initiated by a sufficiently large loss of 'Earth-warming' greenhouse gases from the atmosphere. For the Snowball Earth event at the beginning of the Proterozoic (2.3 Ga) it is now thought that methane was the lost greenhouse gas, stripped from the atmosphere in the oxidising conditions created by the build-up of atmospheric oxygen generated during photosynthesis.[47] The fossil record covering the Snowball events at 750 and 600 Mya suggests that these did not affect the diversity and distribution of (unicellular) life[48] and we might hypothesise the same for the earlier event.

The name Proterozoic, from the Greek 'earlier life', denotes a period preceding the first abundant complex (sic) life on Earth, where 'complex' is taken to mean hard-bodied multicellular organisms. Up to a billion years, yes, a 1,000 megayears, of the Proterozoic Eon had to pass before eukaryotes, large single-celled organisms containing a membrane-enclosed *nucleus* and other novel structures, particularly *mitochondria* and *chloroplasts*, appeared in numbers alongside prokaryotes in marine ecosystems.

Meanwhile, prokaryotes continued to evolve by natural selection. While continuing to reproduce asexually, many evolved to have their genetic material, their DNA as it had become, organised into a single circular chromosome containing a single copy of each gene and a little repetitive ('junk') DNA. Some types (e.g. spirochaetes) developed *flagellae* (propeller tendrils) and became *motile*, i.e. able to move towards food or more equable environmental conditions. This obligate linking of a motor (movement) response to an environmental stimulus has kept re-appearing in increasingly complex ways through subsequent evolutionary history, e.g. instinctive behaviour in animals and human agency.

Nitrogen, an essential component of the proteins, etc. which all life forms must synthesise, was present in quantity in the Proterozoic atmosphere but not in a form which microorganisms could use. Sometime after the first Snowball Earth event, perhaps 2.2 Ga, prokaryotes, probably cyanobacteria, evolved a capacity to 'fix' atmospheric nitrogen into biologically available forms—such as nitrate and ammonia—and thereby decreased their dependence on the supply of these nutrients which had hitherto been produced as by-products of lightning discharges.

Notwithstanding, this development may have been much earlier. There is evidence that, early in the Archean, cyanobacteria evolved a capacity to form multicellular 'filaments' or strings of connected cells, some of which fixed nitrogen and were anaerobes while others were aerobic photosynthesisers.[49] If this is correct, cyanobacteria were pioneers of not just multicellularity (see below), but also of the use of differentiated cells to carry out specialist functions.

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[47] Kasting, J.F., 2005, Methane and Climate during the Precambrian Era, *Precambrian Research*, **137**, pp.119–129.

[48] Corsetti, F., 2006, The Biotic Response to Neoproterozoic Snowball Earth, *Palaeogeography, Palaeoclimatology, Palaeoecology*, **232** (2–4), pp.114–130.

[49] Bonner, J.T., 1998, The Origins of Multicellularity, *Integrative Biol.,* **1**, pp.27–36.

The evolution of biological nitrogen fixation, an energy-intensive process, suggests that, at some point, the demand for fixed nitrogen exceeded the supply from abiotic sources; but the timing and causes of the emergence of biological nitrogen fixation remain unclear. Both the nitrogen 'drought' and life's nitrogen-fixing adaptive response may have been triggered by the unmet demands of a growing population of microorganisms tied to a trickling supply of fixed nitrogen, or by declining production of fixed nitrogen in an atmosphere where CO_2 levels were declining and oxygen levels rising only slowly.[50] The point here is that the chemical reaction which fixes nitrogen in the atmosphere requires the splitting of a CO_2 molecule at high temperature. And, illustrating coevolution once again, the reasons CO_2 was being removed from the atmosphere at the time included its increasing use in photosynthesis and its increasing role in the weathering of freshly exposed continental rocks. Rock weathering, accelerated by bacterial secretions (particularly from cyanobacteria) perhaps, was already producing the *soils* which, in time, would allow plants to migrate from lakes and oceans and colonise the land.[51]

Creation of a life-protecting ozone layer in the (upper) atmosphere was another far-reaching consequence of the build-up of free oxygen. Ozone, a three-atom variant of the oxygen molecule, absorbs high-energy ultraviolet radiation which would otherwise reach Earth's surface and destroy any biological molecules encountered. It is synthesised from oxygen by the very photons it dissipates. Without an ozone layer it is doubtful if terrestrial (land-based) multicellular life could ever have evolved. Putting this another way, coevolution between aerobic photosynthesisers and the atmosphere (and the lithosphere) had created a habitable niche, a platform, for a wide range of evolutionary possibilities.

It would seem that cyanobacteria (cyan means 'sickly green') have played a leading role in the evolution of each of the three most important adaptations by prokaryotes to the Archean and early Proterozoic worlds: aerobic photosynthesis, aerobic respiration and a capacity to fix atmospheric nitrogen. Introducing a term which will presently prove useful for understanding human cultural evolution, these adaptations are, metaphorically speaking, *technologies*—'recipes' which are perceived as contributing to the persistence of the system using them.

Even more, cyanobacteria have always been important *symbionts* (community members) within the *biofilm* and *microbial-mat communities* into which, from earliest times, most microorganisms have commonly self-organised. *Stromatolites* are colonies of, predominantly, cyanobacteria which form macroscopic mats by trapping passing debris in slime secretions and cementing it in place with a precipitate of calcium carbonate. Biofilms are formed when large numbers of single-celled microorganisms live together in a matrix of slime (mucilage) which protects the cells within it while allowing them to communicate through biochemical 'signals'

[50]Navarro-González, R., McKay, C.P., and Nna Mvondo, D., 2001, A Possible Nitrogen Crisis for Archaean Life due to Reduced Nitrogen Fixation by Lightning, *Nature* **412**, pp.61–64.

[51]Retallack, G.J., 1990, *Soils of the Past: An Introduction to Paleopedology,* Unwin-Hyman, Boston.

and to obtain nutrients by diffusion along inbuilt water channels. While some organisms form single-species biofilms, most such films are ecosystems in which various species perform specialised biochemical functions.

Slime is a brilliant ‘social’ technology. It is sticky enough to anchor a community to something solid, protecting it from dispersal, keeping members close enough to interact (e.g. exchange genes) and develop a collective organisation; the first truly multicellular organisms may well have emerged in biofilm or mat communities. Slime acts as a barrier to predators and as a buffer against sudden environmental changes, in salinity for instance. Indeed, because slime also protects against dehydration, microbial colonies in biofilms and mats may well have been the first life forms, long before plants, to live on land; in tidal zones perhaps.

Enter Eukaryotes

Convinced by some bold thinking from Lynn Margulis (formerly Sagan) and her predecessors,[52] it is generally accepted that unicellular eukaryotes did not evolve by natural selection alone but also by *endosymbiosis*, a concurrent process of self-organisation in which several prokaryotic ‘partners’ came together to form a minute ecosystem within a single cell. *Symbiosis* means ‘organisms living together’ and *endosymbiosis* implies one organism living inside the body of another. Specifically, the mitochondria found in all eukaryotic cells and the chloroplasts found in photosynthetic eukaryotic cells are similar in a number of ways to certain aerobic proteobacteria and cyanobacteria respectively. Even the enclosed nucleus (karyon) that characterises all eukaryotic cells may have evolved in this way. It seems plausible that a host cell could have engulfed (enfolded) both types and that, in time, a close symbiotic relationship, including gene exchange, could have developed.

It was suggested earlier that whenever a radically new type of dissipative system emerges, it processes free energy/produces entropy at a higher rate per gram of its constituent matter than the systems (platforms) from which it emerged. The emergence of life conforms to this principle too. Thus, primitive unicellular organisms have a higher *free energy rate density* than the pre-biotic oceans and eukaryotes and multicelled organisms process free energy at a higher specific rate than prokaryotes.

Some 1.2–0.9 Ga, eukaryotes began to proliferate and complexify, lifted perhaps by their capacity to exploit Earth’s rising oxygen levels (see below) to power the emergence of new energy-intensive behaviours, intra-cellular structures, molecular-scale processes, etc. Most importantly, by the late Proterozoic many types of eukaryotes were able to reproduce sexually as well as asexually, a development which has been authoritatively called one of the ‘major transitions in evolution’.[53]

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[52] Sagan, L., 1967, On the Origin of Mitosing Cells, *J. Theor. Biol.,* **14** (3), pp.255–274.

[53] Maynard Smith, J., and Szathmáry, E., 1997, The Major Transitions in Evolution, Oxford University Press, New York.

In asexual reproduction, one parent cell divides into two daughter cells, two 'clones' which each carry the same genetic information (genes) as the parent; the parent cell's genetic information is first replicated and, thereafter, one replicate is assigned to each daughter cell. The process is rather different between prokaryotes, where it is called *binary fission,* and eukaryotes, where it is called *mitosis*, but the result is the same.

Unlike prokaryotes which evolved to hold their genetic information in a single circular chromosome, eukaryotes evolved to hold their genetic information (genotype) in multiple linear (threadlike) chromosomes inside a membrane-bound nucleus. In sexual reproduction, each 'daughter' cell is bequeathed a full complement of essential genetic information, half coming from each of two 'parent' cells. However, because a daughter-cell's parents are always genetically a bit different from each other, no daughter cell is quite the same as either parent. This process of *genetic recombination* is a continuing reliable source of moderate genetic variability in populations of eukaryotic microorganisms (cf. intermittent gene mutation). Natural selection follows, i.e. genotypes (and hence genes) which reproduce more successfully in the prevailing environment become more common; the composition of the population's combined gene pool changes from generation to generation as the population adapts to (learns to better survive in) its environment. Observe that it is the capacity of sexual reproduction to speed up the rate at which populations adapt to environmental change that makes sex such a powerful technology. After all, populations (species, say) go extinct when rate of environmental change exceeds their capacity to adapt! Obversely, sexual reproduction prunes 'out-of-date' genes from a population's gene pool.[54]

Sexual reproduction in unicellular eukaryotes has taken several paths. As one example, consider *Chlamydomonas,* a green alga. This organism is *haploid* for most of its life cycle, meaning that, like egg and sperm cells in humans, it has just one copy of each chromosome (a *diploid* cell has two copies of each chromosome). Every cell can be described as either a 'plus mating type' or a 'minus mating type'. When a plus and a minus meet, their cell contents mix and their nuclei fuse to form a single diploid *zygote,* this being the term for a cell formed when two *gametes* or 'sex cells' come together, whether in unicells or 'higher' forms of life. This zygote, the only diploid cell in the life cycle, eventually undergoes meiotic divisions or *meiosis,* to form four new (haploid) *Chlamydomonas* cells. This is true sexual reproduction because (a) chromosomes are reassorted during the meiotic divisions and (b) new individuals are formed. Note that in this early type of sexual reproduction, the gametes are morphologically identical; the distinction between sperm and egg has not yet been made. Nor, being unicellular, can there be a distinction between body (*somatic*) cells and specialist sex cells.

Another particularly important way in which unicellular eukaryotes continued to evolve through the Proterozoic was to get bigger. Eukaryote cells are typically some ten times the size of prokaryote cells and necessarily have a smaller surface area per unit volume than prokaryotes. This reduces the eukaryote cell's ability, on a per

[54] http://en.wikipedia.org/wiki/Evolution_of_sexual_reproduction (Accessed 29 May 2010).

volume basis, to exchange materials with the environment, and hence, ultimately, limits their maximum possible cell size. This is because, given an underlying biochemical similarity, all forms of living matter have roughly similar energy requirements per unit mass (volume) for their maintenance. It follows that, in parallel with growing body size, eukaryotes would have needed to improve their strategies for acquiring energy from the environment, as well as their cell-repair and regulatory technologies, in order to maintain the rate of energy supply to their operations at the required level.[55] One estimate is that it took 60 major innovations, including thousands of new genes, to convert prokaryotes to eukaryotes.[56]

To take a pervasive example, some eukaryotes became sufficiently large, flexible and mobile enough to be able to find and 'swallow' prokaryotes for food, digesting them internally rather than externally as prokaryotes do, i.e. by secreting digestive enzymes into the environment to break food particles into molecules small enough to diffuse through the cell wall. Internal digestion was not only more efficient (calories acquired per calorie expended) than external digestion, it freed these 'protoanimals' to become the first 'predators', able to spend more time searching for food. We have here the beginnings of a *trophic strategy*—actively seeking prey for food—which has remained important ever since for many *heterotrophs*, i.e. organisms such as animals and fungi which, unlike *autotrophs*, cannot synthesise their own food. To take a remarkable example, some heterotrophs evolved a capacity to detect and home-in on the type of radiation absorbed by autotrophs during photosynthesis!

Other heterotrophs, 'filter feeders', developed feeding strategies which relied, not on being mobile, but on capturing prokaryotes delivered to them in passing currents (a form of 'energy subsidy') or in currents created by the vibrating of the cell's own *cilia*, these being hair-like protuberances from the cell surface. Photosynthesising *algae*, the unicellular eukaryotic ancestors of plants, did not have the same need for mobility and flexibility to ensure their food supplies, but some nevertheless benefited from being able to propel themselves towards sunlight and away from salty, acid, etc. conditions.

How, more generally, do we explain the emergence and multiplication of eukaryotes in a world that had been dominated for two billion or more years by prokaryotes and which, in terms of their share of the world's biomass, still dominate? The short answer is 'size and sex'.

Increased cell size was the technology which allowed eukaryotes to exploit the unoccupied *ecological niche* created by the proliferation of prokaryotes. The chemical energy locked up in prokaryote populations could be degraded more rapidly inside eukaryotes than by death and decomposition. The seas and fresh waters of the late Proterozoic were certainly ecosystems, but not ones where prokaryotes and eukaryotes were competing for the same resources; nor ones where eukaryote predators were numerous enough to drive prokaryote numbers down in any significant way.

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[55] Makarieva, A.M., Gorshkov, V.G., and Bai-Lian, L., 2005, Energetics of the Smallest: Do Bacteria Breathe at the Same Rate as Whales? *Proc. Biol. Sci.* **272** (1577), pp. 2219–2224.

[56] Cavalier-Smith, T., 2009, Predation and Eukaryote Cell Origins: A Coevolutionary Perspective, The International Journal of Biochemistry & Cell Biology, **41**, pp. 307–322.

These were also ecosystems where *viruses*, a third form of life, were already important community members. A *virus* is a tiny microorganism consisting only of a DNA or RNA strand with a protein coat. A virus can only replicate by entering a host cell, either a prokaryote or a eukaryote, and coopting its genetic system into replicating the invader's DNA or RNA, i.e. into making another generation of viruses. This may or may not kill the host cell. Contemporary research suggests that it has long been common for invading viruses to be 'endogenised', i.e. incorporated permanently into the host cell's genome. Such relationships are better seen as symbiotic rather than parasitic: while an endogenised virus gains by being assured of replication, its presence also seems to protect the host from attack by virus strains similar to itself. Second, when dissimilar genomes do manage to combine in a viable way, the evolutionary possibilities are greatly expanded.[57]

Multicellularity

Once established, complete with an efficient system of aerobic respiration (inside mitochondria), a disciplined system of sexual reproduction gave the eukaryote cell an enhanced capacity to (further) evolve internal structures (e.g. membranes, cytoskeletal scaffolding), which provided sites and compartments where various metabolic processes (e.g. synthesising particular proteins) could be localised (i.e. protected from dispersion) and separated from each other. Acquiring a capacity to isolate different, sometimes incompatible, operations inside a single 'multi-functional' unicell may have been a step on the way to the future development of special-purpose cells (e.g. for gamete production, for nutrient storage, for sensing food, for locomotion, for protection) in multicellular eukaryotes. Indeed, by the time the first multicellular eukaryotes appeared in the paleontological record, some 1.2 Bya, the evolution of the modern cell in a form which has persisted till the present day, albeit in some hundreds of specialised variations, was largely complete. A platform on which all subsequent multicellular life—plants, animals, fungi—could develop had been established.

Metaphorically, strains of eukaryotic and prokaryotic unicells have relied on somewhat contrasting 'strategies' for surviving spatial variations and temporal fluctuations/shifts in their external environments. Prokaryote strains have relied for survival on, firstly, *culturability*, i.e. a population's capacity to multiply rapidly and regenerate quickly after near-destruction.[58] Being small and simple, prokaryotes have a shorter generation time and a higher rate of evolution than eukaryotes, advantages they would lose if they evolved to be larger. When environmental conditions deteriorate at a particular time or place, the local prokaryote populations simply die off or form hard-cased *cysts,* these being cells which remain inactive until conditions improve. Having numerous widely distributed populations makes it unlikely that all members of a strain will be wiped out simultaneously.

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[57] Ryan, F., 2009, V*irolution*, Harper Collins, London.

[58] Conrad, M., 1983, *Adaptability: The Significance of Variability from Molecule to Ecosystem*, Plenum Press, New York.

By comparison, the basic eukaryote strategy for surviving environmental fluctuations has been one of slowly increasing *relative autonomy*,[59] a strategy based on trading-off culturability and opportunistic growth at the population level for better survival prospects at the cell level. That is, a complex eukaryote cell is less likely than a simple prokaryote cell to be incapacitated by fluctuations in the external environment; and eukaryote populations were probably more stable, numerically, than prokaryote populations. Nonetheless, it would be wrong to regard one strategy as 'better' than the other, and neither strategy is 'conscious' of course.

Relative autonomy is achieved in several ways. Simply because they are larger, environmental impacts are transmitted more slowly through eukaryote cells, a 'buffering' effect which smooths out changes caused by environmental fluctuations and allows time for a cell's homeostatic (counteracting) responses to kick in. Buffering is further increased to the extent that cell operations are compartmentalised in internal structures. Also, at the cost of being dependent on a larger energy flow, a larger cell provided space and sites for the evolution of other protective strategies such as storing food reserves, improving mobility, detoxifying poisonous chemicals, excreting wastes and manufacturing protective toxins.

Multicelled eukaryotic organisms, the next great transition in biological evolution after sexual reproduction, evolved independently many times and in many *phyla* (broad taxonomic categories of cell types based on similarity of body plan) of unicells but only a few went on to become plants, animals or fungi. However, being soft-bodied, the first multicellular eukaryotes do not appear in the paleontologists' record of fossilised shells, skeletons and other hard body parts. A somewhat puzzling exception is an *Ediacaran* fauna of animals comparable to jellyfish, polyps and worms which, while present in late Proterozoic sediments (700–545 Mya), appear unrelated to the plethora of clearly visible fossil types which 'suddenly' appeared 545 Mya at the beginning of the Cambrian period and the Phanerozoic eon.

While a detailed series of steps in the evolution of multicellularity cannot be presented with confidence, it is clear that there were several paths that could have been taken and that several platforms and plausible pre-adaptations had already evolved at least once and were 'in waiting' for this development. As noted earlier, some prokaryotes, notably cyanobacteria, had long achieved simple multicellular forms (e.g. cells connected in one-dimensional chains) and some differentiation of cell function (e.g. photosynthesising cells versus nitrogen-fixing cells). So, indicatively, it was clearly possible to evolve surface molecules which allowed cells to adhere (interlock) rather than remain separate.

The technologies which allow genetically identical cells to perform different metabolic tasks are based on activating or inactivating (silencing) particular genes in some cells but not others. Initially this may have been achieved by the evolution of hormones or other 'signalling molecules' able to diffuse between neighbouring cells. Later in the evolutionary story, as studied in the science of *epigenetics,* all cells with a particular function (e.g. liver cells) may have inherited, not only a

[59]Rosslenbroich, B., 2009, The Theory of Increasing Autonomy in Evolution: A Proposal for Understanding Macroevolutionary Innovations, *Biol. Philos*. **24**, pp.623–644.

genome (set of genes), but an *epigenome*, a set of *epigenetic marks*, these being groups of molecules attached to particular genes, allowing them to be turned 'on' or 'off'.[60] While epigenetic marks can and are routinely inherited, along with the genes they are marking, they can also be modified, or even removed, by exposure to environmental or other internal stimuli. It is becoming increasingly clear that the technology of 'epigenetic silencing' has long functioned as a powerful and subtle complement to genetic information in providing guidance for life's self-organising physical/chemical/biological processes, notably its protein synthesis mechanisms.[61]

Meanwhile, it is reasonable to assume that the first multicellular organisms did not have specialised cells with different functions and that they arose within colonies of unicells, e.g. biofilms or microbial mats, where community members were already enjoying clear benefits (nutrition, protection, etc.) from living in close association. It also seems plausible that all cells in the first multicellular organisms would need to be genetically identical, i.e. cloned from a single cell. This would ensure all of the organism's cells responding in the same way to any environmental stimulus or internally generated chemical signal, i.e. there would be no 'rogue' or 'cancer-like' cells in the organism. Under this 'colonial' theory, a multicell can be regarded as a symbiosis between organisms of one 'species'.

What were the adaptive benefits of such a simple form of multicellularity? By reason of size alone, the first multicells would perhaps have been less vulnerable to predation than their predecessors. Conversely, if they were heterotrophs, they would have had access to larger prey. Those heterotrophs that were motile, and able to synchronise the wavings of their flagellae through chemical signals between cells, would have been able to move faster and further in search of prey. Those that were stationary autotrophs (photosynthesisers) would have been able to better resist being swept away and to capture more light energy by extending themselves (e.g. as branching filaments) into the surrounding environment. Thus, the earliest multicellular organisms, *protoplants* and *protoanimals*, were probably already using the two feeding strategies—extension into the environment and selectively searching the environment—that plants and animals, respectively, have continued to use ever since.

How did the first multicellular organisms reproduce? Perhaps they just broke into fragments when they reached an unstable size, with each fragment or bud resuming growth, through mitotic cell division. While this may have happened to some degree, and still does with, for example, sponges, sea anemones and plant cuttings, it is a method of reproduction which would have allowed damaged segments of DNA—*molecular lesions*—to accumulate in many of the organism's cells. Both normal metabolic activities and environmental stressors, such as ultraviolet light and cosmic radiation, can cause DNA damage, including gene malfunctions and mutations

[60] Grosberg, R.K. and Strathmann, R.R., 2007, The Evolution of Multicellularity: A Minor Major Transition? *Ann. Rev. Ecol. Evol. Syst.* **38**, pp.621–654.

[61] Grosberg, R.K. and Strathmann, R.R., 2007, ibid.

(which are usually harmful). It has been suggested, for example, that humans might incur as many as a million individual molecular lesions per cell per day.[62] Genes have evolved which allow many lesions to be routinely repaired,[63] but, equally, lesions can accumulate to the point where the cell dies or becomes non-functional. It is this problem of cumulative DNA damage which makes sexual reproduction almost a necessity for multicelled organisms. Apart from its value in generating the genetic variability which allows natural selection, sexual reproduction, including meiotic cell division, is a technology which produces distinct generations and which allows some-to-most members of each generation to begin life as a single cell containing relatively undamaged DNA.

While the precise evolutionary steps from unicells to multicells must necessarily remain speculative, what has been suggested as a transition from something like today's unicellular *choanoflagellates* to one early group of multicellular animals, namely the sponges of the phylum *Porifera*, is plausible and illuminating.

Sponges, which first appear in the fossil record for the late Proterozoic, do not have distinct circulatory, respiratory, digestive, and excretory systems. Rather, they rely on water flow to support these functions along with a filter-feeding system composed of flagellate cells, pores and canals. Their bodies consist of two thin layers of cells sandwiching a gelatinous matrix which functions to both connect cells and carry chemical signals between cells. They exhibit cell differentiation to the extent of containing non-feeding cells and specialist food-acquisition cells. Most sponges reproduce sexually, releasing sperm cells or, depending on species, sperm cells and egg cells into the water. Fertilised eggs develop into *larvae* which swim off in search of places to settle, grow and divide.

Choanoflagellates are a group of unicellular flagella-waving eukaryotes, living either individually or in colonies. They are considered to be the closest living relatives of the *metazoa,* i.e. multicellular animals. Genome sequencing (gene identification) suggests that today's choanoflagellates and sponges share a common ancestor. In particular, colonial-living choanoflagellates produce a surprising number of equivalents to the signalling and cell-adhesion molecules found in, amongst other animals, sponges. Morphologically too, choanoflagellate cells and sponge 'feeding' cells (choanocytes) are similar, e.g. both have 'collars', which trap prey. We can speculate that that it was a small evolutionary leap from colonies of unicells like choanoflagellates to multicells like sponges. Recall that the prokaryote 'pioneers' of multicellularity, the cyanobacteria, had long before evolved to be able to 'switch' genetically identical cells between the tasks of photosynthesis and nitrogen-fixing.

Humans cannot comprehend the three billion years it took for life to emerge and evolve into the handful of simple multicellular forms which mark the transition from a world of unicellular organisms to one with a wide variety of more complex multicellular organisms, organised into diverse ecosystems and characterised by, most obviously, mineralised (hard) body parts and diverse types of specialised cells and organs.

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[62] Lodish H., Berk, A., et al., 2004, *Molecular Biology of the Cell*, 5th ed., WH Freeman, New York, p.963.

[63] http://en.wikipedia.org/wiki/DNA_repair#DNA_repair_mechanism (Accessed 23 June 2010).

Notwithstanding, while evolutionary developments during the Archean and Proterozoic eons were unimaginably slow from a human perspective, most of the biological technologies and strategies that evolving life forms would subsequently utilise were in place in nascent form by the beginning of the Phanerozoic eon, meaning the geological eon of 'clearly visible fossils'. Mapping Earth's existence onto a 24-h clock face, it was now 8.50 pm. Thus, by the beginning of the Phanerozoic, starting 542 Mya with the Paleozoic era and Cambrian period (eons contain eras and eras contain periods), the world's oceans comprised a rich dissipative ecosystem of unicellular autotrophs and heterotrophs, plus some minimally differentiated multicellular organisms. Lichens (fungi and cyanobacteria living symbiotically) and mosses may even have been already present on moist shorelines. A long period of worldwide glaciation was coming to an end and the supercontinent Pannotia was breaking into four continents (Laurentia, Baltica, Siberia and Gondwana). The planet was primed for an era of (relatively) rapid bio-physical change.

Paleozoic Era (542–251 Mya) Cambrian Explosion to Permian Extinction

Within a brief 20 million years of the beginning of the Cambrian, the period's opening complement of simple multicellular animals had diversified or, in evolutionary terms, *radiated* into early representatives (species, etc.) of all the major groups (phyla) of animals present on Earth today—what is popularly known as the Cambrian 'explosion'. Shelly creatures such as the louse-like 'three lobed' *trilobites* and *brachiopods* (lampshells), of whose ancestors there is little sign in earlier rocks, are suddenly everywhere. Trilobites, for example, are *arthropods*, a phylum of animals without backbones (invertebrates), but with an external skeleton. The arthropod body plan, as seen in today's insects, spiders and crustaceans, consists of repeated body segments, each with a pair of appendages, e.g. claws, feelers and legs. Trilobites themselves however disappeared from the paleontological record after a *mass extinction* event at the end of the Permian period, some 250 Mya. A mass extinction is a major drop in global diversity.

More generally, a variety of early Cambrian marine animals evolved to have hard (mineralised) body parts which provided protection for soft tissues and a firm base against which muscles could pull during grasping or swimming movements. The hard components were commonly formed from calcium carbonate, as in shellfish, while it was *chitin*, a complex carbohydrate, which provided crustaceans and insects with durable exoskeletons. Trilobites had remarkably functional eyes with calcite lenses, for finding prey and avoiding predators such as the giant (up to a metre) *Anomalocaris*. Indeed, this was a period in the fossil record marked by the rapid appearance of diverse trophic (feeding) strategies, including primary, secondary and tertiary carnivory; and of rapid *escalation* ('arms races'), meaning the adaptive improvement of multicellular species in coevolutionary response to the increased hazards of their biological surroundings—as competitors and predators and prey all improved their survival technologies.

Many immediate and background reasons have been offered for this elaboration of the marine ecosphere in the early Cambrian and, with hindsight, it was an unsurprising development. *Niche expansion* was pivotally important. Thanks to a population boom in marine plankton, the main energy source, directly or indirectly, for Cambrian animal life, emerging animal types were able to proliferate without having to compete too much for limited food. That is, selection pressures were low and 'experimental' body plans and 'tools' (teeth, claws, etc.) were not ruthlessly eliminated.

Equally though this could not have happened unless the early Cambrian's multicellular eukaryotes already had the genetic potential to reproduce rapidly and to generate a variety of body plans. For this, 'master' genes had to be in place to regulate the expression and interaction of other genes, particularly during the development process from zygote to adult, e.g. genes for controlling the number of modular body segments created. As happens throughout evolution, the paths that might be taken are narrowed down by the path that has already been taken.

Nor could the Cambrian radiation have happened without the conditions that favoured the proliferation of planktonic life forms. These included shallow warming seas on the shelves of the continents as these 'wandered' rapidly away from the South Pole. Atmospheric CO_2 could have been 15 times the present level and temperatures were 'greenhouse' high. Most importantly, the marine environment grew rich in phosphate, calcium and iron as Pannotia's 'supermountains' eroded into the seas. As Pannotia was pulled apart, volcanism increased, further fertilising the seas with deposits of ash. Both the calcium and the carbonate needed to make animal shells and skeletons were now freely available.

Every rise in atmospheric and oceanic free-oxygen levels since Archean times has been associated with the emergence of new animal or plant groups, each characterised by having a higher metabolic rate per gram (free energy rate density) than pre-existing groups. For example, this holds true for the evolutionary sequence: crustaceans, amphibians, insects, rodents and primates. It is not so much that increased oxygen concentrations *cause* more complex life forms to evolve; it is rather that, for any nominated level of organismic complexity, there is a threshold concentration of oxygen above which it becomes *possible* for that level of complexity to evolve and persist—a necessary but insufficient condition. To take a simple example, body volume increases faster than surface area when organisms get bigger. Hence, one change which allows organisms to get bigger while remaining fully oxygenated is a higher dissolved-oxygen concentration, leading to a greater intake of oxygen per unit of surface area. More generally, because Cambrian organisms were, in some sense, more complex than their predecessors, they had a higher specific metabolic rate and, hence, oxygen requirement per gram. Presumably, the cost of having to take in more food and oxygen per gram of bodyweight is an 'investment' which is more than offset by allowing adaptations such as a reduction in body size, better access to food, higher reproductive rate or more efficient conversion of food into usable energy.[64]

[64] Conrad, M., 1983, ibid. p.256.

Great Ordovician Biodiversification Event

Taxonomists group plant and animal life into increasingly inclusive categories, running from species through genus, family, order and class to phylum. The foundational nature of the early Cambrian explosion is indicated by the fact that not only have no new phyla appeared since then, but no new classes have appeared in 150 myrs and no new orders since the post-dinosaur radiations some 65 Mya.

During the Cambrian, the number of marine families peaked at nearly 200, declining thereafter and being replaced by a rapidly radiating Ordovician fauna. This so-called *Great Ordovician Biodiversification Event*[65] (c.485–460 Mya), much larger than the Cambrian explosion, introduced numerous new families. If the Cambrian period is thought of as producing the modern phyla, the Ordovician radiation can be considered as the 'filling out' of these phyla with the modern (and many extinct) classes and lower-level taxonomic groups. While Precambrian and Cambrian communities were mostly limited to the sea bottom, the Ordovician radiation filled the water column as organisms adapted to this previously unoccupied niche.[66] Bottom-dwellers too extended their constructive activities, building up and burrowing down. Ordovician seas kept rising to, perhaps, 200 m above present levels, the highest in Earth's history.

Notwithstanding, around the end of the Ordovician (c.430–440 Mya), as the number of marine families was rising above 400, an extinction of about 100 marine families occurred. This, the *Ordovician-Silurian mass extinction event*, was the first (and third largest?) of five such events that have occurred in the past half billion years.

Just as a changing geophysical environment primed the Cambrian and Ordovician radiations, it was changing environmental conditions (e.g. asteroids, glaciations, stagnant oceans, ozone depletion, atmospheric pollution) which precipitated this and subsequent mass extinctions. At the time, Gondwana was moving back towards the South Pole, triggering a period of intense glaciation, and hence cooling and falling seas, both on continental shelves and in marginal seas, i.e. those not fully connected to the oceans. Widespread loss of habitat would seem to explain the Ordovician extinction. In the event, the Gondwanan ice sheet melted quite rapidly, for reasons not understood (volcanic activity possibly), and family numbers recovered within 15–20 myrs.

Smaller-scale extinctions have been commonplace throughout evolutionary history. Unlike mass extinctions, the reasons are as likely to be ecological as (physical) environmental (e.g. regional drought). That is, species can be wiped out by predators or parasites, especially small populations in isolated niches, and they can be wiped out by *competitive displacement,* as when a species is out-competed for a resource (e.g. food, shelter) by an invader or immigrant species.

[65] Servais, T., Harper, D.A.T., et al., 2009, Understanding the Great Ordovician Biodiversification Event (GOBE): Influences of Paleogeography, Paleoclimate, or Paleoecology, *GSA Today*, **19** (4/5) pp.4–10.

[66] Servais, T., Harper, D.A.T., et al., 2009, ibid.

Silurian-Devonian Period 438–417–362 Mya

Although the union was not concluded until 275 Mya, the Silurian-Devonian time period saw Gondwana and Laurasia (Laurentia plus Baltica) beginning to come together to form what would be Pangea, the all-inclusive supercontinent. From their Ordovician high, sea levels slowly fell to about present-day levels, leaving extensive shallow seas around the continental margins. Day length crept up to 22 h. About 16% of the atmosphere was oxygen, sufficient to support a protective ozone layer that would allow complex life forms to survive on land. The atmosphere's CO_2 level fell from c.5000 ppm (parts per million) to c.3000 ppm over the period. Climates were generally equable, even 'greenhouse', and, after recovering from the Ordovician extinction, the number of marine families hovered around 400 until, at the end of the Devonian period, another mass extinction struck.

These were times of great change for the ecological stage and its evolutionary play, to borrow Evelyn Hutchinson's metaphor.[67] In the sea, life evolved to more-fully occupy and exploit the *pelagic* or upper reaches of the water column. Calcareous coral reefs, built from algal skeletons and secretions, became a rich and quite new type of ecosystem. Elsewhere, both plants and animals evolved in ways which allowed them to occupy moist shorelines and, in time, drier landscapes; the first true terrestrial ecosystems began to emerge.

Ammonoids (the ancestors of squid and octopus) and fish, the first animals with backbones (vertebrates), evolved and quickly diversified. First came jawless fish (agnathans) which, while remaining filter-feeders, evolved from bottom-feeding to swimming freely through plankton-rich surface waters. Jawed fish evolved from and preyed on jawless fish, filling a 'vacant' niche and adding another trophic (food chain) level to an increasingly elaborate marine ecosystem.

The first animals to occupy dry land—wingless arthropods such as insects, spiders and centipedes—did so in a period of rising oxygen levels in the middle-late Silurian, c.420 Mya. But moss-like plants, descended from green algae and living symbiotically with fungi, had reached water's edge well before. Such were limited in size though because they relied on diffusion to distribute water and nutrients through their tissues. The first plants with specialised *vascular tissues* for distributing water and nutrients were descendants of mosses and appear in the paleontological record at 425 Mya. These were very simple—spiky green stems with no leaves, but with spore-bearing reproductive structures. It was vascular technology which, in time, would allow the evolution of large trees and a skyward extension of the ecosphere's envelope.

By 400 Mya, forests of *pteridophytes,* a group of shrub-like plants with roots and leaves, including lycophytes (clubmosses, etc.), horsetails and ferns had spread widely. Most importantly, *progymnosperms*, ancestors of seed-bearing *gymnosperms,* now emerged. Unlike ferns, gymnosperms have the flexibility of not depending on

[67] Hutchinson, G.E., 1965, *The Ecological Theater and the Evolutionary Play,* Yale UP, New Haven.

free water for their fertilisation; they have air-borne pollen. By 380 Mya the continents were green with, for the first time, forests of woody trees. These forests were a 'sink' which lowered atmospheric CO_2 (storing it in peat swamps and sediments) and, in the absence of *herbivorous* (plant-eating) animals that might have recycled and oxidised this plant material, the source of a marked increase in atmospheric oxygen. Thus, the Devonian period produced an unoccupied ecological niche, along with an 'explosion' in plant groups and their growth forms.

About 380 Mya (late Devonian) the first land vertebrates appeared. Descended from fish similar to modern coelacanths and lungfish (living fossils!), these were large *amphibian tetrapods* (some up to 5 m long) which had evolved four multi-jointed leg-like fins that allowed them to crawl along the sea bottom. Tetrapods have four legs and amphibians are animals that live both in water and on land. The *Tiktaalik,* for example, was an intermediate form*,* living in anoxic (low oxygen) swamps, where it was evolving to support itself on solid ground and, with the help of a lung-like air sac, possibly adapted from a swim bladder, to breathe air.

Early amphibians had to return to water to lay their shell-less eggs and to avoid 'drying out'. It was not till much later that some amphibians evolved into *reptiles* which had scales to minimise water loss and shelled eggs that permitted babies to be hatched on land. The egg, a small pool of 'water' inside a largely waterproof shell, is a brilliant niche-extending technology. Meanwhile, it was amphibians that were destined to become predators at the top of the food chain in this and following periods.

And then, over 20 myrs, starting 374 Mya, came the Eon's second mass extinction or, more correctly, a prolonged series of extinctions. However, while some 70% of marine species, especially reef-dwellers, died out, land plants were little affected, notwithstanding a change in climate from mild maritime to harsh continental. Descendants of the aquatic organisms which survived would be the ones to rule the Earth for the next 60 million or so years. These included new types of corals, brachiopods, ammonoids and a number of lineages of fish and tetrapods.

Various causes have been suggested for the *Late Devonian Extinction*, none totally compelling.[68] They include anoxic oceans, acidic oceans, cooling oceans, sea level changes, asteroid impacts, plate movements and combinations thereof.

Falling temperatures associated with falling CO_2 levels may have cooled surface waters by as much as 5°C, stressing tropical ecosystems in particular. These cooling waters may also have absorbed more CO_2, making them acidic enough to inhibit shell formation. Falling temperatures may also have produced a level of glaciation sufficient to lower sea levels in shallow marginal seas, leaving reef systems stranded. Equally when temperatures rose again for a time, triggered by a temporary CO_2 rise, sea level may have risen rapidly enough to 'drown' reef systems, which need to be in near-surface waters. The CO_2 rise itself may have come from volcanic emissions set off by asteroid impacts. Asteroids may also have brought anoxic, sulphurous deep waters to the surface where oxidation could have produced acidifying sulphate ions. Hydrogen sulphide may have been released in lethal quantities. Oxygen levels

[68] Southwood, R., 2003, *The Story of Life*, Oxford University Press, Oxford, p.87.

may have been further reduced as Laurasia and Gondwana came together, blocking off 'conveyor belt' currents that had been important for keeping the oceans stirred and aerated.

A final driver in this complicated mix of possibilities might have been a surge in oxygen-capturing algal blooms in coastal waters. This could have been set off by a rise in nutrient runoff levels, a rise associated with an increase in soil formation and erosion as deep-rooted forests spread across the continents.[69]

Carboniferous-Permian Period 362–290–251 Mya

The early part of these periods was everywhere warm, but, as Gondwana moved polewards, it experienced a pronounced cooling and glaciation. Although the equatorial regions remained warm, wet and tropical, a vast ice sheet spread over what is now Antarctica, southern Australia, most of India, the southern half of Africa and much of eastern South America. Pangea, the pole-to-pole supercontinent, was fully formed by 275 Mya, and stayed together for a hundred million years before beginning to break up, a process which continues to this day.

In equatorial seas, coral reefs and invertebrates flourished and diversified. Among the fish, groups which had dominated Devonian seas were disappearing and being replaced by an amazing variety of sharks.

The equatorial lowlands were covered by swampy forests of large lignin-rich trees which eventually became great coal deposits (Carboniferous means 'coal bearing'). Lignin and cellulose are strengthening materials which decompose slowly. Some fern-like seed-bearing progymnosperms grew to 35 m. The drier uplands remained a sparsely occupied niche. Because the vigorously photosynthesising lowland forests were not being decomposed (oxidised) as fast as they died, atmospheric oxygen levels rose to an all-time high of 35% and, correspondingly, CO_2 levels fell. Insects, spiders and other types of arthropods radiated rapidly in the forests' abundant leaf-litter. Some of these, capitalising on the oxygen-rich atmosphere, increased their metabolic rates to levels which would support the energy-intensive technology of flying. Some grew big; one dragonfly-like aerial predator was the size of a seagull. In waterbodies and water margins the tetrapods flourished and dominated, including various crocodile, eel and salamander-like forms.

It is at this time that the first reptiles appeared. These, while well adapted to live exclusively on land, remained ecologically insignificant until at least the very end of the Carboniferous. They developed larger and more powerful legs than amphibians, and were much more mobile because their legs sat beneath their bodies, not splayed, like amphibians, at their sides.

[69] Algeo, T.J., and Scheckler, S.E., 1998, Terrestrial-Marine Teleconnections in the Devonian: Links Between the Evolution of Land Plants, Weathering Processes, and Marine Anoxic Events, *Phil. Trans. R. Soc. Lond. B,* **353**, pp.113–130.

Meanwhile, under a cold dry Antarctic climate, the Gondwanaland continents evolved a distinctively different flora, one dominated by *glossopterid* (having tongue-shaped leaves) seed-ferns. It was from this group that the major plant groups of the coming Mesozoic Era (251–65.5 Mya), and possibly (much later) even the flower-bearing angiosperms, would evolve. By the end of the Carboniferous-Permian periods, true gymnosperms (seed-producing plants whose seeds are not enclosed in an ovary) such as cycads and early conifers had appeared. Gymnosperms, equipped with the three technologies of seeds, fertilisation by pollen and efficient vascular systems, were adapted to become widespread in the drier continental climates of the early Mesozoic Era, conditions which more tropical groups could not tolerate.

From early Permian times (say, c.280 Mya) the global climate became steadily warmer and milder. Marine and terrestrial faunas which had been pruned back during the relatively cool Carboniferous diversified into new families. Gondwanaland's glaciers receded, and inland areas became drier. Far from the moderating influence of the global ocean, much of the interior of Pangea was probably quite arid, albeit with distinct wet and dry seasons. This drying tendency, along with alternating warming and cooling periods, continued through to the late Permian. A plethora of insects and reptilian herbivores and carnivores coevolved in step with the supercontinent's changing plant formations.

At the very end of the Permian, sea level, and hence the area of continental shelf and lowland-swamp habitats, fell from its Ordovician maximum to an all-time low. This loss, an indicator of heavy glaciation, helps explain why there was a low rate of coal formation and a dramatic drop in atmospheric oxygen—to about 16%—during the first five million years of the Triassic period. Giant firestorms too may have played a part, consuming oxygen and forests.

Permian-Triassic Mass Extinction c.260–245 Mya

The Permian-Triassic mass extinction, the most destructive on record, saw the loss of, perhaps 90% of all multicellular species, including many amphibians and many trees, particularly pteridophytes which had flourished in the Carboniferous forests. Eight orders of insects became extinct. As with the Devonian extinction, this too was probably a series of extinctions over some 15 million years, albeit with a sharp 'spike' in the rate of loss around 251 Mya. That is, the end of the Paleozoic era was marked by both an extinction spike and a steady turnover (replacement) of older lineages by newer, better-adapted lineages in many niches.[70]

[70]Bottjer, D.J., Clapham, M.E., et al., 2008, Understanding Mechanisms for the End-Permian Mass Extinction and the Protracted Early Triassic Aftermath and Recovery, *GSA Today*, **18** (9), pp.4–10.

The spike in extinctions at 251 Mya is widely believed to have been triggered by massive volcanic activity in China and Siberia. The flood of lava released from the so-called Siberian traps, over about a million years, could have covered as much as 7 million km^2. Looking for causes, this exceptional volcanism may have been related to the beginning of Pangea's breakup, or, more plausibly, it could have been associated with an asteroid strike directly opposite (antipodal to) Siberia on the other side of the globe (Wilkes Land in Antarctica?). On a sphere such as Earth, 'shock waves' from any large impact first spread and then converge on an antipodal point, generating large earthquakes and releasing lava there. Something similar may have happened during the Cretaceous extinction (65.5 Mya) when the Deccan traps, which are directly opposite the Chicxulub impact crater, extruded comparably large quantities of lava.

More specifically, how might the combination of an asteroid strike and megavolcanism have triggered the Permian extinction? Consider asteroids first. Even during periods of strong ocean currents, flowing as they do from warm to cool regions, the ocean deeps and bottom sediments are low in oxygen and home to anaerobic bacteria, busy producing large quantities of hydrogen sulphide and methane hydrates; more so when atmospheric oxygen is falling and ocean circulation is weak, as happens in a warm world. Should a large asteroid strike in an ocean basin, it will generate toxic, anoxic tsunamis, many hundreds of metres high perhaps. Methane-saturated waters may have 'exploded' when released from the pressures of the deeps. The potential for destroying life in coastal areas is great, not to mention the wider effects as atmospheric methane and H_2S move inland. An H_2S concentration of even 100 ppm will kill most animals.

Apart from the on-ground effects of megavolcanism, enormous quantities of CO_2, sulphur dioxide and particulate ash would have been spasmodically ejected; smaller ejections of chlorine and fluorine would have sufficed to destroy Earth's life-protecting ozone layer. Sulphur dioxide in the atmosphere leads to acid rain, while dissolved CO_2 acidifies the oceans. Particulates block out sunlight and produce 'volcanic winters', perhaps even persistent glaciation. Conversely, a CO_2 'blanket' raises air and water temperatures, perhaps to levels that trigger extinctions. Warm and cold conditions might well have alternated during the Permian-Triassic extinction. Overall, one might wonder how *any* multicellular organisms could have survived this convergence of traumas in the late Permian.

Mesozoic Era (251–206–65.5 Mya) Dinosaurs, Mammals, Birds, Flowers

For present purposes, the importance of the Mesozoic Era is that it was the 'age of reptiles', hosting not just the radiation and subsequent extinction of a dominant *dinosaur* fauna, but the emergence of the reptilian lineage which gave rise to we mammals.

The Mesozoic Era, like Gaul, is divided into three parts: the Triassic (oldest), Jurassic and Cretaceous (youngest) periods. Archosaurs ('ruling reptiles') and synapsids (mammal-like reptiles) were two consequential reptile lineages, both descendants of large amphibians, which first appeared during the Permian period and survived into the Triassic. Thus, *Lystrosaurus* ('shovel lizard'), a hippo-like burrowing and browsing synapsid, was pre-adapted to low-oxygen conditions and was the only largish (about a metre long) land animal to survive and, for a time, to thrive. It was such advanced synapsids (*theraspids*) that were evolving into true mammals by the end of the Triassic, even as they were largely disappearing and being replaced by archosaur lineages, particularly the *dinosaur* lineage.

In a short space of time, dinosaurs rose from being small, swift and bipedal, but ecologically unimportant, to a group occupying nearly all terrestrial niches. They were to increase in size and 'rule' the Earth for the next 150 myrs (over twice as long as their successors, the mammals, have so far been predominant). Some herbivorous dinosaurs became huge, perhaps to keep warm (called inertial homeothermy), perhaps to accommodate the large guts necessary to slowly digest the nutrient-poor plants of the time.

Why were they so successful? Atmospheric oxygen declined sharply in the Triassic and archosaurs probably had comparatively advanced respiratory systems; being somewhat erect, they could run and breathe at the same time. Also, the early Triassic was largely arid; most of the Earth's land area was concentrated in one supercontinent and the mountain ranges pushed up during Pangea's formation produced extensive 'rain shadow' deserts. Fibrous conifers and palm-like cycads, still gymnosperms, were becoming the dominant plant groups. Archosaurs were also probably better at conserving water than early synapsids because they had glandless skins and excreted nitrogen as a uric acid paste (like today's birds) rather than as a watery solution of urea (like today's mammals).

End-Triassic mass extinction. More generally, the end of the Triassic period marks the world's fourth mass extinction event, i.e. coming after the Ordovician, late Devonian and Permian-Triassic events. This event, 200 Mya, lasted less than 10,000 years and occurred just before Pangea started to break apart. At least half of the species now recognised to have been living on Earth at the time went extinct. All large non-dinosaurian archosaurs, some remaining advanced synapsids and many of the large amphibians were wiped out. Niches were being emptied out, ready to be filled by diverse dinosaur lineages during the Jurassic period.

There is no widely agreed explanation for the End-Triassic mass extinction. Sea level fell and rose sharply at the time, suggesting the possible formation of an anoxic marine environment and a release of toxic gases. More suggestively, as Pangea began to rift apart, a flood of volcanic lava and CO_2, comparable in volume to the Siberian and Deccan traps events, was released in the Central American Magmatic Province (CAMP). Not only did this initiate greenhouse conditions that persisted through the Jurassic, the oceans may have been warmed sufficiently to become slow-moving and stagnant and primed to release large quantities of methane from bottom sediments.

Pangea's continental plates continued to move apart throughout the Jurassic and Cretaceous periods, allowing plant and animal evolution to follow somewhat different trajectories on each relatively isolated continent. The present-day configuration of continents had been largely achieved by the time of the End-Cretaceous (fifth) mass extinction (65 Mya), the event which marks the transition from the Mesozoic era to the Cenozoic (recent animal) era.

In the late Jurassic period (c.140 Mya), angiosperms, i.e. flowering plants, evolved from a particular lineage of gymnosperms and a landscape dominated by ferns, cycads and gymnosperms gave way to one populated with seed- and fruit-bearing trees and other types of still-familiar angiosperms. By 100 Mya the angiosperms had diversified considerably and were widespread.

Fruits and *flowers* (petals are modified leaves) were the adaptations that allowed angiosperms to permanently displace gymnosperms as the dominant flora; over three quarters of all today's plants are angiosperms. Fruits (modified plant ovaries) facilitate seed dispersal and manuring by animals. Mobility is all-important to animal survival and the ability to spread provides plants with their own form of mobility, albeit in slow motion. Flowers facilitate pollen dispersal by animals, especially insects such as bees. But it was not just insects and angiosperms which were coevolving. The rise of the angiosperms as a food source triggered a burst of coevolution in both mammals and dinosaurs, including the dinosaurs we know today as birds.

During the Mesozoic era, mammals and some forms of dinosaurs (e.g. bird ancestors) evolved to be warm-blooded, i.e. able to generate body heat internally and control, through insulation, the rate at which that heat is lost, e.g. fur and blubber. While warm-bloodedness, or *homeothermy*, is energetically expensive, it allows instant mobility and nocturnal, cold-night mobility. It allows specialised organs (e.g. brain, glands) to operate independently of the outside temperature. Nocturnal mobility may have been particularly important for small insectivorous mammals trying to avoid dinosaur predators.

Sometime during the early Jurassic, two groups of reptiles gained the ability to fly and one of these groups later gave rise to the birds (the taxonomic class of Aves). Flying is energy-intensive but expands access to dispersed food sources. Apart from warm-bloodedness, birds developed a range of flight-assisting adaptations such as feathers and hollow bones. Bats became the only flying mammals. In Jurassic seas, apart from fish, the main vertebrates were marine reptiles, including ichthyosaurs ('fish lizards'), plesiosaurs, pliosaurs and marine crocodiles. While the first true mammals appeared in the early Jurassic, the three extant mammal groups appeared, probably independently, in the early Cretaceous, say 120–130 Mya; these are the monotremes (egg-laying mammals), the marsupials (pouched mammals) and the placental mammals (others).

It was during the late Cretaceous that humanity's order of placental mammals, the *primates*, began coevolving with and adapting to an increasingly diverse angiosperm flora, including trees producing much larger fruits than their predecessors. Thus, primates began shifting towards a vegetarian diet and a largely arboreal lifestyle.

End-Cretaceous Mass Extinction

The end of the Cretaceous, about 65 Mya, is marked by a mass extinction which included all lineages of dinosaurs, save the birds. Up to this point mammals had been largely confined to nocturnal, insectivorous niches but, once dinosaurs were out of the picture, placental and marsupial mammals diversified, throughout the Cenozoic era, into many new forms and niches. Notwithstanding, 35% of all mammal species died out at this time. It appears that the marine food chain based on photosynthesising plankton and the terrestrial food chain based on green leaves both collapsed for a relatively short, but catastrophic, period. Mammals and the other broad categories of terrestrial life that flourished in the wake of this extinction—birds, insects, flowering plants—are those that characterise the global ecosystem to this day.

Explanations are always contestable but what happened is consistent with evidence that an Everest-sized asteroid created the Chicxulub crater (170 km wide) off the coast of Mexico, throwing up a long-lasting (years?) Sun-dimming dust cloud and, on the opposite side of the world, triggering tsunamis and the flood basalt event known as the Deccan traps. Vaporised limestone might have fallen as acid rain. Wildfires might have consumed much dead vegetation, adding a layer of soot to the already-opaque atmosphere. Vast quantities of toxic gases, e.g. methane and hydrogen sulphide, could have been released during the two antipodal events.

As with the four previous mass extinctions, the End-Cretaceous event was associated with a sharp fall in sea level, a fall not associated with an asteroid impact but, more probably, with the convergence of India and Africa on Eurasia which led to the Himalayas and the Alps being formed. Less probably, the cause might have been a period of aberrant glaciation in Antarctica. Either way, marine invertebrates were heavily depleted.

The greenhouse conditions which characterised much of the Cretaceous continued into the Paleocene and the Eocene, the first two epochs of the Cenozoic era. The *Paleocene-Eocene Temperature Maximum* (PETM) was a short spike of high temperatures associated with volcanism and lasting approximately 100 kyrs during the late Paleocene and early Eocene epochs (roughly 55 Mya). Sea surface and overland air temperatures increased by more than 5°C and a further round of terrestrial and marine extinctions followed. A few million years later came another particularly warm period, the *Eocene Optimum*—the world was ice-free and largely subtropical—but thereafter the Earth entered a fluctuating cooling trend which, in broad terms, has continued till the present day.

It was then that the broad ecosystems (ecozones) which we have today began to take on their global pattern: tundra, coniferous forest, deciduous forest, tropical rainforest and grasslands. The last major group of plants to evolve was the grasses (family *Poaceae*), which became important from around 40 Mya. In areas of intermediate rainfall (500–900 mm per annum), grasslands and savannas (grasslands with some trees) replace forests—as happened in east Africa at the time our hominid ancestors were evolving. More generally, grasslands coevolved with new and diverse suites of grazing mammals.

Ideas for a World View

This chapter is a brief version of science's story of the extended origins of our ancestors, the first primates, and the world into which they emerged some 60–65 Mya. Some may still be puzzled by the idea that this, the earliest instalment of the human story, could be a useful platform (among others of course) from which to contemplate the converging problems of the contemporary world; a bit like studying climate change before deciding to take an umbrella, perhaps. The puzzled may be right but, saying it again, and more explicitly, there are several ways in which a familiarity with this story stands to support and inform those responding to perceptions of an Overshoot Crisis in which primates are heavily implicated.

Overall, it is a story from which elements of a science-based, naturalistic *world view* can be extracted, a world view being *a coherent system of fundamental beliefs that describe reality*.[71] More specifically, it suggests various core propositions about our lineage's identity, about the way the natural world behaves and about processes which drive change in the natural world.

Humans Are Primates

An entity's *identity* is the characteristics by which it is recognised or known, such things as its history, its similarities-differences with comparable entities and its functional links inside some larger entity. This chapter is an invitation to envisage a wider-than-usual identity for the primate (and hence human) lineage.

Primates, including humans, are not only Sagan's 'children of the stars', they are children of the Sun, the Hadean Earth, the first prokaryotes-eukaryotes, the first vertebrates, the first amphibians and the first mammals. And, for good measure, the big bang. All primates are 'cousins'. In terms of adapting to global change, the primate lineage should be recognised as having survived five mass extinctions, various icehouse and greenhouse regimes, 5–6 supercontinent cycles, oxygen poisoning, hydrogen sulphide poisoning, oxygen surges, nitrogen drought, great sea level changes, asteroid strikes, irradiation events, a slowing Earth and a slowly warming Sun. Adaptive technologies (survival-promoting ways of doing things) evolved by the primate lineage at different times include slime, aerobic respiration, endosymbiosis, mobility, sexual reproduction, heterotrophy, multicellularity, specialist cells and organs, air-breathing, warm-bloodedness, small litters, bipedalism, omnivory and group living.

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[71] Aerts, D., Apostel, L., et al., 1994, *World Views: From Fragmentation to Integration*, VUB Press, Brussels; Internet edition 2007, http://www.vub.ac.be/CLEA/pub/books/worldviews.pdfInternet (Accessed 3 Jan 2011).

Evolution and Ecology Are Inseparable

None of these technologies is exclusive to primates of course. Biological evolution is a 'branching' process in which genetically similar populations begin to diverge (become genetically different) and, over time, become separate species, i.e. split into separate branches on the tree of life, to use a ubiquitous metaphor. When one lineage branches into several, each branch retains most of the technologies developed by their common ancestor. Over evolutionary time, the tree of life has sprouted innumerable twigs and branches only to have nearly all of these 'pruned' as species, families of species, etc. have gone extinct. Still, despite a plethora of major and minor extinction events, the variety of life forms on the planet, its *biodiversity,* has increased, in saw-tooth fashion, since Archean times.

For example, an analysis by Robert May suggests that the number of orders of aquatic animals jumped in Cambrian, and Ordovician times, and remained more or less stable (at 80–100 orders) through the Silurian, Devonian, Carboniferous and Permian before dipping in the Triassic.[72] Orders of land animals only increased with the Silurian and reached a sort of plateau of about 50 by the Permian. A large increase in the number of mammal orders after the Cretaceous was because different orders arose to play similar ecological roles on different continents.[73] One of May's conclusions is that once all of a region's ecological niches are filled, the numbers of extant species tend to stabilise.

Lineages do not persist, radiate (branch), adapt (evolve without branching) or go extinct in isolation. While lineages come and go, those extant at any time coexist interdependently in ecosystems and coevolve with each other and with the physical environment. That, in a nutshell, is what was happening within the ecosphere from Archean times till the emergence of primates. Indeed, suitably elaborated and transformed, the same model provides a first understanding, of the contemporary human ecosystem, including its economic and political structures. Strange as it sounds, today's world is still very much the world of the first primates.

More explicitly, the history of the ecosphere can be understood as a dynamic (ever-changing) tapestry of niches and the lineages which occupy them. Since Archean times lineages have been organised into ecosystems of niches occupied, respectively, by primary producers (e.g. green plants, phytoplankton), or consumers (e.g. zooplankton, herbivores, carnivores, primates) or decomposers (e.g. fungi, prokaryotes). Most relationships between populations of species in ecosystems are based on the trophic niches they occupy as producers, consumers or decomposers, e.g. plant and herbivore, predator and prey, phytoplankton and zooplankton, parasite and host, scavenger and carrion. Equally important though are the many symbiotic and competitive relationships that develop within and between species.

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[72] May, R.M., 1973, *The Stability and Complexity of Model Ecosystems,* Princeton University Press, Princeton, p.178.

[73] May, R.M., 1973, ibid., p.181.

Symbiosis and Competition Are Both Important

Competitive relationships usually involve organisms from one or more species seeking access to the same resource. This may mean direct competition for a limited food resource (as in overgrazing, overfishing), or less-direct competition as in technologies for allocating various 'instrumental' or 'positional' resources, e.g. living spaces such as nesting sites, forest plants seeking sunlight and males competing for females. When a contested resource is consistently scarce, natural selection leads to the preferential survival of the lineages and 'sub-species' which, in one way or another, capture relatively more of the energy and materials accessible from the niche. *Competitive displacement* is competition's extreme outcome, wherein one species, an invader or immigrant perhaps, crowds out a niche's incumbent species, e.g. the placental dingo displacing the marsupial thylacine.

Symbiotic relationships within and between species have been important in the ecosphere since the time of the earliest bacterial ecosystems. Broadly defined, such relationships are patterns of activity which enhance the survival prospects (e.g. make life more predictable) of the interacting partners or *symbionts*, and can take disparate forms under labels such as endosymbiosis, exosymbiosis (e.g. lichens, mycorrhizae), gene sharing (e.g. sexual reproduction), synergy, association, mutualism (e.g. pollination by insects), commensalism (e.g. tree orchids), cooperation (e.g. hunting in packs), division of labour (e.g. castes in beehives), and information sharing (e.g. alarm calls). Indeed, persistent ecosystems are themselves complex multi-partner symbiotic relationships in that the 'stocking rate' (population size) in each species' niche is stabilised (within limits) by the stability (within limits) of the 'stocking rate' in all other niches, particularly those 'close by' in the food chain. Conversely, if the population in one niche crashes or booms, there will be a chain of repercussions through other niches; more so if the species involved is a highly connected or *keystone* species.

Symbioses are emergent relationships, i.e. they are the opportunistic, largely unpredictable products of spontaneous self-re-organising interactions, and they persist for as long as both the partners and the conditions that induced the symbiosis persist. What then are the conditions necessary to bring forth and sustain symbioses? While every situation is different, a general answer can be given in thermodynamic terms. Ecosystems are dissipative systems, components of the universe-wide thermodynamic process which degrades high-quality energy into low-quality energy as rapidly as circumstances permit. Diverting some of the energy flowing through an ecosystem into a new symbiotic relationship increases the rate at which the ecosystem is degrading energy, as well as making it more complex, i.e. having a higher free energy rate density. So, if the pre-conditions for a symbiosis are in place, it will emerge when sufficiently activated, e.g. when an appropriate immigrant species arrives.

When a symbiotic relationship persists over generations, it becomes a selective environment, a niche in which the symbionts evolve and coevolve, both genetically and behaviourally, e.g. angiosperm fruits become more attractive to primates and primate hands adapt to the fruit-harvesting task. As the lineages in a symbiotic relationship coevolve, their previously separable (though interacting) evolutionary fates move irreversibly together. They stand to become an 'evolutionary individual', capable of entering new symbiotic relationships.[74] If such a new entity does become stabilised and persists, then it will, in turn, be able to participate in a similar process, one leading to the construction of a more stratified or hierarchical form of ecological organisation.

The Ecosphere Is Vulnerable But Resilient

Whether it be ecosystems or other forms of dissipative systems, the standout lesson is that every dissipative system persists only by courtesy of a stable-enough parent system from which a supply of free energy, and materials perhaps, can be drawn. Thus, every dissipative system has a dual nature: it is a whole in itself, and it is a part of some other whole. Energised by its high-temperature core and the Sun, the planet has, for four billion years, been a remarkably stable parent system for the global-scale material-energy cycles of the hydrosphere, atmosphere and lithosphere.

And, notwithstanding extinctions, for the emergent ecosphere too. The global life cycle has abstracted increasing quantities of energy and materials from the Sun, Earth's core and pre-existing global material-energy cycles. From Precambrian times when it comprised only communities of bottom-dwelling species, the ecosphere has been drawn to expand spatially into previously unexploited environments, physical and geographical. Thus life has successively colonised the full depth of the marine, etc. water-column, the water's edge, 'dry' land and, finally, airspace. Geographically, life has spread through a full spectrum of warm and cold, wet and dry, landscapes and seascapes; at all latitudes and altitudes. A 'quilt' in which the 'squares' are large ecosystems or *land systems* has been thrown across Earth's surface. It is a powerful idea that even complex landscapes are built up from a relatively few types of 'building blocks', small open ecosystems called *land units*. These are repeated in characteristic patterns over large areas (perhaps hundreds of sq km) with each pattern being called a *land system* or *ecoregion*. Each type of land unit can be described as having (co)evolved a characteristic type of natural vegetation growing in a characteristic soil on a characteristic type of terrain.[75] For example, cracking-clay soils impose such expansion-contraction stresses on tree roots in seasonally wet-dry climates that only grasses can survive on these soils.

[74] Griffiths, P.E., and Gray, R.D., 1997, Replicator II: Judgement Day. *Biology and Philosophy,* **12**, pp.471–492.

[75] Cocks, D., 1992, *Use with Care: Managing Australia's Natural Resources in the 21st Century,* University of New South Wales Press, Sydney, p.46.

When a mature land unit loses all or most of its trophic structure, and its constituent organisms, to a short-term exogenous (external) disturbance such as flood, fire, drought, pests or diseases, or to endogenous (internal) random fluctuations in lineage numbers, it will begin to recover its previous structure once the perturbation passes or exhausts itself, e.g. the parent system's weather and landscape return to their 'normal' steady state. Recovery commonly takes the form of a temporal *succession* in which each lineage re-establishes itself, for a time at least, depending on which other lineages have already returned and what is available from outside 'reservoirs' (e.g. nearby land units) for recolonising the system's emerging niches.

Lineages come, stay and go. The dynamics of succession are such that many returning lineages enter symbiotic relationships with already-returned lineages, only to find themselves out-competed and eliminated as the succession proceeds and the extant mix of lineages changes, e.g. low-growing early colonisers get shaded out by later colonisers. Indeed, some lineages appear to depend on a periodic simplification of their environment to persist, e.g. grasses in a fire-prone shrub-savanna environment. More generally, if the physical environment (weather, landscape, etc.) does not return to 'normal', some returning lineages may prove to be so poorly adapted to the changed conditions that they become *locally* extinct.

The History of the Ecosphere Is Graspable

Something comparable happens in mass extinction-mass diversification sequences, but on a grander scale in space (e.g. ecozones, clusters of ecoregions, continents, the globe) and time (e.g. millennia, megayears) than at succession's scale of land units-ecoregions and decades-centuries. Despite being ultra-slow by human standards, it is at this scale that the history of the ecosphere can be best grasped in the mind's eye.

From the Big Bang to the Hadean Earth, the pre-history of the ecosphere centres on the emergence at progressively lower temperatures of a succession of increasingly complex and energetic dissipative systems, each encased, like Chinese boxes, in a larger, slower 'parent' system. Since the Hadean Earth cooled to a temperature at which life could emerge in a form stable enough to persist, the planet's quilt of ecosystems has been constantly reworked at all scales. At global scale, this reworking can be explained in terms of processes which have led to habitat loss-degradation for suites of lineages over very large areas and, conversely, to broad-scale habitat creation-improvement for other lineages. While large niches can remain more-or-less unoccupied for a long time (up to tens of megayears) the quilt persists overall because what is niche-degradation for one lineage has commonly proved to be an upgrading for another. The supreme example, with gigayears of consequences, is the widespread replacement of anaerobic microorganisms by aerobes as free oxygen levels first rose in ocean and atmosphere.

Like progressive oxygenation, most of the processes which have initiated mass extinctions and/or afforded opportunities for mass diversifications have been relatively slow and progressive. Examples include oceanic and atmospheric warming and cooling; acidification, fertilisation, de-oxygenation and toxification of the oceans; sea level change; ozone build-up; supercontinent formation, erosion and breakup; and extensive glaciation.

A few, like asteroid strikes and the supervolcanoes whose ejaculates have occasionally produced ‘volcanic winters’ have been brief and highly energetic. In contrast, the slow build-up of CO_2 from long-lasting volcanism over extended areas has produced ‘greenhouse’ climates on occasions. More ‘normal’ patterns of volcanic activity and CO_2 production have, several times, proved sufficient to slowly reverse the very low CO_2 levels associated with ‘Snowball Earth’ conditions.

The ecosphere itself has initiated many processes which, sooner or later, have affected the broad-scale reworking of the ecosphere. Apart from the assimilation of CO_2 and the generation of oxygen by plants and algae, these include the production of H_2S and methane by anaerobic organisms in deep-water sediments; production of atmospheric aerosols; accelerated rock weathering-soil formation; and the accumulation of biological residues in coal and limestone deposits.

The history of the ecosphere can be likened to an incoming tide with each new wave taking suites of adapting, radiating and colonising lineages further up the beach and each retreating wave taking suites of declining and defunct lineages out to sea. The balance between lineages gained and lost varies between clusters of ecoregions (different ‘beaches’) depending on the particular broad-scale changes in the physical environment associated with each ‘wave’.

Lineages and communities of lineages decline or die out as their reproduction rates decline or fall to zero. The reasons can be many and interlinked but, broadly speaking, changes in the physical environment destroy some lineages directly—their homeostatic limits are exceeded—and other lineages decline when their trophic niches shrink. For example, a predator dies out when its prey dies out; or a temperature rise which is tolerable for one coral may be intolerable for another. In a mass extinction all ecosystems in a very large area, a suite of ecoregions, stand to be drastically simplified, regressing to fewer lineages interacting via fewer trophic, symbiotic and competitive relationships. Whole trophic levels might disappear, e.g. top carnivores.

The following wave of diversification (if not interrupted) will see the remnant ecosystems evolving anew, both genetically and ecologically, towards a replacement set of mature ecosystems incorporating increasing numbers of lineages and linkages. But, unlike a local succession following a local extinction, the makeup of the incoming ecosystems here stands to be markedly different from the ecosystems being replaced. With local extinctions, the physical environment is less likely to have been permanently changed and neighbouring land units can seed the recovering ecosystem with plant and animal colonists similar to those eliminated in the extinction event.

So, what sorts of species stand to survive the forces of progressive extinction and become founder members of radically different ecosystems? They are more likely to be *generalists* as to their niche requirements (e.g. omnivores, rather than carnivores or herbivores) and not *specialists*, i.e. not obligatorily dependent on a few tight coevolutionary relationships for their survival (e.g. corals). And they are more likely to be genetically diverse, already existing as a number of *ecotypes,* any one of which might prove to have the physiological and behavioural flexibility needed to survive the threats to survival associated with the beginning of an extinction event. However, if they are to continue to survive cumulating extinction pressures and initiate a wave of diversification, these founder lineages will need to keep adapting genetically and radiating genetically and geographically into their depleted and still-changing environment.

The Australian biota provides clear examples. Since separating from Gondwana in Cretaceous times, and since the End-Cretaceous mass extinction, the Australian flora has been dominated by just two genera, *Acacia* and *Eucalyptus*—wattles and gums. Both are now widely distributed and both are rich in species, collectively over 1,000. And from an ancestral kangaroo-like creature there developed the big Red Kangaroos that live on the inland plains and the forest-dwelling Gray Kangaroos. Heavy-footed kangaroos, the rock wallabies, also evolved, as well as a variety of small swift things that haunt tussock and undergrowth. Two kangaroos, in tropical Cape York, have climbed back into the trees and eat fruit and leaves. Wallaby, Wallaroo, Tungoo, Paddymelon and Potoroo are all kangaroos springing from one or perhaps two kinds of ancestors.[76]

And, at any time, a mass diversification can be enriched or depleted by immigrants. Thus, immigrants from south-eastern Asia began arriving in Australia 30 Mya, as it was 'colliding' with Asia.[77] These 'recent' arrivals include the bats, the ancestors of which were able to fly here. Then there are the true rats and mice, the forebears of which probably drifted here on floating debris. The small Asiatic wolf, the Dingo, almost certainly arrived recently (within a few thousand years), brought by the nomadic Aborigines perhaps, and so it has not differentiated, and now probably never will, into more than one of its kind.[78]

Adaptive Technologies Enhance Survivability

Alongside a long-term erratic trend towards greater energy use (capture and dissipation) by the total ecosphere, there is a similarly extended trend for more recently evolved organisms (and their ecosystems) to be more complex than their ancestors, i.e. by Chaisson's measure of complexity,[79] they process more free energy per unit bodyweight.

How? Why? Once aerobic respiration had evolved, greater complexification became possible to the extent that oxygen was now available to better drive the

[76]Cocks, D., 1992, ibid., p.24.

[77]Flannery, T.F., 1988, Origins of Australo-Pacific Land Mammal Fauna, *Australian Zoological Reviews* , **1**, pp.15–24.

[78]Marshall, J., 1966, *The Great Extermination: A Guide to Anglo-Australian Cupidity, Wickedness and Waste*, Heinemann, London.

[79]Chaisson, E., 2004, ibid.

conversion of food molecules into energy-storing ATP molecules. That is, additional energy could now be mobilised to allow and support new ways of cycling materials, which is what complexification means. Possible new ways for an organism to function, e.g. incipient symbioses and genetic mutations-reorganisations, would no longer be automatically rejected (selected against) on energy-shortage grounds. Any tentative new adaptive technology now stood to be incorporated if it enhanced the survival-reproductive prospects of the lineage.

More generally, the trend towards complexification in persistent lineages and ecological relationships has, for much of the ecosphere's history, probably been oxygen-limited. That is, each long-term rise in the atmosphere's oxygen content has seen a corresponding rise in the complexity of the ecosphere's radiating lineages and their associated ecosystems, e.g. from eukaryotes to mammals. At times of falling oxygen levels, lineages which had become adapted to higher oxygen levels either re-adapted (e.g. became smaller, became air-breathers) or tended to be displaced by lineages which were less oxygen-dependent. By primate times, coral reefs and rainforests were well established as examples *par excellence* of highly complex ecosystems, characterised by long trophic chains and richly connected food webs; and by evolving and coevolving lineages and niches.

As illustrated through this chapter, complexification can take many forms, most of which can be understood in functional terms as adaptive (survival-promoting) technologies. Ecologically, these include adjustments which increasingly stabilise competitive and symbiotic relationships, i.e. reduce their variability and increase their reliability. Once stabilised, such relationships become platforms on which a further hierarchical level of relationships can be established (if the requisite time and energy flow are available).

At the biological level, that of the individual organism, and grafted into an ever-changing mix of lineages, certain categories of adaptations keep re-appearing at all stages of ecosphere history. Thus, from prokaryotes to primates, we can identify how diverse adaptive technologies have been 'invented' which, in one way or another, enhance the organism's capacities for such generic tasks as:

Energy storage and mobilisation (e.g. ATP, fat cells, muscle)
Acquiring oxygen, food and water (e.g. gills, mobility)
Acquiring, storing and using information about the environment (e.g. sensory organs, DNA, instincts, memory)
Reproducing and dispersing offspring (e.g. breeding cycles, seeds)
Internal communication and transport (e.g. hormones, nerves, sap)
Regulating internal temperature (e.g. evapotranspiration, sweating)
Habitat modification (e.g. burrows, rock weathering)
Building protective structures (e.g. bark, shells)
Using limiting resources more efficiently (e.g. egg-laying, recycling nutrients)

The common theme behind these (and other) categories of adaptive technologies is not just that they are all survival-promoting, but that they all seek to improve a lineage's survival prospects in one way, and that is by reducing the impacts on the lineage of environmental variability of one sort or another, including fluctuations, shifts and shortages at various space-timescales. Attempting a further generalisation, such adaptations are achieved by either avoiding impacts or by absorbing them without losing functionality. Thus, the closing of leaf-stomata on a hot day or migrating with the seasons are clear examples of *avoidance technologies.* Homeothermy and plants which can tolerate flooding for long periods are examples of *absorption technologies*. Risk-spreading (e.g. widespread seed dispersal), internalisation (e.g. egg production, implanted embryos), redundancy (e.g. multiple sensory channels) and anticipation (e.g. memory) are other terms used to understand how organisms counter environmental variability.

This completes my summary and explanation of the history and dynamics of Earth's ecosphere, up to the evolution of primates. The next chapter turns to the biological, ecological and early cultural history of the primate lineage, that which, in time, would spawn modern humans.

Appendix: More on Self-Organising Systems

A Mathematical Analogue

What is happening when a system self-organises? And why? One way of explaining the behaviours of real-world dissipative systems is to map them into (draw analogies with) the behaviours of isomorphic (similarly structured) systems of mathematical relationships. For so *modelling* dissipative systems, the relevant mathematics appears to be the study of trajectories through time of solutions to systems of differential equations—what is known as the *theory of non-linear dynamic systems*, meaning systems which change through time but far from smoothly.[80] More popularly, this body of theory is called *chaos theory*. Drawing on this theory and its vocabulary, when a system self-organises (restructures itself) from one network of paths for cycling its component materials to another network, it is being pushed out of one *basin of attraction* and into another. Once inside such a new basin of attraction, the system spontaneously moves, under the impetus of (predominantly) positive feedback processes, along a trajectory towards a restricted part of the basin called the *attractor*.

Francis Heylighen defines an attractor as a region in state space (this being the set of all conceivable system configurations) that a system can enter but not leave; not leave easily perhaps.[81] Once a dissipative system enters an attractor region, its trajectory—the sequence of states it subsequently cycles through—will tend to

[80] Abraham, R.A., and Shaw, C.D., 1992, *Dynamics: The Geometry of Behavior*, 2nd edn., Addison-Wesley, CA.

[81] http://pespmc1.vub.ac.be/ATTRACTO.html (Accessed 4 February 2010).

stay inside that region. That is, it will be in a steady state of *dynamic equilibrium* and following an *equilibrium trajectory* from which, left to itself, it will show no tendency to depart. However, if it is nudged or pushed off this equilibrium trajectory by ‘noise’, meaning small random fluctuations in its material-energy throughflows, or by a modest change in rates of material-energy inflows to the system, negative feedback processes will start up and take the system back to the attractor trajectory. A system which returns to its former equilibrium after being thus moderately disturbed is defined to be in *stable equilibrium*. In contrast, a system which is in *unstable equilibrium* would continue to deviate from its equilibrium trajectory once such deviation is initiated. Unlike most human-designed systems, self-organising systems have a strong capacity to restore themselves after disturbance.

The extent to which a dissipative system’s trajectory can be displaced from an attractor region and still return to the attractor when the disturbance ceases is a measure of the system’s *resilience* or *homeostatic capacity* to absorb and recover from disturbance. Commonly, the larger the initial displacement, the faster the return to the dynamic equilibrium of the attractor.[82]

So, a *basin of attraction* can be looked at in two ways. One is to see it as the set of all initial system configurations such that, starting from any of them, the system will spontaneously move towards one specific attractor or sequence of states. The other is to see it as setting the limits to the system’s homeostatic capacity, namely the set of states beyond which, after disturbance, it cannot move and still return to the basin’s attractor.

The theory of non-linear dynamic systems recognises at least four types of state trajectories that systems can follow once they have entered an attractor region:

Point attractors are ‘one-state trajectories’. That is, the system appears to remain the same even though its materials are continually turning over and it is degrading energy. A system reaching a point attractor is said to be in a stationary state.

Cyclic or periodic attractors (also called limit cycles or stable oscillations) are trajectories in which the system passes through a fixed sequence of states and then repeats the same sequence indefinitely.

Strange attractors (also called chaotic attractors) are trajectories which, without leaving a bounded region of the current basin of attraction, traverse an infinite number of states without ever returning to a previously visited state. A system following such a trajectory is said to be behaving chaotically and behaviour can vary from nearly periodic to apparently random.

Developmental attractors (also called homeorhetic attractors) are sequences of states (i.e. trajectories) corresponding to developmental stages in classes of systems which have well-defined life cycles, e.g. organisms. More generally, a

[82] Schneider, E.D., and Kay, J.J., 1994, Life as a Manifestation of the Second Law of Thermodynamics, *Mathematical and Computer Modelling,* **19** (6–8), pp.25–48.

homeorhetic system is regulated around 'set points' as in homeostasis, but those set points change with time, e.g. migrate across the basin.

When observing real-world dissipative systems, it is difficult to confidently detect point and cyclic attractors, partly because such only occur in simple systems with a few degrees of freedom (i.e. unlike global cycles) and, also, random (inherently unpredictable) disturbances obscure the underlying form of the attractor. More bluntly, cyclic and point attractors exist only approximately and for limited periods. It seems that global cycles and other physical dissipative systems are generally better described as having an underlying tendency to behave chaotically and, in the presence of frequent external disturbances, more or less randomly, at least within the confines of the attractor associated with the system's current basin of attraction. Developmental attractors, on the other hand, seem to be more the province of biological dissipative systems. A dynamic system will stay within its attractor, transporting materials, making static structures perhaps, and degrading energy, until it is pushed into a different basin by a sufficiently prolonged and sufficiently large perturbation or *disturbance,* meaning a change in the pattern of availability of energy/material inputs from the system's environment. The caveat here is that the disturbance should not be so large as to overload and destroy the system.

More completely, disturbances which trigger such self-organisation do not have to be *exogenous,* meaning 'from the outside'. They could be *endogenous*. What does that mean? An *endogenous disturbance* in a self-organising system is a fluctuation in the external environment of a component *sub-system* which is itself self-organising. That is, an endogenous disturbance is a fluctuation which is external to the reorganising sub-system but internal to the total system. A small change in one sub-system triggers a large change and, from there, a reorganisation in other sub-systems. The energy to drive this sort of reorganisation from inside will normally be energy which has been stored within the system itself after being captured from the energy flowing into the system from the environment. So, even though it is lagged, the reorganisation is still being powered by environmental energy flow.

If a dissipative system is located in an environment which is not variable enough to spill it out of its current basin of attraction, the system is said to be *stable*—at least in that environment. Putting that another way, stability in a real system means staying within some basin of attraction. As well as being a function of its environment's variability, a system's stability will also be function of its own resilience. Greater stability goes with a system's greater tendency to pull in (through positive feedbacks), concentrate and dissipate thermodynamic potential, i.e. organised materials and high-quality (free) energy. Other things being equal, a system which is supplying its own feedstock materials through recycling is more likely to be stable, and hence persist. To take a global example, when the energy and moisture load of the atmosphere above a tropical sea of the appropriate temperature becomes too large to transport moisture aloft in the normal way, the transport system may spontaneously re-organise (self-organise) itself to include a new attractor called a cyclone. A cyclone, because it comprises fast-moving material, can dissipate a much greater quantity of energy per unit time for every gram of water it contains than the normal evaporation-rainfall cycle (doing things faster consumes more energy). When the energy load on the tropical sea drops back to more normal levels, there will no longer be a tendency for cyclones to form.

Recapitulating then, each of the global cycles, networks, through which energy and stuff passes, dissipating as it goes, reservoir by reservoir, link by link, is, in the language of non-linear dynamic systems theory, an attractor in a basin of attraction. It is to this state of dynamic equilibrium that the system returns, quickly or slowly, after disturbances from outside or noise from inside—provided, as noted above, these disturbances are not too large. If the degree of noise/disturbance is above some critical threshold level, part of the global cycle will shut down (collapse) through lack of feedstock. Alternatively, it will react to the changes by self-organising, by spontaneously jumping into another of the system's latent basins, one containing, perhaps, an attractor 'trajectory' that can successfully process the post-disturbance flows of materials and energy as they enter the global cycle in question.

A system which has been driven away from its dynamic equilibrium state towards a point, a *bifurcation point*, where it is close to undergoing a self-organising change is said to be in a *critical state.* A self-organising system which has reached a bifurcation point is unstable in the sense that it requires only a small pulse of energy to push it into one of several adjacent basins of attraction. Which of the available basins will be entered is quite unpredictable; the outcome is effectively random and, in this sense, evolving physical self-organising systems display the same 'blind variation' as biological systems evolving in accordance with the Darwinian 'variation and selective retention' model. To complete the parallel with natural selection, evolving physical dissipative systems are also *selected* in the sense that successive variations will be 'rejected' until the system reaches a basin where it is stable, i.e. where it can persist within its attractor trajectory without being rapidly nudged or jolted, endogenously or exogenously, into a new basin.

Maximum Entropy Production

Something which cannot be proven, but which is strongly suspected by many, and which can be mathematically modelled with some degree of confidence,[83] is that the global dissipative system, the stable self-organising Earth, is behaving in accordance with the maximum entropy production principle introduced above (see page 7). That is, at all times and places, within the bounds of what is kinetically (materially) possible, the Earth is spontaneously attracted to that mix

[83] Dewar, R., 2009, Maximum Entropy Production as an Inference Algorithm that Translates Physical Assumptions into Macroscopic Predictions: Don't Shoot the Messenger, *Entropy,* 11, pp.931–944.

(network) of material-cycling energy-dissipating pathways which produces more entropy, dissipates more energy per gram, than any other feasible organisation.

There are normally many alternative pathways potentially available to the material-energy passing through any global cycle. To the extent that these alternative paths are incompatible, i.e. cannot proceed simultaneously, only one can emerge, can be selected. For example, a cloud can produce rain in Belgium or in England, but not both. Storms can blow up anywhere. At any time a particular path may be blocked or open, depending on what is happening in other global cycles or indeed in that same cycle, e.g. clouds can reduce evaporation. What is being suggested, at least in regard to the physical dissipative systems of the pre-biotic Earth, is that the particular mix of paths adopted for moving stuff around will always be changing in the direction of increasing entropy production. This capacity to spontaneously readjust the operating mix, the active network of paths, in a dissipative system in order to better meet, at least locally, the cosmic imperative to maximise entropy production is at the heart of the self-organisation-reorganisation process. Let me explain further.

Energy can only be degraded in the presence of matter, basically (but not exclusively) as a corollary of moving it around, which means doing work to overcome its inertia—matter's tendency to resist such movement. It is just not possible for a dissipative process to occur without producing some transient non-equilibrium structuring of its material constituents. What Rod Swenson has usefully observed is that, in such systems, ordered (internally correlated) flows of disaggregated matter—kinetic structures—produce local entropy faster than disordered flows which rely mainly on friction and conduction to produce entropy.[84] So, to the extent that different paths are feasible, the 'most ordered' mix of paths, the one which produces the largest amount of entropy and degrades the largest amount of *exergy* will be spontaneously selected. *Exergy* is a useful term for high-quality freely available energy which when used to do work is degraded to a lower quality unsuitable for doing further similar work. Exergy lost always equals entropy produced.

This *thermodynamic selection* is the behaviour which locally satisfies the cosmological (thermodynamic) imperative, namely the universe's tendency to eventually eliminate all its own energy and material gradients. Distinguishing it from the additional sorts of selection processes which occur in chemical, biological, social and psychological dissipative systems, it is helpful to define thermodynamic selection as the process wherein a self-organising dissipative system 'gropes' its way towards

[84] Swenson, R., 1991, Order, Evolution, and Natural Law: Fundamental Relations in Complex System Theory, In Negoita, C., (Ed.), *Cybernetics and Applied Systems*, Marciel Dekker Inc., New York, pp.125–148. The degree to which a system is ordered or structured is measured, in principle, by the amount of information (usually measured in binary bits) required to describe how it is configured, molecule by molecule. More prosaically, order in a system means there are fixed relationships (correlations) between the parts of the system.

the physically feasible set of kinetic paths which degrade energy at the maximum rate possible for that system.

In the language of non-linear dynamic systems, thermodynamic selection is the process whereby a dissipative system passes through a sequence of basins in each of which it is in unstable equilibrium until it reaches a basin-attractor where it is in stable equilibrium. It is stable because all the incoming exergy is being used to build and maintain kinetic structures rather than to perturb existing structures. And, in a situation where all the incoming available energy is being actively processed through kinetic structures, entropy production from that system-environment combination will necessarily be as high as it could be. Expressed in this way, 'thermodynamic rejection', i.e. sequential rejection of the unstable, is perhaps more descriptive than thermodynamic selection. Of course both words have connotations of 'purpose' which are not intended.[85]

So, while energy can be degraded by moving material around in a disordered way, more energy can be degraded by moving the same material around in an ordered or structured way such as a convection current. For example, when a vortex forms around the plughole of an emptying bathtub, the rate of emptying accelerates. Moving any material faster uses more exergy and produces more entropy. From the observer's perspective, a structure here is a persistent macro-pattern of stuff, one in which the finer-scale material components in each part of the pattern are being turned over (imported and exported) incessantly, more or less regularly and more or less accurately in terms of reproducing the macro-pattern. The system will tend to be kinetically unstable (tend to keep changing) as long as a still more ordered structure, a new attractor requiring still more energy throughput to maintain it, can be constructed from the available materials. It is only when this is no longer the case that the system will be kinetically stable, will be maximally ordered, will be producing entropy at the maximum feasible rate and will be degrading a maximum amount of usable energy.

Succinctly then, the more structure there is in a dissipative system, the more entropy it is producing, the more free energy (exergy) it is degrading, the more energy it is storing, the more outside energy it is using to maintain itself and the more rapidly the cosmological drive towards equilibrium is being satisfied. And, to complete the mutually causal loop here, the more energy it is degrading, the more structure it is producing and the further it is from equilibrium.

Not only is such behaviour illustrating Swenson's principle of maximum entropy production, it is consistent with Chaisson's view of evolution as a grand self-organising process in which 'islands' of increased complexity (increased structure) and increased *free energy rate density* emerge from a falling 'sea' of pre-existing less complex systems and persist when conditions are right, i.e. when constraints on what is possible are relaxed.[86] Free energy rate density is the rate at which, per gram

[85] Salthe, S.N., 2010, Maximum Power And Maximum Entropy Production: Finalities in Nature, *Cosmos and History: The Journal of Natural and Social Philosophy*, **6** (1), pp.114–121.

[86] Chaisson, E., 2001, ibid.

of material, a system is processing energy. As we shall see, Chaisson's process is most dramatically illustrated by biological evolution but, as noted earlier, it is also evident in the pre-biotic universe. Self-reorganisation in the direction of maximum entropy production is also self-organisation in the direction of a system in which free energy rate density has been increased. Chaisson's work has focussed on the jump in free energy rate density which occurs when a radically new sort of dissipative system emerges but, less spectacularly, the same is happening when any dissipative system self-reorganises in response to an increased energy throughput.

A final idea which neatly links the ideas of self-organisation and maximum entropy production is that a self-organising system which has settled into a strange attractor region in a state of dynamic equilibrium is also, plausibly, producing entropy at the maximum rate possible for that system.

Chapter 2
Stages in the Evolution of Modern Humans

From Placental Mammals and Primates to the First Humans

A convenient place to begin a brief history of the human lineage is with the placental mammals—hairy, sweaty, toothed, lidded, flap-eared four-limbed animals with lungs, four-chambered hearts and developed brains. They maintain a high constant body temperature. Their young are produced from embryos attached to the placental organ in the uterus and, after birth, are nourished by milk from mammary glands. The oldest fossil of a placental mammal, dated to c.125 Mya (million years ago), is a 'dormouse-like creature' 10 cm long.

Towards the end of the Cretaceous period (70–65 Mya), atmospheric changes, including cooling and reduced sunlight, caused, perhaps, by dust from a super volcano or by an Everest-sized asteroid led to the extinction of dinosaurs, plesiosaurs, ichthyosaurs, pterosaurs and much else. In fact no animal species weighing more than 10 kg survived this shock. Since this event, mammals and flowering plants have been the dominant groups of organisms.

Primates, distinguished by their good eyes and flexible hands and feet, are a taxonomic division (an *order*) of the placental mammals that includes the prosimians (primitive monkeys such as lemurs), apes, monkeys and humans. The earliest primates appear in the fossil record at the end of the Cretaceous (65 Mya) and become abundant during the Paleocene (65–55 Mya). They were small-clawed shrew-like quadrupeds living on the ground and in the security of trees. In the Eocene (55–38 Mya), primates finally took wholly to trees and developed many novel methods of coping with that environment. Through natural selection various innovations in body structure and function suited to an arboreal environment appeared.

D. Cocks, *Global Overshoot: Contemplating the World's Converging Problems*,
DOI 10.1007/978-1-4614-6265-1_2,

These adaptations[1] included manipulative grasping hands (with opposable thumb and forefinger) and feet for leaping from limb to limb and stereoscopic vision for depth perception (enhanced by a rotation of the eyes to the front of the skull and a reduced snout). Parallel development of the cerebral cortex (cortex is Latin for bark) led to ever-better coordination of hand and eye (important for picking fruit rapidly). Sight and touch began transcending smell and hearing as the important senses. Primates began living in social groups in more-or-less 'fixed' territories and relying increasingly on socially learned rather than instinctive behaviour. Being territorial included a willingness to expel trespassers, particularly of their own species. These adaptations can be plausibly traced to the tree-dwellers' diet of fruits from widely scattered trees. Large territories of scattered 'randomly flowering' trees can be better defended and better exploited by groups of primates with good colour vision for finding fruiting trees and fingers suited to picking the crop. The use of group 'scouts' is an effective way of amplifying the individual's senses.

Large litters are a disadvantage for mobile animals in an arboreal environment and primate reproductive strategy evolved towards more intensively caring for but one or two offspring. Also, being in a relatively tropical environment there was little need to limit sexual receptivity to certain periods of the year. Being able to mate throughout the year encourages pair-bonding and is helpful for increasing numbers in a species with a low birth rate. Having young with an extended dependency period and having a habit of living in groups for assistance, protection and food-finding were two developments promoting band cohesion and forms of social organisation that eventually led to human culture.

Throughout the Oligocene epoch (38–25 Mya), monkeys and apes, the 'higher' primates, flourished. By 25 Mya the short-tailed dryopithecine apes regarded as ancestors of humans and other extant apes were well established. Their evolutionary success was enhanced by a coevolution between the seed-distributing primates themselves and seed-producing trees, a symbiosis which led to seeds of high food value and an omnivore diet of seeds, insects and small reptiles.

During the Miocene epoch (25–5 Mya) the great ape family, the Hominidae, split into the ancestors of orangutans, gorillas, chimpanzees and humans. Some 17 Mya orangutan ancestors were the first group to diverge, with the gorilla-chimpanzee-human divergence coming towards the end of the epoch. Sarich and Wilson, drawing on molecular dating of DNA, suggested that gorillas, chimps and humans could have had a common ancestor as recently as 5 Mya.[2] Other more mainstream estimates have the gorilla splitting off some 8 Mya and put the chimpanzee-human split at 6–7 Mya.

[1]In biology, adaptation is a word used to describe both a process and its product. Adaptation is a process of natural selection (differential reproductive success of genotypes in a population) which produces adaptations. An adaptation is an unprecedented anatomical structure, physiological process or behavioural trait in a population of organisms which, at least in the short term, increases that population's capacity to survive and reproduce.

[2]Sarich, V.M., Wilson, A.C., 1967, Immunological Time Scale for Hominid Evolution. *Science,* 158, pp. 1200–1203.

The species *Ardipithecus ramidus* has a strong claim to being the earliest forerunner of modern humans to be identified. In 2001, a specimen found in Ethiopia was carbon-dated at around 5.2 Mya. Other specimens confirm that early hominines (human ancestors), including *Australopithecus afarensis*, walked upright on two feet 4.3–4.5 Mya.

Down on the Ground

Australopithecines and Their Brains

So, starting in east Africa some 5 Mya, around the beginning of the Pliocene epoch (5–1.8 Mya), the human lineage evolved from being well-adapted tree-dwellers to being ground-dwellers. It is believed that, as ecosystems changed in response to a drying, cooling climate, proto-humans, australopithecines (meaning 'southern apes'), moved from a gallery-forest habitat to a more open savanna habitat.[3] And, as they moved out onto the grasslands, they stood up. This was a key innovation which, amongst other consequences, reduced heat loads, made it easier to look over the grass for predators, to use tools and weapons, to bring food to a home base and to carry helpless infants. Thus, it was an adaptation contributing something to meeting each of the three big challenges facing all animals—food, safety and reproduction.

In time, because it allows a steady sustained gait, bipedalism (plus a unique capacity to lose heat by sweating) would allow humans to kill much faster animals, by chasing them to exhaustion. Note though that bipedalism does have an important limitation; it requires the development of a weight-bearing pelvis, one in which the birth canal cannot be too wide, which, in turn, bounds the size of the neonatal skull.

These proto-humans were small agile creatures about 1–1.3 m high, living on nuts, fruits and berries. They were a heterogeneous group, some with large teeth and huge jaws, some less robust. Over time, jaw and snout became less prominent as hands came to be used to break up food and convey it to the mouth.

Although australopithecines of 4 Mya walked like humans, they had chimpanzee-sized brains (which still made their brains somewhat larger relative to body size than chimpanzee brains). While some may have been able to use tools, australopithecines showed little sign of any cognitive (thinking power) evolution.

[3]The cause of this climate change is contentious. Starting with the northward movement of the Australian tectonic plate, there may have been a northerly movement of the connecting seaway between the Indian and Pacific oceans which then led to a flow of cold north Pacific water through to the Indian Ocean in place of warmer South Pacific water. A colder Indian ocean meant less evaporation and less rainfall over Africa. An alternative, perhaps complementary, explanation for the drying of east Africa at this time attributes it to the delayed buildup of northern hemisphere ice sheets following the closure of the Panama seaway and the loss of warm currents in the north Atlantic about 4 Mya.

Still, as the functions of fore and hind limbs differentiated, there came a parallel selection pressure for increased (frontal) cortical representation of the specialising body parts.[4] For example, a much-expanded representation in the brain of hand activity led to improved manipulative skills and, more generally, a richer neural interplay between brain and body. Neurally, these extra tasks were at first accommodated not so much by brain growth as by a rudimentary redundancy-exploiting division of labour between the brain's left and right halves: the earlier bilaterally symmetric brain was redundant in that either half could manage all motor (muscle moving) activities. With a set of new tasks being managed from the left brain, there also came a consequential need for improved channels of communication (more nerve fibres) between left and right cortical areas.

What was being initiated here was a period of hand-brain co-evolution. Once hands had evolved enough to make tools, it became advantageous for the brain to evolve in ways which facilitated the making of better tools. The important underlying principle here is that learning has evolutionary consequences. The skills an animal acquires in its life cannot be incorporated into its genome and transmitted genetically to the next generation. It does not follow, though, that such changes in individual phenotypes are of no evolutionary consequence for these changes *alter the selective forces acting on that animal*, and hence make a difference to the generation-by-generation action of selection on a lineage. For example, an animal with newly learned skills might modify its environment in a new way (use more or different resources, say) or move into a somewhat different environment.

In a savanna habitat, rich in large carnivores, the 'somewhat undersized hominids must have found themselves outclassed, outfought and outrun'[5] These circumstances led them to form cooperative teams or packs whose effectiveness for protection and food acquisition relied on coordinated action.[6] However (and for Zoltan Torey[7] this is the crucial point) since the neuro-somatic (brain-body) equipment for supporting such cooperation was not already inbuilt as instincts, the required skills (e.g. food sharing) had to be acquired and perpetuated through imitation (mimesis) and through learning.

Both of these techniques, mimesis and trial-and-error learning, are highly brain-dependent, the consequences being further selection for cortical skills and further reliance on *brain-managed behaviour*. Mimetic skill is the ability to represent knowledge (e.g. how to make a stone tool?) through voluntary motor acts. Beyond being immediately useful, the evolution of mimetic skills and their associated neural structures became the platform from which language skills would eventually evolve.

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[4] Torey. Z., 1999, ibid. p. 34.

[5] Torey, Z., 1999, ibid., p. 32.

[6] In many circumstances cooperation can be thought of as a 'technology' for synergistically amplifying the capacities (sensory, physical and mental) of individuals.

[7] Torey, Z., 1999, ibid., pp. 1–38.

Habilines and Erectines

Australopithecines survived in the African landscape till about a million years ago. Along the way, perhaps 3 Mya, the first member of the genus *Homo*, namely, *Homo habilis* ('handy man') split from the australopithecine lineage. *Homo habilis* is perhaps best described as a confusing collection of transitional forms (habilines) between australopithecines and *Homo erectus*, the first large brained hominid to appear in the fossil record, about 2 Mya in both Africa and East Asia. In fact, the stone tool record suggests that erectines (*Homo erectus* and variants) could have emerged 2.5 Mya. It seems that between 2.5 and 2 Mya the forests and savannas of east Africa could have been home to a mixture of australopithecines, habilines and erectines.[8]

Australopithecines had a 450 cc brain, habilines a 450–600 cc brain and erectines a 900 cc brain. This increase in brain size over several million years was largely in regions controlling, respectively, the hand, proto-speech (of some sort) and hindsight-foresight, i.e. some appreciation of cause and effect. How and why did this transition occur? It may well have been in response to various lifestyle changes including a switch in diet from, first, leaves to fruit, nuts and roots and then to an omnivore diet containing quantities of meat. Food-acquisition techniques concurrently expanded from gathering plant parts to scavenging carcases to group-hunting of large game.[9]

Becoming meat eaters in competition with, first, scavenger carnivores like jackals and then with well-armed primary carnivores like lions required not only group cooperation but the development of tools such as stone hammers for breaking marrow bones (of particular importance for creating a secure ecological niche), sharp stones for tearing tough hides and clubs for killing game. Evolving a brain which could support the cognitive and motor skills (e.g. stone throwing) underpinning such behaviours allowed hominids to compete with better-armed carnivores. More than this, a bigger brain was an 'open ended' adaptation with the potential to coevolve in parallel with a widening range of social, cultural and cognitive skills and, indeed, to cope with a further-changing environment. Along with changes to lifestyle, brain architecture/organisation and a slowing rate of maturation (see below) came a change in hormone balance, namely, from adrenaline dominance, the mark of fearful or prey species, to noradrenaline dominance, the mark of aggressive, predatory species. Selecting hominids for delayed development automatically selects for adults with a more juvenile and hence more 'aggressive' hormone balance, meaning one more suited to hunting than gathering.

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[8]Wills, C., 1998, *Children of Prometheus: The Accelerating Pace of Human Evolution,* Perseus, Reading, p.229; Donald, M., 1991, *Origins of the Modern Mind: Three Stages in the Evolution of Culture and Cognition,* Harvard University Press, Cambridge, MA.

[9]The 'radiator' hypothesis suggests that the dramatic increase in brain size that occurred in Homo was facilitated (not directly caused) by the evolution of a radiator network of veins which relaxed the thermal constraints on overheating that previously kept brain size in check. See Falk, D., 1990, Brain Evolution in Homo: The 'Radiator' Theory, *Behavioral and Brain Sciences*, **13**, pp.333–381.

A period of major climatic fluctuations, the precursor to the Pleistocene ice ages perhaps, began some 3.5 Mya (the first major ice build-up began about 2.5 Mya). Intelligence turned out to be an ideal general-purpose highly evolvable 'tool' for coping with the associated environmental challenges while not becoming trapped in an evolutionary dead end. Most successful but specialised genetically based adaptations to currently prevailing conditions are burdened by an inability to 'go back' when conditions change once more. This is why most species that have ever been are now extinct. As Jacob Bronowski says, the environment exacts a high price for survival of the fittest—it captures them.[10]

Judging by the dramatic continuous increase in brain size between *Australopithecus* (450 cc) and modern man (1,350 cc) it can be reasonably assumed that increasing brain size (and brain complexification), with its increasing capacity for cause-effect reasoning, remained evolutionarily advantageous under a range of markedly different environments. John Tooby and Irven De Vore suggest that it was *H. habilis* who first moved from instinctive behaviour to the 'cognitive niche' where knowledge of how things work can be used to attain goals in the face of obstacles.[11] This involves what we largely mean by intelligence, namely, the building of mental models, of cognitive schemata if you prefer.[12]

Two Million Years Ago

Some 2 Mya, perhaps earlier, as east Africa continued to dry and cool, erectines migrated outwards, reaching Europe, Java, Pakistan and south China by 1.7 Mya.[13] The pressure to keep moving on, migrating, would have been a result of any net population growth in a savanna environment able to support only 1–2 people per square mile. William McNeil makes the suggestion that this first spurt in human numbers may have been boosted by the jettisoning of various tropical parasites as humans moved into colder dryer regions.[14]

Indeed, by the time the Pleistocene epoch proper began, *H. erectus* had dispersed across the still habitable parts of Europe and the near and far East. And it was around 1.9–2 Mya that erectines began to use fire and invented cooking.[15]

[10] Bronowski, J., 1973, *The Ascent of Man*, British Broadcasting Corporation, London, p. 26.

[11] Tooby, J., and DeVore, I., 1987, The Reconstruction of Hominid Evolution through Strategic Modelling, In W.G. Kinzey (Ed.), *The Evolution of Human Behavior: Primate Models*, SUNY Press, Albany, New York.

[12] D'Andrade, R.G., 1995, *The Development of Cognitive Anthropology,* Cambridge University Press, Cambridge.

[13] Stone tools 2.5 myrs old have been found in Israel and Pakistan, suggesting to Wills (1998, ibid.), that habilines also left Africa for Asia, and perhaps Eastern Europe, at least 2.5 mya, while climates were still mild.

[14] McNeill, W.H., 1979, *Plagues and People*, Penguin, London.

[15] Wrangham, R., Jones, J. H., et al.,1999, The Raw and the Stolen: Cooking and the Ecology of Human Origins, *Current Anthropology*, **40** (5), pp. 567–594.

Cooking tubers, by making their starches digestible, allowed this increasingly common cold-climate underground food source to become a concentrated and reliable (more so than fruits) part of the human diet. Together, it was fire and cooking which allowed humans to spread into cold areas. Mastery of fire would have allowed erectines to camp and live in the presence of large predators.

Increased energy intakes at this time would have lifted constraints on increased brain size, further increased reproduction rates and increased life spans, all relative to habilines and australopithecines. In turn, grandmothers would have been useful for the hard work of finding and digging tubers, and feeding them to children. Perhaps gender roles—hunting for men and food-gathering and protecting the cooking hearth for women—arose in part because women became less efficient bipedalists as their hips widened to allow the birth of larger-brained children. This natural sharing of complementary contributions to the hunter-gatherer economy may also help explain male-female pair-bonding within larger groups and the low degree of sexual dimorphism (male-female size difference) in humans relative to other apes.[16] That is, with less competition for females there could have been less selection pressure for ever-larger males to evolve.

Portending the arrival of *Homo sapiens*, another anatomical consequence of the invention of tools and cooking was the shrinking of powerful teeth and jaws and loss of the brow ridges that anchor the jaw muscles. Because cooking increases the energy-density of food, the human gut began to shrink. Also, for reasons that are not clear unless one assumes a very early development of language (as singing perhaps?), *H. erectus* acquired a greatly extended vocal flexibility due to a rearrangement of the palate and larynx. Even if, improbably, the vocal tract in erectines had been sufficiently developed for articulated speech, as distinct from other forms of vocalisation, a brain capable of managing speech still would have been lacking.

Upgrading the Habiline-Erectine Brain

While a higher-energy diet permitted a cognitively useful but energy-guzzling erectine brain to increase sharply in size over evolutionary time (to 70% of that of a modern human), what was the actual mechanism?

In large part, it was selection for *neotenous development* or, more accurately, neotenous regression. *Neoteny* is a not-uncommon evolutionary process in which successive generations increasingly retain, through to maturity, what were baby-like features in their ancestors. In humans, this means retaining such things as looking forward when standing upright, a flat face with big eyes, playfulness and unclosed skull sutures. It may be noted that modern adult humans resemble, uncannily, the juvenile forms of the other great apes, none of which has experienced neotenous development.

[16]Based on observation of many mammalian taxa, a low degree of sexual dimorphism is an indicator of monogamous mating behaviour.

This progressive infantilisation had a range of consequences. It not only allowed babies with bigger brains to pass through the birth canal (because of their flexible skulls), it allowed brain growth to continue till reproductive maturity. And it did so continue, part of the neoteny package being a delayed activation of the regulatory genes which switch the brain from a higher growth rate characteristic of juveniles to a lower, more characteristically adult growth rate. On the other side of the ledger, postponed development has meant a loss of strength, speed and agility relative to other apes.

Neoteny, Cooperative Behaviour and Individual Autonomy

Equally importantly, this just-noted delay in brain development meant that babies were being born before various instinctual 'survival-promoting' tendencies had been 'wired-in'. One consequence of this was babies who were totally dependent on parental and group nurturing to survive.

This dependence of infants might have had, plausibly, two further evolutionary consequences. One would have been a selection pressure to further enhance the group bonding and cooperative behaviour which had been part of the lineage's evolution for 50 myrs. Part of that social evolution would have been selection for cooperative and teachable children, able to evoke the support they needed.

A second consequence of infant helplessness, the antithesis of selection for cooperation at first glance, would have been a selection for autonomy, a drive to actively learn survival skills through play and other self-initiated actions.[17]

Together, as Mary Clark puts it:

> These simultaneously increasing propensities to bond on the one hand and have autonomy on the other became part of genetically ingrained 'drives' embedded in the motivational centers of the evolving brain, as are our 'drives' for water, food, shelter, and mating. Obviously the pair of them exacerbated the opportunities for inner psychic tensions as well as social stress when bonds came into conflict with independent behaviors.[18]

In contemporary humans of course, this tension, in the form of managing both the drive to individuate and the drive or need for secure attachment, to belong within the group, has come to be seen as central to the problem of achieving mental health; within the family too, where marriage is sustained by holding in tension the twin needs for intimacy and autonomy.

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[17]Drives can be thought of as generalised instincts involving much-heightened perception and motivation. In comparison, most instincts exhibit as more specific behavioural patterns which may be elicited under certain circumstances. In the case of humans, two conditions must be fulfilled for actual acting out of instinctual behavioural patterns: relevant stimuli and the absence of other modes of regulating behaviour. Drives are extremely plastic in humans. For example, sexual and feeding drives do not tell the individual where to seek release or what to eat; specific behavioural responses to these drives are acquired through socialisation. See Berger, P., and Luckmann, T., 1966, ibid. p. 181.

[18]Clark, M.E., 2002, *In Search of Human Nature*, Routledge, London, p. 130.

Neoteny and Playfulness

It is easy to overlook the importance of hominids having been selected for a prolonged capacity for juvenile, playful, exploratory behaviour as an ancillary to being selected for neotenous development; an importance beyond facilitating the learning of extant survival skills. How is this? Because play involves trying things 'at random', it leads, on occasions, to the discovery of useful new ways of behaving. And to this extent the drive to playfulness, including mental play, is the process underlying the increasing capacity to behave in a wide variety of ways (depending on context), which, as discussed below, is at the heart of the hominid lineage's 'strategy' for achieving adaptedness.

The Pleistocene Ice Ages

Earth's most recent period of ice ages or repeated glaciations (*glacials*) began about 2.5 Mya after 250 myrs without an ice age.[19] Note that while commonly referred to as the Pleistocene ice ages (including here), the start of the geologists' Pleistocene epoch is normally set at 1.6–1.8 Mya, not at 2.5 Mya. Caused by regular variations in the Earth's orbit around the Sun, there have been some two dozen warming–cooling cycles (plus and minus 3–4°C) in that 2.5 myrs, each lasting, very approximately, 100,000 years (much less till about a million years ago). Each cycle comprises (a) a long cooling period of (say) 90 kyrs, with temperatures fluctuating but getting much colder towards the end, followed by (b) a short transition (centuries) characterised by very rapid, high-amplitude climatic oscillations which leads to (c) a 'sudden' warmer *interglacial* period of (say) 10 kyrs.

For example, in the last ice age, which started 115 kya and ended 12 kya (defined as the end of the Pleistocene), huge ice sheets advanced and retreated several times over most of Canada, northern Europe and Russia. Sea levels rose and fell by as much as 200 m in concert with this locking up and releasing of much of the world's water from glaciers. The advancing glaciers, covering up to 27% of the Earth's surface, obliterated most plant and animal life in their paths and pushed the inhabited temperate zones of the northern hemisphere south. In the southern hemisphere mountain-top glaciers grew enormously. Much of the tropics became cool deserts. More generally, cold-climate vegetation types tended to replace warm-climate types. Some 18–20 kya the Earth was as cool as it had ever been in a million years, just as, now, it is as warm.

By a million years ago *Homo erectus*, dispersed half way around the world, was the only surviving hominid. And then, some 800 kya, came what was to be the second of three waves of human emigration from Africa.[20] By 500 kya *H. erectus* began

[19]Because 250 myrs is the time it takes the solar system to revolve around the centre of the galaxy (the 'galactic year'), we can speculate that there is a cloudy, Sun-dimming region which the solar system encounters for several million years once every revolution. If that is so, there is a possibility that the present epoch of ice ages might be the last for another 250 myrs.

[20]Templeton, A., 2002, Out of Africa, Again and Again, *Nature*, **416** (6876), pp. 45–51.

to give way to several other types of Homo. For example, by 250 kya an archaic *Homo sapiens*, with a brain as big as ours (but with behaviour that showed no sign of art or symbol use) had appeared. Neanderthal man, heavy-jawed and even bigger-brained, was certainly here 100 kya. A longer lifespan and a larger brain both facilitate the transmission of culture and both began to increase in line with the increasing importance of learned behaviour some half million years ago.

As for modern humans, the fossil evidence for an African origin is strong. It is clear that modern humans (*H. sapiens sensu stricto*) were certainly present in Africa by 130 kya, and perhaps as early as 190 kya depending on how certain fossil specimens are interpreted. Modern humans, the third wave of people to emigrate from Africa, first left c.100 kya (during the last interglacial), but rather unsuccessfully, and then left again about 80 kya. Recent evidence suggests that modern humans were present in Australia as early as 62 kya.[21] In a warmer period following the particularly cold millennium triggered by the Mt Toba eruption 71 kya (see below), humans migrated into north Asia. From there, after encountering a subsequent period of cooling and glaciation, they migrated back into Europe, first appearing there (and in central Asia) c.40 kya. And, by 25–30 kya, with the disappearance of Neanderthals from Europe, *H. sapiens* was the planet's only species of human.

Cultural and Genetic Evolution in the Pleistocene

While the erectine brain continued to grow and reorganise through most of the Pleistocene, culminating in the emergence 150–200 kya of modern humans with 1,350 cc brains and a capacity for structured language, this was, in some ways, a period of very slow change, almost stagnation, in human evolution.

The single most important change over that period of more than a million years was the eventual arrival, at a young enough age, of a brain organisation and size—around 750 cc—capable of supporting rudimentary speech skills. A 1-year-old sapiens and a 6-year-old erectus both have a 750 cc brain but the erectus brain, even though meeting the capacity threshold, cannot learn language simply because it has grown too slowly. That is, the parts of the left frontal cortex which might have been appropriated for learning and using language—a sophisticated motor skill—have already been appropriated for learning and using basic motor skills more needed for immediate survival.[22] Indeed, there is evidence that even in adults the cerebral cortex is constantly readjusting and fine-tuning its assignment of processing space between tasks, reflecting the constantly changing use-patterns imposed by the environment.

[21] Thorne, A., Grün, R., et al., 1999, Australia's Oldest Human Remains: Age of the Lake Mungo 3 Skeleton, *J. Hum. Evol.*, **36**, pp. 591–612; Stringer, C., 2002, Modern Human Origins: Progress and Prospects, *Phil. Trans. R. Soc. Lond. B,* **357**, pp. 563–579.

[22] Donald, M., 1991, ibid.; Torey, Z., 1999, ibid., p. 36.

Also, as Terrence Deacon points out, an individual brain which is maturing in parallel with its increasing language skills is positioned to (indeed, must) build up those skills hierarchically (words before syntax), and hence more efficiently, than a more mature brain grappling with several hierarchical levels simultaneously.[23]

Apart from cranial changes associated with brain changes, Pleistocene evolution would have seen a continuation, but slowing, of other existing trends in outward appearance such as loss of body hair, increasing height and shrinking face, teeth, jaws, gut and rib cage. In terms of cultural evolution the general view is that things moved slowly prior to a surge in the development of tools, art, burial practices, artefacts, etc., in the late Pleistocene, say, 30–40 kya.

What is of more interest here though is contemporary speculation as to the ongoing evolution through the Pleistocene of what Clark calls the *behavioural guidance system*, and the behaviour patterns generated by that system.[24] In one or another form, most of the tools or technologies or elements of that guidance system—feelings or emotions,[25] memory, skills in learning through imitation and repeated personal experience, simple reasoning skills, non-verbal communication, cultural norms—would have been present in early *Homo erectus*.

In a general way, the evolution of the behavioural guidance system through the Pleistocene hinged on bringing more and more information of various sorts to bear on and influence individual behaviour. Relatively at least, there would have been decreasing reliance on purely genetic information (instinct) and immediate sensory information (as when responding reflexively to stimuli) and more reliance on stored (memory-based) information and internally generated (e.g. reason-based) information. And, towards the end of the Pleistocene, symbolic information, particularly in the form of spoken language, would have become increasingly available.

Continuing to generalise, can something be said about the survival value of more-informed behaviour? Perhaps having more, and more sorts of, information available may have allowed the species to occupy a wider niche (live in more environments) or live in an existing niche more securely. Or, as a variation on the latter, modify a niche to make it more secure. Or, another possibility, allow the species to more readily adapt to niche change, i.e. to a changing environment. All of these can be interpreted as variously securing improvements in the magnitude and/or reliability of the energy supplies needed for maintenance and reproduction. A simple example might be the storing of information needed to crack marrow bones open.

The survival value of improved information does however come at a price, namely, the additional food energy required to maintain an upgraded information system, a bigger and better-organised brain. That is, an improved information system has to cover its own increased energy costs before it can deliver any increased

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[23] Deacon, T., 1997, The Symbolic Species: The Co-evolution of Language and the Brain, Norton, New York, p. 137.

[24] Clark, M.E., 2002, p. 160.

[25] The concept of emotions as strong feelings has weakened to the point where the two words are interchangeable. An operational distinction might be that a feeling is a private experience of an emotion, one that cannot be observed by anyone else.

survival benefits. It can be argued that throughout the Pleistocene, at least up till the late Pleistocene, the survival value of an increasingly informed behavioural guidance system self-evidently outweighed the additional costs in energy terms of improving and maintaining that system; the brain kept getting more energy-demanding. And if brain size did plateau with the emergence of modern humans, was this due to an encounter with some physical limit (e.g. the exhaustion of neoteny or the speed of intra-brain communication) or due to diminishing returns to brain size, i.e. did enabled improvements in energy supplies come into balance with increased energy demands?

Memory and Learning

Some form of memory, that is, a capacity for storing acquired information in the central nervous system from where it can be retrieved for future guidance of behaviour, would have been present in the earliest mammals. Indeed, memory may well have been the first transformative development in animal information systems after a long evolutionary period in which the senses were the predominant sources of information (with motor nerves linked directly to sensory nerves). Here, we will not discuss the cellular processes which underlie the conversion (encoding) of patterns of experience into patterns of neural processes, i.e. into learning and memory. Suffice to say that these appear to be much the same for all animals from 'snails to simians'.[26]

In hominids each hemisphere of the brain has four cortical lobes, of which three—visual, temporal and parietal—are dedicated to parallel distributed (meaning simultaneously in several places) processing and storing of sensory information, creating diffusely stored patterns of experience, i.e. memories. The fourth lobe, the frontal, especially its most forward part, the prefrontal cortex, is much less involved with such processing and storing and more involved with sampling information from the other lobes and recombining it, i.e. with thinking. It is what Luria called the *planning cortex*, as distinct from the three lobes of the *sensory cortex*.[27] To this end, the planning cortex has multiple connections with the areas of the sensory cortex that are used for storage/retrieval of long-term memories.[28] Additionally and importantly, it has a capacity for holding short-term memories (lasting up to 30 s) which can be used to guide rapid-response behaviour and which have the potential to become long-term memories.

The planning cortex is also well-connected (via 'thalamocortical pathways') to the emotional centres of the brain; primarily the thalamus and the limbic system, this latter being a group of subcortical brain structures surrounding the thalamus.

[26] Deacon, T., 1997, ibid., p. 163.
[27] Cited by Clark, M.E., 2002, ibid., p. 150.
[28] Clark, M.E. 2002, ibid., p. 150.

In the course of forming a memory, data flows from the sense organs, via the thalamus, to the frontal lobes and finally to the sensory cortex where it is stored. To embed incoming information in long-term (permanent) memory storage, i.e. to form a memory retrievable in the future, a threshold degree of attention to what is being sensed and a degree of emotional arousal are required. Failing that, repeated exposure to a pattern of experience can still embed it in permanent memory. And always, as Antonio Damasio points out,[29] feelings evoked during the passage of sensory information to the sensory cortex via the brain's emotional centres are stored along with the memory; and retrieved with it.[30]

When retrieved (to the planning cortex), a memory is experienced as a sequential sampling ('frames') from the original experience, passing from detail to detail, from perspective to perspective, much like a story or narrative. At some stage during the Pleistocene the ability to voluntarily retrieve memories emerged. This meant that the 'chain' of details being retrieved could be interrupted at any 'link' and, depending perhaps on the emotional associations of that detail, the sequence could be redirected towards other memories. Modern apes and, presumably, our pre-Pleistocene ancestors, appear to retrieve memories of episodic experiences only after stimulation from the environment. As an indication of how this learning-memory process might have been upgraded over the Pleistocene, a 9-month-old human brain is too immature to firmly register experiences, while at 17–21 months it has developed enough to record and retrieve a memory of a single distinctive experience.

Learning as a Process of Percept Formation

In one sense, any act of storing a newly encountered pattern of experience in memory is an act of learning, i.e. the stock of information available for guiding behaviour has been increased. More generally though, learning is thought of as taking place when further similar patterns of experience are encountered, and the original memory is successively refined in a process of *percept formation* analogous to the use in modern humans of *inductive reasoning* to form *concepts*.[31] We might guess that a capacity for percept formation began overtaking a capacity for remembering only specific events (episodic memory) early in the Pleistocene.

[29] Damasio, A., 1999, The Feeling of What Happens; Body and Emotion in the Making of Consciousness, Harcourt Brace & Co., New York.

[30] It needs to be stated clearly that while science has learned much about correlations between brain activity and having feelings, science cannot explain how a feeling is generated any more than it can explain how a gravitational force is generated. See Harnad, S., What is Consciousness? Letter to *New York Review of Books*, 23 June, 2005, p. 56.

[31] In logic, induction is the process of generalising over multiple examples, commonly by emphasising similarities and ignoring differences between them. A percept is anything which can be identified and, in principle, named. A schema is a 'super percept' made up of multiple percepts in a stable relationship. Percepts tend to be abstractions from direct experiences. Concepts tend to be more abstract than percepts and language-based in a way that percepts are not.

How are percepts (cognitive categories is another name) formed? No two patterns of experience will be quite the same but each recurrence of any experience which is accepted as being in the same 'family' as the original experience (how? similar enough to some prototypical example?) strengthens the likelihood of certain components within the pattern being linked and being retrieved together. Components which are commonly retrieved together (i.e. the relevant neurons tend to fire together, a tendency which increases with repetition) become pieces of the percept being built up, e.g. storing and retrieving 'long neck' and 'black feathers' together contributes to building up the percept of 'swan'. Similarly, patterns of experience accepted as being outside the 'swan' family, contribute to stabilising the percept 'not a swan'.

A percept and the degree to which various inherently variable components are recognised as integral to that percept both evolve in the light of experience. Or, putting it differently, a percept is a fuzzy composite of all patterns of prior experience currently accepted as being members of the same family of experiences. A percept's boundaries can be expected to stabilise with experience and with practical success in using it. This process of learning by inductively forming percepts is also a process of acquiring *information*, at least when the sense in which that word is taken is 'that which decreases doubt concerning *meaning*' (answers to questions). And what is meaning? It is the recognition of relationships between entities. Percepts (and concepts and schemata of relationships) are thus bearers of meaning. Learning is the memorisation and refinement of meaning.

The information that learning produces can be retrieved from memory and delivered as input to the complex process of *thinking*. Basically, it is thinking which realises the potential value of memory and learning. While thinking will be further discussed presently, we can note here that, amongst other functions, it allows alternative future behaviours to be compared, cheaply, for their survival value; increasingly so with the development of verbal language, the tagging of percepts with names. Names can be thought with more easily than percepts themselves.

We might also note, finally, that while learning has been described in terms of storing and generalising patterns of sensory stimuli, the process is not restricted to acquiring information about entities in the outside world. In later hominids at least, perceptions of associations between components of distinct existing memories also emerge; a case of learning from oneself or *generative learning*. Again, possibilities for learning from others multiplied with the advent of language.

Feelings and Emotions

Evolution of Feelings-Emotions

Before mammals, animal behaviour (observable activity) was instinctual and reflexive—stimulus in, motor response out. Reptilian motor (muscle control) centres reacted to visual, auditory, tactile, chemical, gravitational and motion-sensory cues with one of a limited number of preset body movements and programmed postures. With the arrival of night-active mammals c.180 Mya, smell replaced sight as the dominant sense, and a newer, more discriminating way of responding, one directed by emotions and emotional memory,[32] arose from the *olfactory sense*. In the Jurassic period, the mammalian brain invested heavily in *aroma circuits* designed to function at night while reptilian predators slept. These odour pathways, carrying messages of threat, food, etc., gradually became the neural blueprint for what would eventually be the limbic (early mammalian) brain. By c.150 Mya, the nerve network for emotions and moods had largely evolved from neural structures previously committed to smell.

Emotions are responses within individuals to memories, other thoughts (e.g. motor intentions) and experiential situations which raise issues of survival, directly or by implication, e.g. threats, attacks, poisonous substances or the sighting of a potential mate. What form do they take? Emotions are of a few basic types (see below) and take the form of (a) a neural impulse to act, (b) a characteristic range of internal physiological changes in the digestive tract, lungs, circulatory system, etc., and, debatably, (c) feelings, meaning perceptions fed back to the planning cortex that these in-body events are happening and that they are ‘pleasant’ or ‘unpleasant’. I say ‘debatably’ because psychologists are divided on whether the term ‘emotions’ should include ‘feelings’ along with the loose collections of impulses and bodily changes comprising ‘emotions’ in early mammals. Perhaps it is best to think of emotions and feelings as two separate but inter-related perceptual systems, the emotional system being evolutionarily earlier (from the beginning of the Cambrian) and the feelings system being associated with the late mammalian brain. The distinction is important because it is the perception of feelings in the late mammalian brain which confers on later mammals (e.g. hominids) a capacity to inhibit an initial impulse to act and initiate a ‘more appropriate’ response, i.e. ‘appropriate’ as determined in a higher cognitive centre.[33]

Emotions are mammalian elaborations of early-vertebrate *arousal patterns*, in which neurochemicals (e.g. dopamine, noradrenaline and serotonin) step-up or step-down the brain’s activity level for a period, in response to sensory stimuli. It is the associated physiological changes in blood pressure, heart rate, etc., which raise the organism’s capacity to react spontaneously, immediately, energetically and persistently to the triggering situation.[34] The particular type of emotional response to the brain’s perception of a situation reflects the brain’s prior interpretation of that situation, that is, the meaning given to it. For example, the interpretation of a situation as threatening triggers a fear response. Because it happens automatically and very rapidly in an inaccessible part of the brain, even modern humans are, for the

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[32] Emotional memory is memory involving the implicit (probably unconscious) learning and storage of information about the emotional significance of events of particular types.

[33] http://www.scaruffi.com/nature/emotion.htm (Accessed 10 Nov 2010).

[34] The physiological component of emotion has been traditionally identified as activity in the autonomic nervous system and the visceral organs (e.g. heart and lungs) that it serves.

most part, unaware of this process of interpretation or assignation of meaning to events and situations; only the subsequent emotional state.

By contrast, *instinctive behaviour* does not need to be motivated emotionally but is strictly limited in the range of trigger situations and matched responses it can recognise. The value of the new system of *emotionally directed behaviour* was that it allowed the learning (e.g. by imitating a parental example) of a somewhat broader choice of behavioural responses to a more finely classified, a more informed, perception of the environment. For a long time, behaviour would still have been largely impulsive but nevertheless, increasingly discriminating.

Emotional states, because they are sustained chemically rather than neurologically, tend to persist and, for the time that an emotional state is persisting, the individual will continue trying behaviours as if in search of an altered situation which will be interpreted by the brain as one no longer requiring an emotional response. What evolution has produced is a *reflective mechanism* which uses emotions as internally generated signals (information) for guiding behaviour towards correcting situations which cause negative emotions (anger, fear, shame, sadness). Conversely, positive emotions (sexual arousal, parental tenderness) are adaptations which accompany and reinforce behaviours that have been genetically and experientially selected as survival-promoting, e.g. the propensities in primate social groups for both bonding and autonomous behaviours. Behaviours which are successful in neutralising or gratifying emotions rapidly become learned habitual responses in similar situations. For most of the time, humans are purposive rule-following animals, living a life which, metaphorically, is like a giant chess game.[35] Novel situations tend to produce strong emotions and hence strong 'motivation' to find an appropriate behavioural response. We have here a *causal loop* in which emotions guide (evoke) behaviours and evoked behaviours guide (step up, step down) emotions. More explicitly, emotion rouses the individual into activity and activity ineluctably generates a change in emotion as it changes the situation being experienced. Without emotions, the hominid brain would not be aroused to initiate anything (other than instinctive behaviour), nor have any constraints on or guidance as to what to do. That is, emotions both initiate behaviour and, to a degree, reduce uncertainty as to how to behave.

This emotion-based system for guiding behaviour is sometimes described, metaphorically, as a reward–punishment system. Starting with the idea that being in a state of emotional arousal amounts to an unwanted 'disequilibrium', any behaviour which moves the individual into a more restful state, one of less arousal, can be thought of as having been rewarded. Conversely, behaviour which increases emotional arousal is, by definition, being 'punished'. By moving between seeking rewards and avoiding punishments, the individual can grope (call it negative feedback) towards an emotional equilibrium. Notwithstanding, the range of behavioural options available for reducing emotional arousal under a purely emotion-based guidance system would have been limited. This brings us to the choosing brain.

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[35] Peter, R.S., 1958, The Concept of Motivation, In R.F. Holland (Ed) *Studies in Philosophical Psychology*, Routledge and Kegan Paul, London and New York.

The Choosing Brain

At some stage in its evolution, moving beyond unalloyed instinct and beyond emotionally directed behaviour, the hominid lineage began to acquire an additional capacity, namely, to identify, evaluate and choose amongst (not necessarily consciously) a wider range of possible behavioural responses to survival-relevant situations. How might we envisage this emerging capability? In situations where the associated emotional response is below some threshold level (i.e. the impulse to act is not irresistible), the thinking brain is able to override the limbic brain's emotion-based impulses. What then follows, in a process that is strongly comparable to Darwinian natural selection, is that the brain imagines the consequences of alternatives to impulsive behaviour and chooses the first imagined alternative to generate sufficiently positive feelings.[36] The implication here is that imagined behaviours generate emotional responses, and then feelings, in much the same way as 'real' behaviours. Just as the bodies of terrestrial animals evolved to internalise the watery environments of their ancestors, the choosing brain is internalising (and elaborating) the exploratory sequences of impulsive behaviours and feedbacks associated with emotionally directed behaviour.

Emotions and the Social Environment

Beyond guiding individual behaviour, feelings-emotions have a second role. They consistently produce external signals and signs observable by other members of the individual's social group.[37] These include pheromones and body changes (skin colour, posture, etc.) which, being largely involuntary, are reliable indicators of behavioural intentions or propensities. Similarly, all humans, and presumably all hominids, employ the same facial muscles when expressing a particular emotion.[38] Going back millions of years, these observable accompaniments of feelings became a form of *indicative communication* about an individual's emotional state to which hominid brains have become particularly sensitised.[39] Darwin recognised the largely biological (genetic) nature of emotional expression 130 years ago, suggesting that such expressions were derived from actions that originally served biologically adaptive functions, e.g. preparation for biting became the bared teeth of the anger expression, courting behaviour spun off signals of friendship, nurturing behaviour lies

[36] Chaisson, E., 2001, ibid., says 'selection' is a misnomer—there is no agent that 'selects'. Selection is not so much an active force or promoter of evolution as a passive pruner of the unfit. A better term might be 'non-random elimination'. The brain's strategy is to try out ideas until one is found which is 'emotionally fit'.

[37] In biology, a signal is any behaviour that conveys information from one individual to another, regardless of whether it serves other functions as well.

[38] Ekman, P., (Ed.), 1982, *Emotion in the Human Face* (2nd Ed.), Cambridge University Press, New York.

[39] Deacon, T., 1997, ibid., p. 431.

behind gestures to soothe anger, to ask for help. In his classic study of emotions,[40] he concluded that while expressive movements may no longer serve biological functions, they clearly serve critical, social and communicative functions.

The evolved function of such communication of information is to regulate the behaviour of the group. For a large part of the Pleistocene, prior certainly to the arrival of functional language, the easy transmission and spread of an emotional state amongst group members would have served as an important mechanism (along with instinctual responses and a propensity to imitate others) for co-ordinating group behaviour. Indeed, the metaphor of the group behaving as a 'super-organism' is not overblown.

Sensing an emotional response in others tends to have the same effect as being exposed oneself to the stimulus which triggered the original response. More than this, such transfers of emotions convey to inexperienced juveniles how to respond to particular environmental situations. We might also note here that while the impulse to respond to an emotion-laden situation may be biologically strong, it will be filtered in that the actual response will usually depend on how the individual has been previously socialised or conditioned.

Such *emotional learning* is in keeping with *constructivist theories of emotions*,[41] which suggest that the set of situations eliciting emotional responses is co-determined (a) genetically and (b) by the individual's experiences, most particularly their learning experiences in their social environment. For example, a behaviour which is punished by a mother displaying anger will come, in time, to elicit the same emotional response in the juvenile.

The involuntary communication of emotions by indicative signs would have been augmented at some stage during the Pleistocene by voluntary forms of indicative communication, including purposive gestures, vocalisations and the simulated expression of emotion. Speech, which can be presumed to have been added to the hominid communication repertoire at a later stage again, was a dramatically different form of communication, one based on the use of arbitrary or symbolic signs rather than indicative or natural signs. Whereas indicative signs are abstracted from, are some aspect of, the information being communicated, the signs used in *symbolic communication* have no apparent indicative content but still manage to reflect a mutual understanding amongst the communicants as to what object, idea, behaviour, etc., the symbol stands for.[42] Having said that, the boundary between indicative and symbolic signs is frequently blurry, e.g. pretending to throw versus pointing.

While the set of stimuli tending to produce a learned emotional response would have been ceaselessly changing over the long Pleistocene, there is no reason to

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[40] Darwin, C., 1872, *The Expression of the Emotions in Man and Animals,* John Murray, London.

[41] Averill, J.R.,1980, A Constructivist View of Emotion. In R. Plutchik and H. Kellerman (Eds.), *Emotion: Theory, Research and Experience, Vol. 1. Theories of Emotion*, Academic Press, New York, pp. 305–339.

[42] Bates, E.L., Benigni, I., et al., 1979, *On the Evolution and Development of Symbols*, Academic Press, New York, p. 64.

believe that the range of emotions available for guiding hominid behaviour would have changed in any significant way from the ancient set (with variations) of anger, fear, shame-guilt, happiness, sadness and, debatably, sexual arousal.[43] Over the Pleistocene, an increasing proportion of all situations producing emotions would involve some form of social interaction, arising mostly during the meeting of the individual's physiological and psychological (bonding, autonomy and meaning) needs and the meeting of the group's need to maintain, transmit and, occasionally, modify its culture.

A group's culture, meaning its accumulated learned behaviour (way of life), is passed on in a variety of ways from generation to generation, slowly changing in the process. When learning to habitually behave in accordance with cultural norms, children will simultaneously be acquiring the associated reward–punishment feelings that will motivate them to continue behaving in culturally compatible ways.

It can be noted here, for later recall, that if new behaviours can be attached to particular emotions and feelings, the possibility suggesting itself is that 'human nature' is malleable, that humans can be successfully socialised in multiple ways. This is also consistent with Fromm's observation that a society's social character is 'mobile' and can be changed relatively easily.[44]

The Further Evolution of Non-verbal Communication

Gestures (e.g. pointing), postures (e.g. standing tall) and body movements (e.g. shoulder shrugging) are all ways in which information could have been communicated between group members throughout the Pleistocene. Like expressions of emotion, some of these signs would have been involuntary and, originally at least, indicative, i.e. metaphorical rather than arbitrarily symbolic. But, at some stage (perhaps half a million years ago as archaic *Homo sapiens* was speciating?), evolving in parallel with an increasing cognitive capability, such non-verbal communication (popularly known as body language) must have come under voluntary, purposive control. This switch from a reactive to a proactive (goal directed) cognitive system (see below) represented the beginnings of hominids' capacity to mentally model real-world situations and reflect on them, not necessarily consciously, in order to choose a 'best available' response, e.g. to gesture or not to gesture.

[43] There are a number of candidate lists of primary emotions (collectively grouped as 'affect') in the literature. For example, Robert Plutchik developed a theory showing eight primary human emotions; joy, acceptance, fear, submission, sadness, disgust, anger and anticipation, and argued that all human emotions can be derived from these. See Plutchik, R., 1980, *Emotion: Theory, Research, and Experience: Vol. 1. Theories of Emotion*, **1**, Academic, New York.

[44] Fromm, E. 1942, *Fear of Freedom*, Routledge & Kegan Paul, London; Berger, P., and Luckmann, T., 1966, *The Social Construction of Reality: A Treatise in the Sociology of Knowledge*, Doubleday, New York, p.165; http://en.wikipedia.org/wiki/Little_Albert_experiment (Accessed 19 Nov 2010).

The Importance of Mimesis

> Mimetic action is basically a talent for using the whole body as a communication device, for translating event-perceptions into action. Its underlying modelling principle is perceptual metaphor; thus it might also be called action-metaphor. It is the most basic human thought-skill, and remains fundamentally independent of our truly linguistic modes of representation. Mimesis is based in a memory system that can rehearse and refine movement voluntarily and systematically, guided by a perceptual model of the body in its surrounding environment, and store and retrieve the products of that rehearsal. It is based on an abstract 'model of models' that allows any voluntary action of the body to be stopped, replayed, and edited, under conscious control. This is inherently a voluntary access route to memory, since the product of the model is an implementable self-image.[45]

To be useful, the meanings of non-verbal signs have to be mutually understood across the social group and need to be transmitted from one generation to the next. In Berger and Luckmann's phrase, meanings of signs must have 'sedimented'.[46] The general capability which allows groups to develop and maintain systems of non-verbal communication, and it probably evolved well before *Australopithecus*, is *mimesis*. As discussed enthusiastically by Merlin Donald,[47] mimesis (call it motor mimesis perhaps?) is most simply thought of as a capacity for imitation and rehearsal of physical behaviour, of action sequences. It takes place in two steps. Step 1 is to remember a previously observed or personally experienced sequence of body movements. Step 2 is to reproduce, to act out and to mime the remembered sequences.

Imitating others is widespread in the animal world, even amongst 'lower' orders.[48] In many circumstances it is a quick and reliable way of learning useful behaviours. When hominids' inherent tendency to spontaneously imitate others began to give way to a capacity to voluntarily control the timing of such expression, the implied increase in cognitive development may, in parallel, have allowed the memorising and imitation of more complex behavioural sequences, e.g. making fire, making stone tools.

Furthermore, in tandem with a propensity for spontaneous exploratory behaviour, the capacity to imitate oneself, to voluntarily rehearse one's own previous behaviours, meant that behavioural sequences could be practised till perfected—something that other primates cannot do. Think of how children actively and routinely rehearse and refine all kinds of action, including facial expressions, vocalisations, climbing, balancing, building things and so on.[49] Further again, the capacity to voluntarily pause when practising a behaviour sequence suggests the beginning

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[45] Donald, M., 1993, Précis of Origins of the Modern Mind, *Behavioral and Brain Sciences,* **16** (4), pp.737–791.

[46] Berger, P., and Luckmann, T,, 1966, ibid. p. 68.

[47] Donald, M., 1993, ibid.

[48] Dugatkin, A.L., 2000, The Imitation Factor: Evolution Beyond the Gene, Free Press, New York.

[49] Donald, M., 1993, ibid.

of a capacity to adapt the sequence for successful performance under a variety of conditions.[50] For example, if a sequence such as tool making is being practised and conditions such as the lack of suitable materials do not allow its completion, a pause followed by spontaneous exploratory behaviour (trial and error, trial and success) might create a variant of the failed behaviour more suited to the immediate conditions.

It seems plausible then that mimesis, the capacity to act out observed behaviour at will, could have been the instrument which allowed even early hominids to create and maintain a simple shared semantic environment, a culture of meaningful (although non-verbal) signs and behaviours. Amongst the tasks responsive to this emerging capability would have been the voluntary expression of emotions and the transfer and slow improvement of technical skills. It also opened the way for group rituals involving a number of people acting in concert. The challenge in all this of co-ordinating brain-eye-limb activity might well have provided sufficient selection pressure for explaining the rapid increase in human brain size and complexity over much of the Pleistocene.[51]

Especially Mimetic Story-Telling

Somewhat later (c.300–400 kya?), in tandem once again with a still-expanding cognitive capability, the hominid capacity for mimetic communication may have become a sufficient basis for the evolution of a further suite of cultural innovations, of shared behaviours with shared meaning.

To quote Donald again[52]:

> The 'meaning' of mimed versions of perceptual events is transparent to anyone possessing the same event-perception capabilities as the actor; thus mimetic representations can be shared, and constitute a cognitive mechanism for creating unique communal sets of representations. The shared expressive and social ramifications of mimetic capacity thus follow with the same inevitability as improved constructive skill. As the whole body becomes a potential tool for expression, a variety of new possibilities enter the social arena: complex games, extended competition, pedagogy through directed imitation (with a concomitant differentiation of social roles), a subtler and more complex array of facial and vocal expressions, and public action-metaphor, such as intentional group displays of aggression, solidarity, joy, fear, and sorrow. These would have perhaps constituted the first social 'customs', and the basis of the first truly distinctive hominid cultures.

Something not on this list of Donald's, but of great importance, is *mimetic story-telling*, the voluntary presentation by a story teller of an extended sequence of

[50] Later we will note that a capacity to 'pause', not physically as here but while mentally modelling a behaviour sequence, is a necessary part of being able to 'solve problems'. Learning to internalise behaviours which were previously physically observable is indeed a recurring feature of hominid evolution.

[51] Dunbar, R., 1998, The Social Brain Hypothesis, *Evolutionary Anthropology,* **6** (5), pp. 178—190.

[52] Donald, M., 1993, ibid.

mimetic actions—call them *mimes*—for the purpose of triggering in members of an audience an equally extended sequence of stabilised memories, i.e. percepts.[53]

Perhaps story-telling started as play or as a bonding device or as exploratory behaviour but, in time, it must have acquired purpose, namely, the conveying of information in a meaningful way, outside the context of the 'here and now'. The meaning of a single mime is the percept it first triggers plus any flow-on sequence of related percepts. A story teller's sequence of mimes has meaning to the extent that the whole sequence of percepts which the sequence of mimes produces constitutes a readily retrievable set. That is they hang together in terms of time, space, emotional content, etc. Isn't that what is meant by a 'story'? Just as in spoken language, where sentences mean more than their individual words, a mimed story would mean more than its component mimes—the beginning perhaps of an advance from lexical (word) communication to syntactic (sentence) communication.

Note also that it is the sequence of mimes as a whole which is voluntary, not just the component mimes. And that, being voluntary, a mimed story is not produced as a response to any immediate stimulatory situation; it can be told anywhere

Looked at from a higher level, the great importance of mimetic story-telling is that a case can be made that the acquisition of this capability was a key step in the evolution of both spoken language and creative thinking.

Thinking, at its simplest, involves the assembly of a meaningful sequence of percepts/schemata. For example, mimetic story-telling involves the conversion of a remembered sequence of percepts into mimes on the part of the story-teller and the conversion of that sequence of mimes into percepts by the audience. A story-teller who voluntarily mixes mimes describing aspects of several real world events into one narrative is thinking creatively, not just chronicling. Any suggestion as to when creative thinking might have become deliberately associated with an intent to deceive or entertain or solve a problem would be highly speculative though, e.g. before or after speech?

Language is not an easy word to define. Functionally, it is a tool for voluntarily conveying meaning by the use of mutually understood signs. Each sign used evokes an associated percept and it is sequences of percepts which carry meaning. At the heart of every language then there is a set of sign-percept pairs. Each sign is code for a percept. In spoken languages, for example, the signs are arbitrary phonic symbols called words[54] and each word evokes its own particular percept in speakers of that language.

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[53]Note that the word being used is 'mimes', not the better-known 'memes'. Richard Dawkins defines a meme as 'a unit of cultural transmission, or a unit of imitation.' See Dawkins, R., 1989, *The Selfish Gene*, Oxford University Press, Oxford Meme is unsuitable for use here because mimes are non-verbal whereas memes can be verbal or non-verbal. Also, the emphasis when using 'meme' is on the spread of new concepts and behaviours through a population whereas mimetic actions are about communicating using known signs in a known way.

[54]Words are themselves arbitrary combinations of the three dozen or so phonemes or units of vocalisation which humans utter.

Telling a story mimetically can be viewed as using a non-verbal language. It is an activity which can only occur successfully in a group where most members share a common repertoire or 'vocabulary' of signs called mimes and where each mime presented evokes a somewhat similar percept (stabilised memory) in most members of the audience. Mimes are code for percepts. At some stage symbolic signs for percepts, as distinct from indicative or metaphorical mimes, may have begun to enter non-verbal language, although it is even hard enough to think of examples of meaningful but truly arbitrary gestures, etc., in today's world. Most seem to be highly stylised versions of plausible mimetic antecedents, e.g. pointing at something may derive from throwing a stone at it.

To the extent that a group of hominids has a common non-verbal language, they can be said to have a shared view of the world (a 'group mind') based on categories of experience which collect many similar events or objects under one sign, e.g. waving the forearms is the abstracted sign for 'bird'.[55] What seems likely is that, as the hominid brain developed over the Pleistocene, the set of mime-percept pairs available for non-verbal communication would have similarly grown. One obvious benefit from evolving such an expanded 'vocabulary' would be an improved capacity to share and collectively exploit information, e.g. consider the value of a story about the location of a fresh carcase.

Summary of Developments in Non-verbal Communication

It is likely that hominids came into the Pleistocene already equipped with a capacity for involuntarily communicating emotional states being experienced and with spontaneous propensities for exploratory behaviour and for imitating simple gestures and postures of others. There followed, it can be suggested, a step-by-step sequence of developments in non-verbal communication and thinking skills which led towards the emergence of spoken pre- or proto-language around the time of emergence of archaic *Homo sapiens*. There is no evidence to date-stamp these developments although it can be assumed that they were somehow in step with the growth and reorganisation of the erectine brain.

1. The first of these developments, representing the beginnings of purposive body language, might have been a degree of voluntary control (if and when) over the expression of a small repertoire of emotions, gestures, etc. Such voluntary control implies some cognitive capability for modelling the consequences (with awareness perhaps but not the reflective awareness of consciousness as modern humans experience it) of expressing versus not expressing some motor behaviour.
2. The further extension of voluntary control to imitating and rehearsing various behaviours of others in the social group would have been the step which allowed

[55] Allott, R., 1989, *The Motor Theory of Language Origin*, Book Guild, Lewes.

useful learned behaviours to be transferred between people and a simple culture to be maintained, and slowly modified.

3. Once a capacity for voluntary rehearsal of a remembered sequence of one's own actions had been acquired, it opened the gate to mimetic story-telling and true non-verbal language. A necessary condition for communication by language to be possible is a group whose members share a common set of sign-percept pairs and who have voluntary control over the expression of those signs (the signs being mimes in the case of non-verbal language).
4. Once established for the recounting of actual experiences, the way would have been open to use non-verbal language for new tasks (fiction? planning projects?) and for the group's common vocabulary of mime-percept pairs to be enlarged, perhaps even to include some symbol-percept pairs. We do not know.

The Transition to Spoken Language

> Given the inherent fuzziness and ambiguity of mimetic representation, it would eventually have reached a level of complexity where a method of disambiguating intended mimetic messages would have had immediate adaptive benefits. Thus it created conditions which would have favoured a communication device of greater speed and power.[56]

Mimesis Was the Springboard

Apart from being more limited in what it can convey, a mimetic language differs most obviously from a spoken language in the type of signs it attaches to mental percepts and schemata—arbitrary vocal symbols rather than indicative motor mimes. Both types of language rely on all individuals in a group being able to imitate and remember signs made by others, to correctly attach each sign to approximately the same percept as others do and to voluntarily retrieve and use signs as required for conveying the information carried by the associated percept or sequence of percepts. The suggestion here is that the cognitive skill to form percepts would have pre-dated the capacity to invent and vocalise word-signs. Or, putting it another way, vocal and mimetic signs are cognitively equivalent.

Acquiring a Vocal Apparatus

The vocalisations of our australopithecine ancestors were probably very similar to those of apes with alarm calls, grunts and squeals punctuating non-verbal language,

[56] Donald, M., 1993, ibid.

just as gestures embellish modern vocal language. Emotional states would have been expressed vocally via signals such as cries of pain and joy, laughing, crying and whimpering in fear. But vocal communication approximating human speech would have required extensive alterations to the australopithecine vocal tract, as well as a shift from predominantly subcortical (midbrain) to cortical (forebrain) control over vocalisation. The physical and cognitive apparatus required for speech can be usefully thought of as a specialised *mimetic sub-system*, one for imitating, remembering, recalling and voluntarily reproducing, not mimes, but, the sounds of spoken words.

It is this system's ability to produce a dynamic, rapidly changing stream of diverse sounds that makes spoken language possible. Unlike an involuntary vocalisation which describes a whole event and cannot be meaningfully disaggregated, advanced speech is combinatorial; it uses a small number of basic elements—phonemes or syllables—which are combined and recombined at high speed into words and phrases.

It can be plausibly supposed that evolutionary change in the vocal tract first accelerated with habitual bipedalism.[57] Whereas quadruped locomotion puts pressure on the thorax and drives breathing in time with steps, bipedal animals (and diving mammals) must be able to inhale and exhale voluntarily. Controlled exhalation is a prerequisite for laughter, song and speech. Serendipitously, selection for anatomical changes which enhanced breath control simultaneously produced changes in the vocal tract which 'pre-adapted' it for speech production. For example, the descent of the larynx (voice box) in the throat, an adaptation allowing more air to be gulped in, also produced a larger pharyngeal cavity which would later prove useful for making a variety of vowel sounds. The same requirement for better breath control, plus dietary changes perhaps, produced the fat lips and flexible tongue which would later facilitate consonant production. What we have here is an example of *exaptation*, meaning that changes being selected primarily to promote one function (breath control) create traits which, subsequently, are used in the development of quite another function (speech).

Unlike other mammals, where the vocal tract can be considered a single tube, the human vocal tract comprises two linked tubes, the pharyngeal cavity and the oral cavity, which are divided by the body of the tongue. It is an arrangement which allows a much larger repertoire of possible sounds than a single tube. Because the human tongue is important in controlling articulation, needing to move rapidly when producing speech, it is relatively small compared to the tongues of other primates, and extremely well innervated.

Human hearing is also adapted to speech. Humans are very sensitive to sounds between 1 and 4 kHz, the range of frequencies within which the human vocal tract resonates and which characterises the sound of human speech.

[57] Bipedalism, it might similarly be noted, had also freed the hands for miming.

Origins of Words and Sentences

These changes in the vocal tract were probably not fully complete until relatively late in hominid evolution, perhaps only with the emergence of modern humans some 150,000 years ago. Meanwhile there surely would have been intermediate steps on the way to spoken language. Early erectines may have been able to produce more sounds than australopithecines but only in slow, relatively unmodulated sequences. It was Charles Darwin, in fact, who first suggested that prosody, the ability to voluntarily control volume, pitch and tone, was the initial step towards spoken language. Donald also sees prosody as more fundamental than and prior to phonetic control.[58] Perhaps music and singing, which also rely on a capacity for prosody, are equally old? Perhaps each erectine had his or her own identifying prosodic song or call?

Julian Jaynes, in his imaginative hypothesising about the origins of spoken language (as recently as 70 kya he suggests), sees the addition of terminal modifying phonemes to voluntary prosodic calls as an important turning point, e.g. modifying the ending of a danger call to distinguish between 'near danger' and 'far danger'.[59] Detaching such *modifiers* from the rest of the call and using them in differing circumstances would have made them the first words; for example, using them as *commands* to emphasise gestures when seeking to modify the behaviour of members of a hunting group, e.g. when waving someone to go far back. *Nouns* might have been next—adding a phoneme to a modifier to indicate more precisely the entity being referred to, e.g. 'near lion' or 'far lion'. Notwithstanding, the major transition from 'one sound-one meaning' to meaningful words made up of strings of arbitrary phonemes does remain a mystery.[60]

Beginnings of Syntax

Constructions such as 'near lion' are actually simple sentences. They show the beginnings of syntax in verbal language. Syntactical language has single words for objects and actions; non-syntactical language has words only for events (made up of objects and relationships between them). Whereas a different prosodic call is required for each whole situation being described, a syntactic approach to conveying the same information implies a capacity to analyse that whole situation into parts and their relationships and to attach an established verbal sign to each part/relationship. It is easier perhaps to think of spoken-language syntax as having developed from the pre-existing syntax of mimetic story-telling. For example, in

[58] Donald, M., 1993, ibid.

[59] Jaynes, J., 1976, *The Origin of Consciousness in the Breakdown of the Bicameral Mind*, Houghton Mifflin, Boston. Ch. 6.

[60] Calvin, W.H., 1997, *How Brains Think: Evolving Intelligence, Then and Now*, Basic Books, New York, Ch. 5.

miming the story of a raptor diving on its prey, any of the mimes for raptor (noun) or diving (verb) or prey (noun) could be replaced with vocal-symbol equivalents.

Nowak et al. argue that syntactic communication could have evolved gradually as the number of needed vocal signals passed a threshold where holding them all in memory became difficult.[61] Why? The number of vocal signals required increases much more slowly than the number of events or situations that can be described if the *components* of events have their own verbal signals. For example, two ‘words’ have to be remembered to describe both ‘near lion’ and ‘far lion’ whether the approach is syntactic or not. But to convey the 12 combinations of ‘near’ and ‘far’ with any of 6 species requires 12 non-syntactic words versus 8 syntactic words, Due to the possible combinatorial interrelationships between words, the addition of even one word to a modest vocabulary will sharply increase the number of additional events which can thereafter be described.

Remember that we are talking here of syntax at its simplest, i.e. associating words for percepts which are already associated in a memory. Conventions such as word order in sentences, or what constitutes a sentence, or the distinction between reportive and expective statements (i.e. tenses) would have arisen over time as unconsciously learned rules for conveying information with fewer misunderstandings. There does not seem to be much explanatory need to postulate an innate, largely genetic syntactic capability.[62]

Where Do New Words Come From?

We might imagine that names for animal species were amongst the first nouns and that, most simply, the sound of the word for a species would be an excerpt from one of that species’ calls. And, in time, with group use, the sound used to denote the pre-existing percept of that species, just like the percept itself, would stabilise. Even today, many words have such onomatopoeic origins, e.g. the hiss in ‘snake’. Similarly, we can imagine that nouns for the emotions would emerge easily from the vocalisations long-associated with the expression of emotions; thereafter, any story could routinely include a report on the narrator’s emotional state at the time of the situation being described.

But what of objects and actions without regular sound associations? Here is a scenario. Suppose someone carrying out behaviour X accidentally makes a distinctive noise, any distinctive noise, while doing so. Suppose that someone observing and imitating behaviour X includes that distinctive noise as part of the mimesis. The particular distinctive noise might first become a habitual part of behaviour X itself and then a habitual part of the miming of behaviour X during story-telling. Finally,

[61] Nowak, M.A., Plotkin, J.B, and Jansen, V.A., 2000, The Evolution of Syntactic Communication, *Nature*, **404**, pp. 495–498.

[62] Schoenemann, P.T., 1999, Syntax as an Emergent Characteristic of the Evolution of Semantic Complexity, *Minds and Machines*, **9**(3), pp. 309–346.

the distinctive noise becomes detached from behaviour X or the miming of it. Thereafter, when the distinctive noise is made voluntarily, it evokes a memory of the behaviour itself and vice versa. It has become an arbitrary vocal symbol for that behaviour. In time, the word and its meaning (referent) will become stable components of the group's language repertoire. Notwithstanding, any new word would stand to undergo continuing slow phonemic change, making it, for example, easier to say or more distinguishable from other words.

This scenario would have words being created by accident and then persisting because they are useful. Might there have been, at some time well before modern humans, a realisation that things and actions can be given arbitrary vocal labels and that this can assist communication? Such a feat of abstraction, so early, does seem unlikely.

Metaphors

New words expand the range of events and situations that can be described verbally, but so do old words used in new ways. Once a modest vocabulary has been established, metaphor becomes an important way for language use, meaning what is describable, to grow. Metaphor is the use of existing words normally used to describe or name a first entity as a way of describing or naming some seemingly unrelated second entity. But, for a metaphor to be useful, there must indeed be some kind of similarity between the entities or (in the case of analogues) between their relations to other things.

The most useful metaphors not only bestow names on newly perceived things (and actions) of importance, they draw attention to the possibility that the second entity (called the metaphrand) may be similar to the first entity (called the metaphier) in ways not alluded to in the metaphor itself, i.e. language is an organ of perception as much as a means of communication. Jaynes gives the example of 'snow blanketing the ground' with its nuances of warmth and comfort until it is spring and time to wake up.[63] Equally, metaphors may lose their richness over time and become truly arbitrary vocal symbols. For example, 'concrete' metaphors may get hidden by phonemic drift and longer metaphorical descriptions may shrink to short labels. In principle this does not matter, but it may make metaphorical words harder to remember and increasingly misunderstood, e.g. when historians misleadingly translate and interpret terms in ancient texts.

Much more importantly, as each culture built up its own metaphoric conceptualisation of the world, its verbal language would have become increasingly incomprehensible to others. Unlike mimetic language which would have been more or less understood by strangers, most metaphoric references are not to universals but are extracted from a local context and reflect only one culture's framework of reality. It may be that the origins of 'them' and 'us' thinking go back to the emergence of verbal languages.

[63] Jaynes, J., 1976, ibid., p. 57.

Presumably the metaphors of early verbal language would all have been concrete, likening something which could be pointed at to something else which could be pointed at. Abstract concepts which are not observable and therefore can only be described metaphorically would not have arisen till there was sufficient concrete language to support them; at the end of the Pleistocene perhaps. For example, an animistic belief system requires words for the spirits which inhabit the natural world.

Why Did Language Evolve?

All manner of reasons have been advanced as to why spoken language evolved once the required preconditions (a flexible vocal tract, breath control and a capacity for mimetic narrative) were in place, even as non-verbal communication was reaching limits to what it could do.

For example, Dunbar hypothesises that language evolved to replace one-on-one grooming which becomes unwieldy as group size increases. Grooming another's fur is common amongst primates and widely held to be important for promoting group cohesion. Increasing group size, despite its negative impact on foraging success, may have been selected for in response to inter-group competition for limited resources during glacial advances.[64] Talking to and about others might help one to identify trustworthy and helpful individuals and to predict how others will behave during collective activities. In particular, he talks about the problem of dividing potentially reliable allies from 'free-riding' individuals who habitually accept favours without reciprocating. Somewhat similarly, coming from an historical perspective, William McNeill and Ernest Gellner are two who have concluded that language is primarily an instrument for maintaining social cohesion and cooperative action.[65]

Replying to Dunbar, Donald suggests that language evolved for multiple reasons simultaneously, one of which might have been 'verbal grooming'; others that he suggests include being able to coordinate fighting and hunting, food classification, teaching skills and forming functional hierarchies.[66] We might add to this list of 'common sense' reasons that speech permits one-to-many communication at night, over long distances and where there is no line of sight. Also, you can speak when your hands are busy.

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[64] Dunbar, R., 1993, Co-evolution of Neocortex Size, Groups Size and Language in Humans, *Behavioral and Brain Sciences*, **16** (4), pp. 681–735.

[65] Gellner, E., 1992, *Plough, Sword and Book: The Structure of Human History*, University of Chicago Press, Chicago; McNeill, W.H., 1980, *The Human Condition: An Ecological and Historical View*, Princeton University Press, Princeton, NJ.

[66] Donald, M., 1993, ibid.

Certainly, for language development to have continued as it did, the benefits must have been very substantial, given the ever-increasing cost of an enlarging brain in terms of energy required for maintaining and growing the neocortical structures needed for managing language.

But, in the full context of human history, speech must be seen as much more than a flexible tool for transferring diverse ‘here and now’ information between group members more efficiently (usually) than non-verbal language. Specifically, the late Pleistocene saw an acceleration and reinforcement of three trends in hominid culture which could not have occurred without structured verbal language. The three are a trend towards advanced thinking, a trend towards the accumulation of ever-more collective knowledge and a reinforcement of tribalism as a means of social organisation.

Speech Improves Thinking

As noted above, the hominid brain, at some stage, acquired the ability to voluntarily recall memories by the overt or covert use of word-symbols as well as by mimetic imagination. By covert (inner) speech we mean that words are being articulated, but without motor (muscular) execution. Imagining past acts can similarly be thought of as mimesis without motor execution. This development of voluntary control over learned behaviours, including verbal and non-verbal language use, already implies some cognitive capability for modelling the consequences of one’s actions. For example, as Bronislaw Malinowski points out, even a skill such as fire making requires a ‘theory’ of what will work and what will not work.[67] The suggestion being probed here is that being able to use symbolic syntactical language would have further improved such modelling capability.

Derek Bickerton, for example, suggests that having symbolic language speeds up thinking and thereby reduces the time to assemble propositions, stories, etc.[68] While thinking by assembling percepts in imagination (thinking in pictures) is possible without verbal language,[69] using word assemblies instead of image assemblies allows for more complex thoughts to be generated within the limitations of short-term memory.[70] Thus, the word ‘dog’ makes it easier to think about dogs in general than if we only had separate words and images for ‘labrador’, ‘spaniel’, etc. The organisation of such assemblies into syntactic structures (e.g. phrases, adjective-noun pairs) would further clarify and accelerate thinking, e.g. by reducing memory load.

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[67] Malinowski, B., 1944, *A Scientific Theory of Culture and Other Essays,* University of North Carolina Press, Chapel Hill.

[68] Bickerton, D., 1996, *Language and Human Behaviour,* UCL Press, London.

[69] Lyra, P., 2005, Review of José Luis Bermúdez: *Thinking without Words, Psyche,* **11**(2), pp. 1–12.

[70] The mental operation we call ‘imagination’ can be seen as mimesis without motor execution of the imagined acts.

Jaynes suggests another way in which language aided thinking.[71] While more instinctive behaviours do not need priming and re-priming on their way to completion, learned behaviours do and talking to oneself overtly, covertly or in the (contentious) form of auditory hallucinations may help one to keep focussed on the activity at hand.

Having an established vocabulary, attached to stabilised percepts and extracted by experience from the environment, also stood to improve thinking by refining the thinker's perception of what was being experienced. The reference here is to the speed and precision with which incoming stimuli could be either discarded or responded to.

And as that vocabulary grew, cognition would have developed beyond basic associative and reinforcement processes in the sense of being able to tell more complex stories and more types of stories. For example, an abstract cognitive category is particularly difficult to think about without using its verbal label. As for types of stories, we might suppose that verbal story telling, whether overt or covert, would have progressively encompassed (a) simple factual 'then and there' stories linking objects and actions in time and space, (b) simple fictional 'play' stories, (c) problem-solving stories assembling a sequence of actions recalling or proposing the achievement of some desired outcome (the invention of 'time'?), and (d) explanatory or 'just so' stories embodying a cause-effect chain, teasing out, step by step, how things got to be the way they are.

Being able to tell problem-solving and explanatory stories would have brought humans to the brink of 'constructivist' (as opposed to 'observational') learning, i.e. to learning without having followed any direct examples (learning from oneself!). Henceforward, a hypothetical 'what if?' model of behaviour-plus-consequences could be constructed before carrying out some novel action. Such a model (story) would or could then be tested empirically, i.e. did it work?

Nowadays, we recognise the process of generating an explanatory hypothesis that is consistent with the known facts as *abduction*, a way of reasoning that is as legitimate as induction and deduction.[72] Or, from another angle, if *meaning* is, as suggested earlier, the recognition of relationships between entities, abduction is a tool or skill for imposing meaning on what is being thought or experienced.

Uncritical Thinking

It is important to emphasise here that there are strong practical and emotional rewards (the aaahah feeling!) from imposing meaning on mental and real-world experiences. However, one perverse consequence of early modern humans being strongly motivated to 'search for meaning' is that if there are factual gaps in one's

[71] Jaynes, J., 1976, ibid., p. 313.

[72] http://en.wikipedia.org/wiki/Abductive_reasoning (Accessed 21 Nov 2010).

story, the brain's so-called interpreter tends to fill them in with entities and relationships which are fictional or out of context, e.g. introducing 'spirits' as causal agents. As is perhaps illustrated by the rationalisations offered by people carrying out post-hypnotic suggestions, the brain seems to prefer any story to no story. More than that, the brain seems to prefer a 'good' story to a 'bad' story, i.e. it tends to choose fictions which are emotionally satisfying over fictions which rouse negative emotions. Presumably there are many situations where such flawed stories are still worthwhile in terms of memorability, usability, etc., even though they contain false or redundant elements.

Presently, we will discuss Valentin Turchin's suggestion that such 'uncritical' or 'pre-critical' thinking was the norm in the early stages of speech development[73]; and that it was not till the emergence of civilisations in Mesopotamia some 5–6 kya that humans began to develop a cognitive apparatus (a technology) for changing, once established, their *verbal* models of behaviours and causal chains.

Before any arrival of such a capacity to change linguistic models, customary behaviour based on rigid verbal models was probably pervasive in hunter-gatherer societies; only an external shock which made those rules unworkable could lead to their reworking. In that era of uncritical thinking, language would have been playing a paradoxical role. On the one hand, it would have been a very useful tool for the dissemination and accumulation (see below) of practical information. On the other hand, it carried the potential to lock a group into false views of how parts of the world worked without any prospect of these being corrected, views likely to generate maladaptive behaviour in face of a changing environment.[74] Several of these perspectives, including animism (everything is alive) and the perceived reality of names and images are discussed below.

Speech Accelerates Information Accumulation

We turn now to the second of three trends likely to have been strengthened by having spoken language available, namely, a quickening rate of expansion of the stock of useful information (knowledge) hunter-gatherer groups could access for guiding members' behaviour.

Note that the reference is to a whole group's information stock, not that of any individual. A group's collective information is 'distributed' in that some information with widely agreed meaning (e.g. vocabulary) is held in memory by most members of the group whereas other information is only held by a proportion of the group or, perhaps, by just one member, e.g. specialist information held by fire makers, tool makers and hunters.

[73] Turchin, V., 1977, *The Phenomenon of Science*, Columbia University Press, New York, Ch. 8.

[74] Turchin, V., 1977, ibid., Ch. 8.

The starting point for suggesting that the information accumulation rate would have increased with spoken language, compared with mimetic language, is the idea that information breeds (new) information. Armed with new information, people behave differently and have new learning experiences which, if they are communicated to others, provide those others, in turn, with new information. Note that we are concentrating here on the contribution to accumulation that comes from sharing and communicating with others rather than from the accumulation of new information via better thinking (see page 99) or novel experiences.

While it may have been very slow for a very long time, there is no reason to doubt that this process of near-exponential accumulation (i.e. rate of increase in the stock is proportional to its size) was already occurring when non-verbal language was the medium of communication. However, just as a group's reserves of useful information might have begun to grow more rapidly when the sharing of information through mimesis was added to sharing through genes and instincts, so with speech.

'I killed a heffelump by myself'. With speech, not only can such an important new experience be shared using less time and energy than mimesis would require, it can also be transmitted in more detail and, most importantly, at any time.[75] As Berger and Luckman put it, language provides a means of objectifying new experiences and allowing their incorporation into the knowledge stock.[76] And, for some purposes, such as teaching manual skills, words can be added to the mimetic instructions to clarify and reinforce them.

The rate at which information is accumulated depends on the rate at which it is lost as well as the rate at which it is generated. There are two points to be made here. One is that using standard 'verbal formulae' allows more memories to be held in readily accessible form. The other, remembering the hominid propensity to imitate, is that currently inaccessible memories can be readily retrieved by hearing the right verbal formula spoken by another. And, if speech did perhaps promote the formation of larger groups, the probability of such verbal formulae being lost to the group is reduced even further. That is, information would no longer be automatically lost from the group if it were lost from the memory of one or several individuals.

Finally, we come to the possibility that speech, by speeding up communication between people, leaves them with more time, perhaps, to discover useful variants on current behaviours.

Overall, spoken language is being presented as a development which increased the rate at which learned behaviour (culture) accumulated in human groups, largely by facilitating improved cognitive skills and by improving the sharing of information. And it happened through the underpinning of multiple improvements in the generation, acquisition, storage, accessibility and communicability of useful information.

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[75] Bickerton, D., 1996, ibid., p. 172.

[76] Berger, P., and Luckmann, T., 1966, ibid., p. 68.

Speech Reinforces Tribalism

Tribalism is a social system in which people live in small, more or less independent groups called tribes. Each tribe, rarely more than 150 people, comprises a number of regularly interacting clans which may or may not be related (a clan is a group of extended families whose members believe that they have a common ancestor). It is a social system in which there is no level of authority above any tribe. Within the tribe, where there may or may not be an individual leader, collective actions are agreed by reaching a consensus or agreed by tribal elders or imposed by the leader.

While this description of tribalism draws on contemporary and recently bygone examples, it is plausible to imagine that, for much of the Pleistocene, erectines and humans, ancient and modern, lived in roughly comparable social units—perhaps more in minimally interacting clans or bands rather than tribes. The scenario being suggested here is that the advent of spoken language might have changed the tribal system in various ways.

One idea that has already been alluded to is that verbal language, by supplanting time-consuming physical grooming, did allow groups to build a capacity to cooperate while opportunistically expanding numbers to levels where the group was more likely to survive various contingencies. At some group size, even speech-based cohesion must break down but whether this level is above or below maximum numbers as set by other constraints (e.g. the logistics of hunting and gathering) can only be speculated.

Leslie White[77] argues that it was speech which allowed the development of cooperative relationships between families of a tribe. As vocabulary expanded, people outside the immediate family could be designated, for the first time, as 'cousin', 'uncle', etc. This in turn opened the possibility of inventing incest taboos, a near-universal practice which allows families to be united by 'marriage' and which, by controlling marriage, can control the size of the tribe.

For the group as a whole, language can be used to construct tribal histories, origin myths and other stories which provide all the members of the tribe with a common set of meanings, explanations and beliefs about the world. The argument from there is that it is easier to bond with, act jointly with, share food, etc., with people who have the same 'mental model' of the world as you do.

The obverse of this of course is that, much more so than in a mimetic world, a tribe's language and its products inadvertently accentuate the perceived differences between tribal members and others. Even in a homogeneous environment, different languages are likely to be built on different metaphors. This in turn increases the probability of intertribal suspicion, hostility, misunderstanding, mistrust and, most importantly, the evolution of a dual moral code. Morality is largely a willingness to take the interests of others into account when making decisions. The suggestion here is that,

[77] White, L., 1959, *The Evolution of Culture: The Development of Civilization to the Fall of Rome,* McGraw-Hill, New York, p. 80.

within the tribe, attitudes towards others were driven more by amity than enmity whereas this was reversed in dealing with strangers. What is more, such shared enmity towards others would have encouraged further bonding within the tribe.

Taken together with low population densities, territorial boundaries and physical barriers in the landscape, this primal language-driven mentality would frequently have imposed an isolation on individual tribes which was conducive to their further cultural and genetic (via inbreeding) divergence.

Selecting for Language Skills

How the Brain-Language Relationship Evolved

We have already spoken of the way in which the hominid vocal apparatus first evolved to meet a need for improved breath control that came with bipedalism and then further evolved to also meet the needs of prosodic communication and, eventually, of verbal communication. Here, we briefly consider the evolution of the hominid brain over much the same period, viewing it in particular as evolving, first, to coordinate the eye-limb interaction required for complex mimetic behaviour and, second, to both service and enable a growing capacity for facial expressions, speaking and thinking. Taken together, these selective factors probably suffice to explain the brain's rapid increase in size and complexity over the last two million years; brain and language have co-evolved and complexified in tandem. Later we will return to the additional idea that over this period hominid body size was increasing and brain size was therefore also increasing—not just proportionately but, reflecting a phenomenon known as *positive allometry*, more than proportionately.

While there remains much debate over their precise functions, two areas of the human brain are regarded as centrally important to the production and processing of language. One is Broca's area, a portion of the left hemisphere's neocortex adjacent to the mouth-tongue-larynx region of the motor cortex. The other, found adjacent to the auditory cortex, is Wernicke's area. Neither is a distinct anatomical structure although Broca's area in particular is sometimes thought of as a 'bulge'. Both these specialist areas are most simply regarded as developments of pre-existing parts of the brain which have evolved to service, from nearby, the input and output routes associated with language exchange, i.e. Broca's area to service speech production and Wernicke's area to analyse incoming sound. As Deacon points out, there is no reason to expect language processes to map directly onto the structural-functional areas of the cortex, not if it is accepted that the cerebral cortex reassigns existing processing space in accordance with tasks being undertaken.[78]

[78] Deacon, T., 1997, ibid.

The fossil record shows that Broca's area (located in a region concerned since the Miocene with reciprocal gesturing) was already developing in *Australopithecus'* 500 cc brain and Wernicke's area appears in *Homo habilis* (700 cc). It seems that Broca's area was initially a locus for the spinal pathways which permit mimesis and only later developed the cranial pathways which give the very fine motor control that speech requires.

Why a Lateralized Brain?

The hominid brain exhibits 'localisation of function', meaning that, unlike other organs, its different parts do different things; and that not all parts do the same thing. In particular, for the present discussion, left and right cerebral hemispheres perform different functions. This hemispheric specialisation, this 'sidedness', is called *lateralisation*. Thus, much of the speech making-understanding process, along with numerical and logical thought, is controlled from the left hemisphere of the brain (in right-handed people). The right hemisphere is dominant with respect to, amongst other things, perception and expression of emotion, spatial abilities, visual imagery, music and, generally, diffuse and global operations. These are generalisations of course and, in normal people, the two hemispheres do work together, sharing information through a connecting bridge of 200–250 million nerve fibres called the *corpus callosum*, a bridge that would have needed increasing capacity with increasing lateralisation.

Are there suggestions as to why the left hemisphere or, better still, one hemisphere, dominates speech operations? For instance, could the possession of language induce cerebral asymmetry rather than vice versa? Given that the production of speech requires rapid and precise motor switching, any management arrangement requiring the coordination and (relatively slow) exchange of neural information between hemispheres would appear problematic. For this reason, there may have been a selection pressure for unilateral control of the speech function. And, for the same reason, there may have been selection for the speech control area to be close, in terms of path length, to the motor cortex.

An alternative view, from Jaynes (1976), speculates that the development of the language capacities of the left hemisphere occurred very late, and that they were forced into the left hemisphere by a previous specialisation of the right hemisphere.[79] In his proposal the right hemisphere became the storage place of mnemonic and hortatory/admonitory formulae ('the voices of the gods') which served to guide complex behaviours. Others have relatedly proposed that 'automatic' or 'formulaic' speech is located in the right hemisphere while 'propositional' speech is in the left.

Lateralisation is much more pronounced in the hominid than in other vertebrate brains and a more general hypothesis as to the origins of lateralisation is that it saved on the space occupied in non-human brains by symmetrical duplication of behaviour-controlling processes. That is, for the cost of losing the 'back-up' capacity

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[79] Jaynes, J., 1976, ibid., p. 106.

of duplicated control, the human brain acquired a major increase in overall cognitive capacity when it evolved towards lateralisation.

Who Gets Selected?

As language moved from non-verbal towards verbal communication, those with a lower-capacity neural bridge between hemispheres may have been able to acquire speech skills more readily, or to speak more rapidly—a 'perverse' consequence of being less able to rely on good inter-hemispheric communication. Or, putting it another way, those anatomically and hormonally predisposed to using a single hemisphere for the task, and, on the evidence, that meant men more than women, had an easier time picking up the skills of spoken language.

Sexual Selection

This leads to the further idea that there may have been some degree of *sexual selection* (also called *assortative* or *non-random mating*) for speech skills, i.e. for males with smaller corpus callosa. Sexual selection is a process in which people get picked as sexual partners on the basis of physical or other traits (e.g. social class) that are preferred within their society or group, often for reasons that have nothing to do with reproductive potential. Jared Diamond gives a salutary example for Europeans of the many ways in which New Guinean men find European women unattractive.[80] In time, no matter how small the dependence of the preferred traits on genotype, this leads to significant genotypic and phenotypic differences between peoples from different societies.

In non-human primates, Small notes a 'Coolidge effect', namely, that females show a sexual preference for males exhibiting novel and various behaviours.[81] In the present case, the hypothesis is that, around 40 kya, just as women had previously picked men as procreative partners based on their (left hemisphere) talents for mimetic song and dance, they now picked men for their skills with the new storytelling tool. Certainly modern males are more laterally committed than modern females.

Just as assortative mating has proven problematic for deer with unwieldy antlers and birds of paradise with enormous tails,[82] it has the potential in humans to select physical traits at the expense of mental and behavioural traits leading, for example, to reduced intelligence.

[80] Diamond, J., 1977, *Guns, Germs, and Steel: The Fates of Human Societies,* W.W. Norton and Co., New York, Ch. 1.

[81] Small, M., 1993, *Female Choices: Sexual Behavior of Female Primates,* Cornell University Press, New York, p. 183.

[82] An alternative, perhaps complementary, explanation for such over-developed features is that they are allometric by-products of increasing body size (see later discussion of allometry).

Baldwinian Selection

To be clear, no suggestion will be made here that language skills acquired by an individual can be directly transferred to that individual's offspring. There may be a handful of situations where that Lamarckian process operates (e.g. acquired immune responses) but the inheritance of learned behaviours (e.g. habits) is not one. What does seem plausible though, sitting somewhere between pure cultural transmission of new speech skills and traditional Darwinian natural selection for new speech skills, is the possibility that something called, variously, *Baldwinian selection, cultural biofeedback* or *genetic assimilation* is operating.[83]

The defining characteristic of Baldwinian selection is that 'phenotype change precedes genotype change—but not immediately' rather than, as classically presented, 'genotype change precedes phenotype change'. At its simplest, Baldwinian selection occurs when a change in the environment evokes a useful morphological change in certain individuals (morphological plasticity) and, eventually, in later generations, that same change becomes genetically 'fixed' or 'assimilated' within the population, i.e. it appears in most individuals whether or not the original environmental stimulus is present. In the case of learned behaviours (as distinct from other types of phenotypic change), such as inventing novel language skills, we will have a version of Baldwinian selection if, over generations, and as a result of genetic changes to brain or vocal-auditory apparatus, language-learning becomes easier or more innate or happens more reliably under diverse conditions.

While our concern here is with brain-speech coevolution, there is no shortage of respected evolutionary biologists willing to attest to the importance of Baldwinian selection's role throughout the history of multicellular life. Ernst Mayr declared that 'there is little doubt that some of the most important events in the history of life, such as the conquest of land or of the air, were initiated by shifts in behaviour'.[84] It is a process which is likely to be especially important for organisms which, like primates, have a great degree of behavioural plasticity. Notwithstanding, the actual path of evolutionary change will necessarily continue to be constrained at each step by reigning biological limits to that plasticity.

When a new useful behaviour is invented by a few individuals, there are two consequences which, in time, stand to affect what is being inherited in the larger population. One is that the innovators are likely to be more successful reproductively and hence that their genes are likely to become more common in the population's gene pool. To the extent then that above-average learning ability has a heritable genetic basis, the population's learning ability will undoubtedly improve over time, including, amongst other things, the ability to learn the behaviour that first conferred a selective advantage.

[83] For a useful review, see Pigliucci, M., and Murren, C.J., 2003, Genetic Evolution and a Possible Evolutionary Paradox: Can Macroevolution Sometimes be so Fast as to Pass us by? *Evolution* **57**(7), pp. 1455–1464.

[84] Quoted (p.55) in Lieberman, P., 1984, *The Biology and Evolution of Language*, Harvard University Press, Cambridge, MA.

But the Baldwinian-selection hypothesis goes further than this. It suggests the existence of a process, genetic assimilation, in which the previously learned behaviour eventually becomes genetically embedded, becomes more innate. Suppose that the behaviour learned was the ability to pronounce certain consonants more distinctly. Genetic assimilation would imply that, in time, the ability to pronounce those consonants would not have to be learned but would be present in all members of the population from the time they began speaking. How could this happen? One suggestion is that a widespread genotype which is plastic enough to allow that new behaviour will be 'only a few mutations away' from a genotype which *canalises* or prescribes that particular behaviour. Perhaps, but this is not the place to explore such contested ideas.[85]

Rather, let us turn to *niche construction*,[86] this being a second consequence of individuals learning a useful new behaviour, say, to use the same example, how to pronounce consonants more clearly. Particularly in social groups, where a large part of the total environment comprises interactions between individuals, the introduction of any successful new behaviour changes the environment, the niche, to one where there is now a pressure to select for genotypes adapted to the new environment, e.g. one where clear pronunciation is rewarded. And one adaptation which would be likely (but not certain) to succeed in the newly modified niche would be the very behaviour which redefined the niche. So, while there is no guarantee of subsequent selection for better pronunciation of consonants, to the extent that there may be a tendency for mutations which favour that particular behaviour (as in the genetic assimilation argument), that is an adaptation which will tend to occur.

The idea that learned behaviour can, by altering the selecting environment and/or by altering differential reproductive success, have evolutionary consequences is not contentious. What is contentious is the degree to which that behaviour might eventually become genetically assimilated, i.e. more like an innate 'instinct', a behaviour that does not have to be learned at all, rather than something learned by imitation. In the case of speech, there is debate over whether humans have a genetic capability (genes? hard wiring?) for 'universal grammar' or have a genetically embedded 'language acquisition device'. Majority contemporary opinion would be that both speech and syntax are largely learned skills.[87] We do not need to explore this debate, apart from noting that there are both costs and benefits in terms of survival prospects from replacing learned flexible behaviours with genetic equivalents.

[85] Godfrey-Smith, P., 2003, Between Baldwin Skepticism and Baldwin Boosterism, Ch.3 in Weber, B., and Depew, D., (Eds) *Evolution and Learning: The Baldwin Effect Reconsidered*, MIT Press, Mass. A species' capacity for phenotypic plasticity under environmental change presumably reflects a past accumulation of genetic changes (mutations) which, until then, had been selectively neutral, i.e. neither adaptive nor maladaptive. Several authors have discussed whether the useful capacity to generate selectively neutral variation is itself open to selection, e.g. Conrad, M., 1983, *Adaptability*, Plenum Press, New York.

[86] Odling-Smee, F.J., Laland, K.N., and Feldman, M.W., 2003, *Niche Construction: The Neglected Process in Evolution*, Princeton University Press, Princeton, NJ.

[87] http://en.wikipedia.org/wiki/Language_acquisition (Accessed 23 Nov 2010).

For example, a capacity for flexible behaviour will be more beneficial in a highly variable environment.

Along with the idea from developmental systems thinking that organisms inherit much more than a genome, the idea of Baldwinian selection, irrespective of how prevalent it is, reinforces the idea that the plastic phenotype, the environment, the culture and the genome co-evolve in complex ways; just as, in complex ways, genotype and environment co-determine the development path of the individual organism.[88]

Group Selection

> Now, if some one man in a tribe, more sagacious than the others, invented a new snare or weapon, or other means of attack or defence, the plainest self-interest, without the assistance of much reasoning power, would prompt the other members to imitate him; and all would thus profit. The habitual practice of each new art must likewise in some slight degree strengthen the intellect. If the new invention were an important one, the tribe would increase in number, spread, and supplant other tribes. In a tribe thus rendered more numerous there would always be a rather greater chance of the birth of other superior and inventive members. If such men left children to inherit their mental superiority, the chance of the birth of still more ingenious members would be somewhat better, and in a very small tribe decidedly better (Charles Darwin, 1871).[89]

Between writing *The Origin of Species* in 1859 and *The Descent of Man* in 1871 Darwin's understanding of the process of evolution underwent a profound but unnoticed change. As the above quote reflects, he had come to see group selection, based on the relative fitness of different tribes, to be as important as selection based on the relative fitness of individuals within a breeding group such as a tribe.

Notwithstanding, there were vigorous debates amongst evolutionary biologists through much of the twentieth century as to where in the hierarchical organisation of life—macromolecules, genes, cell lineages, organisms, groups, and structured societies—natural selection had occurred or might occur. Richard Lewontin was one who first made it clear that Darwinian natural selection is a generic process that will occur in any situation where members of a population of reproducing 'development-units' vary from each other in ways which are both (a) reliably passed on to their descendants and (b) disposed to differentially affect their capacity to produce surviving offspring.[90]

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[88] Pigliucci, M., 2005, Evolution of Phenotypic Plasticity: Where are we Going Now? *Trends in Ecology and Evolution,* **20**(9), pp.481–486.

[89] Darwin, C., 1871, *The Descent of Man, and Selection in Relation to Sex* (1st Ed.), John Murray, London, Ch. 5.

[90] Lewontin, R.C., 1970, The Units of Selection, *Annual Reviews of Ecology and Systematics,* **1**, pp. 1–18.

Tested against these criteria, it is now generally accepted, under what Brandon calls *hierarchical* or *expanded evolutionary theory*, that selection occurs at multiple levels, from macromolecules to cultures, in the hierarchy of biological-social organisation.[91] The development-units at each level in the hierarchy are being selected (sorted) by their environment, an environment made up, to a greater or lesser extent, of relatively larger development-units from 'higher' levels of biological-social organisation. In the case of an individual human, think of it this way: her fitness is a function of her adaptation to her environment *and* the adaptation of her environment to its environment

Again, a 'gene-environment' interaction occurs between DNA and the local cellular machinery. Genetic variants are sorted through a process of differential birth rates and death rates which are a function of organism-environment interactions, i.e. genetic variants are selected in the context of the cellular environment. The persistence, or continued replication, of lower level development-units is crucially dependent on the maintenance of the organised unit interfacing with the habitat.

The hierarchical perspective emphasises that the results of natural selection are not 'traits' in the usual sense of static features possessed by an organism, but relational linkages between organism and environment. Moreover, these relations are specific to the situation in which they occur. For example, there is no basis for assuming, as the trait view does, that an individual who may be socially dominant in a pairwise relationship will also be socially dominant in a group of five people working on a shared problem.

As earlier noted, moving from non-verbal to spoken language probably accelerated each tribe's accumulation of pooled knowledge and the creating of a shared way of understanding the world, as well as improving individual cognitive skills.[92] It is through speech that pooled knowledge and common mental models can be reliably transmitted between generations. Meeting that condition would have set the stage for the selection process to move towards favouring fast-learning tribes as well as fast-learning individuals within tribes. Under conditions of limited resources, a tribe of intelligently cooperating individuals stood to outgrow and displace tribes less competent.

Humans of the Late Glacial to Early Post-glacial Period

After the Mt Toba Eruption

The last ice age was a close call for humanity. Greenland ice cores confirm that 71 kya Mt Toba in Sumatra erupted with more force than almost any previous volcano, producing enough sulphurous gas and ash to darken the sky for 6 years. Temperatures plummeted by as much as 21° at higher latitudes around the planet

[91] Brandon, R., 1990, *Adaptation and Environment,* Princeton University Press, Princeton.

[92] Berger, P., and Luckmann, T., 1966, ibid*.,* p. 68.

and, in the northern hemisphere, up to three quarters of all plants may have died. The following millennium was the coldest of the last ice age.

A number of scientists believe that this volcanic winter could have reduced the world's population of modern humans, those who had been spreading from Africa for some 30,000 years, to less than 10,000 adults.[93] It follows that all of today's humans would be descendants of those few, specifically, according to one hypothesis, those of the few who survived in (north east?) Africa. If all modern humans come from such a small and recent founder-group, it would explain why everyone today has very similar DNA despite humanity's two million year evolutionary history, i.e. there has not been time for mutations, etc., to accumulate differentially.

This is not the place to review competing models of the origins of modern human beings, but an interesting alternative hypothesis is that a handful of small isolated groups across Eurasia and Africa survived Toba and while all of these started out genetically similar, they were isolated from each other and their genomes diverged rapidly enough to produce the superficial differences in appearance of today's major population groupings, e.g. Mongoloid, Negroid and Caucasoid.[94]

Notwithstanding, within perhaps 20,000 years of Toba, humans, spreading at a rate of just a few kilometres a year, had reached and settled in Australia. This epic movement, if indeed it was out of Africa and not from further west, could have followed the Indian coastline and thence to Timor. The presumption here is that hunter-gatherer tribes kept splitting and moving on as they grew too numerous to be sustained locally. The Aborigines' final hop to Australia was helped by a period of rapid glaciation which briefly dropped sea levels by 80 m and reduced the sea gap between Timor and Australia from 480 km to a more navigable 160 km.

It is not widely appreciated just how variable climatic regimes were in the late Pleistocene. While always an ice age, conditions could warm dramatically within as little as a decade and then cool equally quickly.[95] These changes appear to have been linked to the incursion and retreat of warm currents in the North Atlantic in response to the release of fresh water lakes from behind slipping glacial barriers. As noted, glaciation reached its peak (called 'the last glacial maximum') about 18 kya and was largely over by 15 kya, although climates continued to fluctuate markedly till about 10 kya. Modern humans reached the Americas about 15 kya and New Zealand about 800 years ago. It was another drop in sea level, one associated with this final glaciation, which made the Americas accessible from Eurasia, via a dried-out Bering Strait.[96]

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[93] Ambrose, S.H., 1998, Late Pleistocene Human Population Bottlenecks, Volcanic Winter, and Differentiation of Modern Humans, *Journal of Human Evolution,* **34** (6), pp.623–651.

[94] Ambrose, S.H., 1998, ibid. This is what sometimes happens with invading species that spread rapidly across a new environment. They differentiate into observably dissimilar ecotypes. The arrival of sparrows in North America provides an example.

[95] Burroughs, W.J., 2001, *Climate Change*, Cambridge University Press, Cambridge.

[96] A contrary view, backed by some evidence, is that the Americas could have been settled by seafarers much earlier. See Burroughs, W.J., 2001, ibid., pp.207–217.

For post-Toba humans who remained in tropical Africa, the ecological niche they could exploit in a very tight web of life was small; energy was hard to capture, and sharp increases in numbers were not possible. However, as people began spreading into colder dryer regions, supported by the twin technologies of fire and (probably) clothing, they left their tropical parasites behind and found new energy sources in unexploited populations of large game animals. Together, these factors (plus better tools?) led to a population release (a boom) such that there were perhaps four million people worldwide by 15 kya.[97]

Over this period, the cultural norms (how to behave) required for successful living were transmitted between generations by imitation and word of mouth. While there would have been a degree of selection and novelty in what was passed on, most would have been handed down unchanged. Neither agriculture nor the herding of domestic animals was yet practised. Social organisation within tribes was minimal, i.e. there were few status differences and everyone did much the same work. In terms of material technology, the major advance between 70 and 40 kya was a series of improvements in stone tools, particularly flaking techniques. For example, the length of cutting edge obtainable from a source rock improved perhaps 10–12 fold over this period. At one stage, the most advanced techniques were to be found in Australia and New Guinea.

New Behaviours

From the archaeological record, it seems that a cultural shift, one significant enough to be designated the Upper Palaeolithic revolution, began about 40 kya.[98] That is, it began in step with the beginning of an intensely cold glacial period that would last till 15 kya and end the Pleistocene. This was the time when artefacts such as cave paintings and carved figurines first appeared, particularly in a European core area, and in a variety of forms which can be clearly differentiated as to time periods, regions and groups (including contributions from our soon-to-disappear Neanderthal cousins).[99]

Material Technologies

Technological changes during this tail end of the Pleistocene include the disappearance of heavy tools such as hand axes and choppers (in favour of longer, narrower 'blade' tools) and the introduction of a much wider range of special purpose tools

[97] McNeill, W.H.,1979, *Plagues and People*, Penguin, London.

[98] The Upper Palaeolithic, meaning the last part of the 'old' is best regarded as a time period, one lasting from c.40 kya till c.12 kya.

[99] Childe, G., 1936/1981, *Man Makes Himself*, Moonraker Press, Bradford-on-Avon, England, p. 51.

(e.g. harpoons, darts, needles), including, for the first time, many made from antler, bone and ivory. The new tools and fabrication technologies suggest a major change in patterns of human energy expenditure, with tools being prepared in advance and retained, rather than made and discarded expediently. Simple mechanical devices such as the spear thrower and the bow appeared and allowed muscular energy to be concentrated when despatching projectiles. Composite tools appeared, e.g. spears with stone points. More energy was also going into the construction of semi-permanent structures such as hearths, pavements and shelters (some partly underground) built of skins on a frame of bone or wood; evidence perhaps of a more settled lifestyle.

Survival continued to depend on hunting and gathering although the role of plant foods is difficult to determine. Despite the intense cold, Europe was a food-rich environment for well-equipped groups of cooperating hunters. Vast migrating herds of reindeer, bison, mammoth and wild horse grazed the plains of Russia and central Europe.

There is also evidence for the increasing use of other foods, such as rabbit, fish and shellfish. In comparison with large animals, these produced smaller amounts of food, but they were an important addition because of their greater reliability. What appear to be hunting nets have been documented in central Europe. In fact, there is conclusive evidence that products based on plant fibre—cordage, basketry, netting and perhaps textiles—were being produced in central Europe more than 25 kya and, soon after, elsewhere in Europe, the Near East, and the Far East. While tool remains are more durable, fibre technologies may have been just as important for survival. In terms of an implicit energy strategy, effort invested in making fibre products reduced subsequent energy expenditures or allowed human energy to achieve results (e.g. catching fish) which would not otherwise have been possible.

Symbolism and Representation

Representational art in the form of painting, sculpture and engraving has been widely documented at Upper Palaeolithic sites in Africa and Australia as well as Europe. Animals and humans are common subjects as well as abstract lines, dots, chevrons, etc. Around the world, people used similar natural materials such as red and yellow ochre, manganese and charcoal to create cave art. The earliest known musical instruments also come from the Upper Palaeolithic. Flutes made from long bones and whistles made from deer feet have been found at a number of sites. Deliberate and careful human burial becomes more common, often with graves containing tools and personal ornaments such as bracelets, beads, pendants made of animal teeth, ivory, shells, etc.

Trade and Migration

Through much of the Upper Palaeolithic, waves of modern humans were comprehensively colonising Eurasia and Australia, gradually replacing, one assumes, any residual populations of non-modern peoples. The details are being increasingly revealed by analyses of DNA similarities and differences amongst contemporary human populations.

Evidence of similarities in artistic styles over extended distances (e.g. podgy 'Venus' figurines) suggests that extensive social networks operated throughout Upper Palaeolithic Europe. Some materials, such as flint, semi-precious stones and shells were moved over hundreds of kilometres. Whether such movements can be interpreted as trade over trade routes is another question (a motive of 'gain from trade' seems unlikely). And to what extent did these interactions facilitate people exchanges and interbreeding between tribes, exchange of information about frontier environments and new technologies, collaborative hunting and ceremonial gatherings?

Aggression Between Groups

Conversely, did interactions between tribal groups become more violent and aggressive during the Upper Palaeolithic, particularly as glaciers advanced and reduced the land's carrying capacity (numbers of people who could be fed) during the last glacial maximum (20–15 kya)? Despite a lack of evidence, there is indeed a popular school of thought (in the writings of Robert Ardrey and Desmond Morris for example) that tribal groups of the Upper Palaeolithic and well before, had a predisposition to attack, for little or no reason, any other groups they encountered.[100] Indeed, it is often part of this perspective to suggest that, for a large part of the Pleistocene, groups were being selected for intelligence on the primary grounds that this enhanced their ability to kill other humans. Steven LeBlanc argues that lethal inter-group violence and dispossession was a commonplace response to overpopulation and hunger caused by runs of poor seasons.[101]

Such thinking has complex sources, one being the idea that things *ought* to be like that on a simple interpretation of Darwin's thinking. But there are many forms of competition besides killing. What about selection for intelligence on the primary grounds that it improves intra-group cooperation and synergy? Another source idea for the 'killer ape' hypothesis is that there are species of primates alive today which are highly aggressive (e.g. savanna baboons) and, since humans are primates, they must be intrinsically aggressive. The problem with that argument is that there are other primate groups (e.g. Bonobo chimpanzees) which exhibit little externally directed aggression. Analogical arguments across primate groups are generally unconvincing.

Perhaps a better argument is that, as noted above, early savanna-dwelling hominids began acquiring the hormone balance of a predator species as distinct from a prey species. Of course, aggression towards prey species does not auto-

[100] Ardrey, R., 1966, *The Territorial Imperative: A Personal Inquiry into the Animal Origins of Property and Nations*, Atheneum, New York; Morris, D., 1967, *The Naked Ape: A Zoologist's Study of the Human Animal*, Cape, London; Burnet, M., 1970, *Dominant Mammal: The Biology of Human Destiny*, Heinemann, Melbourne, p. 72.

[101] Le Blanc, S., with Register, K. 2003, *Constant Battles: The Myth of the Peaceful, Noble Savage*, St Martin's Press. London.

matically translate into aggression within and between conspecific (same species) groups. And it has been further suggested, under the name of *shift theory*, that in selecting males for language skills, they were also being selected for higher testosterone (the 'male' hormone) levels and hence, eventually, for levels of male aggressiveness more compatible with a patriarchal than a matriarchal style of social organisation.[102]

Even though inconclusive, and especially if free of ideological prejudices (e.g. social Darwinism), such speculations remain important, given our need to understand the prevalence of violent conflict in today's world. To anticipate later discussion, a reasonable working hypothesis is that human groups, then and now, have/had inherent tendencies towards both amity (within the group) and enmity (between groups) and that the expression of these tendencies depends in complex ways on how the young are socialised and how stressful and difficult it is proving for a group of interest to obtain the resources it needs.[103] We need to keep remembering that behaviour is a function of nature, nurture and environment.

Social Organisation and Regulation

It has already been suggested, based largely on relative (male versus female) body size, that dominance hierarchies within groups were minimal in earlier *Homo sapiens* and there is no reason to suggest otherwise for the Upper Palaeolithic. Nor is there any hard evidence from this period that tribes were moving from a clan or collective mode of decision-making to a hierarchical or chief/leader mode of decision-making. Nonetheless, this is what happened.

Karl Polanyi, in his revelatory book, *The Great Transformation*, argues convincingly that late Pleistocene economies were based on *reciprocity* and *sharing* and that this mode of economic organisation came to influence (coevolved with?) many other aspects of social organisation, including the shared ideas which reinforced that system.[104] Thus, the suggestion is that Upper Palaeolithic humans never hunted or gathered food for just themselves or their immediate family but rather for sharing with the whole clan or tribe. This is not a new idea, or a new behaviour, it should be pointed out. Palaeontologists, including Isaac Glynn, have traced food-sharing behaviour back to the beginning of the Pleistocene.[105]

[102] Lehmann, A., 2001, Exploring Patterns in Neuropsychology for Support for an Alternative Theory of Evolution, *Glozel Newsletter 6.5*, pp. 1–90

[103] Le Blanc, S., with Register, K., 2003, ibid.

[104] Polanyi, K., 1944/2001, The Great Transformation: The Political and Economic Origins of our Time, Beacon Press, Boston.

[105] Glynn, I., 1978, The Food-sharing Behavior of Protohuman Hominids. *Scientific American*, **238**, pp. 90–108.

Continuing the important example of food, *reciprocation* implies that when one tribal member gave food to another, they would expect something of equal worth in return, either from the recipient or someone else. So, if I give you food, you will give me equivalent food or will help with some task, etc. I might not get something back immediately, but the recipient has to reciprocate within a certain time or lose standing. An ongoing failure to reciprocate could lead to exclusion or expulsion. As an aside, a broader concept of reciprocation, one between humans and the forces of Nature, may lie behind the practice of sacrifice at a later stage in human history.

The ongoing success of such a system relies in the first instance on each individual being willing to contribute to the 'economy' according to their capabilities and trusting others to do likewise. This in turn requires that the young be so socialised. And, to reinforce such learned behaviours, there would be a place for sanctions (exclusion, shaming) against 'free riders' and cheats, and, perhaps, a place for external (cf. internal) rewards for above-average contributions. On the latter, for example, successful hunters might be preferred mates. Perhaps also, as Polanyi suggests, rituals and ceremonies evolved, partly at least, to ensure that reciprocation went smoothly.

The economic cum social system being described here is remarkably complex, involving as it does behaviours such as trust, sexual selection, socialisation, delayed reciprocity, sanctions, rewards, etc. But are such enough? Could such a system function without well-developed language? Mention has already been made of the hypothesis that language evolved to replace grooming as a bonding device in larger groups; and as a tool for 'social bookkeeping'. Paul Mellars is an archaeologist who, judging from technology shifts and the appearance of imagery as well as beads and pendants, suggests that fully modern language and symbolic expressions emerged at or slightly prior to the Upper Palaeolithic.[106] The way to view the role of language in the Upper Palaeolithic revolution might be as one of allowing, even accelerating, useful complexifications within a pre-existing but simpler economic system. That is, language improves decision-making today at the price of complicating decision-making tomorrow.

From Tribes to Chiefdoms

Except in extreme circumstances where only a few can survive, a tribal system based on self-organised reciprocity and sharing within the tribe would seem to be a sound strategy for smoothing out unpredictable food supplies and maximising group survival prospects. The process may well have been further routinised by following ritualistic procedures. And yet it is widely accepted that, by the end of the ice age, hierarchical governance systems centred on a tribal chief or leader with some degree of coercive power had been invented and become commonplace.

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[106] Mellars, P., 1996, Symbolism, Language, and the Neanderthal Mind, In Mellars P., and Gibson, K., (Eds.), *Modelling the Early Human Mind*., McDonald Inst. Archaeol. Res., Cambridge, UK, pp. 15–32.

Was this just a natural development of an established primate instinct to accept dominance-submission relationships? How else might this change in decision-making processes have occurred? As an example, think of deciding when and where to hunt. In long-established bands and small tribes, custom and tradition might simply dictate the answer. Everyone would just know what the group was going to do. Under unseasonable or other unusual conditions, and with the help of verbal language, the question might be discussed till consensus emerged. Given a strong similarity in the vocabulary, concepts and inbuilt behaviour rules understood by each individual, the perceived options might be few and consensus readily achievable. However, there could perhaps be a place for a 'chairperson' to articulate, nothing more, that consensus had been reached. And, in particularly unusual circumstances, the long memories of tribal elders might contain candidate options not familiar to younger people.

Under even more difficult and pressing conditions, during, say, emigration into new territory, the 'chairperson' might have to choose, hastily, amongst whatever options are being perceived and, in doing so, become a *leader* for a time. Or, different leaders might emerge in different situations. Still, we can only speculate about governance processes in the Upper Palaeolithic, and be informed but not blinkered by observations on contemporary hunter-gatherer societies.

So, speculating further, another area of tribal life where, on occasions, it could be useful to have non-consensus but rapid decision-making is daily food distribution. A need for some degree of task specialisation (division of labour) is beginning to appear in the Upper Palaeolithic, along with activities such as art and music and the use of new food sources. Reciprocation is quite transparent when all contributions are of the same type; symmetrical exchanges within small groups of families might suffice. But, on the (major) assumption that exchanges have to be seen as 'fair', how do you equate contributions which demand the same effort but yield different results? There is no right answer, but, so the hypothesis goes, people might accept the judgements of a leader who is trusted and recognised as trying to be fair. This in turn might lead to acceptance of pooling and redistribution of all the day's acquisitions. If the leader's redistributions came to be seen as unfair or self-serving, he or she would be simply replaced.

This idyllic system was not to last. Some time before recorded history began, leaders were becoming, to use William McNeill's word, macroparasites; tribes were becoming chiefdoms. Relying, perhaps, on religious authority, or enforcers, 'permanent' chiefs, often hereditary, were learning to make decisions reflecting a degree of self-interest as well as keeping their increasingly complex societies functioning. This was the solution which evolved from an increasingly unworkable system based on reciprocation, sharing and trust. Perhaps the value of an aggressive chief able to lead the defence of a home territory against refugee groups or covetous neighbours outweighed any loss of trust and fairness. Having a social technology for selecting a leader would certainly have been conducive to social stability at times of leadership transition. More generally, possibilities for innovative behaviour may have been greater without the inertia of group thinking; the individual mind is a better problem-solving tool than the group mind. And, once chiefdoms were established, perhaps people did not have the cognitive skills to be able to question this new system of governance.

New Minds

The Upper Palaeolithic revolution probably saw the transformation of human minds as well as human behaviours. Indeed it is that revolution's marked changes in economic and social behaviour and in material and social technologies which first suggest the arrival of new ways of thinking and new things to think about. For example, a cultural artefact such as a necklace suggests a capacity to think symbolically. Perhaps it is better to think of the Upper Palaeolithic revolution as a time of change in humanity's underlying capacity to form and use culture rather than simply as a time of rapid cultural change.

Turning from the material record to speculation, what might have initiated the Upper Palaeolithic revolution and what can be inferred about the developing mentality of Upper Palaeolithic people? Assuming that language was already reasonably well-developed (and some would disagree), the simplest suggestion here is that as the scope, vocabulary and fluency of language increased, as described earlier, there was an even faster expansion (positive feedback) in each tribe's pool of technological knowledge and their common set of meanings, explanations and beliefs about the world.

Perhaps there were genetic and neuroanatomical changes as well as language-driven cultural changes, for example a mutation which markedly increased language capabilities. Or mutations which allowed information from different parts of the brain to be coordinated rather than processed in relative isolation. There may well have been such changes but, if they occurred, it was likely to have been much earlier, perhaps 150 kya when modern humans are thought to have evolved from archaic humans.[107] It is commonly believed that there has been little change in brain anatomy since then. What cannot be revealed by the fossils on which such thinking is based are changes in organisation (pathways, etc.) within the brain.

Primitive Thinking

We can only infer the characteristics of primitive minds from ethnographic studies of contemporary hunter-gatherers, from studying the developing minds of children and from some limited archaeological evidence. Even then, questions abound. Would a person from the late ice age, say 20 kya, be able to understand and answer a question as to whether they had a spiritual sense of feeling at home in their environment? Or who they were? Or which tribe they belonged to? Or why they had behaved so in some what-to-do situation? By 'what-to-do' situations I mean situations of hesitancy or doubt or stress where none of habit, tradition, custom, instinct, emotion, etc., dictates automatically how to behave; in general, problems that have not as yet been routinised. Indeed, did anyone ask any questions then? Were they

[107] Mayr, E., 2001, *What Evolution Is,* Basic Books, New York, p. 252.

conscious in the same way as readers of this book are conscious? The answer to the last is almost certainly No, but we will come to that.

Still, despite the ignorance and uncertainty, there is a measure of agreement amongst paleo-anthropologists as to what post-speech minds may have been like prior to, and, probably, for a while after, the Neolithic Revolution (see page 149). We will discuss this mainstream view under the headings of (a) animism and magic and (b) cognitive and representational skills.

Animism and Magic

It was suggested earlier that, under a broad rendering of their motivations, humans and their ancestors have drives (generalised instincts) for autonomy (self-assertion), for bonding with others and for meaning, the last being an urge to explain things. *Animism* is the belief system widely held to have been at the heart of the primitive or pre-critical mode of thinking and imposing meaning on the world which emerged in parallel with the emergence of spoken language. In animism, the behaviour of natural phenomena, both living and non-living, is explained by assigning (all) objects (including places) and processes a human-like agency, a *spirit*, with a capacity to act intentionally. To take an important example, this means that dead people are still alive in some sense. That might further mean, for instance, that one leaves food out for corpses or that the dead can still speak.

Furthermore, in many of the world's contemporary hunter-gatherer populations, and perhaps in the most recent ice age, a common extension of animistic thinking is the idea that the world is further populated with invisible spirits, 'ancestors' perhaps, which are not attached to particular real objects and processes. Other elaborations of animistic thinking include 'essences' such as souls and 'real' objects which are only visible to certain people.

It is challenging to even speculate as to the origins of animism but one suggestion is that it is an unsurprising product (as indeed is the drive for bonding with other humans) of the sort of *symbiotic consciousness* (to use Arthur Koestler's term) or *participatory consciousness* (to use Jay Earley's term) which early Upper Palaeolithic humans enjoyed.[108] It is hypothesised that this form of consciousness involved people having feelings of being connected to and belonging, metaphorically, to the world around them. More prosaically, it can be suggested that people had not yet learned to distinguish between external objects and events and the mental images representing them. Given that these people would hardly have been able to express (inadequate vocabulary) or see introspectively that they were having such feelings (if they were!), consciousness seems too grand a term here, except

[108] Earley, J., 1997, Transforming Human Culture: Social Evolution and the Planetary Crisis, SUNY Press, Albany; Koestler, A., 1970, *The Ghost in the Machine,* Pan Books, London, p. 277.

perhaps that it flags a contrast with the sort of reflective self-aware consciousness that emerged after the advent of civilisation. While we cannot step outside our own consciousness and imagine symbiotic 'consciousness', perhaps it was like being in a vivid dream where things just happen (no sense of causal process) and one responds reflexively.

Magic goes hand in hand with animism and is the idea that the behaviour of the 'spirit people' in things and processes can be influenced advantageously by appropriate human activity; for example, that the weather can be influenced through symbolic activities and rituals such as rain dances. A *shaman* is someone with developed magical skills.

Early anthropologists, such as James Frazer of 'Golden Bough' fame, described magical thinking in terms of two 'associative laws', contagion and similarity.[109] The *law of contagion* is summed up by the idea that when objects come into contact, there is a permanent exchange of properties between them and they remain causally connected thereafter. For example, contact with an object considered to be impure will transmit the impurity to the handler, who cannot be rid of it without recourse to purification rituals. The *law of similarity* is based on the notion that 'image equals object' or, more generally, that similar things are causally connected. Operations on one are automatically (magically) carried out on the other. For example, when a 20,000-year-old Cro-Magnon cave painting shows a spear in a bison, some real bison was being supposed to have a similar experience in store. Rituals are behaviours which imitate some aspect of the desired result, e.g. sprinkling water on the ground during a rain dance.

Words are treated in the same way as images and rituals. Once the percept has been formed, every time a swan (say) appears, the word 'swan' also reliably appears. It is a small step from there to believing that the name of an object is part of the object, a belief behind many magic rituals, taboos, etc.

Before smiling, take note of the survival of these two principles of magical thinking into modern times, for example when demonstrators hang or burn public figures in effigy. Also, to the extent that it is introducing an associative sense of cause and effect, magical thinking is the precursor of scientific thinking. And painted images may have been precursors to writing. Here is Ashley Montagu's sympathetic perspective on magical thinking:

> The trouble with the non-literate is not that he isn't logical, but that he applies logic too often, many times on the basis of insufficient premises. He generally assumes that events which are associated together are causally connected. But this is a fallacy which the majority of civilized people commit most of the time, and it has been known to happen among trained scientists! Non-literates tend to adhere too rigidly to the rule of association as causation, but most of the time it works, and by the pragmatic rule what works is taken to be true.[110]

[109] Frazer, J.G., 1922, *The Golden Bough*, Abridged Edition, Macmillan, New York.

[110] Montagu, A., 1957, *Man: His First Million Years*, World Publishing Company, New York.

Cognitive and Representational Abilities

First, it bears repeating that hypotheses about the minds of Upper Palaeolithic people rely heavily on backcasting from ethnographic studies of remnant hunter-gatherer populations. Having said that, let us speculate boldly.

What is most surprising to present-day people about the minds of early hunter-gatherers, as hypothesised, is not their animistic-magical models of reality but the extreme resistance and insensitivity of these 'pre-critical' minds to the data of experience. To moderns, pre-critical thinking is inconceivably conservative and closed. Not only is there no capacity to question beliefs, rules, customs, etc., there may not even have been a capacity to formulate any questions, given that asking a question implies the possibility of alternative answers. Obvious facts which, in our opinion, would, ineluctably force someone to reconsider certain convictions do not, for some reason, have any effect on them at all.

While it is not an explanation, it helps to recognise that the pre-critical mind made no distinction between belief and knowledge. Or perhaps not helpful: Bertrand Russell in *Analysis of the Mind*[111] says that, at first sight, knowledge might be defined as belief which is in agreement with the facts. And then says, 'The trouble is that no one knows what a belief is, no one knows what a fact is, and no one knows what sort of agreement between them would make a belief true'.[112] Notwithstanding, for pre-critical minds, animism and magic constituted a knowledge system, not a belief system.

Valentin Turchin provides a further insight into pre-critical thinking by contrasting it with *critical thinking*, a capacity which he sees as only beginning to emerge in the irrigation civilisations of the Middle East some 6,000 years ago.[113] Critical thinking allows alternative verbal models of problem-solving behaviour or explanations of reality to be compared and for just one of these to be adopted as a working model. In logic, this selecting of the particular explanation which is better than its rivals is called the *law of sufficient grounds*. The law of sufficient grounds is absolutely foreign to pre-critical thinking. It is here that the 'metasystem transition' which separates modern thinking from primitive thinking is seen most clearly. Turchin locates this transition from the uncritical brain to the *choosing brain* in the emergence of linguistic activity directed to linguistic activity, i.e. in thinking about thinking. Thus, it is not enough to think about something: one must also ask why one thinks that way, whether there is an alternative line of thought, and what would be the consequences of these particular thoughts. If a chosen action does not work, one asks why not.

Because pre-critical thinking cannot reject a belief once formed and stands to generate multiple animistic explanations for any situation and, also, because it

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111 Russell, B., 1921, *Analysis of the Mind*, Allen & Unwin, London.

112 Russell then relents enough to say that, speaking broadly, it is our 'verbal habits' which crystallise our beliefs, and afford the most convenient way of making them explicit.

113 Turchin, V., 1977, *Phenomenon of Science,* Columbia University Press, New York, Ch. 8.

cannot organise or integrate these multifarious beliefs, pre-critical thinking is riddled with contradictions and misperceptions. Not to put too fine a point on it, pre-critical thinking would appear to be next to useless for yielding rational (i.e. likely to succeed and likely to improve things) responses to novel what-to-do situations. Despite their cultural developments and their practical achievements, Upper Palaeolithic people would still have been reliant on instinctual responses and random exploratory behaviour in what-to-do emergencies not envisaged by custom and tradition. Thinking was not a tool for solving problems at this time.

Representational Abilities

> I remain, therefore, entirely unconvinced that there is any such phenomenon as thinking which consists neither of images nor of words, or that 'ideas' have to be added to sensations and images as part of the material out of which mental phenomena are built (Bertrand Russell, *The Analysis of Mind*, Ch 11).

We can suppose that over the long Pleistocene humans developed an increasing capacity to mentally reproduce (imagine) visual and auditory perceptions that had been stored in memory. Without (imagined) images, there can be no awareness of past or future, only a fleeting present filled by impressions, emotions and bodily impulses (e.g. defecation). There can be no differentiation of inside and outside; no awareness of a boundary between self and other; and no different categories for internal experience versus perceptions of external objects and events. A sense of time is not possible if past perceptions cannot be retained in the mind and then invoked.

We can also suppose that this process of forming stable cognitive categories would have been much enhanced with the emergence of language, both non-verbal and verbal. This is because the scope (what is to be included) of a percept associated with a 'fixed' linguistic symbol could be cumulatively refined over time. The 'symbiotic' external world would increasingly have been categorised into discrete parts by cerebration, by a process of 'carving nature at the joints' in search of practical distinctions.

Notwithstanding, people's repertoires of verbal representations (likenesses) of persons, relationships, social systems, mortality, the self and many other less-concrete concepts familiar to contemporary humans would have been small. Another way of saying this is that those ancestors did not yet have a vocabulary which would allow them to think about these things; a characterisation that depends on the idea that a large part of what we call *thinking* is talking to oneself (perhaps out loud in those days?). Sometimes the conversation is one-sided, sometimes not. *Thoughts* are the separate sentences in that conversation.

The more general suggestion to be made here is that cognitive and representational achievements would have advanced arm in arm through the Upper Palaeolithic. You can't think about thinking if there are no words for thoughts, memories, questions, etc. A tribe's vocabulary and shared verbal habits was its collective model of reality, changing but slowly over many generations, e.g. words changing meaning, beliefs falling into disuse (as distinct from being rejected).

Consider, for example, how the very useful concept of *oneself* might have evolved. Once language had developed to the point where individuals were given names, the stage would have been set for people to be able to learn to represent themselves mentally and verbally, to develop an inner working model of oneself, a self-sense. Drawing on Thomas Jordan's speculations,[114] something of what this might possibly have meant initially can be suggested, namely, an ability to describe one's own behaviour in the third person, although largely in bodily rather than mental terms. The capacity to recognise that one is having thoughts and that these are an important part of oneself (and ditto for other people) would come much later. This elaboration of the sense of self is called *individuation*, the term being the same whether it is taking place over an individual life or over hundreds of generations.[115]

We will return to the evolution of critical and conceptual thinking when we come, presently, to the next great revolution after the Upper Palaeolithic, namely, the post-glacial Neolithic Revolution.

Dependence of the Individual on the Group

Notwithstanding the emergence of language and, later, of chiefdoms as means of social coordination in hunter-gatherer societies, it seems likely that Upper Palaeolithic tribes functioned like super-organisms, made up of people with a very weak sense of self; not as collections of individuals well aware of their bodily and mental differences from others. In *The Gutenberg Galaxy*, Marshall McLuhan suggests that tribal people learn to regard themselves as rather insignificant parts of a much larger group and not as independent, self-reliant entities.[116] Personal ambition and initiative are permitted little outlet and a meaningful integration of experience along personal individualistic lines is never achieved. Indeed, the very possibility of 'thinking for oneself' is scarcely even acknowledged; and, if it does occur, it is shunned, not only by others but by the thinker himself or herself. In contrast to this intellectual constriction, tribal society allows the individual considerable temperamental freedom—to be extroverted and express one's feelings freely.

As noted above, people then would have had little capacity to model consequences and choose, neither consciously nor unconsciously, between alternative behavioural options in what-to-do situations. But would that evaluative skill have been needed anyway? In a reasonably stable environment, habit, custom and tradition based on past learning would have adequately guided behaviour much of the time. And in a few recurring classes of emergency situations, instinctual and spontaneous group responses, guided by rapid communication of emotional states

[114] Turchin, V., 1977, ibid.

[115] Fromm, E., 1942, *Fear of Freedom,* Routledge and Kegan Paul, London, pp. 23–25.

[116] McLuhan, M., 1962, *The Gutenberg Galaxy: The Making of Typographic Man,* University of Toronto Press, Toronto, p. 18.

(anxiety, fear) would have been triggered. Imitating the behaviour of a recognised chief, and obeying his or her verbal commands, would have further served to synchronise and co-ordinate individual behaviours. Because role differentiation was minimal (male hunters, female gatherers, the old and the young), there would have been little need for unique individual responses.

In fact, it goes further than that. In the harsh conditions at the end of the ice age, many tribes would frequently have been on the brink of extinction. Under those circumstances, any innovative deviation from inculcated 'proven' behaviours would have carried high risks. Perhaps, until conditions improved as the ice age ended, there could even have been selection against cognitive skills!

Implications of a Weak Sense of Self

Tribal people would have had physical and stage-of-life differences from each other of course, but mentally, it is being suggested, they would have had few differences and little awareness of how they differed from others—what has been called the membership mind.[117] They probably had short time-horizons, a poorly developed sense of past and future which, if so, would have made it difficult for an individual to undertake sustained tasks (e.g. travelling to a distant hunting ground) for which the rewards were not immediate; they would have been unable to envisage an extended sequence of activities and consequences leading to a goal. Here, perhaps, lies the origin of group rituals which use rhythmic, coordinated, invariant, mimetic movements which reinforce the emotional appeal to the individual of the task or wish being pursued, e.g. singing and chanting. Indeed, ritual, and imitative behaviour in general has to be recognised as a social coordination mechanism, along with drives-instincts, shared emotion, tradition, custom and verbal commands.

We might also note that having short time horizons and a weak self-sense would make it difficult for individuals to play and sustain specific roles within the tribe. Even chiefs might have needed group support on occasions.

Another implication of weak self-sense is that impulsive, emotional behaviour stands to swamp the individual's fragile, tentative attempts to act intentionally to satisfy his or her vague wishes. To control antisocial behaviour, the tribe would have had to rely on individuals conforming to custom and obeying taboos (avoiding forbidden behaviours).

Conscience (internalised social rules) and guilt about breaking rules would not have, as yet, appeared.[118] Morality would have consisted in 'not getting caught'. Conversely, active deceit of others would have been minimal prior to people having an awareness of how their own minds functioned. Without such awareness a deceiver would have no basis for modelling and then exploiting another's behaviour. What is

[117] Wilber, K., 1996, *Up From Eden: A Transpersonal View of Human Evolution,* The Theosophical Publishing House, Wheaton, p. 270.

[118] Berger, P., and Luckmann, T., 1966, ibid.

that person thinking about me? Once established though, a capacity to deceive would have been much facilitated by language. Especially amongst people who had little capacity to critically evaluate linguistic statements, lies about others would be readily believed.

Reflections on Hominid Evolution

This chapter is yet another version of the story of how the human lineage and human social groups might have evolved. And, like all stories, it has a provenance, foci, in-built constraints and a purpose. The very word 'lineage' signals that this is a story which assumes that humans and prehumans and their social groups have been changing in significant ways even as they have been surviving for millions of years.

Thus the chapter takes up the story of hominid evolution with the evolution of placental mammals (125 Mya) into primates (65 Mya) who took to the trees to live during the Eocene (55–38 Mya). There, in east Africa, they stayed until the branch[119] of the great ape family from which humans evolved moved from their declining gallery-forest habitat to an open forest (savanna) habitat (5 Mya). Perhaps 3 Mya the first 'species' of the *Homo* genus (*Homo habilis*) became identifiable; and, by 2 Mya, as the Pleistocene epoch and its ice ages approached, *Homo erectus* had not only evolved from *H. habilis*, but was on the brink of migrating out of Africa into distant parts of Eurasia. It was from the erectines who remained in Africa that archaic forms of *H. sapiens* evolved circa 200,000 years ago. And it was perhaps a 100,000 years ago that groups of modern *H. sapiens* began moving out of Africa *en route* to settling the whole world, displacing any remnant erectine populations in the process. The chapter takes the story to the end of the last ice age (15 kya) and into the period just before the Neolithic Revolution (12 kya) when some humans stopped being full-time hunter-gatherers and began growing crops and domesticating herd animals.

It has been necessary, for space reasons, to keep the chapter as short as possible consistent with telling a story which does not leave too many gaps and which is substantive enough to yield—if they are there—some principles and facts applicable to better managing social change today. Despite the considerable competent effort that scholars have put into reconstructing the human story, hard evidence is limited, particularly when trying to understand such important intangibles as the emergence of language, beliefs and cognitive skills. Often the difficulty is more one of knowing when some change occurred rather than what occurred. For example, estimated dates for the emergence of developed language vary by more than a 100,000 years. Unequipped as I am to explore every alternative hypothesis, I have used a 'satisficing'

[119] I am reminded of the joke about the aristocrat who claimed that his ancestors' family tree went back to the time when they lived in it.

approach of looking through the literature for answers to my what-when questions up to the point where something 'plausible enough' turns up.[120]

How then can we most simply understand, give meaning to, this fragile story of hominid evolution? A good starting point, so obvious that it might be overlooked, is that the hominid lineage was there at the start of the Pleistocene and there at the end. Unlike most biological lineages that have ever existed, it survived. Tautologically, just as survival of the fitter means no more than survival of those that survive, extinction is the fate of species that fail to reproduce themselves!

When Is a Species Vulnerable to Extinction?

More usefully, we might ask what makes a lineage more or less vulnerable to extinction, to becoming the end of the line. But still there are no operational answers. Any lineage and the environmental niche (adaptation zone) in which it is located are undergoing continuous change, sometimes faster, sometimes slower. Considered together, a lineage and its niche constitute a *developmental system*, importing and exporting energy and materials like other dissipative systems.[121] What is transferred between generations is not traits, or blueprints or symbolic representations of traits, but developmental means, call them resources or interactants. While some resources persist independently over generations (e.g. sunlight), others are transmitted from parent to daughter generation (e.g. genes). Once brought together, the resources in a developmental system spontaneously interact (self-organise) to produce a new generation of organisms.

There is, in principle, a joint set of niche specifications and of lineage specifications within which the lineage can survive (its 'survival space') and vice versa; the developmental system can be thought of as ineluctably moving through 'survival space'. So, it can be suggested that when the specifications of the niche-lineage system are approaching the boundary of the system's 'survival space', the lineage is vulnerable to extinction. Unfortunately, those boundaries are only knowable in a very general way.

Adaptation

One well-recognised process which tends to make a species less vulnerable to extinction is *adaptation*. Somewhat confusingly, this word is also the name given to

[120] *Satisficing* is Herbert Simon's (1956) word for adopting a strategy which is 'good enough' when decision-making resources are limited, as they usually are, i.e. any strategy which yields adequate, albeit not optimal, results is acceptable. See Simon, H.A., 1956, Rational Choice and the Structure of the Environment, *Psychological Review*, **63** (2), pp. 129–138.

[121] Griffiths, P.E., and Gray, R. D., 1994, Developmental Systems Theory and Evolutionary Explanation, *Journal of Philosophy*, **91**, pp.277–304; Walker, B.H., 2008, *Building Resilience: Embracing an Uncertain Future*, The Alfred Deakin Lectures, Deakin University, Vic.

the products of the adaptation process—these products being themselves processes. Adaptation is a process of natural selection[122] which produces adaptations. An adaptation is an unprecedented capability or process (including physiological-biochemical processes, behavioural traits, building anatomical structures), which, once spread through a population of related organisms, increases that population's capacity to survive and reproduce, at least in the short term. In general, adaptations work by amplifying/reshaping some of a species' behavioural or reproductive possibilities, e.g. natural selection for incrementally longer necks made it possible, eventually, for the giraffe to browse on tall trees. In energy terms, successful adaptations allow a species to maintain or increase energy throughput.

But the consequences of adaptation do not end there. When a species' behaviour changes, the environmental niche it is occupying will necessarily be changed also, in as much as the species will be taking in and exporting energy and materials in a somewhat different way. The effect may be large or small but, either way, there will be a tendency for natural selection to then produce further adaptations in the species. This in turn will further change the niche; what is being initiated here is a process of circular causation in which the lineage and the niche will continue to co-construct each other.[123] For example, the giraffes' browse trees get eaten out (local extinction) or the trees themselves co-adapt, generation on generation, by growing still taller. In the latter case there will be a tendency for giraffes with even longer necks to be selected.

The giraffe example illustrates the point that some traits in some interbreeding populations continue to evolve, over very long periods of time, through a cumulative or 'directional' sequence of adaptive changes, implying that each successive change does something to increase the population's capacity to survive and reproduce—not necessarily in absolute terms but relative to reproductive capacity in the absence of such adaptation.[124] A trait will stop evolving when its further change is no longer genetically possible or reproductively useful, whichever comes first. Here it can be noted that, like all animals, hominids have been somewhat restricted in their genetic plasticity, their intrinsic possibilities for directed evolution, simply because, unlike plants and single-celled protista, they have a fixed body plan under which, for their effective functioning, limbs and organs depend on each other in complex ways. That makes it difficult to change one character without disrupting other characters, a limitation called *channelling* or *canalisation*.[125]

In a classic paper on adaptation, Richard Lewontin points out that adaptive evolution requires 'quasi-independence'.[126] By quasi-independence he means that selection

[122]Formally, *natural selection* is the process of differential reproductive success of heritable variants of developmental systems due to relative improvements in their functioning.

[123]The rich idea that the niche and the organism co-evolve is explored under the rubric of *constructivism* in the literature. See Odling-Smee, F.J., et al. 2003, ibid.

[124]Thomas Huxley called this a process of 'progressive adaptation' but 'progress' is a problematic word, to be avoided when possible.

[125]Conrad, M., 1983, *Adaptability*, Plenum Press, New York, p. 260.

[126]Lewontin, R.C., 1978, Adaptation, *Sci. Am.* **239**, pp. 156–169.

must be able to act on a trait without causing deleterious changes in other aspects of the organism. If all the features of an organism were so closely developmentally integrated that quasi-independent variation did not exist, then 'organisms as we know them could not exist because adaptive evolution would have been impossible'. In terms of defining an organism's further evolutionary possibilities, the related idea of *modularity* is the suggestion that most changes in a body process only have to be compatible with processes in the same regulatory module, not other modules.

A niche's characteristics are changing continuously, not only being modified in response to its lineage's adaptive disturbances, but also in response to ongoing noise, fluctuations, shocks and trends in the material-energy flows through the larger systems which enfold every niche-plus-lineage developmental system. For example, there will be changes in energy flows through the food web of the lineage's enfolding ecosystem, e.g. changes in populations of parasites, predators or food species. In turn, these changes might be reflections of flow-rate changes in climate, landscape, soils, waterbodies or other aspects of the Earth's larger, slower material-energy cycles. As a consequence of niche changes, formerly adaptive traits can become maladaptive (hinder survival and reproduction) and disappear from the gene pool while other pre-adaptive as-yet-uncommon traits[127] might acquire an enhanced survival value and become increasingly common.

In a general way, any extant species has to adapt genetically at a sufficient rate relative to the rate at which it is changing its niche, or its niche is changing, or it goes extinct. Needless to say, what constitutes a sufficient rate is context-dependent. Still something, admittedly non-operational, can be said. In a rapidly changing environment a genetically diverse species, one with a heterogeneous gene pool, is more likely to survive on the grounds that it is more likely to be pre-adapted; as is one which is *adaptable*, i.e. which generates adaptations relatively rapidly.[128] Succinctly, species die out when the rate of environmental change exceeds the species' capacity to adapt.

Specialised Versus Generalised Adaptation

Before coming specifically to hominid survival, there is one more distinction to be made to fill out this much-simplified discussion of the determinants of extinction. It is, to use a modification of Edgar Dunn's terms, the distinction between *specialised*

[127]Gould, S.J., and Vrba, E.S., 1982, Exaptation—A Missing Term in the Science of Form, *Paleobiology,* **8** (1), pp.4–15. Gould and Vrba use the term *exaptation* rather than pre-adaptation on the grounds that exaptation has no teleological flavour of purpose. I prefer pre-adaptation as being more immediately understandable. There is no implication that the organism 'knew' in advance that some adaptation would acquire further utility at a later time. *Cooption* is another term for pre-adaptation.

[128]*Adaptability* is the capacity to thrive and survive when the environment changes whereas *evolvability* is proactive, i.e. the entity has capacity to try something different in the absence of environmental change.

adaptation and *generalised adaptation*.[129] The former refers to sequences of adaptations which make survival in a species' existing environmental niches more likely and the latter to adaptations which expand the environmental niche within which the lineage can survive. Commonly, but far from always, the difference between the two can be understood as the difference between being able to get the same food more efficiently versus getting access to more foods in more situations and locations.

Specialised Adaptation

The giraffe's neck is an example of specialised adaptation. Others involve such things as changes in colouration, size and shape of body parts. The process is one of fine-tuning a species to be more energy-efficient in a more or less trend-free environmental niche, e.g. the honeyeater's beak is reshaped to better extract nectar from the local flowers. Eventually, under specialised adaptation, a stage might be reached where the existing state of adaptedness[130] is simply maintained (called stabilising selection) with genetic variation across the population being progressively reduced to a stable level, i.e. with alleles of various genes being eliminated from the species' gene pool. Such a process may or may not leave the species experiencing it with some pre-adaptive traits but, either way, that species will become vulnerable to extinction, even under slow environmental change, simply because its former specialist adaptations are now increasingly maladaptive (and largely irreversible); and, also, it has little genetic variability from which adaptations appropriate to a changing niche might be generated. On the matter of genetic variability it can be noted though that to the extent that the niche is spatially or temporally heterogeneous, and to the extent that sub-populations within parts of the niche (sub-niches) can interbreed, the species will tend to remain genetically diverse and somewhat less specialised.

Specialised adaptation is also the process by which a common ancestral species evolves into two or more species (called cladogenesis). This is what happens when different sub-populations of the common ancestral species become and remain separated (no interbreeding) for long enough in differing sub-niches of the ancestral species' niche. As the separated sub-populations accumulate their own unique adaptations (called disruptive selection) they first diversify into different subspecies and then different species within the same family. While geographical separation is particularly important here, separation could be reproductive (e.g. different breeding seasons) or ecological (e.g. living in different strata within the tree canopy).

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[129]Dunn, E.S., 1971, *Economic and Social Development: A Process of Social Learning*, Johns Hopkins, Baltimore. Dunn's terms (Ch.2) are *adaptive specialisation* and *adaptive generalisation*. Other terms for the same distinction are specific versus general evolution and cladogenesis (branching evolution) versus anagenesis (upward evolution). See also Rensch, B., 1959, *Evolution above the Species Level,* Columbia University Press, New York.

[130]*Adaptedness* is an absolute measure of the capacity to survive and reproduce. Fitness is a relative (to others) measure of survival and reproductive success.

Generalised Adaptation

The clearest examples of *generalised adaptation* occur when a species comes to occupy a radically different type of niche (in contrast to specialised adaptation where a species radiates into 'sub-niches'). Thus, the development of the wing in the reptilian lineage opened up the aerial niche to the avian descendants of that lineage. The development of homeothermy (internally regulated body temperature) in birds and mammals was a generalised adaptation which vastly extended the terrestrial habitats of these groups.

When a lineage evolves in ways that allow it to occupy a new type of niche, the products of that process will normally be recognised, taxonomically, as being species in a new family (group of related species) or higher taxonomic category. In contrast, specialised adaptation by either disruptive or stabilising selection results, at most, in new species within the same family or variants of existing species.

How does generalised adaptation happen? When, with hindsight, a line of evolutionary change is recognised to have been one of the generalised adaptations, of major change in organism characters and environment, it can be seen that each adaptive step made possible further adaptations which were formerly not possible or not adaptive or even viable. It is this 'unshackling' effect which explains the paleontological fact that, when they do emerge, new families and orders emerge much more rapidly than new species emerge within families.

For example, as noted, the Cambrian 'explosion', some 540 Mya, is the well-known phenomenon during which, over 10–20 myrs, all extant animal phyla, and several others now extinct, arose abruptly in the geological record. But even though generalised adaptation produces large changes, often quite rapidly, such are still produced by a succession of genetic changes, just as happens in specialised adaptation. Theories about new orders, phyla, etc., emerging as a result of multiple small mutations occurring simultaneously (the so-called hopeful monsters) have few supporters.

What helps here is to understand that, sometimes, a single viable and 'harmonious' mutation—a sudden alteration of heritable characteristics in a gene, a chromosome, a genome, a plastid or a plasmon—can have dramatic effects on the developmental trajectory (ontogeny) of a mutating organism's offspring.[131] Thus, as discussed in Chap. 1, it has been learned in recent years that around the time of the Cambrian explosion, not only were there major environmental changes (e.g. in atmospheric oxygen, in the extent and composition of coastal waters), but a new system of genetic control, one not present in unicellular organisms, was evolving from duplicated copies of pre-existing genes. The innovation here was *homeotic or regulatory genes* which control the positioning of major structures in an animal's body plan; which can change the relative growth rates of various organs, limbs, etc., and so produce phenotypes with characters that are exaggerated or reduced relative

[131] An organism's *plasmon* is the aggregate of its cytoplasmic or extranuclear genetic material. A *plastid,* a specialised component organelle in a photosynthetic plant cell that contains pigment, ribosomes and DNA, serves specific physiological purposes such as food synthesis and storage.

to the parents; and which act as on-off switches for repressing or evoking activity in (non-regulatory) *structural genes*.[132] For example, in a mammal, a single homeotic mutation might produce an arm that is shorter, or longer, or broader. Regardless, it will probably still look and work like an arm. It is now accepted by mainstream biologists that a single homeotic mutation may have multiple effects on diverse characters, including behaviour, development pattern and morphology, without rendering the offspring non-viable, especially when those offspring are not being subjected to strong selection pressures. It seems that the Cambrian explosion could have depended in part on a flush of newly possible homeotic mutations occurring at a time of broad-scale environmental change.

Extending One's Niche

If a species is to successfully extend its niche, changing markedly in the process, there would seem to be at least three preconditions to be met. One is that the new niche needs to be geographically accessible from the old. For example, an aquatic species adapted to a deep-ocean niche could not have served as a 'phylogenetic bridge' to amphibian and terrestrial existence; it would have to be a species at home in the shallows. Second, the colonising species would need to have some minimal set of selectively neutral pre-adaptations.[133] For example, an aquatic animal species colonising the land would need to be pre-equipped with a means of locomotion there such as wriggling or walking on its fins.

A third precondition for achieving successful occupation of a new niche is what might be called *ecological access*. That is, within geographical range there must be an ecological web sufficiently developed to contain niches which the colonising species is somewhat equipped to fill but which are not already occupied by other well-adapted species. For example, at intervals during the evolution of multicellular life there have been mass extinctions of species caused by cosmic and planetary events such as large-scale volcanism or impacts by asteroids, comets, etc. While new, different ecosystems are quickly re-established after such catastrophic events, there are inevitably many empty niches for some time. Thus, on the (debateable) assumption that dinosaurs were cold-blooded and that this partly explains their demise during a long winter triggered by a comet strike some 65 Mya, a niche was created for mammals, these having some pre-adapted capacity for regulating body temperature, to emerge as the dominant form of animal life.

While not preconditions, there are several other situations that appear to be conducive to the onset of generalised adaptation. One of these, sometimes called the *law of the unspecialised*, suggests that new families and orders tend to emerge out

[132] Carroll, S.B., 2000, Endless Forms: The Evolution of Gene Regulation and Morphological Diversity, *Cell* **101**, pp. 577–580. Structural genes are genes that code for polypeptides or other structural units of a cell.

[133] 'Selectively neutral' means that organisms with these pre-adaptations were as reproductively successful as those without them.

of less specialised subgroups within a species or out of the less specialised species in a family of species. One reason for this might be that in a specialised species all its tissues have already acquired highly specific functional tasks whereas in unspecialised species there may well be tissues that have not yet been co-opted for specialised tasks and which may therefore be available for reshaping into generalised adaptations.[134] A related observation here is that generalised adaptation tends to occur in (geographical) transition zones between major ecological provinces, perhaps because the *ecotypes* (variants within a species) located there are already pre-adapted to some extent and because the environment in the transition zone, being the 'edge' of the niche, is more variable than in the 'core' part of the niche. Because they have to cope with multiple environments, species in transition zones are under less selection pressure to specialise. Indeed, such species may well get selected for phenotypic plasticity, the capacity to develop or behave differently depending on the reigning environment.

It does seem that, when conditions are right, new families and orders do enter the fossil record very quickly in terms of geological time and seldom through a succession of many small genetic changes (gradualism) within a given environment such as envisaged under specialised adaptation. This is the process that Stephen Gould and Nils Eldredge termed *punctuated equilibrium*[135]; perhaps *periodic acceleration* (in the rate of phylogenesis, meaning differentiation through evolution) would be a more informative name. What the fossil record suggests is that, following the occupation of a previously unexploited niche or a newly created niche, in a situation where selection pressures are low, it is common for the invading species to rapidly split into a diversity of 'fit enough' species, most of which then begin their own journeys towards specialised adaptation.

Constraints and Trajectories in Phylogenesis

To what extent are the evolutionary possibilities open to a species at any time channelled in a particular direction or moulded by internal constraints on what is physically, developmentally (e.g. bodyplan constraints) or biochemically possible or by

[134] Sometimes, because genes can have multiple effects, non-functional tissues can arise as by-products of selection for some functional character. Unspecialised tissues can be formed as allometric 'by-products' and then be later coopted for new functions. Specialisation removes surplus unspecialised tissues which otherwise might have been available for moulding into generalised adaptations.

[135] Gould, S.J., and Eldredge, N., 1977, Punctuated Equilibria: The Tempo and Mode of Evolution Reconsidered, *Paleobiology,* **3** (2), pp. 115–151. A common argument against gradualism is that forms with characteristics intermediate between orders or even families are essentially unknown.

external environmental parameters such as atmospheric-oxygen levels or the presence of other species? From knowing what has gone before, i.e. what past adaptations have produced, are there things that can be said about what tends to happen or about what cannot happen? As an illustration of the latter, we might note that the development of the wing deprived birds of potential hands that could be used to manipulate the environment and, in the interests of flight, limited potential size—including a brain of size sufficient for the development of intelligence.[136] As a trade-off for these 'lockouts', birds acquired high mobility and, thereby, access to new food sources.

As a sample of what tends to happen, consider one of palaeontology's basic generalisations, namely, that trends are common, i.e. morphological, etc., changes in a particular direction tend to continue once initiated, as with the giraffe's neck. A more important example, one with many flow-on effects, is the tendency of body size to increase in many lines of descent. Historically, there has been much debate as to whether such trajectories can be plausibly explained by natural selection alone or whether there is a need to postulate additional *orthogenetic mechanisms*, ones which imply goal-directed evolution. Today, most opinion would be that a sufficient explanation for most persistent trends is that internal and external constraints on what changes will be viable have left just a few feasible directions of change available for natural selection to find. To quote Gould[137]:

> …the constraints of inherited form and developmental pathways may so channel any change, even though selection induces motion down permitted paths, the channel itself represents the primary determinant of evolutionary direction.

Notwithstanding, once a favourable 'biological technology' has been 'invented' (no purposiveness intended), it might be expected to persist (with or without some trending) in the lineage for as long as no better way of carrying out that adaptation's function emerges.[138] Thus, chromosomes, structures which transmit synergistic genes in tandem, have persisted since their emergence because they help ensure that all new cells contain all genes. The cell itself is a similarly favourable and persistent 'invention'; it is a modular 'building block' which has the property of selectively limiting the influence of its chemical environment on its contents. As a third important example, the emergence of a nervous system conferred an enhanced ability to react appropriately to external stimuli, e.g. by prompting muscles to contract for fleeing when danger appears. In general, organs and organ systems such as the

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[136] Dunn, E.S., 1971, Economic and Social Development: A Process of Social Learning, Johns Hopkins, Baltimore, p. 57.

[137] Gould, S.J., 1982, Darwinism and the Expansion of Evolutionary Theory, *Science*, New Series, **216** (4544), pp. 380–387.

[138] Rensch, B., 1959, *Evolution above the Species Level*. Columbia University Press. New York, p. 71.

brain, blood vessels, nephridia (insect 'kidneys'), labyrinth (internal ear), etc., have remained largely unchanged since their beginnings.

Some Rules of Phylogenetic Development

As already noted, sequences of adaptive changes can cumulate directionally (directional selection), either in response to a changing or changed environment or via a process of coevolution between lineage and environment. In practice, knowledge of an animal's mode of life and habitat often allow a degree of prediction as to the direction of its functional-anatomical evolution. Bernhard Rensch[139] has collated some of these insights as 'rules of phylogenetic development'. For example:

Large terrestrial vertebrates must develop heavy columnar legs with disproportionately large bones because, as body size increases, body weight increases much faster than the strength of the animal's leg bones, e.g. elephants, extinct orders of large birds and giant reptiles.

Speed through air and water is increased by streamlining the body.

Sessile animals can only evolve in water, an environment where they can rely on eddying to bring them food.

There are only a limited number of models for evolving legs for jumping or for digging.

Heterotrophs (mainly animals) could not evolve before the evolution of autotrophs (mainly plants) to feed on.

Autotrophic organisms require a large surface area because their uptake of nutrients and energy is through those surfaces.

Evolution of larger bodies in multi-celled animals requires a transport system for food and oxygen (blood vessels, tracheae). Without such systems, tissues must be close enough to the sites where food and oxygen molecules enter to allow for the slow rate at which these diffuse through tissue. Flatworms, for example, have no circulatory or respiratory system but succeed because of their flat bodies and richly branched intestines.

Generalised adaptation in multi-celled animals results in major reorganisation and specialisation of internal organs and their increasingly centralised control from the brain.

Some of these rules illuminate the well-recognised phenomenon of *convergence* in which different species follow parallel evolutionary paths, i.e. the same sorts of adaptations appear quite independently in diverse species that have become adapted to a similar habitat or way of life, e.g. the similar body shapes of the North American grey wolf, a placental mammal, and the Tasmanian tiger (*Thylacine*), a marsupial mammal.

[139] Rensch, B., 1959, ibid., p. 73.

The Importance of Allometry and Heterochrony for Evolutionary Trajectories

Allometry is the term recognising that, in most animals, different body parts grow at consistently different rates as the size of that organism increases. Empirically, the results of such differential growth rates can normally be expressed as power law relationships of the form:

$$\log X = a \log Y$$

where *X* and *Y* are the sizes of any two allometrically related body parts.

While the relative growth rates of organs and parts of organs remain constant during much of an individual organism's development, there can be periods when an organ or structure grows faster than the body as a whole (positive allometry) or more slowly (negative allometry). For example, the human head exhibits positive allometry till birth and negative allometry thereafter.

Such relative growth rates and the length of time for which they operate during the organism's normal development sequence are under regulatory-gene and hormonal control and open to adaptive selection. Within limits, allometric relationships are as subject to selection as static morphology itself.[140] In principle then, in a well-adapted organism each body part grows to a size where it can meet the 'peak performance' needs of other body parts, and have its own needs met, in a balanced way, i.e. without surplus or insufficient capacity.

The reality is more complicated. The functions of regulatory genes appear to be organised hierarchically with, in many cases, a single regulatory gene controlling the development of not one but a whole group (module), or even whole groups, of allometrically linked body parts/traits. This means that one or a few mutations in a lineage's regulatory genes can dramatically change the timing and duration of developmental events during morphogenesis—a change called *heterochrony*—and hence change the allometric relations (proportions) between the body parts of the phenotype. Selection for neotenous development in early hominids, as described earlier, provides a clear example.

Selection for Increasing Body Size

In most mammalian lines of descent there have been, at times, increases in body size, e.g. giant types evolving from smaller ancestors. Why? In many environments, there are a number of advantages, up to a point, in being larger.[141] Thus the last glacial age saw an increase in types of large homeotherms such as mammoths, giant elk, red deer and giant wombats, all benefiting from needing relatively less food to maintain body temperature than their smaller ancestors.

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[140] Gould, S.J., 1966, Allometry and Size in Ontogeny and Phylogeny. *Biol. Rev.,* **41**, pp. 587–640.

[141] Rensch, B., 1959, ibid*.*, pp. 211–218;. See also Reiss, M.J., 1989, *The Allometry of Growth and Reproduction,* Cambridge University Press, Cambridge.

Because of genetically embedded allometric correlations, selection for larger body size commonly brings with it the 'overdevelopment' or 'underdevelopment' of various body parts, compared with smaller ancestors. Some of these, like proportionately stouter legs for enlarged vertebrates, are necessary in an absolute sense. Some may prove maladaptive, others adaptive. For example, positive allometric growth of the permanent teeth in many lines leads to excessively (fatally?) large canines and incisors, e.g. the sabre-toothed tiger. Conversely, under the negative allometric growth typical of the smaller organs (heart, liver, etc.), there is more space available in the body cavity of larger types for intestines and a developing foetus. While the brain is relatively smaller in large types the 'newer' forebrain is relatively larger, the individual neurons are absolutely larger and have more dendrites (extensions) per neuron, implying a brain with more possibilities for associating images and perceptions with each other.

It might be noted here that the allometrically guided evolution of the vertebrate brain illustrates the idea that excess 'overdeveloped' tissue can, in time, be employed for new functions or even to form new organs. Thus, several functions located in the midbrain shifted to the forebrain once its relative size increased by positive allometry during the amphibian-reptile stage of vertebrate evolution. That same shift may have initiated the eventual development of the cerebral cortex possessed eventually by all higher vertebrates. Thus, in hominids, as noted earlier, new cortical tissue became available for allocation to new or expanded functions such as making plans, making associations between ideas and between percepts and, eventually, managing the motor functions of speech.

Selection for increasing body size then is likely to bring, along with major changes in body proportions, both adaptive benefits and adaptive costs; size will only continue to increase for as long as the costs of the 'allometric by-products' of increasing size remain tolerable. Or, and this is genetically difficult, until the allometric links between favourable and unfavourable traits are broken. And, to the extent that there is already pre-adaptive variation within a population in the genetically embedded allometric and heterochronic relations governing organ development, selection for increasing body size stands to bring not one but a range of major changes in body proportions. These variations could, in turn, trigger rapid speciation, especially if the accessible and actual environment were itself spatially variable.

To round things out here, recall, from earlier discussion of Baldwinian selection, that accumulated genetic modifications which, before environmental change, were selectively neutral, and perhaps 'invisible', might, under environmental change, trigger a plastic response in the phenotype. That is, genetic change, phenotypic change and environmental change may all be contributing to any change in body proportions.

Notwithstanding some discussion in the literature,[142] what is not clear is the source of the genetic plasticity which allows a trait such as body size to keep increasing over, perhaps, hundreds of generations. Part of the answer might lie in selection for alleles of the regulatory gene or genes which control the timing between switching on and switching off the secretion of growth hormone. Again, the pituitary gland's capacity for secreting growth hormone may itself be allometrically dependent on the organism's past size increases.[143] Or, perhaps it is nutritional levels rather than genes that limit increases in body size—size improves nutrition, improved nutrition increases size.

The Hominid Experience

While the story will continue to be refined, or even recast, the main stages in hominid evolution—from (say) the hominid-chimpanzee divergence until modern humans precariously survived the last ice age—are clear enough. In those six million or so years, the lineage radiated into a small number of species several times (punctuated equilibrium?); just like many other vertebrate lineages. While several coexisted at times, all but one of these species has now died out. But just why the *Homo sapiens* lineage survived and others did not is a topic we have not explored.

Not only did the human lineage survive massive global-scale climatic and ecological changes during its evolution but, by the beginning of the Holocene epoch (10–11 kya), which is where this chapter ends, populations of modern humans had migrated to and were established in all lands except Antarctica and some south Pacific islands. The world's human population at that time could have been five million, all organised into hunter-gatherer bands of up to 150 people. Developmentally, morphologically and behaviourally, these people were markedly different from the ancestral great apes who first adapted to a shrinking of their tree-top habitat by obtaining an increasing part of their food on the ground and, eventually, becoming ground-dwellers.

Of three previously noted requirements for a lineage to successfully occupy a new niche, *geographical access* to savanna habitats came ineluctably as grasslands replaced drying forests in the east Africa of the late Pliocene. Understanding of how hominids had *ecological access* to an unoccupied or uncompetitively occupied niche is more speculative. Still, apparently there was room for a forager-scavenger-food-sharing species capable of coordinated group behaviour.

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[142]For example, http://www.science.siu.edu/zoology/king/metapt.htm (Accessed 3 May 2006); Heyland, A., Hodin, J., and Reitzel, A.M., 2004, Hormone Signalling in Evolution and Development: A Non-Model System Approach, *BioEssays,* **27**, pp. 64–75.

[143]Shea, B.T., 1992, Developmental Perspective on Size Change and Allometry In Evolution, *Evolutionary Anthropology,* **1**(4), pp. 125–134.

This leads to the third requirement for successful niche extension, namely, that the immigrant species be 'sufficiently' pre-adapted to the new conditions and not be too burdened with specialised adaptations carried over from their previous niche. For example, over millions of years of arboreal life, the primitive grasping hand continued to function without any specialised adaptation (such as becoming claw-like), maintaining its versatile mobility and its direct nerve-connections to the forebrain. Indeed, it is hard to think of any adaptations to tree-life which would subsequently prove patently maladaptive once the lineage moved to the ground. In this sense proto-humans were remarkably unspecialised.

Indeed, one can readily list a number of pre-adaptations (some predating arboreal life) which, immediately or with further selection, appear to have improved survival prospects for australopithecines in a drying, cooling world. For example:

Capacity to regulate body temperature
Group living (important for cooperative scavenging and gathering, food sharing, defence)
Forward-facing eyes for stereoscopic vision
Good hand-eye coordination
Omnivore dentition and digestive tract
Feet which would adapt easily to walking and running
Erect posture of the trunk (an essential prerequisite for erect walking)

Once on the ground, adaptation to a savanna niche could begin, starting with selection for increasingly efficient bipedal locomotion and a larger body size than would have been practical for life in the treetops. And as body size increased (a distinct advantage in that new habitat), so did brain size, the forebrain in particular. The long march from a chimpanzee-sized brain to a modern human brain had begun. Indeed, the paramount feature of hominid evolution over the last two million years has been the growth and reorganisation (e.g. lateralisation) of the brain, along with closely associated changes in morphological traits (e.g. vocal apparatus), in behavioural traits (e.g. cultural practices) and in the timing of life-cycle events (e.g. neotenous development). Over the same period a large number of proto-human traits have persisted with relatively little change.

Improving Adaptedness

The *adaptability* of an evolving lineage is its proficiency in generating, via natural selection, adaptations that, within its niche, improve *adaptedness* (fitness, reliability), i.e. improve survival and reproduction prospects. Like other higher animals (less so for plants and simple animals), the hominid lineage has relied on ongoing evolution within a particular family of adaptations, namely, *phenotypic plasticity*, to maintain and improve adaptedness in what has proved to be a variable environment. Recall that an individual organism's phenotypic plasticity is its capacity to continue surviving and developing in a changing environment, by changing physiologically, morphologically and behaviourally. Anurag Agrawal, discussing the 'adaptive plasticity hypothesis' says that 'the modern view of plasticity can be generalised to the statement that phenotypic plasticity evolves to maximise fitness in variable environments'.[144]

Focusing here on behavioural plasticity, the basic requirement for achieving flexible behaviour—meaning context-sensitive observable activity, particularly in terms of mobility and discrimination—is a developed centralised nervous system linked, on the one hand, to organs for perceiving the environment and, on the other, to a skeleton and muscles capable of versatile movement. But, to move beyond the reflexive and instinctual, achieving flexibility in observable activity eventually requires a brain that is also capable of learning and memorising. A lineage with limited behavioural plasticity will necessarily be more reliant on physiological and morphological responses to achieve adaptedness. For example, prokaryotes synthesise their own metabolites to a degree multi-celled animals cannot match; plants have a putative 'strategy' of acquiring resources by extending into the environment.

As noted severally above, a variety of processes have been implicated in explaining the growth and reorganisation of the hominid brain over the Pleistocene epoch: the allometric relationship between brain (parts) and body size; selection for neotenous development; selection for tighter neural control of the hand following the transition to bipedalism; the management of mimesis and, eventually, prosody and speech; the impact of shifting between niches; and variability/change in both the abiotic and biotic (including socio-cultural) selecting environments.

How have these processes expanded phenotypic plasticity, the individual's ability to respond appropriately to changing circumstances? In particular, how has an increasing emphasis on *brain-managed behaviour* led to increasingly plastic behaviour? At one level, increasingly plastic behaviour is nothing more than a many-to-many elaboration of the one-to-one stimulus-response mechanism recognised in the simplest plants and animals (e.g. the oyster that closes when touched). In brief, the plastic organism, compared with the implastic organism, differentiates incoming stimuli more finely, has more motor options available and uses a more elaborate comparative procedure to select a motor response to a received stimulus.

So, behavioural plasticity increased over the Pleistocene as:

Streams of sensory inputs from the external and internal environments were being represented in a centralised brain in ever more categorical detail and being coordinated more closely.

The range of motor actions (behavioural outputs) available to the organism increased as the brain acquired finer control over evolving sets of muscles and their movements.

The brain acquired an increased capacity for memorising experiences and associating them (equals learning); and using these capacities for generating and modelling the consequences of alternative motor actions in response to current

[144] Agrawal, A., 2001, Phenotypic Plasticity in the Interactions and Evolution of Species, *Science*, **294**, pp. 321–326.

sensory inputs. In novel situations the brain's capacity for generating images of alternative motor actions depends on its capacity for exploratory *mental* behaviour which in turn is linked to earlier selection for delayed development and, with it, extended childhood.

The brain acquired a (preconscious) decision-making or choice-making capacity for searching candidate motor responses until it identified, and then implemented, one with consequences which were 'good enough' in terms of the emotional associations attached to those consequences.

The range of traditional and routine behaviours available to the individual accumulated reliably from generation to generation.

Evolutionary Ecology of Hunter-Gatherers

For most of the Pleistocene, hominids were hunter-gatherers organised into nomadic bands that roved between relatively more productive (in food terms) patches distributed across a loosely defined territory. Their basic means of acquiring food (there being no imports or exports) was to harvest available plant and animal biomass, while paying a degree of attention to securing the ongoing reproduction of that biomass, e.g. taboos on certain food sources at times.

In good times (plentiful food) band numbers may have grown and, in bad times (high population relative to the territory's immediate carrying capacity), contracted as a result of increased mortality and emigration by some of the band (called fission) into new territory. On coarser spatial and temporal scales, a further factor driving hominid spread during the Pleistocene was 'biome shift', this being the ways in which various biomes (forests, deserts, coasts, etc.) shifted backwards and forwards across Eurasia as glaciers and sea levels responded to warming and cooling periods within and between the epoch's several dozen ice ages. Like other animal groups, hominids would have moved with or tracked the expansions and contractions of biomes to which they were adapted. In some situations biomes may have contracted rather than shifted, forcing groups into competition for declining resources and, perhaps, for we do not know, into violent conflict.

In these ways, we can imagine erectines and, possibly, australopithecines, colonising much of Eurasia by a process of slow frontier expansion. That is, while the global hominid population probably zig-zagged slowly upwards, through glacial and interglacial periods, for much of the Pleistocene (until the post-Toba crash), the process was more one of growth by extensification (more occupied hectares), not intensification (more people per occupied hectare).

Depending on the type of biome being exploited, omnivorous hominids would have been in competition with carnivores for herbivore prey and with herbivores for plant foods; and would be prey themselves sometimes. But, having control over no energy sources beyond their own somatic energy (at least till fire was mastered), and despite a growing phenotypic plasticity, hominids are unlikely to have extinguished other species, except very locally perhaps. There may even have been a degree of coevolution with prey species and with other predator species (leading in places to hominids focusing on some subset of the available prey species).[145]

What seems likely is that in most seasons, in most biomes, the hunter-gatherer population would have harvested only a small proportion of the available biomass (much less than 1%) and, even in harsh seasons, it is unlikely that resources would have been depleted to the point of being thereafter unusable.[146] The persistence (many would call it sustainability) through geologic time of the hunter-gatherer mode of livelihood (or, in economic language, system of production) and its extension into the most demanding of terrestrial habitats are indications of the success, under a diversity of changing and changed conditions, of the core hominid evolutionary trajectory, namely, the cumulative amplification of the lineage's brain-based behavioural plasticity.

Without hindsight, that conclusion would not be obvious. Maintaining and, over evolutionary time, growing a centralised, albeit functionally differentiated, nervous system requires the unceasing delivery of large quantities of metabolic energy. Even allowing for the decreasing specific metabolic rate which accompanies increasing body size, this is a strategy premised on being able to capture large quantities of energy and using much of that yield to maintain the very organ which allows larger quantities of energy to be captured in the first place. Expressed in that way, the 'big brain strategy' is a continuation of the homeotherm strategy; compared with cold-blooded animals, warm-blooded animals need to capture large quantities of energy to maintain their capacity to be more independent of external temperatures.

Considering the lineage as a whole, as a metaphorical 'super-organism' perhaps, hominids were processing and extracting more and more energy from their environment as the Pleistocene progressed (the 'super-organism' was growing). More correctly, this is a general trend which has to be seen against a background of major shifts in the type and level of productivity of the larger environment.

Within this trend, two component trends can be distinguished; one in the extensification of energy extraction and one in the *intensification* of energy extraction. The process of population growth by extensive spread was equally a process by which the hominid lineage, as a whole, was extracting more energy from the environment—not by capturing more joules per ha, but by capturing much the same joules per ha from many more hectares.

As regards the intensification trend, what is being suggested is that hunter-gatherer societies were also *netting* increasing amounts of energy per ha (per unit bodyweight?) from their territories as the Pleistocene progressed. That is, the difference between energy captured and energy expended to capture it was increasing. To the extent that energy captured per unit of energy expended was also increasing, hunter-gatherers were also capturing energy more efficiently. And, perhaps, also more

[145] Brantingham, P.J., 1998, Hominid–Carnivore Coevolution and Invasion of the Predatory Guild, *J. Anthropological Archaeology*, **17**, pp. 327–353.

[146] Haberl, H., 2002, The Energetic Metabolism of Societies Part II: Empirical Examples, *Research And Analysis*, Massachusetts Institute of Technology and Yale University.

reliably, meaning less variability over time in the net amount of energy captured—a most important determinant of group survival, sometimes interpreted, misleadingly, as greater independence from the environment.

Lumping these variations on the intensification theme together, what might have made such intensification possible? An answer has already been suggested, namely, the cumulative amplification and application of the lineage's brain-based behavioural plasticity, in combination with the advent of a number of physical and developmental adaptations. Apart from changes in the brain itself, these latter include adaptations in body size, in vocal apparatus, in the hands, in the pelvis and, of course, in the timing of maturation.

Cultural Liftoff

One way of thinking generically about the contributions to hominid adaptedness of the increasingly plastic brain is to see it as having generated a succession of *technologies* or *behavioural recipes*—stepwise procedures for completing tasks, for realising imagined goal states. And, to the extent that they persist, that they survive in the selecting environment, all such technologies, indirectly but ultimately, raise, at least in relative terms, the (net) mean quantity of energy captured by the group and/or reduce variability in the (net) quantity of energy captured over time. The Darwinian assumption being made here about the selecting environment is that newly generated technologies or new variants of existing technologies will not be adopted and persist unless they 'save' or 'earn' more disposable energy than existing technologies. The ability to acquire disposable energy is central to adaptedness. Nonetheless, the forces of habit and tradition or side effects on the availability of non-energy resources or high transition costs (the effort required to switch from an old to a new technology), could all militate against the adoption of a new technology on the basis of its energy gains alone.

But what were these technologies? While it could be seen as stretching the concept of technologies too far, it can be suggested that technologies group readily into:

Material technologies involve making things from source materials, including prostheses such as tools and weapons, cooked food, clothes and shelters.

Social technologies which involve habitual, cooperative, coordinated action between people, e.g. food sharing, hunting and gathering in groups, defending the group, attacking other groups, rituals, taboos, division of labour and the invention of leadership.

Communicative technologies involve the transfer of information and knowledge between people using, for example, mimesis, demonstration, stories, displaying emotions and spoken language.

Cognitive technologies which use the resources of sensory inputs (both internal and external), memories and learned relationships to model, in words and images, the consequences of alternative behaviours and events. Applications include making decisions, classifying entities and solving what-to-do problems.

A group's *culture* is largely defined by the extent to which the habitual application of particular technologies within these categories is common to, or, at least, understood by the group's members. And, in this sense, Pleistocene cultures evolved as these various shared behaviours became better adapted to existing circumstances or became modified to suit changing circumstances. Most of these evolving technologies can be seen to have had roots in pre-Pleistocene minds and social relationships (the first hominids were already social animals with sizeable brains) and appear to have changed only slowly thereafter and in readily understandable ways, e.g. achieving more cutting edge per stone core.

Then, some 40 kya, came the Upper Palaeolithic revolution in which developments in material, social, communicative and cognitive technologies, both singly and in concert, began accelerating the rate of cultural change; and, overall, a group's capacity to reliably capture energy from its territory. The oldest known flute and the oldest known ground stone axe both date from 35 kya. Was this largely a matter of separate technologies having accumulated to a point, a critical mass, where synergistic possibilities between them began to appear? Were pre-existing simpler technologies now being brought together to create, incrementally, more complex new technologies, e.g. combining sharper flakes and straighter shafts to produce a new generation of spears? Perhaps, but it seems more likely that the development of extended spoken language, the master technology, massively augmented the lineage's capacity to create, transfer, bequeath, accumulate and integrate the sweep of material, social, communicative and cognitive technologies.

And, we might note, assuming that fire had been mastered well before the Upper Palaeolithic revolution, this cultural transformation was achieved without a bonanza of technologies for accessing radically new energy sources (e.g. wind) or for accessing prior energy sources (e.g. photosynthates) in fundamentally different ways.

The essence of the scenario being presented here is that during the Pleistocene, particularly towards the end, the human lineage was unconsciously building up its repertoires of two sorts of *intellectual capital*. One was working knowledge of material, social, communicative and cognitive technologies which, directly or indirectly, gave groups an enhanced capacity to reliably capture biomass energy from an area. The other was knowledge (information, understanding, a model, etc.) of how the world works, meaning its constituent cause-effect relationships, both hypothetical and observed. It is not too bold to suggest that without verbal language there would have been little accumulation of intellectual capital; just as there was little opportunity for mobile nomads to accumulate material capital beyond portable possessions.

Cultural Evolution and Population Trends

As noted above, group sizes would probably have expanded in good times and contracted in harsh times. Increasing levels of technological competence (adaptedness) might have slowed any fall in group numbers in harsh times and, in better times, at least till numbers grew to match the territory's rising carrying capacity, the dividend from better technologies might have been more 'leisure' or 'play' time for practising and further improving all types of technologies. And there could have been more time for devising behaviours for dealing with emerging what-to-do situations; and more time for transmitting traditional behaviours through rituals, mimesis, etc.

But when it comes to judging the significance of cultural evolution in raising average population density and lowering its variability there are too many factors involved to allow generalisations. For example, how often did improved technologies lead to over-harvesting? How draining was the overhead cost in energy terms of maintaining an ever-larger suite of material, social, communicative and cognitive technologies? How often did entrenched technologies become maladaptive under changing conditions?

A reasonable guess for the Upper Palaeolithic, and it is nothing more, is that advancing technologies tended to facilitate small increases in average population density, moderate reductions in population variability and somewhat larger improvements in groups' capacities to survive major changes in environmental conditions, the sudden bitterness of the last glacial maximum for example. It would not be until the invention of fundamentally different energy-acquisition technologies (farming and herding), well after the end of the last ice age, that population densities would rise markedly.

Is This Story Remarkable?

We have now traversed the prehistory of the hominid lineage from well before the Pleistocene epoch to its end. Our lineage entered the Pleistocene as primates and mammals and left the same way. Indeed we are still mammals and primates and will, almost certainly, long remain so (widespread species undergo little evolutionary change[147]). We might ask then, is the human story remarkable?

An entity (or a process) is remarkable to the extent that it is observably different from other entities in the same *family*, the word 'family' here meaning a set of entities which have some defining characteristics in common, e.g. primates have good eyes and flexible hands and feet.[148] Humans have all the characteristics of mammals but they are remarkable mammals in terms of their easy bipedalism, their slow maturation and the large highly organised brains which make their material, social, communicative and cognitive technologies possible. Reflecting their own adaptive paths, other mammals are remarkable too of course; for strength, speed, sensory acuity, etc.

We might also ask whether the hominid lineage has been remarkably lucky, because it probably has! 'Lucky' here means lucky to have survived; and not too

[147] Mayr, E., 2001. *What Evolution Is,* Basic Books, New York, p. 254.

[148] Lakoff, G., and Johnson, M., 1980, *Metaphors We Live By*, University of Chicago Press, Chicago, p. 117.

cruelly. Most obviously, if the Toba eruption, 71 kya, had been a little bigger, or had lasted a little longer or had been followed up with some more large eruptions—and any of these scenarios would have been unsurprising—the lineage may well have not survived.

In terms of the large dissipative systems within which the hominid lineage (itself a dissipative system, albeit dispersed in space and time) is embedded, the Pleistocene was, luckily, more or less stable. The Earth suffered no impacts from large meteors/comets and no extended bursts of high-energy radiation. Insolation levels, the composition of the atmosphere and the positions and tectonics of the continents were all effectively stable, i.e. were changing slowly, in human terms. After all, the Pleistocene is a very short period relative to the lifetimes of these large systems. It was mainly shifts in climate, over decades and centuries, and associated changes in shorelines, ice cover and biomes that provided the challenges to which the hominid lineage had to adapt or die out. Behaviours (technologies) which acquire food successfully in one environment need not necessarily be successful in others.

Metaphorically, phylogenesis via natural selection is a short-sighted process which, almost always, takes species down adaptive paths that turn out to be dead ends, i.e. most species that ever were are now extinct. The hominid lineage however experienced a sequence of adaptations which, despite being routinely short-sighted, did not become maladaptations when the selecting environment changed and indeed turned out to be useful pre-adaptations for new environments. A good example is the adaptations to arboreal life which turned out to be useful pre-adaptations for life on the savannas. That's luck.

Can this line of argument be taken further? Did hominids who were evolving on the cooling, drying savannas of the early Pleistocene acquire adaptations which pre-adapted them and did not maladapt them for the ice ages to come? One positive example is that the mobility acquired on the savannas allowed later Eurasians to survive the harshest of glacial times by intercepting and butchering animals from migrating herds during the short spring-summer and cold-storing them for the following winter.

And next, as modern humans came through the last glacial maximum, did they turn out to be pre-adapted, not maladapted, to the warmer, less variable conditions of the Holocene epoch? A partial answer here is that Pleistocene hominids were never selected to any extent for physiological and morphological characters which might plausibly be viewed as specialised adaptations to ice age conditions, e.g. hairiness. In this sense they were again lucky because these are the sorts of adaptations which, when conditions change, tend to become maladaptations. Rather, hominids were largely being (naturally) selected for brains that showed an appetency and an increasing capacity, in terms of size and organisation, to create material, social, communicative and cognitive technologies. And, as these technologies were evolving and co-evolving, hominid culture was selectively accumulating, from generation to generation, a *capital stock* of shared ideas, percepts, potential behaviours, experiences, etc. A pool of acquired behaviours could accumulate despite the deaths of those acquiring them.

This remarkable process, this *cultural evolution*, was and is strongly analogous to natural (biological) selection and that includes being shaped by analogues of the necessary and sufficient conditions under which natural selection occurs, namely, phenotypic variations which (a) are directly related to variations in reproductive success and which (b) are more or less heritable.

Corresponding to the triplet of phenotype-genotype variation, fitness differences and parent-offspring transmission under natural selection, the necessary and sufficient conditions supporting cultural evolution in hunter-gatherer times were:

Generation of variation—spontaneous exploratory behaviour in what-to-do situations and in atypical situations where existing technology recipes require some adjustment/modification before they can be successfully applied.

Selection for fitness—a tendency for such technological innovations to be selected to replace or be added to previous technologies in situations where trials confirm they improve the group's ability to capture energy, either directly or (like food-sharing) quite indirectly. We might note though that for existing technologies to be replaced, the gains would need to outweigh the 'transition costs' of overturning existing traditions and habits in societies which experience would have taught to be highly conservative.

Perpetuation through 'inheritance'—reliable transmission between individuals and retention within the group memory (social learning) of recipes for successful technological innovations. Initially, transmission was through non-verbal mimesis but, late in the Pleistocene, through verbal instructions on how to implement technology recipes.

Technologies are like genes in several ways. Indeed, they are prime examples of the 'imitable behaviours' which Richard Dawkins' called 'memes' and Edward Wilson called 'cultural genes' or 'culturgens'.[149] They can appear spontaneously like mutations, they are available for use as needed and they can be recombined to create new capabilities.

While the rate of biological evolution slowed after the human brain reached its present size, the rate of cultural evolution, and hence of technology accumulation or *cultural-capital accumulation*, began to speed up at that time and has continued to speed up until the present day. This 'swamping' of biological change by cultural change in human populations is (like biogenesis, sex, multicellularity, sociality, etc.) one of the truly remarkable emergent developments in the evolution of life on Earth. And, at least till the Neolithic Revolution (10 kya), when new energy-capturing technologies emerged, it was developments in one technology, namely, language, particularly vocabulary size, which uniquely allowed, no, hastened, the ongoing upgrading of cultural evolution's processes for generating, selecting and retaining new technologies.

[149] Dawkins, R., 1989, *The Selfish Gene*, Oxford University Press, Oxford; http://en.wikipedia.org/wiki/Culturgen (Accessed 17 Dec 2010).

Bye-Bye Pleistocene, Hullo Holocene

So, there we have it. About 15 kya the end of the ice age was signalled by rising temperatures, rising seas, melting glaciers, declining populations of large food animals and spreading forests (in Europe) and deserts (in north America). The species of present interest, *Homo sapiens*, was to be found over most of Eurasia and Australia and poised to spread through the Americas and the Pacific. Humans would appear to have been remarkably well placed to meet the challenges and opportunities posed by niche loss and niche gain at this time. They had adapted to but escaped capture by low-temperature environments. Their implicit (probably non-conscious) strategy for achieving this had been to develop an 'extended phenotype', a variety of 'prosthetic' technologies—material, social, communicative and cognitive—for amplifying individual and group capabilities in diverse ways. Paramountly, these were not genetically fixed like instincts but available for use as situations demanded, e.g. shedding clothes in warm weather.

For human populations everywhere, this was the strategy they would take forward into the Holocene epoch, accumulating further technologies suited to and possible within the particular biomes they occupied; creating a hunting culture rather than a fishing culture for example. Trade and other contacts (e.g. ceremonial) between groups would continue to ensure a degree of technology transfer between populations and sufficient genetic mixing to preclude further speciation.

With hindsight, many of the technologies coming out of the Pleistocene were precursors to and components of more developed Holocene technologies. For example, fire management comes, and has to come, before metal smelting; the social technology of chiefdoms is the first step towards the role specialisation and stratified societies of the Mesopotamian civilisations; in cognitive technology, magical thinking sets the stage for scientific thinking; and in communicative technology, pictorial images lead to writing.

And, at some stage, as the range of extant technologies increased, 'compound' technologies involving the combining of existing technologies began to be invented with increasing frequency. Why? Because the (theoretical) possibilities for new compound technologies increase in proportion to the square of the number of existing technologies. For several reasons however, the process of technology invention did not thereby 'explode'. One is that most combinations of existing technologies are either infeasible or not useful. Another is that in hunter-gatherer and early Holocene village societies there may not have been enough discretionary time or enough surplus food energy to support the exploratory behaviour that can generate new combinatorial technologies.

Nevertheless, a process of fitful compound growth in the available suite of technologies was now under way and has continued till the present day. Remembering our broad conceptualisation of *technology*, cultural evolution can be usefully viewed as a process of inventing and applying new technologies. Cultural evolution was and is a response which human societies make to changed conditions, to changes in their environment. But it is not a necessary or universal response—'do nothing' is also a possible response.

Nor is there any guarantee that the invention and application of new technologies will improve the species' adaptedness. Certainly it is a strategy which created a new mode of production, a new social and economic system under the enormous shift from Pleistocene to Holocene conditions. And, as measured by the subsequent increase in human population numbers, cultural evolution did not fail this test. Perhaps cultural evolution is a strategy which would have failed under other environmental lurches but that is unknowable.

Whether or not cultural evolution improved quality of life for most people in a Holocene environment is, as we shall see, more debateable. But the even more important question which has now been opened up is whether adaptation by cultural evolution is a dead-end strategy which, if continued, will lead to the extinction of the species, for example, by generating overwhelming rates of cultural and environmental change. At this stage we might just note, with the benefit of hindsight, that by the beginning of the Holocene, cultural evolution had produced a variety of technologies with the potential to become maladaptive in the longer term, e.g. anthropomorphic models of the natural world, a dual morality (amity and enmity) and tradition.

Chapter 3
Emergence and Evolution of Complex Societies

The Idea of a Universal Evolutionary Process

Is there a sense in which the evolutionary process which has produced everything from elementary particles to the industrial age has always been the same process? And, if it is not just one process, how many processes is it?

At a very general level, all evolutionary changes are certainly expressions of a single universal process, namely one in which an existing dissipative system spontaneously reorganises all or part of its static and kinetic structures in a way which converts high-quality energy (exergy) from one form to other forms at an increased rate and, in so doing, increases the overall rate at which low-quality energy (entropy) is being produced and dissipated into the parent environment. In this sense the evolutionary process is a spontaneous equilibrating process, satisfying a 'thermodynamic imperative' to reduce thermodynamic potential (flatten energy gradients) in the most effective available way. Inverting this, the principle, the law perhaps, to which the evolutionary process is conforming is that entropy spontaneously increases at the maximum available rate (see page 69).

Newly organised dissipative systems, singly or in combination, can behave in extraordinarily diverse ways and have diverse impacts on their surroundings. Much effort has gone into recognising recurring 'context free' patterns in such behaviours and impacts. For example, the theory of non-linear dynamic systems (see page 66) suggests various templates for the behavioural trajectory (e.g. cyclic, chaotic, point) of a system entering a new basin of attraction and clarifies concepts like thresholds and resilient behaviour (bouncebackability!). Some systems swing rapidly through a sequence of basins, others persist stably in one basin. Other well-recognised behaviours include the formation of hierarchies of systems (systems contained in or made out of other systems) and various symbiotic interactions between systems. We might also note, as pointed out by Stanley Salthe, that, from a self-organisation

D. Cocks, *Global Overshoot: Contemplating the World's Converging Problems*,
DOI 10.1007/978-1-4614-6265-1_3,

perspective, the distinction between evolution (moving between basins?) and development (moving within a basin?) becomes blurred.[1] They are overlapping historical processes.

Here, it is not our intention to attempt to abstractly and comprehensively classify what is a superabundance of dynamic behavioural possibilities for mixtures of evolving systems. Perhaps it is just semantics, but I find it more useful to think of these diverse behavioural possibilities as variations on one basic evolutionary process rather than as separate evolutionary processes.

Evolution Has a History

The history of evolution can be written in terms of the changing mix of products (types of dissipative systems) which the *evolutionary process* has created, maintained and destroyed. A broad–brush anthropocentric history of how the universe has evolved over time to produce contemporary humans and the world they live in falls readily into three overlapping 'eons', for want of a recognised word. These are the *Physico-chemical Eon*, the *Biological Eon* and the *Cultural Eon*—names chosen to suggest the advent and proliferation (and eventual decline in numbers) of what are, from the perspective of their human significance, three radically different types of dissipative systems. That is, they are radically different in terms of the types of energy and materials they take in and pass out and in the types of kinetic and static structures they use those inputs to create and maintain.

Central to understanding this temporal sequence is the 'piggybacking' idea of *path dependence*, e.g. that biological systems of the Biological Eon could not have evolved without the prior evolution of physico-chemical systems and cultural systems of the Cultural Eon could not have evolved without the prior evolution of biological systems. Nor could the systems of any eon persist without the survival of systems from previous eons, inasmuch as it is these which nourish that eon's systems with flows of materials and energy.

Just as the history of evolution can be subdivided into eons, the history of each eon can be subdivided into overlapping 'ages' identifying periods of emergence and proliferation of markedly dissimilar types of dissipative systems. Thus, in the Physico-chemical Eon, physical systems first emerged during the *radiation age* that followed the big bang and subsequently diversified over billions of years (see page 14). Following the condensation of material particles in a cooling universe (the *particulate age*), this eon produced successive overlapping waves of galaxy formation (*galactic age*), star formation (*stellar age*) and planet formation (*planetary age*). Particles, galaxies, stars and planets are dissipative systems which come into existence and which, in time, 'die' in some sense (see page 17). Each age signifies a major transition in the evolutionary process's reigning product mix.

[1] Salthe, S.N., 2010, Development (and Evolution) of the Universe, *Found. Sci.*, 15, pp. 357–367.

It was only with the formation of planet Earth and its chemically rich water bodies that the *chemical age*, a link between the Physico-chemical Eon and the Biological Eon, became possible (see page 19). It was in the chemical age that life's precursors—sets of linked autocatalytic chemical reactions feeding (metaphorically) off each other—first emerged from an environment capable of sustaining supplies of suitably energetic raw materials to these dissipative cycles.

The Biological Eon

The Biological Eon is conventionally, and adequately enough for present purposes, divided into a sequence of ages characterised by ecosystems that successively support unicells, multicells, fishes, reptiles, mammals plus flowering plants and humans.

Living systems provide an early and important example of dissipation through the conversion of chemical energy to kinetic and thermal energy. Such systems depend for their survival on a process which is conceptually and operationally different from the process determining the survival of the physical and chemical systems which preceded them. At the heart of that novel process was the capacity of early life forms, namely single-celled prokaryotes, to grow (i.e. process energy at an increasingly higher rate) to a physically determined 'maximum' size and then (approximately) self-replicate by dividing into two smaller, but otherwise still similar, physically separate parts, each of which could disperse (e.g. drift away) and regrow to 'maximum' size, provided energy and material resources were not limiting. The fact that its parts are dispersed need not stop us regarding a population of single-cell sub-systems, formed by a cascade of divisions, as just one dissipative system.

Just as all dissipative systems take in energy and materials, they all produce outputs or products which can be described in terms of energy and material fluxes. The terms *autopoietic* (literally, self-creating) and *allopoietic* are a recognition that the outputs of living and non-living systems are fundamentally different. Non-living systems are allopoietic, meaning that they produce things different from themselves, e.g. volcanoes do not produce more volcanoes. Living systems, being autopoietic, produce outputs which, following growth, will be very similar to themselves; a population of unicellular organisms outputs small unicellular organisms, each of which stands to produce a population of unicellular organisms!

Non-living systems rely for their survival on the energy-materials fluxes that drive them staying within certain 'fixed' tolerance limits, limits which can be thought of as defining that system's *niche* in environmental space. If the system's environment keeps changing in any particular direction it will eventually move beyond the environmental limits defining the system's niche and the system will necessarily reorganise. Thus, if energy gradients are flattening, the system will tend to collapse, disaggregate, simplify or shrink and, if energy fluxes are rising, the system will tend to grow or complexify.

Early living systems, e.g. dispersed populations of similar unicellular organisms, were somewhat different. They relied (a metaphor) for their survival in a changing and spatially variable chemical 'soup' on two attributes which followed from their tendency to bud off imperfect copies of themselves (imperfect in terms of the molecular 'species' feeding and participating in the cell's autocatalytic cycles). One attribute was a tendency to occupy (drift into) all accessible parts of the niche. The other was a tendency to extend the niche to include environments where occasional imperfect copies proved able to survive and replicate more reliably than their parents. Both tendencies improved the population's survival prospects. For example, a small catastrophe which wipes out part of the occupied environment will still leave part of the population to survive and perhaps multiply. Or, if the environment changed so that more of it was favourable to some particular sort of 'imperfect copy', then that particular component of the population would expand in numbers to fill the 'new' environment.

For this two-pronged survival strategy (another metaphor) to work, each part of a dividing organism has to reliably 'inherit' a spread, a starter kit so to speak, of all of the chemical resources needed for autocatalytic growth to proceed. But not too reliably; a *population* of cells which all have exactly the same capacity as their parents to process environmental materials through an autocatalytic growth process may be less able to survive a change in the availability of environmental materials than a *population* in which individuals vary to some extent. Conversely, if the inheritance process is too unreliable, then most offspring cells will be unable to continue growing and dividing and the population will remain small and at risk from local catastrophes. The optimum degree of reliability in this 'divide and bequeath' strategy will depend in some complex way on the variability of the environment.

Even though there are, at this early stage in life's history, no genes being transmitted between generations, a form of natural selection is nonetheless operating. When individuals vary in terms of their autocatalytic chemistry, some will grow faster and divide more frequently than others, i.e. they will be selected. Genes and chromosomes evolved subsequently, functioning as a mechanism which reliably transmitted, not so much the molecules required for autocatalytic growth, but encoded information which triggered the construction of all necessary molecules from the raw materials diffusing into the cell. In time it would be the occasional imperfect replication of genes (not of the molecules participating in the cell's autocatalytic cycles) that would generate unicellular organisms of differential fitness and hence create the possibility of natural selection. Gene-based natural selection would, in more time, lead to adaptations such as a capacity for directed mobility or for photosynthesis.

While gene-based natural selection is most commonly thought of as a process which leads to speciation, it is, more fundamentally, a process which increases the survival prospects of multi-organism dissipative systems located in a heterogeneous and changing environment. Just as gene-based natural selection led to populations of organisms of various species being more likely to survive for a time, so did the emergence of *cultural inheritance* and *cultural selection* in populations with a capacity for individual learning and imitation.

The Cultural Eon

When it comes to the Cultural Eon, there is, again, a well-recognised subdivision of history's passing parade of human societies. While culture, in the sense of transmitting learned behaviour to others, could well pre-date the age of mammals, it suffices here to divide the Cultural Eon into a *hunting-gathering* (*or foraging*) *age*, a *farming-herding age*, an *urban age* and an *industrial age*. And while the seeds of a *post-industrial age* have no doubt germinated, the paramount feature of the dissipative systems that will characterise that next age is not yet clear enough to give it a specific name.

Of these several ages nominated as comprising the Cultural Eon, this book has so far looked only at hunting-gathering. We have particularly explored how cultural innovations in the hunting-gathering age, including material, social, cognitive and communicative technologies, coevolved with such consequential biological transitions as those in brain size and organisation, the vocal apparatus, body size and maturation rate. After the end of the last glacial, as energy flows through the biosphere increased and climates changed, the stage was set for the next major reorganisation of the Cultural Eon, namely a shift to a farming-herding age. It is to the evolution of farming-herding and later societies that we now turn.

The Neolithic and Urban Revolutions

The last ice age ended with Eurasia experiencing a period of severe 'glacial aridity'. From 20 to 18 kya temperatures were lower and glaciers more extensive than at any time during the previous 100 kyrs. Sea levels were about 130 m below present levels with, for example, Tasmania and New Guinea being linked to Australia by land bridges. As rainfall diminished, half the land between the tropics turned to desert. In Australia the population was reduced by, perhaps, 80% with plant growth being slowed by low temperatures, low rainfall and low levels of atmospheric carbon dioxide. Humans survived in a few refugia across the continent.

Thereafter, temperatures began to rise, but not reliably; there were sharp cooling periods around 14 kya (called the Older Dryas event) and 13 kya (the Younger Dryas event). Nonetheless, the onset of a warmer wetter climate created opportunities for a variety of more sedentary lifestyles (still based on hunting, fishing and gathering though) in places where food supplies could be obtained year-round. Populations grew under these more settled conditions.

The Neolithic Revolution (12,000–6,000 BP)

Along with the final retreat of the glaciers, about 12 kya, came a dramatic reduction in climate variability. The benign Holocene had begun. Much of Europe became covered with dense forests and most of the large animals of the Ice Age either moved north or went extinct. In the Middle East's 'fertile crescent', wild barley and wheat could be relied on to produce harvestable quantities of seeds in most years while wild sheep, cattle, goats and pigs flourished on the expanding grasslands. Photosynthesis rates rose by, perhaps, 50% in response to atmospheric carbon dioxide levels rising from 190 to 250 ppm.[2] Here, the stage was being set for the emergence between 11,000 and 8,000 BP (Before Present) of a village-based Neolithic (new stone age) society based on the deliberate planting of cereal crops, some primitive irrigation and on domesticating and hand-feeding indigenous social animals. Some, as their flocks of animals grew, became nomadic tribespeople searching for ever-larger areas of grasslands.

There were setbacks. Some 8,200 years ago, sea levels, which had been rising since the last glacial maximum were still some 15 m below present levels. Then, for the third time since the glacial maximum, came the collapse of glacial barriers which had been holding back huge quantities of lake water in North America. Enormous floods spilled into the north Atlantic causing rapidly rising global sea levels, short-term flooding and permanent inundation of coastal areas around the world. These areas included much of south-east Asia (Sundaland) where established Neolithic societies would have been destroyed or displaced. The flooding of the river valleys of the Persian Gulf at that time suggests an origin for the story of Noah's flood. Alternatively, the Black Sea is estimated to have filled rapidly from the Mediterranean at this time.

Just as their pre-hominid African ancestors had adapted to the first stirrings of the Pleistocene ice ages by moving from a declining gallery forest habitat to an open forest (savanna) habitat, Neolithic hunter-gatherers adapted to the suite of ecosystem changes that marked the end of the Pleistocene by becoming farmers and herders. While the first Neolithic peoples flourished in northern Iraq and Turkey, their technology 'revolution' spread to the Balkans by 7000 BP, to Egypt and central Europe by 6000 BP and to Britain and parts of India by 5000 BP. The warm productive period—7000 to 5000 BP—which encouraged this spread is known as the *Holocene thermal maximum*.

Apart from agriculture and herding *per se*, Neolithic peoples developed a large suite of supporting material technologies which would remain useful even as village agriculture began, in the Middle East, to give way to large-scale irrigated agriculture. These included artificial irrigation using canals and ditches; the plough; animal motive power; the sailboat; wheeled vehicles; orchard (hoe and dibble) husbandry; fermentation; production and use of copper; bricks; the arch; glazing; animal hobbles.

Life for Neolithic villagers was mostly peaceful (although not necessarily longer and more leisurely) because food was produced only in subsistence quantities and this left little opportunity for non-producers such as priests and soldiers to be

[2]Richerson, P.J., Boyd, R.B., and Bettinger, R.L., 2001, Was Agriculture Impossible During The Pleistocene but Mandatory During The Holocene? A Climate Change Hypothesis, *American Antiquity*, 66, pp. 387–411.

supported by farmers and little temptation to attack other villages in search of food. Population grew by the spatial spread, rather than the intensification, of settlement. More reliable food supplies led to women being fertile for longer. Also, cereals were useful foods for improving post-weaning survival rates.

Neolithic villages could contain hundreds of people, i.e. they were much larger than most hunter-gatherer groups. Social cohesion was underpinned by kinship systems which imposed elaborate obligations to assist one's 'relations'. While language and chiefdoms had emerged as important tools for organising and co-ordinating individual behaviour in hunter-gatherer groups, their effectiveness was based on face-to-face contact, too unwieldy a method for managing larger groups where people might not even know all members of their group. It was in this context that social control through obedience to the 'voices of the gods' or their Earthly messengers emerged. Whether the 'voices of the gods' were the hallucinated voices of dead chiefs who, over time, became godlike is the hypothesis so marvellously explored by Julian Jaynes.[3] Perhaps the real significance of this hypothesis is that it suggests a first mechanism for achieving social coordination *out of earshot* (just as writing would at a later date). What can be said with confidence is that religion and magic became increasingly important tools for managing society as the size of social units continued to expand.

The Urban Revolution (6000–3000 BP)

Large-scale irrigated agriculture began about 6,000 years ago and, with the invention of writing, marked the beginning of history proper. Sumeria, the first real civilisation—meaning a society supporting cities and specialist occupations—appeared about 5,500 years ago in southern Mesopotamia in the swampy flat lands around the lower reaches of the Tigris and Euphrates rivers. It was a time of drying climates, making rain-fed agriculture difficult, and people were gravitating to large river valleys and their floodplains. Thus, a Nile valley civilisation soon appeared, along with an Indian civilisation in the upper Punjab and a Chinese civilisation on the middle Hwang-Ho. The Mesoamerican and Andean civilisations began around 3500 BP. The classical Greek civilisation on the Aegean Sea emerged about 3100 BP.

In addition to writing, the Sumerian revolution in social organisation quickly spawned three particularly consequential inventions—a solar calendar as still used, numerical notation and bronze (a tin-copper alloy) for making tools and weapons.

Reclamations of the lower Nile and the Euphrates from their swamps were massive tasks which could only be undertaken by large organised communities. The complexities of setting-up and managing big irrigation systems devolved to a specialised priestly class who were fed from large grain surpluses (partly explainable by the invention of the plough as well as by high yields under irrigation), as was the

[3] Jaynes, J., 1976, *The Origin of Consciousness in the Breakdown of the Bicameral Mind*, Houghton Mifflin, Boston.

warrior class which emerged to protect those same surpluses from marauders. These same warriors were responsible for the internal coercion which was beginning to emerge, alongside religion, as an instrument of social control. The need to serve 'the gods' provided priestly oligarchies with a rationale for organising the concentrated use of labour on public projects.

As marauding by horse-riding steppe peoples increased, command (military) management replaced priestly management in the Mesopotamian and other irrigation civilisations. As urban populations grew in the irrigation civilisations, additional specialist occupations emerged and the technologies associated with these new occupations advanced in step with the numbers who practised them. For example, the construction of bronze weapons and tools needed, apart from metal workers, many people, carts and animals to transport ores from far places and large quantities of timber to make charcoal for smelting. It was the dominant military and priestly classes who now took responsibility for the distribution of food in societies organised more and more around occupational classes rather than fragmenting kinship groups; a new form of economic system had emerged.[4]

In time, it was competition among the emerging city-states of southern Mesopotamia (Lagash, Kish, Ur, Erech, Shuruppak, Larsa and Umma) for, *inter alia*, access to scarce ores and timber which initiated an era of 'survival through conquest' that persisted across Eurasia till, perhaps, the collapse of the Western Roman Empire in 476 CE (Common Era). Sargon of Kish defeated the other city states to create the world's first empire, the Akkadian empire, which lasted from 4330 BP till destroyed by drought in 4230 BP. As a way of increasing a nation's food supplies, empire-building proved to be a more effective social technology than marauding once annual food surpluses in surrounding regions had stabilised. In this way, through taxes and tributes, a conquered state makes its maximum contribution to the conquering state in all years. Indeed, in addition to the Akkadian empire, the period around 4300 BP saw natural disasters, particularly drought, causing the collapse of a number of major civilisations, including the Old Kingdom in Egypt, the early Bronze Age societies in Anatolia, Greece and Israel, as well as the Indus Valley civilisation in India, the Hongshan culture in China and the Helmand civilisation in Afghanistan.[5]

It was the availability of food surpluses which induced a second (i.e. post-Neolithic) surge in human numbers, this time in urban rather than rural areas. But waterborne diseases (boosted by closer human contact) and the need to maintain and replace armies acted as major checks on population growth. Only rich urban civilisations could sustain viruses and armies which ate but did not produce. And, of course, once population rises to match increased food supplies, a Malthusian trap closes, meaning

[4]In several medium energy societies, the Aztecs in Mexico for example, a market-based system of distribution emerged rather than a socialist or state-controlled system. See White, L., 1959, ibid., p. 295.

[5]Peiser, B.J., 1998, Comparative Analysis of Late Holocene Environmental and Social Upheavals, In Peiser B.J., Palmer, T., and Bailey, M.E., (Eds.) *Natural Catastrophes During Bronze Age Civilisations*: *Archaeological*, *Geological*, *Astronomical and Cultural Perspectives*, BAR International Series, **728**, pp. 117–139.

that there is great pressure to maintain or further increase food production. While urban populations acquired some immunity to the new diseases of crowded civilisation, rural peasant populations did not—an important part of the success of urban elites in controlling outlying areas. More generally, skeletal evidence indicates that as soon as humans began to farm, health levels declined due, perhaps, to population crowding, altered workloads, and increased nutritional deficiencies.

Across Eurasia societies were now coming to be organised into spatially extensive politically independent imperial command structures. Government-at-a-distance was achieved through the bureaucratic principle of delegation. Taxes, collected on commission for the central authority by feudal warlords, were the price of military protection. Difficulties with transport and communications were persistent challenges to the management of empires, as were fluctuations in crop yields. For instance, in 3628 BP the Santorini volcano exploded, destroying, by tidal waves, the Minoan civilisation in Crete and initiating a period of volcanic winter, and political instability, worldwide. In the words of W.H. McNeill, most of Eurasian political history can be viewed as unending fluctuation between imperial consolidation and peripheral feudal unrest, punctuated at times by epidemics of invasion by mobile horse-riding nomads from the animal-producing steppes which lay beyond areas suitable for cropping.[6] Mass migrations caused by floods, droughts and famines were common and led to invasions and, for some peoples, servitude, e.g. the Jews.

The rate of technical and social innovation was now very low, possibly because most communities were still living precariously, meaning that a close adherence to traditional proven methods was a better strategy for survival than experimentation. Perhaps also, in the interests of maintaining social control, imperial rulers would have actively discouraged potentially disruptive innovations. Indeed, the ruling classes had little respect for or interest in farming and farm workers. Gordon Childe notes only four major innovations in the 2,000 years after the urban revolution, say from 4600 BP—decimal notation in Babylonia, iron smelting, a true alphabetical script (3300 BP) and aqueducts for supplying city water (2700 BP).[7] Massively important here was the advent, c.3400 BP, of economical methods of producing iron, for tools and weapons, on a large scale.

The Bronze Age ended with the somewhat mysterious collapse between 3225 and 3175 BP of at least 50 great Mediterranean cultural centres, including Troy, Mycenae and Knossos. The geophysicist Amos Nur has suggested that a staggered chain of Earthquakes along a major fault line could have rocked city after city, degrading their economic, social and political structures and leaving them vulnerable to marauders and waves of hungry refugees.[8] Certainly it was around this time that chariot armies of various cities in the eastern Mediterranean succumbed to the iron swords of barbarian foot soldiers. Drought too may have played a part.

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[6] McNeill, W.H., 1979, *Plagues and People*, Penguin, London.

[7] Childe, V.G., 1942, *What Happened in History*, Penguin, London.

[8] Nur, A., and Cline, E., 2000, Poseidon's Horses: Plate Tectonics and Earthquake Storms in the Late Bronze Age Aegean and Eastern Mediterranean, *Journ. of Archael. Sc.*, No 27, pp. 43–63.

The Cognition-Consciousness Revolution

The first millennium BCE (Before the Common Era) was an era in the development of human societies when, across Eurasia, human knowledge, beliefs and ways of thinking changed markedly. Before reviewing a little of those changes and times, we will pause to abstract some working perceptions from the tangle of ideas around the phenomenon of consciousness and its relation to cognition.[9]

The Problem of Consciousness

The enormous yet inconclusive scientific (and other) literature on consciousness attests to the difficulty we have in understanding its function, its evolution and its processual nature. Defining it and its various forms, locating it within and between individuals and species, and in time (when did it appear?) are likewise problematic.

The same large literature indicates that many think it is important to understand consciousness. Why? Plain curiosity is part of the answer. Another answer, for some, is that consciousness is a cognitive technology which appears to have played a major role in shaping human history and if we want to understand history we need to understand consciousness. The specific perception here is that the process which produces consciousness—call it the consciousness-generating process—is a general purpose technology which has helped humans to dramatically increase the rate at which they have produced technologies intended to improve survival and life-quality prospects; and to produce one-off plans for solving novel problems. Perhaps a clear understanding of this technology can lead to its further improvement and hence to its making an increased contribution to future human welfare.

Here, I propose to take a selective approach to the concept of consciousness. I will restrict the term to an experience which, I believe, takes place only in humans (not little children), namely the implementing of an ability to observe (watch), and to know that one is observing, some of the operations of one's own (autonomous) mind. Note that in this rendition consciousness (being conscious) is a process of introspective observing and is quite distinct from what is being observed via this process, i.e. what I am conscious of does not constitute consciousness. The telescope is not the landscape. Equally, consciousness is not the cognitive processes which generate that which is being observed.

Failure to make these distinctions is a pervasive source of confusion. Others have avoided this potential muddle by using another term for consciousness as it is being used here, e.g. Gerald Edelman's term is *self-conscious awareness* and Zoltan Torey's is *reflective awareness*.[10] A good metaphor for 'awareness of awareness' is

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[9]Cognition: Mental activities involved in acquiring, processing, organising and using knowledge.

[10]Edelman, G.M., 1989, *The Remembered Past*: *A Biological Theory of Consciousness*, Basic Books, New York; Torey, Z., 1999, *The Crucible of Consciousness*: *A Personal Exploration of the Conscious Mind*, Oxford University Press, Melbourne.

that it is like seeing yourself on a surveillance camera while you are shining a torch on something which has attracted your attention. The portion of experience being irradiated by consciousness appears as clear and distinct against a background reality which is dim.[11]

How does consciousness manifest itself? As a simple example, when you look at your familiar finger, your brain recalls, from memory, a referent couplet made up of (a) a stable and selective visual image, called a percept, of 'my finger' and (b) a verbal label (finger) for that image. You are conscious of your finger if you are both aware of this referent couplet and, reflectively, aware that you are aware of it, i.e. aware that you are paying attention to it. While you might be more aware of your finger if you have just hit it with a hammer, you are not more conscious of that awareness. Differently, you might be subconsciously aware of your finger in the sense that you move it in response to a stimulus, an itchy nose say, without realising consciously that you are aware of your reaction. To be clear here, sub-conscious awareness is not consciousness, i.e. it is not self-conscious awareness.

Clarifying the Consciousness Experience

Before further discussing the mechanism and function of the consciousness process, there are several aspects of the consciousness experience which, in the interests of later discussion, need to be clarified.

Who is the observer, or, alternatively, since they are felt to be one and the same, whose thoughts are being observed? Does it help to say that 'I' or 'I, myself', am the observer; or, to say that the thoughts of which there is awareness are felt to be the experience of an 'inner person', a *self* or an *ego* or a *me*? The verbal labels 'I', 'me', 'myself' and 'my ego' have all come to be applied to that which experiences consciousness—I have thoughts and, when I am conscious, I observe (am aware of) my thoughts, and I am aware of myself and I am aware of myself being aware of my thoughts.[12] Whenever you think 'I am observing such-and-such a thought', it is a sure sign of consciousness. When you answer the question 'What are you thinking about?' you are stating what you are conscious of at that moment. But being an abstraction which cannot be pointed at, we can only know this observed and observing ego metaphorically, viz. the ego is like an observer, like, say, an animal observing its prey. Like other abstract concepts (e.g. energy, gravity) we can only say what consciousness does and how it behaves operationally, not what it is.

Mind-space. One difficulty in referring to one's 'awareness of awareness' metaphorically is that it is just not like anything else we experience. I am attracted to Julian Jaynes' insight that all experiences of consciousness appear to be glimpses

[11] Whitehead, A.N., 1933, *Adventures of Ideas*, Free Press, New York, p.270.

[12] In Jungian psychology the self includes the mind's unconscious processes as well as that which experiences consciousness, namely, the ego. I am using the terms 'self' and 'ego' interchangeably here.

into an imagined mind-space which is a metaphor or model of real space (the real world) and in which an imagined ego, what he calls an analogue 'I' or a metaphorical 'me', can observe and, metaphorically, move around.[13] Each referent we become conscious of appears to have its own definite boundary surface and to be separate from other referents, i.e. can be thought about separately. Referents can be ordered in mind-space in ways analogous to the various ways in which objects can be spatially related in reality. Mental acts are analogues of bodily acts. So, when I am conscious of my finger, I am (metaphorically) looking into my mind-space and seeing 'me' looking at my finger, i.e. I am aware of three things: my finger, 'me' and 'me' looking at my finger.

For abstract entities too, we use the metaphor of seeing, of observing, to understand (give meaning to) how they are related, e.g. (the word) justice seems to be close to (the word) fairness in mind-space. George Lakoff points out that, metaphorically, consciousness is 'up' (e.g. wake *up*), and unconsciousness is 'down' (e.g. she *dropped off* to sleep).[14] As for entities which are related in (abstract) time, we think of them, metaphorically, as being located 'before' and 'after' along a 'time line'. In particular, words in sentences and thoughts emerge sequentially through time and that might explain the pervasiveness of the spatial metaphor for understanding thought processes. It will be suggested presently that the ability to manipulate words in ways which are directly analogous to the ways objects can be manipulated in the real world is the basis of advanced cognitive skills.

Accessible and inaccessible thoughts. What categories of thoughts might be accessed and what cannot be accessed through a consciousness experience? When you are conscious, you are always conscious of something, a *referent* or the so-called *intentional object*, usually a thing or a relationship, perhaps in memory, perhaps in the internal (intra-body) environment, perhaps in the external environment. Thus, the contents of the three main types of memory—short-term, long-term and sensory—are, in principle, accessible by the ego, i.e. can be experienced consciously. Long-term memory includes an organised body of knowledge, a narrative, about one's personal history. According to Freud, the ego is like an agent of the mind (a metaphor), by means of which the subject acquires a sense of unity and identity, 'a coherent organization of mental processes'. For the moment though, we are more concerned with ego as that which experiences consciousness rather than as that which builds identity.

By definition, thoughts in the unconscious mind are inaccessible through the consciousness experience. For example, you cannot observe your thoughts at the moment of making a decision, only, at best, the thoughts that go into the decision

[13] Understanding something is commonly a matter of finding a suitable metaphor (A is B) or simile (A is like B) or analogue (A is like B in part) for the entity we wish to understand. Here, we will use *metaphor* as a catch-all term. See Richards, I.A., 1936, *The Philosophy of Rhetoric*, Clarendon Press, Oxford.

[14] Lakoff, G., and Johnson, M., 1980, *Metaphors We Live By*, University of Chicago Press, Chicago, p.15.

and the thoughts that come out of the decision-making process. It is this apparent spontaneity of our decisions which invites speculation that we might have 'free will'. Similarly when retrieving memories: to the extent that you cannot perceive, at the moment of selection, what memory frame will be retrieved next (it just arrives), there is an inclination to impose meaning on this mystery by attributing the selection made to an act of will on the part of the ego.

Who is thinking? Another basic aspect of the consciousness experience, sometimes called a sense of doership, perhaps better called a *proprioceptive sense*, is the feeling that you are the entity *creating* (cf. experiencing) the sense of awareness of your thoughts. As will be discussed below, the consciousness process has a motor component (sub-vocalisation). The importance of this is that all motor activities are proprioceptive, meaning that when they are (consciously) executed they generate a feeling that you, the executor, the analogue 'I', are carrying out the activity.[15] The consciousness process seems to involve an understandable extension of the proprioceptive feeling from body awareness to thoughts awareness. Thus, if you do become aware of your thoughts, you will recognise them as your thoughts because thinking is a motor activity and all motor activities that come to awareness evoke this feeling of own-body awareness.

Being conscious of certain thoughts need not imply any knowledge of the source or origin of those thoughts. Normally though, irrespective of their specific content and origin, one's 'visible' thoughts are felt to be self-authored. That is, the thinking process which produces 'my' conscious thoughts is felt to be autonomous. The thoughts I am conscious of are not the products of another's thinking which are being channelled through me.

While most people, through socialisation, do come to believe in the autonomy of their own thinking (it can't be proved), there are those, notably schizophrenics, who believe that at least some of their 'thoughts' are freshly planted in them by outside entities. Many schizophrenics experience auditory hallucinations in which authority figures, even gods, tell them what to think and do. And, as will be further discussed below, it is Julian Jaynes' hypothesis that it is only since second millennium BCE that most people have felt themselves to be the authors of their own thoughts and actions.

Consciousness is a thin, intermittent and discrete (i.e. either 'on' or 'off') experience. Few of the brain's hundred billion neurons are involved in an experience of being reflectively aware of one's thoughts and, we suspect, if memory serves aright, that one is conscious for but a tiny fraction of each day. Consciousness is rooted in the 'here and now' reality of everyday life and it is to this reality that consciousness returns after each excursion into the consideration of a what-to-do problem outside everyday experience.

[15]Note that awareness of what your body is doing (i.e. proprioception) may or may not come to consciousness.

Consciousness expands with vocabulary. The set of referents that an individual, and his/her society as a whole, are potentially conscious of is continually expanding. In Jaynes' phrase we are constantly renewing and enlarging our mind-space with each new thing or relation 'consciousised'. Every new suite of words coming into a language mirrors the creation of new percepts and concepts, expanding the spread of what one can be conscious of but not changing the essential nature of the consciousness experience. The exception to that may be consciousness itself. It is at least plausible that you cannot be reflectively conscious if you do not have a vocabulary which allows you to describe (or agree) what it is to be conscious, e.g. non-human animals, little children.

The Consciousness-Generating Process

We have already noted that neither the experience of consciousness per se nor the entities one is conscious of should be confounded with the mental processes which generate the experience of consciousness; there is more to the consciousness process than the consciousness experience. Here, I will draw on ideas in Zoltan Torey's path-breaking book, *The Crucible of Consciousness*[16] to identify what the consciousness-generating process generates in addition to the consciousness experience itself, and how it does so.[17]

Torey's model of the self-aware brain concentrates on three interconnected regions of the physical brain each of which can be regarded as a self-organising (sub) system of neurons—storing and reorganising information as well as continuously receiving and transmitting information in the form of neural messages, electrical impulses, along neuronal pathways. The three are the right hemisphere's *awareness system*, the left hemisphere's *speech system* and the brainstem's *arousal system*.

The Awareness System

The *awareness system* is located in the frontal lobes of the brain's right hemisphere. Metaphorically, it ceaselessly generates an ever-evolving situation report (What's happening?) on the body and its environment based on the receipt of diverse inputs from both outside (via the sense organs) and inside the body (from muscles, other parts of the brain, the nervous system and from the endocrine glands). The awareness

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[16] Torey, Z., 1999, *The Crucible of Consciousness*: *A Personal Exploration of the Conscious Mind*, Oxford University Press, Melbourne.

[17] Calling the consciousness process the consciousness-generating process risks giving the impression that the only thing the consciousness process does is to generate consciousness. What I am calling the consciousness-generating process is similar, I think, to what Torey calls the mind system.

system integrates (totalises) or translates all these inputs into an ever-updating internally consistent set of 'off the shelf' percepts called an *endogram*. An endogram is something like a frame from a movie, a manageable summary of what the brain is aware of at the time, a model of the world outside the awareness system. Being 'internally consistent' simply means that the endogram's constituent percepts are recognised as being related in some fashion. Remember that a *percept* is anything that can be separately identified and named, i.e. be labelled with a word or sentence.

All sensory inputs that signal change in the environment are immediately cycled through an *arousal system* (see below) located in the limbic area and reticular formation of the upper brainstem.[18] Here an emotional 'flag', positive or negative, is grafted onto the percept before it is returned to the awareness system. Depending on the emotional significances assigned to different percepts, different parts of the endogram will thus express different degrees of arousal and, hence, will elicit different degrees of attention from the ego. Any 'insignificant' percepts will not even reach the endogram. Functionally, a 'cognitive technology' of selectively attending to those referents in the endogram with significant emotional overtones protects against sensory overload in the awareness system and, hence, against undirected behaviour. Also, percepts for which the added emotional overtones exceed a threshold intensity are embedded in long-term (permanent) memory storage from where they will be retrievable in the future (along with the added feelings).

The awareness system does more than assemble percepts. The awareness system also has a *word response mechanism* which first classifies and then attaches a word-label to each percept entering the focal or high attention part of the endogram. Thus, all input experiences which make it to the focal area are first converted into stable referent couplets (i.e. percept plus name) drawn from a largely pre-existing 'library' of long-term memories of such couplets.[19]

The main task of the awareness system is to manipulate emotionally significant percepts and, with the help of feedback from the *speech system* (see below) about the meaning of those significant percepts, devise a 'rolling' what-to-do plan, an action schema, a narratise sequence of motor behaviours. Such schemata are automatically read and initiated (imitated) once attention fades, i.e. as the endogram moves on, updates, in response to new sensory and reflected inputs. It is only if and while attention is sustained in some way that motor action is suppressed.

[18] The reticular activation system is a network of fibres and nuclei in the brainstem whose function is to activate portions of the cortex. The limbic area is an evolutionarily ancient part of the brain, concerned with emotions and instinctive behaviour.

[19] Obviously this 'library' is evolving, as when vocabulary increases. Also, the identification of percepts includes a 'constancy mechanism' which allows a changing input, e.g. a moving person, to continue to be associated with the same percept.

The Speech System

The *speech system*, located in the temporal and frontal lobes of the left hemisphere, receives, as its predominant input, words and sentences corresponding to a selection of the percepts in the endogram of the awareness system. That is, it receives, via the cross-cortical link, the word parts (not the percept parts) of those endogram couplets currently being brought to high attention by the *arousal* component of Torey's self-aware brain. In functional terms, this inter-hemisphere information flow facilitates coordination of the activities of the two hemispheres; it ensures that corresponding words in the left hemisphere and word-percept pairs in the right hemisphere are processed, if not simultaneously, then in rapid oscillatory sequence. This means that the two hemispheres will never be processing unrelated data sets.

The speech system manipulates this verbal input, putting it, along with other *associated* words, through a rule-based word-ordering or *thinking* process and outputting the resulting narrative[20] back to the focal region of the awareness system. Thus, there is a 'speech loop', and nothing more, connecting the awareness system and the speech system. As well as transmitting 'covert' speech back to the awareness system, it is this same speech system which activates the vocal apparatus, as needed, to produce 'overt' speech—much as the right hemisphere's awareness system is responsible for generating peripheral motor activity such as moving a finger.

It is the back link from the speech system to the awareness system (call it the S-A link perhaps?) which is at the heart of the consciousness-generating process. Why and how? Basically, it is because the awareness system treats the neural excitations, the stream of covert speech, the thoughts, coming to it from the speech system in much the same way as it treats 'real' speech coming from another person, i.e. as sensory input.[21] This has various consequences:

One is that the verbal thoughts feeding back into the awareness system generate a stream of visual, auditory, etc., percepts, just like referents coming to the brain through the sense organs.[22] We can note in passing that research shows incoming words to be highly effective in evoking their matching percepts when they reach the awareness system.[23] This is because, mostly, incoming thoughts have attentional priority over other sensory inputs.

Now, because a large part of what the speech system transmits to the awareness system is simply a *reflection* of what the awareness system transmitted to the

[20]Narrative: An account of a series of events, facts, etc., given in order and with the establishing of connections between them; a narration, a story, an account.

[21]It helps to understand this to recognise that the speech area of the left hemisphere developed, evolutionarily, from an area of the brain formerly used to control muscular activity.

[22]Jaynes, J., 1986, Consciousness and the Voices of the Mind, *Canadian Psychology*, **27**(2), pp. 128–148. Jaynes makes the further point that before the emergence of modern self-awareness, people treated imagined words as though they were spoken words.

[23]Torey. Z., 1999, ibid., p.53.

speech system some fraction of a second earlier, the speech system is effectively telling the awareness system what it has just been thinking, perhaps ‘loudly’ enough for those thoughts to ‘break through’ to consciousness, to reflective awareness (‘Hey, I have been thinking about X’) and to be perceived, proprioceptively, as self-authored. For this to happen, and it only happens intermittently, the words which the awareness system ‘hears’ from the speech system must have evoked a threshold degree of arousal from the attention-arousal system. In principle, what is happening here is no different from a finger on a hot stove evoking a threshold degree of arousal. Note that consciousness is not being ‘explained’ here beyond saying that, because transmitting sub-vocalised words is a motor act, one is aware of that act no more and no less than one is aware of any motor act the body executes.

Feedback from the speech system to the awareness system has other effects too. One is that the endogram will keep getting updated, not just by ‘real’ sensory inputs, but by the speech system’s verbal understanding of the meaning of the endogram selection it has just processed. We will talk presently about the various cognitive techniques the speech system uses to process input from the awareness system. A related consequence here is that feedback from the speech system amplifies or reinforces the arousal levels already associated with the focal percepts of the endogram and hence reinforces the tendency for these focal percepts to be embedded in long-term memory. Feedback which has sufficient emotional significance to enter consciousness is also particularly likely to enter long-term memory. Note though that while we tend to remember what we become conscious of, it is not because we have become conscious of it. Note also that it is only while ‘reverberation’ around the feedback loop between speech and awareness systems continues that thoughts can remain in short-term memory, and in consciousness, and that motor responses will be delayed.

The Arousal (Limbic) System

The human brain is unique in its asymmetry. Unlike any infrahuman brain, the left and right hemispheres have different functions. The left hemisphere is largely responsible for managing speech-thought and the right hemisphere is largely responsible for managing other behaviours, notably peripheral motor actions. A feedback loop between the two hemispheres carries information which ensures that both speech-thought and other behaviours are co-ordinated, i.e. are working together on what-to-do plans/options for meeting the person’s needs.

The aforementioned *arousal system* in the upper brainstem is strongly connected to the right hemisphere and weakly connected to the left hemisphere. It has several functions:

One, as noted, is to help shape which of the many inputs to the sensory cortices of the right hemisphere will be represented in and focussed on as percepts in the current endogram—and hence which will be sent to the left hemisphere as inputs to the speech system.

But as well as shaping input to the speech system, the arousal system is fundamental to the processing of the reorganised and upgraded words being returned from the speech system to the awareness system. The speech system processes inputs from the awareness system, linking them with related word-percept pairs and generating a sequence of behavioural options which are routed, one at a time, through the awareness system and on to the arousal system. There, each is evaluated by the arousal system until one which does not generate a ‘rejection’ response arrives. In the absence of such an inhibitory response from the arousal system, the behavioural option currently in the awareness system now initiates a corresponding motor response. That is, when attention is released, the endogram moves on and a motor response follows. Each behavioural option which ‘fails’ to trigger a motor response from the awareness system is resent via the corpus callosum back to the speech system for further processing and thereby sustains the brain’s attention to the current what-to-do situation a little longer.

The infrahuman brain does not have such a capacity to delay responding (initiating a motor response) to a stimulus (input) and so has no capacity to make decisions in the sense of selecting a motor response from multiple options generated by interaction between the speech and awareness systems. But neither, for most of the time, is the human brain choosing among multiple behavioural options. In practice, learned customary and habitual responses to the standard situations of everyday life provide immediate answers to most what-to-do questions. But, when these break down, i.e. do not match some novel situation, a behaviour generating and choosing process generates successive behavioural options till one is judged ‘good enough’ and implemented. If the implemented behaviour is associated with a threshold level of emotional significance its image (a) rises into consciousness and (b) is stored, along with its context, in long-term memory.

Imagine walking from A to B. Most of the time the selection of where to place your feet is handled by habituated rules that initiate peripheral motor responses. If an obstacle appears, you stop and, probably unconsciously, try to pick an acceptable way around it, one that meets certain evolving criteria. What you have done, given the ‘warning’ endogram, is switched from one kind of motor response—peripheral—to another kind of motor response—intra-cortical. And if the obstacle is a snake, the situation will rise into consciousness! All endograms produce a motor response of some sort but, if you are a dog and not a human, you can only respond with the best available peripheral motor response in your ‘stimulus-response’ library. You have no ‘off-line’ motor response capability. In either case, dog or human, the stimulus mix changes and the endogram is updated once more.

Is Consciousness an Epiphenomenon?

It is not at all obvious that the effectiveness of the brain’s what-to-do decision-making would decline if consciousness did not keep popping up. Torey says that without reflective awareness we could not upgrade and enrich our range of choice, insight and behavioural options.[24] I am doubtful. These are ‘rewards’ from the

[24] Torey. Z., 1999, ibid., p.155.

consciousness-generating process, not from consciousness per se. While that name is not wrong (it does generate consciousness), it might more accurately reflect the significance of this process to call it the behaviour-choosing process. It is, after all, the process which allows the brain to generate and evaluate alternative responses to what-to-do situations—rather than just accepting and initiating the first behavioural impulse evoked [evoked in the limbic system] by the situation.

So, unless it can be suggested how awareness of one's current thoughts might change one's next thoughts, the simplest conclusion to draw (the null hypothesis) is that it does not. Unfortunately, as with the question of freedom of the will, there does not appear to be a way of testing this hypothesis. The suggestion lurking here is that *realising* what you are thinking does not change what you are about to think. However, this is in no way incompatible with the idea that what you are currently thinking will always influence what you think next. Remember that awareness of an action tends to follow, not precede, the action. Before one utters a sentence, one is not conscious of being about to utter those specific words.

Before writing the consciousness experience off as an epiphenomenon, a by-product of the behaviour-choosing process, consider the speculation that without consciousness' particular contribution to long-term memory one would have little understanding of what others are thinking and, hence, what they might do. The particular contribution being referred to is that each thought coming from the left brain and passing into both consciousness and long-term memory carries with it the knowledge that is an internally generated thought. One consequence of this is a selective memory trace of one's (conscious) thoughts over time, something that ancient people would not have had. Not only are these memories (e.g. of past interactions with the environment) a large part of one's self-knowledge, and hence a large part of the self, they allow one to infer that others, so like oneself physically, may well be like oneself mentally. As psychologist Nicholas Humphrey says, consciousness gives every human a privileged picture of his or her own self as a model for what it is like to be another human.[25] In turn, at least after the invention of 'questions', this recognition opens the way to asking the other what, specifically, they are thinking of and, by comparing percepts, take part in building a 'collective mind' of shared stable percepts—a basis for efficient communication and cooperation. More generally, consciousness is a tool for sharing experiences through verbalisation.

Similarly, having access to a history of one's thoughts and their consequences, plus some understanding of causation, allows one to improve one's thinking by asking questions of oneself about relationships among one's memories, e.g. constructing narratives. Memory is at the heart of cognition. Consciousness is rescued from being an epiphenomenon by its role in tagging long-term memories with the useful realisation that they are past thoughts. I am reminded of the technique of filming an athlete, not to improve the performance being filmed but, after analysis, to improve future performances.

[25] Humphrey, N., 1987, *The Uses of Consciousness*, Fifteenth James Arthur Memorial Lecture, American Museum of Natural History, New York.

Consciousness Is Not Cognition

Before looking to understand the immense significance of the cognition-consciousness revolution of the first millennium BCE, and remembering how consciousness, its content and the processes through which it is generated get confused, it will help emphasise these distinctions to recall a few aspects of the cognitive instruments, the thinking tools, which modern humans use in responding to, and, indeed, constructing what-to-do challenges.[26]

Arguably, *Homo sapiens*' core cognitive skill is *conceptual thinking*, the ability to perceive similarities and differences, to develop abstract concepts by inductive generalisation, memorise and name them, and use those names (words) to construct grammatical sentences expressing relations between concepts, e.g. snow is white. To a large extent, we think *about* concepts and percepts and we think *with* words; concepts are bearers of meaning, as opposed to words being agents of meaning.

We will not attempt to classify the many ways in which concepts can be related/manipulated, verbally or mentally, in sentences and strings of sentences, just mention several which have proved particularly useful in support of what-to-do plan-making:

Factual propositions are statements about concepts, statements which are either true or false depending on the meanings of the concepts. A question is an inquiry into a proposition's truth value.

If this…then that… statements reflect (a) causal understanding of relationships, in time, between concepts or (b) structural understanding of spatial relationships between concepts. If war is declared, then truth will be the first casualty.

Metaphors of the form Xs are like Ys are the starting point for developing and naming new concepts; and for 'understanding' existing abstract concepts. My love is like a red, red rose. Language itself grows by metaphor, helping us to understand the unfamiliar (see page 97).

Narratives (stories) are accounts comprising events, propositions, etc., given in an order which reflects their relationships in space-time. Narratives are the cognitive technology which enables the consequences of alternative behaviours to be simulated mentally. In societies, narratives transfer information between people. *Abduction* is an important form of narratisation in which an explanatory hypothesis that is consistent with the known facts is generated.

Inductive generalisation[27] not only allows concepts to be drawn out of experience but allows the construction of 'super-concepts' which embed concepts within concepts and identify relationships between concepts. This 'chunking' process

[26] In John Dewey's terms, this is an instrumentalist perspective—thought exists as an instrument of adjustment to the environment. Specifically, terms of thought and meaning are relative to the function they perform and that their validity or truth is determined by their efficacy. See Dewey, J., 1922, *Human Nature and Conduct, An Introduction to Social Psychology*, Modern Library, New York.

[27] In logic, induction is the process of generalising over multiple examples, commonly by emphasising similarities and ignoring differences between them.

allows more complex thinking within the constraints of short-term memory, e.g. an ethical principle can guide thinking about the ethics of a particular case.

Bisociation is Arthur Koestler's term for the process behind creativity, namely, intuitively seeing a connection between concepts not hitherto recognised as being connected.[28] Aaahh, lemon juice cures scurvy.

Associative memory is the capacity to recall, from a suite of stored concepts, the concept most closely associated with some 'sensory clue', e.g. as in indexed memory, recognising a whole pattern when presented with a fragment of that pattern.

Rationality is that orientation towards reality which attempts to weigh up the costs and benefits of means and ends of an action before adopting it.

Deductive reasoning is a procedure for drawing conclusions (in the form of propositions) from premises (statements, assumed to be true, about concepts) by applying a set of rules. Deductive systems comprising a set of axioms and a set of rules for operating on those axioms provide an extremely compact way of storing a large number of propositions.

This list of cognitive technologies and the ways in which they can support behaviour-choosing processes could be much extended (e.g. means-ends analysis, hypothesis testing, binary discrimination) but our purpose is no more than to exemplify that modern individuals have a range of thinking tools which apparently do not need consciousness. We can turn now to a time when these skills were less developed.

New Religions, New Thinking, New Societies (3000–2000 BP)

Much of the millennium preceding the Common Era (i.e. the first millennium BCE) was a chaotic interregnum between the passing of the Bronze Age and its great empires and the translation of the centre of civilisation westwards to Greece and Rome. Not that all was destruction in the latter part of the second millennium; new cultures arose in the Indian Punjab (c.3500 BP) and the Chinese Hwang-Ho region (c.3400 BP) as well as in the Aegean (c.3100 BP).

In the early part of the first millennium BCE, disruptions to food production and trade routes reduced energy supplies in many societies below levels needed to support unproductive specialists as well as agricultural workers. Social structures were necessarily simplified with many turning to marauding and migration to survive; others returned to self-sufficient village life. Under stress, the theocracies which had guarded/guided collective decision-making, and imposed social order on increasingly complex societies for some thousands of years broke down, some slowly, some rapidly. Notwithstanding, over the millennium agricultural production expanded rapidly (due not a little to the use of the iron plough) and world population increased from c.50 to c.170 m.

[28] Koestler, A., 1964, *The Act of Creation*, Hutchinson, London, p.35.

It was a time which saw major shifts from oral to literate cultures, from magic-based polytheistic religions to monotheistic religions and in the nature of human consciousness and human cognitive-linguistic abilities. Where the Neolithic period is characterised by the emergence of material technologies and the Urban period by new social technologies, the first millennium BCE was to be a time of great change in cognitive and communicative technologies.

In what Karl Jaspers calls the 'axial age' of new religions, the period c.2800 to 2200 BP saw the emergence of Taoism and Confucianism in China, Buddhism and Hinduism in India, monotheism in Iran and the Middle East (Zoroastrianism) and Greek rationalism in Europe.[29] Beneath their obvious differences all reflected an emerging ability to think with the idea that each human is an independent entity with a faculty of choice in line with their individual character, i.e. each possesses an ego. All shared a concern for how to cope with the misery of life (oppression and disease), how to transcend personal weaknesses and how to live in peace in a flawed world.[30] Personal morality and responsibility were becoming more central to religion in a world where behaviour was no longer so tightly dictated by theocratic rulers; the ways in which the gods might react to one's actions became less troubling.

What was crystallising here was a trend which can be traced back to an *animism* in which everything had its motivating self-interested spirit, a spirit which was often manipulable by magical procedures (see page 117). Next, with the early Neolithic perhaps, came a *manifest polytheism* in which numerous gods (idols), including personal gods, were always near at hand, needing to be placated and directly consulted in what-to-do situations. In time, all manifest polytheisms gave way to *remote polytheisms* (e.g. early Hebrews, Greeks, Romans) in which gods were distant, less talkative and generally less interested in human affairs.[31] It can be suggested that the next shift, to *monotheism* (one god), was an adaptation which, thinking of religion as an instrument of social control, had the virtue of creating a single authority to be obeyed rather than many; especially where a single priesthood had a monopoly on interpreting a single God's will. Going further again, both Buddhism and Greek rationalism began substituting the moral autonomy of the individual for supernatural external authority as society's way of imprinting behaviour supportive of the existing social order.

The emergence of the modern mind can be seen most clearly in the flowering of Greek thought, culminating by the sixth century BCE in a society where people had acquired sufficient cognitive skills, sufficient vocabulary (including the vocabulary of subjective consciousness) and sufficient memory (boosted by phonetic writing) to debate individually and collectively, the nature of the world and society and how

[29] Jaspers, K., 1953, *The Origin and Goal of History*, Routledge and Kegan Paul, London.

[30] Armstrong, K., 2001, *Buddha*, Penguin, New York.

[31] Singer, F.R., 2007, *Jaynes and Comprehensive Paradigm Shifts*, http://www.conceptualstudy.org/Papers/Jaynes%20&%20Comprehensive%20Paradigm%20Shifts.htm (Accessed 13 Jan 2011).

these might be better managed For example, democracy was a social technology made possible, at least in part, by the Greek recognition that people are individuals as well as class members. Speculation was explicitly recognised and ardently pursued. More generally, the classical and Alexandrian periods of Greek civilisation, through their contributions to language, politics, pedagogy, arts, science, and philosophy, laid the foundations on which, eventually, the European Renaissance would be built. There is bite in the aphorism that the history of Western philosophy is a series of footnotes to Plato.

The Greek capacity for systematic thought equalled ours. They knew how to trial candidate behaviours in the mind at low cost and how to bring disparate ideas into a consistent harmony. They knew how to use premises to underpin an argument. They were able to challenge the truth of comforting beliefs. Indeed, it was c.2550 bp that Solon and others recognised that truth was something to be discovered, not revealed.[32] In 2585 bp Thales of Mellitus concluded that every observable effect must have a physical cause. This discovery of causality is now taken to mark the birth of science.

But societies are learning systems in which knowledge acquisition has to build on what has gone before and the process is necessarily slow for a long time. In any case, the knowledge and understanding the Greeks achieved was lost for hundreds of years following their conquest by the Romans in 146 BCE.

Contribution of Writing to the Cognition-Consciousness Revolution

Walter Ong, an early student of the differences between oral and literate cultures, described writing as the most momentous of all human technological inventions, the technology which has shaped and powered the intellectual activity of modern man.[33]

Writing systems developed and spread in two waves. The first, based on pictographic forms, began in Sumer some 5500 BP and dispersed from there through Mesopotamia to Egypt, Europe, India and China. Writing systems in the second wave, beginning in the late Bronze Age, were alphabetic, meaning that they used one sign to represent one sound. A good example is the Phoenician alphabetic system which gave rise to Hebrew, Aramaic and early Greek; and then, via Greek, to Latin and Cyrillic. Around 2800 BP the Greeks invented signs for vowel sounds, making theirs the first complete alphabet with both consonants and vowels.

Writing systems are more than memory aids and more than pictorial depictions of things. They accurately represent someone's uttered or imagined words. Without the distortions which plague memory, they allow the storing of information over long periods. But writing is much more than a substitute for spoken language. Extending language transmission from an oral-aural medium into a visual medium

[32] Saul, J.R., 1997, *The Unconscious Civilization*, Penguin, Ringwood, Vic.

[33] Ong, W., 1982, *Orality and Literacy*: *The Technologizing of the Word*, Methuen, London.

has had, over time, enormous impacts on diverse aspects of cultural evolution, notably, cognitive capabilities, belief systems, knowledge acquisition, inventiveness and social organisation:

As the Bronze Age progressed, and societies became more complex, writing was increasingly used for practical purposes such as keeping records of transactions and contracts; transmitting instructions from supervisors to workers; and providing permanent, accessible public statements of proclaimed laws. In this context writing was a technology which provided certainty as to what had been communicated and which allowed communication across time and space.

It was towards the end of the Bronze Age that culturally important stories and narratives which, till then, could only be transmitted orally began to be written down, the first perhaps being the Zoroastrian Vesta (c.1500 BCE). The oldest of the Indian Upanishads has been dated to around the eighth century BCE—it is the philosophy of the Upanishads which underpins Hinduism, Jainism and Buddhism. In China, Confucian writings date from c.500 BCE. The first-written book of the Hebrew bible, Amos, is now dated at 750 BCE.[34]

It is hard to see how the great religions could have spread and matured without such sacred authoritative texts, unchallengeable as they were by the mindset of the time. Because they record what was said by God or prophet or enlightened one, they have the authority of the spoken voice, especially when read aloud. Think also of the importance of the New Testament and the Koran in the following millennium. Certainly the Greeks and Romans had no sacred or revealed texts of any stature and their religions withered. Rather, texts, particularly for the Greeks, became vehicles for the elaboration of philosophical and scientific inquiries and for the 'fixing' of foundation myths such as 'Homer's' two epic poems, the Iliad and the Odyssey (transcribed c.2700–2650 BP).

While writing a narrative down freezes the words spoken and renders it available in canonical form on demand, it does not wholly capture the experience of listening as the owner of the narrative delivers it. Written words are always an abstraction from a total situation which is more than verbal. Inflections, emotions, emphases, etc., are lost. Particularly if a text is sacred, it cannot be adjusted to reflect a changing world and becomes a source of debate over interpretation. Scientific, philosophical and instructional texts are more open to correction.

It is interesting to speculate that it was only with the transcription of foundation myths and the later realisation that the world was no longer as it was that the concept of historical time entered the consciousness of newly literate societies. Mircea Eliade in *Cosmos and History* suggested that the Hebrews, the first truly alphabetic people, developed a sense of 'one-way' time—an accreting, non-repeating sequence of events against a backdrop of cosmic cycles. Eliade's bold hypothesis, known as *the myth of the eternal return*, is that preliterate people inhabit a cyclical time

[34]Cohn, J., 2007, *The Minds of the Bible*: *Speculations on the Evolution of Human Consciousness*, http://www.julianjaynes.org/ (Accessed 1 Nov, 2007).

wherein, they believe, their periodic ritual reconstructions of mythic events actually recreate (reactualise) those events and return the world to its beginnings.[35]

What of the contribution of writing to the evolution of cognitive capabilities and the buildup of collective knowledge? First, multiple individuals can learn from the writers of texts (i.e. extended discussions) even if such are distant or dead. In principle that can also happen in an oral culture (via teachers) but the scale is likely to be different. Given multiple copies of texts and a core of people able to read (libraries were invented in the late first millennium), more people will be holding more knowledge in common in a literate society than in an oral society of the same size. This in turn will mean more people primed to contribute, through learning, to the creation of further knowledge.

Texts themselves provide a stable starting point for ongoing verbal dialogue about their truth or about how the thinking they embody might be extended. The critical innovation was the simple habit of recording speculative ideas—that is, of externalising the process of oral commentary on events. But a written text has several advantages over verbal discourse as a means of evaluating and upgrading an argument or exposition. Improving a written text can be treated as an iterative task, reviewing and revising one's previous thoughts. Selectively rereading what you have written reloads your working memory, sometimes in novel ways. Rewriting involves a dialectical process in which product and process, content and the tacit rules for writing persuasively and logically, have to be constantly harmonised. Reasons have to be crafted and conclusions synthesised.

Against this, the tacit rules of *spoken discourse* are much looser, a game of verbal ping-pong which can easily wander. It is much easier to get away with sloppy thinking in discussion than on paper. On balance, you are more likely to 'know what you think' when you see what you have written than when you listen to what you say!

Writing, being slower than talking, offers more opportunities to be creative, to reflect, to generalise, to abstract and to integrate ideas. It encourages introspection, including the push to find words to capture the emotions which are expressed otherwise through gesture, mien, etc., when speaking. Metaphor is particularly important as a technique for understanding, exploring, capturing and, eventually, naming fuzzy feelings and values.[36] And insofar as writing gradually evolved syntactical structures capable of expressing metaphors, it may have played a pivotal role in the invention and experiencing of consciousness and selfhood. Finally, without writing, government by (written down) law, would not be possible.

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[35]Eliade, M., 1954, *Cosmos and History*: *The Myth of the Eternal Return*, (Trans. W.Trask), Princeton University Press, Princeton, NJ.

[36]Whitehead, A.N., 1933, ibid., p.120. Whitehead notes the difficulties of Plato, a metaphysician of genius, had in making language express anything beyond the familiarities of everyday life and goes on to say that it is misleading to study the history of ideas without constant remembrance of the struggle of novel thought with the obtuseness of language.

Against these positives, the difficulties of using and learning from early texts need to be kept in mind. In Plato's time a library's documents were stored in unlabelled jars; there were no spaces between words, sentences or paragraphs and no punctuation marks; texts usually had no contents listing and no pages.

Stages in the Evolution of Consciousness-Cognition

Any attempt to overview the evolutionary development of consciousness-cognition cannot be other than highly speculative, even into the period when written records begin. The value though of attempting such is that it might suggest aspects of that process which are still operative and hence part of understanding social and cultural evolution today. Here we will briefly recapitulate three plausible earlier stages in the evolution of consciousness-cognition before coming to the revolution that we are claiming for the first millennium BCE. These are a pre-verbal stage, a syntactic language stage and a 'bicameral' stage.

In fact there is one cognitive operation, an inductive learning operation, which, at least since the first hominids, underlies all expansions in the range of entities of which the brain can become aware. From the early Pleistocene, the hominid brain has been learning to abstract recurring similarities and patterns—called percepts and concepts—from a kaleidoscopic flux of input stimuli and to store representations of these in memory. From there these internalised representations have been available as templates (together with links to action schemata and emotional tags) against which new experiences can be tested for conformity. Francis Heylighen suggests that the emergence of just one further cognitive operation, the capacity to recombine concepts, free of their original context, in a more-or-less controlled way, allows all the typical characteristics of human intelligence to be explained.[37]

What we have here is an evolutionary development under which the brain comes to learn to subdivide, and further subdivide, stimulatory experiences into categories and react differently (i.e. initiate a different motor response) according to which category is being experienced. One way of interpreting this is to view the brain as extracting more and more information from the environment over evolutionary time. A complementary perspective is to see the brain as an adaptation which protects the individual from being overwhelmed by comprehensive awareness of everything they have known in the past and could be aware of now in the present, i.e. the brain acts as a *reducing valve* which, in principle, leaves the individual with the information relevant to their purpose of the moment.[38]

[37] Heylighen, F., 1991, Cognitive Levels of Evolution: From Pre-Rational to Meta-Rational, In F. Geyer (Ed.), *The Cybernetics of Complex Systems-Self-organisation*, *Evolution and Social Change*, Intersystems, Salinas, CA. pp. 75–79. Heylighen points out that 'legitimate' associations conform to (are controlled by) learned rules based on experience, e.g. syntactic rules, cultural rules, selection rules and historical rules.

[38] Broad, C.D., 1925, *The Mind and its Place in Nature*, Routledge and Kegan Paul, London, p.24.

The Pre-verbal Mind

Under several descriptive names, including participatory consciousness, a typhonic state, an archaic state, mind-at-large, a mystic state, and a phantasmic state, empathetic writers have tried to evoke the mental experiences of early humans still equipped with only a small number of percepts.[39] One interesting metaphor is that such a person's experiences might have been like those of someone who has taken mescalin or a comparable hallucinogen which suppresses the higher control areas of the brain, i.e. being a habiline would have been like being in a world of vivid experience where nothing is easily recognisable. The whole of the world is seen as unity, as a single rich live entity. Akin to the reports of modern mystics, there might have been a sense of a floating *self*, immersed in a kaleidoscopic world. This *self* would not have had a sense of agency, of consciousness of thoughts such as we experience, but would have been a 'body self', an image of oneself in terms of joint, muscle and visceral awareness. The implicit suggestion here is that a loose percept of a body self is one of the first 'cleavages' the brain learned to make through the world outside itself, an early step in a still-ongoing internalisation (inner modelling) of the external world.

As discussed in Chap. 2, behaviour at this time would largely have been governed by instinctive and affective responses, not cognitive ones. Behaviours which produced positive emotions or ameliorated negative ones would have quickly become habitual, and, through mimesis, spread throughout the social group, i.e. have become customs.

Custom not only makes individual behaviour predictable, it results in all individuals having a similar behavioural repertoire—like 'cells' in a 'superorganism'. And, for most of the Pleistocene, it would have been through averbal custom that societies co-ordinated themselves. Societies with a sufficiently diverse repertoire of customary responses to particular environmental contingencies would have enhanced survival prospects. In the longer term, the repertoire of customary responses in those societies that survived must have evolved in parallel with environmental trends such as declining temperatures.

In parallel with the evolution of custom, the Pleistocene would have seen slow growth in simple non-verbal language (see Chap. 2). We can suppose an expansion in each group's common stock of concrete (not abstract) percepts, each sculpted from reoccurring emotionally charged episodic experiences. And we can further suppose the emergence of *associative learning*, i.e. a capacity to associate, in mem-

[39] Scaruffi, P., 2006, *The Nature of Consciousness*: *The Structure of Life and the Meaning of Matter*, http://www.scaruffi.com/cogn.html(Accessed 13 Jan 2011); Wilber, K., 1999, *Up From Eden*: *A Transpersonal View of Human Evolution*, Shambahla, Boston and London, p.31; Berman, M., 2000, *Wandering God*: *A Study in Nomadic Spirituality*, SUNY Press, New York; Lévy-Bruhl, L., 1923, *Primitive Mentality*, Allen and Unwin, London; Laszlo, E., 2004, Cosmic Connectivity: Toward a Scientific Foundation for Transpersonal Consciousness, *The International Journal of Transpersonal Studies*, **23**, pp. 21–31.

ory and in recall, percepts previously encountered together in recurring episodic experiences[40]; for example, dead bodies and dry waterholes. In terms of cognitive skills such associative learning is a precursor to causal thinking.

In time some percepts would have separated from their original contexts and associations and come to be associated with ‘context-free’ non-verbal signs, earlier called *mimes*. This would set the stage for the development of syntactic language—strings of mimes assembled according to rules—capable of communicating simple stories. Every language, verbal or non-verbal, is a collective *functional* model of reality, one that stores the experience of preceding generations and one on whose refinement all members of society are working. Imagine the value of an elder’s story which told of the existence of a place of refuge from drought. Or is that asking too much of non-verbal language?

Probably yes, but even as it was reaching its modest developmental limits, towards the end of the Pleistocene, non-verbal communication was creating a template on which oral language could be built. That is, in crude form, percepts, signs (symbols) for percepts and syntax were now in place.

The Syntactic Mind

Wide limits, from 200 to 70 kya, bound the various suggestions for the time of emergence of oral protolanguages.[41] Here we will bypass the various origin hypotheses and take up the story of cognition-consciousness at the time of the Upper Palaeolithic cultural revolution, some 40 kya, when we can be fairly confident that syntactic language (sentences) had become a well-established communicative technology, at least in ‘here and now’ situations.

Chapter 2 noted the various ways in which the advent of structured speech might have led to improvements in thinking, faster accumulation of collectively held information and a reinforcing of the tribal mode of social organisation. As language developed, each new group of words created, literally, new perceptions and attentions, i.e. language was not just a tool for communication but another ‘organ’ of perception, able to direct and hold attention on a particular task. Perhaps the Upper Palaeolithic revolution, with its explosion of advanced stone artefacts, reflects the coevolution of material and cognitive-communicative technologies.

The period between the Upper Palaeolithic revolution and the Neolithic Revolution (15 kya), while climatically difficult, saw the persistence of the hunter-gatherer group

[40] The physiological basis for associative learning is that a synaptic connection which is used often will increase its strength such that the probability that it will be used again increases. Ultimately, associative learning is the only sort of learning there is.

[41] Relative to syntactic language, protolanguage is characterised by a form of expression in which words are merely grouped in short utterances, with no grammatical support. Its characteristics are: no grammatical words, no long-range dependency within the sentence, no inflection, no consistent order. Search engines use protolanguage.

or tribe as the ubiquitous form of social organisation. Terms such as the magic mind, the mythic mind, the membership mind, the group mind and the tribal mind have been used when speculating on aspects of the mentality and social psychology of these late hunter-gatherers.[42] These various terms are drawing attention, first, to the sameness of individual minds within Upper Palaeolithic tribal cultures and, second, to these people's changing models of the world and their place in it.

As is still true today, language could now be used to describe the world to children until they were capable of perceiving the world as described. Under this view, reality is only a description which is shared, largely unconsciously, with those who use the same language. Furthermore, from the perspective of social psychology, a shared language is a form of social control, again largely unconscious. That is, once an individual responds to a description of reality, their behaviour is already circumscribed by that description.[43] Linguistic formulae for norms, customs, taboos, etc., would have been similarly transmitted and internalised. For example, a child's memory of being verbally instructed by its parents would have functioned as a primitive conscience or superego, recalling past instructions, by association, in similar situations. Socialisation through language thus became the main instrument for keeping individual behaviour within functional limits. As a group's culture, its learned behaviours and shared ideas, became richer and more complex than in preverbal days, spoken language would have been essential to reproducing/maintaining that culture.

But, apart from episodic memories, there would have been little qualifying as *personal* in the minds of tribal members. The vocabulary which would allow the modelling and awareness of one's inner feelings and motivations or the minds of others had not yet been invented. Tribal societies were not made up of people who, having recognised themselves as individuals, then identified with the group. Rather, over the Upper Palaeolithic, concepts and words (e.g. one's name?) appeared which allowed the individual to begin to split out from the concept of the group, a dim conception of a 'mental' self, i.e. something additional to a 'body' self.

As was discussed in Chap. 2, there is a variety of evidence that the Upper Palaeolithic was the period when animistic, magical and mythical thinking emerged and flourished. Cognitive tools for questioning the reality of this primitive thinking, based as it was on inappropriate metaphor, did not yet exist. The capacity for causal thinking, which was proving useful enough in everyday tasks, just did not have access to sufficient abstract concepts to provide naturalistic explanations for natural processes.

Nevertheless, as noted earlier, primitive thinking did serve various functions such as providing all the tribe's members with a common set of meanings, explanations and beliefs about the world. And it provided some sense of psychic security and meaning in a capricious and mysterious world for what we would see as the

[42] Wilber, K., 1999, ibid.

[43] Wilber, K., 1999, ibid., p.423.

child-like egos of the time. For example, misfortunes and calamities could be explained as part of an intelligible order and, by following customary rules, be warded off to some extent.[44] Even in the absence of abstract principles, myths and stories were 'case studies' which provided role models and examples for guiding behaviour. Of course, it would only be with difficulty that such guidelines could be updated to reflect changed conditions.

These then were the oral cultures which allowed hunter-gatherers to survive the rigours of the last ice age. We have every reason to believe that spoken language, the master technology, played a central role in driving the evolution of the material, social, cognitive and communicative technologies which collectively define cultural evolution.

The [Early] Post-glacial Mind

As described above, the period from the end of the last ice age (say 15 kya) till the end of the Bronze Age (say 1000 BCE) was a period of dramatic socio-cultural response to dramatic climatic and ecological change. While the period saw numerous interdependent innovations in material, social, communicative and cognitive technologies, it is changes in food production technologies and parallel facilitating changes in social organisation-control technologies which stand out. In a sentence, these core changes were from hunter-gatherer societies to, first, Neolithic farming villages and then to empires based on broad-scale irrigated agriculture.

Looking back, we can see how creating, refining and combining technologies allowed post-glacial societies and groups within societies to make adaptations which, at least for a time, improved the survival and wellbeing prospects of the innovators. In line with mounting archaeological evidence, one can imagine plausible sequences of small steps by which individual technologies might have entered, left or matured within the technology pool-technology mix. And as the technology-mix being used ebbed and flowed, various emergent and collective properties of the society would have responded, entities such as energy throughput, social character, class structure, food security, demographic structure, accumulated knowledge, etc. Thus, a process of cultural evolution similar (albeit faster) to that described for tribal societies in Chap. 2, one based on the selective retention of exploratory behaviours in what-to-do situations, can be presumed to have continued through the Neolithic and urban revolutions.

While the post-glacial mind was confronted with having to manage ever-bigger groups of people in a growing range of interdependent roles, there is little to suggest a system-shift in people's basic mental skills such as their ability to model reality, their learning skills, their memory skills and their capacity to remain focussed on a task. Rather, it was the enhanced *contents* of the post-glacial mind, not its raw

[44] Habermas, J., 1976, *Legitimation Crisis*, HEB, London, p.98.

capabilities, which differentiated it from the tribal mind of the hunter-gatherer. Under 'contents' we can include knowledge of norms, taboos, beliefs, customs, facts, vocabulary, causation, myths, recipes, rituals, values and traditions. That said, these were oral cultures which depended critically, and in diverse ways, on language and memory to make a system of new and more complex farming and social management technologies work and keep working.

Consider the place of language in ensuring that individuals learned and reliably filled the roles assigned to them by tradition. We can assume that post-glacial people were still signal-bound or reflexive, i.e. they responded minute-by-minute to cues from their environment, including a verbal environment characterised by commands and assertions (plus, possibly, questions) uttered by other group members.

An important factor in the primary socialisation of children would have been learning to obey routine parental commands as they absorbed and internalised the group's stock of shared knowledge. As discussed by Laureano Castro and Miguel Toro, humans, at some point, must have learned to express disinterested approval and disapproval of childish attempts to imitate adult behaviours and hence to guide successive improvements.[45] In play, the child could verbalise and practise responding to commands. Once parents had acquired the capacity to express approval or disapproval of children's behaviour, it would lead to the children's associating positive or negative feelings with memories of performing those behaviours, and with the words by which approval/disapproval was conveyed. This, in turn, would lead people to behave, depending on context, in ways which they knew, from memory, would generate positive feelings or avoid negative feelings. In contrast to other primates, episodic memories could be triggered in human children by learned words, nothing more (see page 82). As well as this, emotionally charged words of approval/disapproval would, in time, become decoupled from the particular learning situation while still retaining their ability to guide future responses to those words, be they overt or covert. Here could be the mechanism by which a modern human's limbic system learns to accept or reject verbally proposed behaviours.

Conrad Waddington interpreted human docility, our tendency to accept authority, as an adaptive response by a neotenous species to the need for its young to be teachable.[46] But insofar as the habit of obedience to an authoritative voice carries over to adulthood, it becomes a pre-adaptation for the social technology of leadership (e.g. chiefs, big men, elders), a technology based on giving verbal commands to people within earshot. Leadership is a social technology which co-ordinates the group's behaviour by considering only the options perceived by the leader in what-to-do situations. Presumably, it evolved as a successful balance between the need for timeliness in decision-making and the need to consider a sufficient variety of candidate responses to novel situations.

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[45] Castro, L., and Toro, M.A., 2004, The Evolution of Culture, *European Journal of Sociology*, **45**, pp. 3–21.

[46] Waddington, C.H., 1960, *The Ethical Animal*, Allen and Unwin, London.

Nevertheless, as the food production system was transformed and complexified, and as communities grew larger, face-to-face leadership in non-routine, and hence stressful, situations would have become more difficult. Even for routine tasks, in the absence of the leader signal-bound workers would need frequent cueing. For example, custom, ritual and habit would have each played a part in maintaining a work party's attention to a task. Remembering and obeying a leader's commands in his (her) absence would have been difficult in the face of poor impulse control and a limited ability to self-trigger the recall of instructions from memory in the form of either mimetic imagination or verbal symbols. People would have been willing to obey but not very good at it! Leaders themselves would have had no special capacity for formulating behavioural plans and remaining focussed on their implementation.

Despite these problems, as people's vocabularies grew and their verbal models of practical realities improved, we can postulate that their self-cueing abilities also improved. The self-cueing process in post-glacial people would necessarily have been similar in some ways to the consciousness-generating process outlined earlier for contemporary humans (see page 157). In particular, in what-to-do situations the off-line speech-thought system generates a sequence of schematic behavioural options until one appears which, after being returned to the awareness system, is 'passed' by the limbic system and then implemented. We can imagine though, in contrast to modern self-aware minds, only a small range of customary, formulaic responses would ever be available for such evaluation.

However, if Julian Jaynes, Bruno Snell, Mary Clark, Lancelot Whyte[47] and others are right, post-glacial peoples, at least until the first millennium BCE, did not have a strong enough sense of self, or sufficient vocabulary, to recognise that thoughts they were becoming aware of were self-authored. Rather, they experienced those thoughts, Jaynes argues, as words spoken aloud by an authority figure, i.e. as what we would call an auditory hallucination.[48] And they obeyed (or believed, as the case may be).

Both left and right hemispheres of the human brain are able to understand language, while normally only the left can produce speech. However, there is some vestigial functioning of the right-hemisphere Wernicke's area which could explain the 'voices of the gods'. Jaynes hypothesised a bicameral (two-chambered) process of brain functioning—a 'decision-making' chamber and a 'follower' chamber. He asserts that about 3,000 years ago there was a left brain/right brain difference that

[47] Jaynes, J., 1976, ibid.; Clark, M.E., 2002, ibid.; Snell, B., 1960, *The Discovery of the Mind*: *The Greek Origins of European Thought*, (trans. T.G. Rosenmeyer), Harper Torchbooks, New York; Whyte, L.L., 1948, *The Next Development in Man*, Henry Holt, New York.

[48] Jaynes likens this experience to that of contemporary schizophrenics. Alexander Luria's research on contemporary children posits that a child is at first instructed to do various tasks by an adult, then learns to give himself/herself linguistic commands. These self-instructions are at first uttered aloud and then gradually take the form of internal covert instructions. See Luria, A.R., 1930/2002 A Child's Speech Responses and the Social Environment In Cole, M.,(Ed), *The Selected Writings of A.R. Luria* Sharpe, New York, pp. 45–77.

had, until that time, made the right brain act as ‘god’ to the left brain, which would hear and obey. The emanations from the right hemisphere would produce visual and auditory hallucinations that were powerful enough for the left hemisphere (and the human being as well) to follow.[49]

To appreciate the next part of this plausible scenario (and that is all it is), recall that early post-glacial peoples were animists who believed that every material entity was alive and able to act with purpose. So, while an authoritative voice might, in the first instance, be (mis)attributed to a living leader, it could equally be (mis)attributed to the corpse or remains of a dead leader. Indeed, given that living leaders grew up to have the same dependence on authority as their followers, we can readily imagine that such might attribute their cueing voices to dead predecessors. From there, it is a small step to visiting the remains of one’s dead predecessor to hear his/her advice and commands concerning what-to-do situations. These pronouncements could then be relayed, with attribution, to one’s followers. The elasticity of magical thinking would have further allowed statues or other symbols of the dead leader to become cues for hearing the dead leader’s voice. Indeed, each individual could have their own personal cueing symbol; not that it was a symbol to them—it was the real thing!

And so begins 8,000 years of unquestioned belief in the direct participation of ‘dead’ authority figures in the management of post-glacial societies. As ‘dead’ leaders receded into the past, one can imagine their being transformed into, first, legendary heroes, and then into what we would think of as *gods*. Depending on the particular society, the living leader might be seen as the mouthpiece of the gods or, using magical reasoning, a god himself. Jaynes suggests that an 11,000-year-old propped-up skeleton found in a tomb in the Levantine village of Eynan might have been an early god-king.[50]

As a social technology for accurately guiding the individual’s contribution to society, gods have several advantages over living leaders. Their repertoire of injunctions, their leadership styles are free to settle down over time, be objectified, and provide a baseline of stable guidance during the uncertainties of transition between living leaders. Their authority can be cumulatively strengthened over generations through the development of worship rituals, rites and ceremonies. Of course, for most of the reign (metaphor) of the post-glacial mind, at least in closed self-sufficient societies, there would have been little questioning of divine authority. People were docile, we have suggested. Despite having language, they, like every other animal, had no concepts of introspection, deception, evil, justice, guilt or objective space-time. They had no sense of the future and no memories as we know them. These are all abstract concepts which we understand through metaphor; and the technology of expanding language through the use of metaphor had not as yet been invented.

[49] Jaynes, J., 1976, ibid., pp. 427–430.

[50] Jaynes, J., 1976, ibid., p. 143.

As the climatically favourable Holocene continued and farming technologies continued to evolve to exploit the opportunities entailed therein, agricultural systems delivered food surpluses sufficient to support a priestly class, particularly after Eurasia's great irrigation civilisations grew out of village agriculture. While the respected historian, William McNeill, dubs these first priests 'macro-parasites',[51] it is surely more complex than that. Priests were no more reflectively aware than the workers they organised on behalf of a leader (a king say) and one or more gods. The priesthood can be seen as a managerial class which, plausibly, coevolved with the increasingly complex management tasks associated with population growth, urbanisation and expanding irrigation systems. Over millennia gods too proliferated and specialised in cueing different types of decision-making, e.g. personal gods. It would seem that cultural evolution had produced a set of technological themes which, for a long time and in many places, would prove able to adapt to or cope with both slow complexification and modest environmental variation. Communication by writing was the most promising technological response to complexification, albeit slow to spread. And the best available social technology, in times of drought or other environmental challenges, was placating or pleading with one's anthropomorphised gods.

That is, it was the best until someone invented the more practical idea of stealing grain from another village's granaries. Such marauding inevitably spread and spawned the widespread adoption of defensive technologies, including fortified villages and cities and specialist warriors. The seeds of the twentieth century's wars were being sown. When the idea of stealing grain was extended to stealing people to be slave labourers, the technologies of coercion began to assume an increasingly important role within societies. Slaves knew nothing of local language and customary behaviours, and could not really be re-socialised into a compliant workforce. It was easier to extract their labour using physical coercion.

Increasingly throughout the transition from villages to city states, militaristic management based on maintaining standing armies was now complementing theocratic management. Military conquest (stealing the neighbours' land) and empire-building (setting up tribute states) became recognised social technologies for improving and maintaining a society's survival prospects. For example, Hammurabi, steward king to the Babylonian god Marduk from 1792 to 1750 BCE, formed the city-states of Mesopotamia into an empire and held them together, in considerable part through his use of written proclamations and letters of instruction.

Threats to the post-glacial (*bicameral*) *mind.* But, by the middle Bronze Age the trap had begun to close. It transpired that the militaristic-theocratic states and empires that had spread across Eurasia by then were in ever-present danger of collapsing, both individually and, domino-style, collectively. Jaynes talks about the built-in periodicity of such societies, i.e. their propensity to collapse at intervals back to less energetic tribal forms.[52] And, indeed, around 2200 BCE a number of

[51] McNeill, W.H., 1979, *Plagues and People*, Penguin, London.

[52] Jaynes, J., 1976, ibid., p.195.

major civilisations (including those in Mesopotamia, Old Kingdom Egypt, the Indus valley, Palestine, Greece, and Crete) did collapse. The causes were various. The mix of material, social, communicative and cognitive technologies was changing only slowly and agricultural output was no longer growing strongly. Trade was increasing but was still a minor activity. Population growth continued, providing the state/empire with more warriors and serfs but lower surpluses per head. This left increasingly complex societies increasingly vulnerable to climatic variability, natural disasters and the disruptive effects of military campaigns and invasions. Thus, Harvey Weiss and Raymond Bradley identify a widespread 300-year drought beginning around 2200 BCE.[53]

Joseph Tainter, one of the few archaeologists to have made a comparative study of collapsed societies has concluded that more complex societies are more vulnerable to collapse.[54] Adding new management operations is a sound way of addressing newly perceived problems. At first the strategy works. For example, agricultural production increases through more intensive farming methods, an emerging bureaucracy co-ordinates production and distribution competently, expanding trade brings wealth. However, as the less costly solutions to society's problems are exhausted, it becomes imperative that new organisational and economic answers be found, even though these may well be decreasingly cost-effective. One reason for that is that as new components are added to a system, the number of inter-component linkages that have to be managed tends to increase geometrically rather than linearly. Finally, at some point the costs of additional reorganisation exceed the benefits. Tainter's insight is that, as a strategy for solving a society's problems, complexification is often successful in the short term but, in the long term, may well increase that society's vulnerability to collapse. Western civilisation has avoided this fate so far, says Tainter and we will discuss presently, how a combination of luck and ingenuity has allowed this complexification to continue.

Much of the increasing complexity which Bronze Age societies had to manage was the result of interactions between societies, particularly war, trade and forced migration. To quote Ernest Gellner, violence which in tribal and village times had been 'contingent and optional', had now become 'pervasive, mandatory and normative'.[55] Individual societies were being selected to survive on the basis of their military 'fitness' but, for Bronze Age society as a whole, war was a 'social trap', an extraordinarily costly and unproductive way of allocating resources. And it could not be avoided. In the absence of any overarching institution for internalising the external costs of war, every state had to join its local arms race to have any prospect

[53] Weiss, H., and Bradley, R.S., 2001, What Drives Societal Collapse?, *Science*, **291** (No 5504), pp. 609–610.

[54] Tainter, J.A., 2000, Problem Solving, Complexity, History, Sustainability, *Population and Environment*, **22** (1), pp. 3–41.

[55] Gellner, E., 1995, *Anthropology and Politics*: *Revolutions in the Sacred Grove*, Blackwell Publishers, Cambridge, MA, p. 160.

of survival. Given that bigger societies tend to be 'fitter' militarily, the Bronze Age world was already on a growth treadmill. How familiar all this sounds.

Religion was a second major source of increasing complexification. Religious observances and practices (including the building of temples and monuments), consumed evermore resources in most Bronze Age societies. The adaptive value of this development is not immediately clear to modern eyes. It seems unlikely that the gods needed more authority over what were docile people who believed and did what they were told. Perhaps the cultural evolution of the priesthood had become decoupled from the cultural evolution of the mass of people? But there is nothing to suggest that these changes were primarily for the benefit of the priesthood. There was as yet no recognition of the idea of disparate class interests, even though, in practice, the military and the priesthood constituted a dominant minority. More plausible is the idea that because religious guidance of these societies was apparently no longer solving their problems adequately, they turned to making greater efforts to communicate with their gods.

But things got worse rather than better. Around the end of the second millennium BCE, as Jaynes interprets the historical record, the various hallucinated voices (i.e. misattributed thoughts) became confused, contradictory and ultimately counterproductive. They no longer provided relevant directions in what-to-do situations. This should not surprise us. The vocabulary available for expressing instructions was limited and descriptive-only. So, faced with novel, complex situations, only simple, and likely irrelevant, stock responses could be generated. A related idea here is that the increasing use of written instructions which had to be read out loud before being acted on might have moved the post-glacial mind closer to recognising that verbal instructions can be self-authored and not necessarily divine.

While Jaynes argues convincingly from the historical record that the 'voices of the gods' did indeed fade in light of these failures, it is not clear how thoughts were processed thereafter, at least not till the appearance of the self-aware mind some 500 years later. In the interim, there were several types of technological responses to the loss of direct divine guidance. One was to seek out oracles and prophets, people who retained a capacity to hear divine instructions and to answer questions on behalf of the gods. Thus, oracles (e.g. Delphi) remained important in Greece for another thousand years. Another approach to improving communications was to pray to one's departed gods through new intermediaries such as angels. Then there were techniques based on inferring divine intentions from indirect evidence. These included choosing between alternative scenarios by casting lots, by divination and by reading auguries and omens. While misguided, such inferential methods reflected an expanding awareness of the concepts of both choice and causation.

The Self-Aware Mind

Having now made an effort to understand cognition-consciousness in contemporary humans and to recapitulate several stages in the evolution of the human mind, we have a framework within which to better understand the revolution in cognition-consciousness that occurred in various parts of Eurasia, most spectacularly in Greece in the first millennium BCE.

Under the interpretation offered here, this is the millennium in which humans started to deliberately think metaphorically. The adoption of that one cognitive technology was the 'big bang' which projected the human mind into a whole new universe, metaphorically speaking. More explicitly, thinking metaphorically is a tool which can rapidly extend the range of behavioural options a person might consider in what-to-do situations, and, equally importantly, it is a tool which can extend, enrich and selectively focus meaning (perceptions of relationships between entities). Consider a simple example. 'We will attack the Trojans', is a concrete expression of intention, but 'We will attack the Trojans like a crab catches fish', is a metaphor which makes the idea of a pincer movement readily and immediately understandable; or, 'We will attack the Trojans like a scorpion out of its nest'. But being like a scorpion entails much more than launching a stinging attack from a hiding place (wooden horse!). It means being willing to feint, to hold your weapons high, to fight to the death and so on. As George Lakoff says, metaphors make sense of our experience; they provide coherent structure, highlighting some things and hiding others.[56] If a metaphor 'passes' emotionally, it has the potential to provide a variety of options for understanding and acting, even as it constrains that variety to a manageable level.

Even more powerfully, the act of changing from one metaphor to another changes one's working mental model of a what-to-do situation, e.g. from thinking 'crab' to thinking 'scorpion'. Metaphors make connections between different domains of discourse and what is being suggested here is that during the first millennium BCE people learned to generate metaphorical thoughts in a richer and more controlled way than hitherto. In part this may have been a reflection of an enlarging vocabulary and a densifying network of neural associations between concepts and percepts. On that particular point, the theory of graphs suggests that as more and more contingent links (associations) appear between the words in a lexicon, there will come a critical point where a few more links dramatically increase the probability of there being a chain of links between any two words.[57]

Believing that a metaphor is valid as a basis for understanding or action is an act of faith, something which can't be proven; but then so is any belief in any causal relationship. We can imagine that trial and error experience in using metaphors would have led to various pragmatic rules for narrowing the range of metaphorical associations thought to be worth exploring in various situations: For example, when A is likened to B, both A and B are normally the same part of speech, e.g. both nouns. Metaphors with negative emotional loadings stand to be rejected. As in the 'attack' metaphor above, candidate metaphors need to be consonant with goals and values. And then there will be various culture-specific guidelines based on taboos, memes, traditions, etc., which favour rejection or favour further consideration of

[56] Lakoff, G., and Johnson, M., ibid.

[57] Stauffer, D., and Aharony. A.,1985, *Introduction to Percolation Theory*, Taylor and Francis, London.

metaphors with particular attributes.[58] Within the options remaining after such pruning and prejudging, metaphors which emerge for further consideration are thereafter, for practical purposes, randomly selected—a process reminiscent of gene mutation. And the genetic metaphor leads to the idea that if the rate of cultural evolution is lagging the rate of environmental change, cultural evolution can be speeded up by generating more metaphors around the problem issues. Conversely, some metaphors get cemented into belief systems as truths which can only be changed with great difficulty over a long period.

Where did metaphorical thinking come from? Not out of nowhere. It can be viewed as a refinement of Frazer's two laws of magic, introduced in Chap. 2 (see page 117) as the law of similarity and the law of contagion. Indeed Robin Fox suggests that, in contemporary language, the law of contagion could be rewritten as the law of metonymy and the law of similarity as the law of metaphor.[59]

Not quite perhaps. A metaphor is a type of assertion: If A resembles B in some way, structurally or functionally, then it might resemble B in other ways. However, metaphors do not go as far as the law of similarity which postulates parallel and remote causation. That is, metaphors do not claim, as sympathetic magic does, that operations on A alone have effects on both A and B and those effects are similar; the effects on B *resemble* the effects on A. For example, breaking the arm of a voodoo doll, A, one representing and resembling person B, magically causes the breaking of B's arm. The corresponding metaphorical thought might be that if person B is like a straw doll, then their arm might be easily broken.

Metaphorical Understanding of Mental Experiences

Learning to use metaphorical thinking culminated in its extension to understanding *mental* experiences. Thus, as noted earlier, Julian Jaynes suggested that a human organism's mental experiences can be understood and talked about by thinking of them as being like the natural experiences of a bodily organism in the real world. Natural experiences include direct body experiences and interactions with both the physical environment and with other people.[60] And that is what humans learned to do. People moved from treating imagined events as real events to treating imagined events as being *like* real events. They learned to verbalise and share their thoughts

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[58]Heylighen, F. 1991, Cognitive levels of evolution: from pre-rational to meta-rational, In *The Cybernetics of Complex systems-Self-organisation*, *Evolution and Social Change*, (F. Geyer Ed.) Intersystems, Salinas, Ca. pp. 75–79. Heylighen points out that 'legitimate' associations conform to (are controlled by) learned rules based on experience, e.g. syntactic rules, cultural rules, selection rules, historical rules.

[59]Fox, R., 1994, *The Challenge of Anthropology*: *Old Encounters and New Excursions*, Transaction Publishers, New Brunswick, p.173. Metonymy is treating parts as wholes; e.g. counting 'heads', not people.

[60]Lakoff, G., and Johnson, M., 1980, ibid., p.117.

by (partly) expressing those thoughts with the help of this ‘natural experiences’ metaphor. Nowadays we talk so readily about our mental experiences that it is difficult for us to see how the narratives we produce are based on understanding mental experiences as being like physical experiences such as looking, listening, etc.; and that people had to learn to describe their mental acts and experiences. Language had begun to split into one frame of reference pertaining to publicly observable physical things and one pertaining to privately knowable mental things.

Jaynes called the metaphorical entity which participates in the bodily organism’s stream of imaginings *Analogue I*. We might equally, and more briefly, call it *Ego-I* although ego is a more contentious term. In the real world, the word ‘I’ is most simply thought of as the name which a bodily organism gives to that same bodily organism when conversing. Just as a physical person does things in the real world (moving around, arranging objects, looking, listening, etc.), the metaphorical I does analogous things, has analogous experiences, in an analogue of the real world which Jaynes calls *mind-space*. As well as actively doing things in mind-space, Ego-I participates passively in the body’s mental experiences, e.g. being spoken to as well as speaking. Thus Ego-I plays more than one sort of role.

So, if I have a mental experience in which I imagine I am patting my dog, that experience is very like, is analogous to, a real world experience in which I am watching someone who looks like me patting a dog that looks like my dog. I report that Ego-I looked into mind-space (introspected) and saw a visual image of a ‘metaphorical me’ patting a dog like mine. Or, more shortly, I report that I imagined patting my dog. Thus, ‘seeing in the real world’ is a metaphorical explanation of ‘seeing in mind-space’.

What about the mental experience of imagining syntactic speech without, say, any accompanying visual images or auditory hallucinations? You could interpret that experience as being like a real world experience in which someone talks to you or, alternatively, you are talking to someone. Perhaps the best metaphor for understanding the experiencing of inner speech is the real world experience of talking aloud to oneself? If so, the experiencing of inner speech is like observing an intrapersonal dialogue in mind-space. Call it Ego-I One talking to Ego-I Two. Now you can explain to someone that you had imagined you were talking to yourself and you said ‘X’. Or, more shortly, as the shared metaphor shrunk with familiarity, ‘I was thinking “X”’. Other words for directed mental experiences and mental acts—knowing, believing, planning, speculating, etc.—began to appear in texts of the first millennium BCE. In the same period, words for feelings and emotions, based on the bodily changes associated with these mental states, come into use. We can conclude that the scope of the consciousness experience was being expanded.

Metaphorical Understanding of Consciousness and Selfhood

We can draw on these ideas to suggest how a growing metaphorical understanding of mental experiences opened the way for the emergence of consciousness and selfhood. As noted, consciousness is here understood to mean the implementing of an ability to observe, and to know that one is observing, some of the operations of one's own (autonomous) mind. It is a process of listening to (a metaphor) oneself thinking, and being aware that one is doing so, and that the thoughts being listened to are one's own, i.e. are self-authored.

If you accept this somewhat-constrained (but unmuddled) definition of what consciousness is, then you cannot be conscious unless you can say, or imagine saying, 'I was thinking "X"'. Hence, consciousness could not exist before people had the vocabulary to say 'I was thinking "X"'. As Ludwig Wittgenstein said 'The limits of my language mean the limits of my world'.[61] What happened at the emergence of consciousness was not that inner speech was new but that the stream of inner speech generated by the left hemisphere's offline speech system was now being interpreted as self-authored, as being like talking to oneself, and not as being like the voice of another person or a god (with or without auditory hallucination) talking to you.

Let us return to the word 'I' in the statement 'I was thinking "X"'. In the present discussion of mental experiences 'I' is short for 'Ego-I One'. Ego-I One is a metaphorical entity which, in contemporary terms, is like a person in the left brain who is thinking-saying X and, because this is a motor activity, such thinking-saying is proprioceptive or experiential. Recall that proprioception accompanies all motor activity and is the feeling that the body knows it is doing or experiencing something—if that something comes to consciousness. In the case of thinking-saying, it is thoughts which are sufficiently charged with emotion that come to consciousness and which thereby tend to be remembered in the longer term. Note that the thought that is remembered is not 'X' but 'I was thinking "X". The particular proprioceptive feeling in the case of thinking-saying is the feeling that the thoughts X which are being conveyed to the metaphorical person in the awareness system in the right hemisphere (Ego-I Two) are assembled and 'spoken' by Ego-I One. If X happens to be a command, we can interpret it as the metaphorical Ego-I One saying 'Ego-I One told Ego-I Two to do "X"'.

Constructing the Self

The concept of 'self' is entering this story in several ways. In real world conversations words like 'oneself', 'yourself' and 'myself' are grammatically useful extensions of the word 'I'. But what about 'the self' as appears in discussions of mental experience? The understanding favoured here is that the self is, *structurally*, a family or library (more metaphors) of narratives constructed from the sequence of autobiographical memories which is a record of the thoughts and images of which the individual has previously become conscious. Examples might be the story of where and why you lived in particular places at different times, or 'my first day as an

[61] Wittgenstein 1921/1974 *Tractatus Logico-Philosophicus*, (Trans by Pears, D.F. and McGuinness, B.F.), Routledge and Kegan Paul, London, Proposition 5.6.

apprentice', or 'what I have learned about women'. In very general terms, such narratives identify and report, syntactically, similarities and differences among one's episodic memories. This is what gives them meaning.

Viewing the self *functionally*, narrative chains abstracted by a process of association from the brain's library of memories are available to the speech-thought system as inputs which, along with inputs from the awareness system, can be used for constructing behavioural options (schemata) in what-to-do situations. Depending on the emotional acceptability (to the limbic arousal system) of a narrative which is being suggested as a behavioural option, it may be reflected, more than once perhaps, between the awareness and speech-thought systems; and it may be modified in the process. When a narratised behavioural option is accepted and physically implemented it is as if, metaphorically, the body has acted as the *agent* of the mind, of Ego-I.

Thus, the link between consciousness and the self is that consciousness is the process which gets thoughts that the (unconscious) mind evaluates as emotionally significant into long-term memory, tagging them as mental experiences; once stored, these memories are the stuff of which the self's narratives are made. It follows that it is misleading to regard the self as a metaphorical person and that the thoughts one becomes conscious of are not so much self-authored as authored, metaphorically, by Ego-I One *with the aid of the self*.

More than this, the self, still understanding it as an ever-changing library of memory-based narratives, is available to become an integrated object of consciousness, a gestalt, which, as it develops over a lifetime, becomes the basis of the individual's unique identity. It is worth emphasising here that part of any individual's self-awareness (conscious awareness of one's self) is the realisation that it is but one entity which is accumulating memories. That is, the concept of the self includes a recognition that something which all its memories have in common is the fact that they record the experiences of a single unique bodily organism. It is an idea which is so blindingly obvious to us, at least till we encounter the 'pathological' idea of multiple selves, that we find it hard to comprehend that it had to be learned. Somewhat similarly, Snell describes how archaic Greeks had words for the limbs but no word for the living body. By classical times they had learned to recognise that collectively the joints, limbs and torso formed a single entity.[62] It is to one's self-based narratives that Solon, the great Athenian law giver and founder of Greek democracy, is referring when, in 600 BCE, he coins the injunction: 'Know thyself'. Jaynes suggests that Solon might be the first person to seem like us, talking about the mind in the way we do.

Identity and Accountability

In contemporary everyday life, knowing yourself, having a sense of self, means, to make a useful distinction, having a sense of both a social and a personal identity.

[62] Snell, B., 1960, ibid., Ch. 1.

Your *social identity* is derived from playing roles in the various social groupings you feel part of and are identified as belonging to (e.g. teacher, mother). You learn to play the role of being a member of a social group by building up memories of past participation in group activities and drawing on these to visualise and narratise normative behaviours for yourself which accord with the group's precepts and institutions. Institutions are defined by Douglass North as the humanly devised constraints, formal and informal, that structure political, economic and social interaction.[63] As in a tribal society, generalising and imitating the behaviour of others still remains important to the acquisition of a social identity. Your identity within a social group is confirmed when you are able to say: 'I am an X which means I do Y'. As discussed somewhat chillingly by Arthur Koestler,[64] a sense of belonging to a group can be very rewarding emotionally and the 'need to belong', the need to be approved, is dangerously strong in most people.

Your *personal identity*, on the other hand, is based on an awareness, an identification, of how your habits, appetencies, beliefs, experiences, etc., differ from those of others and, indeed, how your preferred behaviours might not be as satisfying to others as they are to you—and therefore, you predict, they might not behave as you would. Being able to articulate one's sense of personal identity means being able to say 'I am John Smith and I am the sort of person who behaves in such-and-such ways when…' And you do. You act out what you believe yourself to be like, and, in doing so, test your understanding of your relationship with the world, e.g. your powers, skills, etc.[65] Under this perspective, your *personality* is your consistent behaviours, your *character* is the values to which your behaviour conforms.

While one's personal and social identities evolve throughout life, they nonetheless provide reasonably stable day-to-day guidance, 'suggesting' behavioural options which previous experience has found to produce emotionally acceptable outcomes (as well as rejecting emotionally unacceptable options). *Habits* are formed and, much of the time, habitual behaviour does not even reach consciousness. Notwithstanding, there is commonly a tension between the behavioural suggestions offered by, respectively, one's social and personal identities. One's social identity suggests behaving in ways which reinforce the group's continuation and your membership therein and one's personal identity suggests behaving in ways which, foremostly, will produce satisfactory emotions in oneself, even at the cost of undermining the functionality of the group. And that tension, in one form or another, is of course one of the great recurring themes of literature, the humanities and the human sciences. Perhaps the pervasive idea that humans (have a capacity to) make *choices* had its origins in the overt recognition of this perennial tension and its somewhat unpredictable consequences.

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[63] North, D.C., 1991, Institutions, *Journal of Economic Perspectives*, **5** (1), pp. 97–112.

[64] Koestler, A., 1970, *The Ghost in the Machine*, Pan, London, p. 277.

[65] Taylor, C., 1971, Interpretation and the Sciences of Man, *Review of Metaphysics*, **25** (1), pp. 3–51.

Over the first millennium BCE, the directions in which vocabularies were expanding suggest that people's personal identities were evolving and developing far more than their social identities. Homer's Achilles could never have said, 'When I was a little boy back in Greece…' but, written some centuries later, his Odysseus could. More generally, the idea began to spread that, as well as gods and authority figures telling people what to do, people could, metaphorically, tell themselves what to do, i.e. authorise their own behaviour; just as leaders tell followers what to do in the real world.

And then, early in the first millennium another new insight appears to have been grafted onto people's understanding of their mental experiences, one which helps explain the rise of that age's new religions. This further idea was that when people make choices between behavioural options, it is as though, metaphorically, they are agreeing with themselves about what to do—just as, in the real world, hunters might debate and agree on a hunting strategy.

Once the idea is perceived, rightly or wrongly, that people 'agree to and authorise' their own behaviour, it can be re-expressed as the idea that people are *responsible* for or *accountable to themselves* for their own behaviour. The opposed idea of being accountable to an external authority figure for one's behaviour first appears in the written record in the legal code of Hammurabi (3760 BP). For example:

> If a man uses violence on another man's wife to sleep with her, the man shall be killed, but the wife shall be blameless.

The suggestion here is that in the 'axial age' of the first millennium BCE, the idea of *accountability* was internalised. Just as external authorities can hold you responsible for your behaviour and punish you for breaking society's rules, you can be accountable to yourself and punish yourself for breaking your own or another's proposed rules, e.g. by doing penance or by feeling guilty. It is at this time, independently in China, India and the Mediterranean world, that there emerged spiritual leaders and philosophers who, supported in some cases by sacred texts and claims of divine revelation, provided people with moral codes and psychological insights to guide their behaviour, both social and personal.

Even though the great empires of the Bronze Age had given way to a raft of smaller states, the power of state apparatuses to control individual behaviour through a legal system backed by coercion remained. For instance, in the middle of the sixth century BCE, a penal code of law formed the system of political control in China.[66] The elites there believed it more important to keep the people, through strict laws, from doing 'evil' than to encourage them, through moral persuasion, to do good.

Despite such attitudes, a massive change was occurring in the psychological control of behaviour. Unlike being told what to do on a case-by-case basis by the gods or their messengers or their signs, individual behaviour was now beginning to be

[66] Ames, R.T., 1983, The Art of Rulership: A Study in Ancient Chinese Political Thought, University of Hawaii Press, Hawaii.

controlled through a process of obeying, *in absentia*, authority figures who were seen to have no direct coercive power over one. The origins of *morality* lie in interpreting and obeying the behavioural rules proclaimed by a spiritual leader or secular (non-theistic) philosopher while the origins of *individualism* lie in obeying 'rules' derived from one's own experience.

Institutions, including legal systems and traditions, customs, and widely shared moral codes are all powerful technologies for stabilising and integrating societies, protecting them from disruptive individual behaviour and fostering predictable behaviour. But societies also need to be able to adapt to internal and external changes, must learn to do things differently, if they are to have any prospect of surviving. The advent of morality and individualism both created possibilities for novel behaviours to be suggested and tried at a rate in line with the rate of social change.

How was this so? In the case of received moral codes, it was because disciples and priests had to adapt general injunctions about 'right' and 'wrong' behaviour from a sage or prophet to particular situations. For example, this might require the meanings of words to drift, amounting over time to a major reinterpretation of the original teachings. Particularly for 'divinely inspired' teachings, most people, eschewing individualistic interpretations (few could read), chose to accept priestly interpretations of the authority's words. Provided that their priests were flexible enough, this would suffice for a society to learn new ways of behaving while not exceeding the society's capacity to change without breaking down.

However, it was individualism and secular philosophy rather than flexible morality at group level which led to the major changes in social and cognitive technologies that characterise the Greek enlightenment. For example, it was the broad acceptance in Athenian society of the idea that individuals are responsible for their own behaviour and free to think and worship as they please, plus the additional idea that all male citizens have an equal claim to positions of authority (e.g. public office), that produced the group governance technology we know as *democracy*. Metaphorically, democracy can be thought of as an externalisation to the group of the individual's capacity to internally generate and evaluate alternative behavioural options. Politically, rule by democratically agreed law had now emerged as a technology which challenged the arbitrary powers of kings. Thus, for some, democracy was more a threat to order than a wellspring of responsive decision-making: Plato condemned the city-state of Athens for giving power over their own lives to people who had neither the inclination nor training to accept it.

Reflecting on the First Millennium BCE

Three thousand years ago the world was coming to the end of its Bronze Age. Cities, states and empires were being destabilised or even destroyed by various sorts of internal and external shocks. Some of these were widespread like drought and earthquake and others were transmitted from place to place as people were displaced by marauding and famine and as trade routes closed down. Military technologies were increasingly destructive, armies increasingly mobile. Far-flung and growing populations had to be managed. Bronze Age society had become a dissipative system which was reorganising to something simpler as its material and energy supplies failed.

This was the world in which the post-glacial 'tribal' mind, or what Jaynes calls the bicameral mind, proved inadequate for making decisions which could protect Eurasia's complex theocratic-militaristic societies from disruption or breakdown. Whether or not what-to-do plans were being interpreted as divinely ordered, the fact remains that such were relying heavily on an accumulated reservoir of custom, tradition and myth. It was a reservoir which, till then, and not withstanding some earlier collapses, had evolved fast enough to routinely supply plausible responses to the slowly complexifying suite of problems thrown up during the essentially benign Holocene. However, now that, in many societies, multiple shocks had to be managed simultaneously, multifaceted decisions were needed. As Ashby's law of requisite variety says, the larger the variety of actions available to a control system, the larger the variety of perturbations the control system is able to compensate for.[67] Custom, tradition and myth were not providing enough control.

As it transpired, a powerful new way of thinking did emerge; metaphorical thinking grew out of magical thinking. Over time, the fruits of this cultural adaptation, this cognitive technology, were astounding—consciousness, the self, personal and social identity, morality and individualism. For the first time people were thinking about and learning to talk about their mental experiences. More generally, drawing on a vocabulary of concepts which, with the aid of metaphorical thinking, continued to expand steadily, people began asking and postulating answers to an ever-wider range of questions about society, the individual, religion and the natural world. This was the environment within which the axial age's great religious and secular thinkers emerged.

For Eurasians, the world became an intellectually richer, better understood and more predictable place. But, while science, art, literature and philosophy flourished in various urban centres, did decision-making and plan-making improve? In what-to-do situations, were more, and more creative, options being considered and evaluated more realistically in terms of their consequences? Were societies in the second half of the first millennium BCE more able to cope with or prevent internal and external shocks? Or did the fierceness of the disruptive forces, natural and social, swamp the new cognitive technologies? Given many confounding factors it is difficult to say, but the evidence suggests the latter. Certainly the Greeks, despite being in the vanguard of the consciousness-cognition revolution, and despite building a mighty empire under Alexander the Great (336–323 BCE), were finally conquered by the Romans in 146 BCE.

Notwithstanding the spread of Greek culture in the wake of Alexander's conquests and the eruption of cognition-consciousness revolutions in various centres

[67] Ashby, W.R.,1960, *Design for a Brain*: *The Origin of Adaptive Behaviour*, (2nd Ed), Chapman and Hall, London.

across Eurasia, the world, in many respects, did not change. After the chaos of the late Bronze Age, nation states slowly recovered and re-formed, but were soon turning frequently, as before, to war, empire-building (Assyria, Persia, Babylon, etc.) and the enslavement of conquered peoples as technologies for boosting energy surpluses available to their military and priestly ruling classes who continued to dominate their own societies through coercion, religious obligation and patronage. For a variety of reasons, the internal management of urban populations was becoming more difficult. These included population growth per se, an increasing diversity of occupations due to changing technologies, and an increasing diversity of tribal and religious affiliations among the residents. Other reasons included the need to replenish armies and, under the influence of the new individualism, the greater willingness of a few to question authority. Still, not to put too fine a point on it, as a technology for improving Holocene society's survival prospects, consciousness-cognition was a failure, at least in the short term. That is, Greek enlightenment was an adaptation which had limited impact on politics and international relations at the time but would re-emerge during the Renaissance.

Nonetheless, with the conquest of Greece by Rome, the world did enter a period of increased geopolitical stability. By the end of the first millennium BCE, most of the world's people were to be found in four major agricultural civilisations stretching from the Atlantic to the Pacific Ocean, north and south of the Mediterranean and across southern and eastern Asia. To the east of the Roman Empire was the neo-Persian or Parthian Empire (covering Iraq, Afghanistan, Iran). To the west of the Chinese Han Empire was the Kushan Empire covering parts of northern India, Afghanistan and central Asia.

Coevolution of Food Production, Society and Ecosphere (12000–2000 BP)

Standing back from just the first millennium BCE, what did the entire post-glacial period up to the beginning of the Common Era demonstrate about the ability of humans to survive and thrive? Accepting that there is no way of making reliable estimates, we can suggest that human population grew over this period from, perhaps 5–10 m to 150–200 m. As for thriving, average life expectancy before the health transition of the modern era is thought to have varied between about 20 and 35 years. But, as noted earlier, it seems that life expectancy might have fallen after the Neolithic Revolution (a) because of higher infection rates associated with larger, denser settlements and (b) poorer nutrition, the result of a low-variety diet deficient in certain amino acids. For comparison, life expectancy at birth in the United States in 1900 was still only 47 years. One can further imagine that life, at least for the lower classes, would have been unremittingly physically demanding and psychologically unhealthy. By our standards, coercion and superstition dominated people's lives—perhaps they acculturated and were not too miserable.

One illuminating way to view the human story over this 10,000 year period, putting it into the context of a much larger story, is to see it in terms of energy flows through various dissipative systems. The starting point for taking this perspective is to see the globe as a single, but multilayered (hierarchical), dissipative system which began processing, dissipating and storing increased quantities of energy from the sun as the last glacial period was coming to an end. These increased energy flows went, first of all, into speeding up the rate at which materials (primarily water and gases, but also minerals) were being cycled through the atmosphere, hydrosphere and lithosphere. More than this, flows through these cycles spontaneously reorganised themselves into somewhat different kinetic structures (persistent flow paths). In other words, circulation patterns changed.

The world's ecosystems are dissipative systems that are embedded in, that redirect materials and energy from, these global cycles, as well as taking in direct solar energy. They are organised into persisting *trophic structures* (food webs) where energy and nutrients captured by primary producers (plants) are consumed, degraded and recycled by herbivores and then by carnivores and finally by soil organisms. The functional reason why such structures persist is that each trophic level contributes, by way of stabilising energy or nutrient sources, to making the environment more equable or less demanding for organisms at other trophic levels. The population of any species in an established ecosystem is likely to be more stable in face of perturbations in global cycles than it would be outside that system. In their turn, in response to post-glacial changes in global cycles, the world's ecosystems self-reorganised, migrating, expanding and contracting.

As hunter-gatherers, humans were adapted to a variety of ecosystems during the last ice age. They occupied *niches* where they survived by harvesting and eating local components of the food-web flows (plants and animals). At this stage in their history, humans, in many ways, were just another large predatory mammal, one which successfully displaced other large predators from their niches. Subsequently they survived the further suite of climatic and ecospheric changes associated with post-glacial changes in the global energy budget. At first they adapted to this new environment by simply changing their harvesting behaviours. For example, seed-gathering became a way of life as grasses proliferated across the Fertile Crescent and the Asian steppes. And then, momentously, perhaps triggered by the temporary return of harsher times, they began to actively adapt the environment itself to more reliably provide for their energy needs. They learned to use their own human energy to trigger and guide increasing energy-material flows through selected edible plant and animal species (crop plants and grazing animals), and then through animal species which could provide draft power and transport. The significance of grazing animals is that they can assimilate, and convert to usable energy, parts of plants which humans can't eat directly. Because they store sunlight which would otherwise be dissipated as heat, plants retard the dissipation of energy while plant-eating animals accelerate it. *Agro-ecosystems* is a useful term for ecosystems whose material-energy flows have been substantially modified in order to increase human-food production. New adjunct technologies, i.e. other than cropping and herding per se (e.g. better ploughs, milking sheep and cattle), can be viewed as ways of further increasing the yield and reliability of supply of useable plant and animal energy per unit of human energy expended.

These adaptations or, equally, *technologies* for harvesting domesticated species increased usable energy supplies to the point where populations within Neolithic villages expanded. For a long time, land was not a limiting factor in the food production system and when a village passed optimum size in terms of organisation, walking distance to cropping areas, etc., a new village was established nearby and populated from the old village. Such fissioning, so commonplace in biological and physical dissipative systems when a system's size or its energy supplies increase, can also be seen as the tribe's way of reducing the world to size, to terms with which they could deal.[68]

Several factors combined to bring Eurasia's Neolithic Revolution to an end and trigger an Urban Revolution based on the social technologies of urban consolidation and task specialisation and on the material technologies associated with extensive irrigated agriculture. A drying climate was certainly one factor. Another was that, under ongoing population growth and fissioning, land for dryland cropping did start to become limiting, both in quality and quantity. Another was that, while small by modern standards, the surplus energy made available by domesticating plants and animals was sufficient to encourage marauding and, conversely, to encourage the aggregation of villages for defence reasons.

So, once populations began to grow and aggregate on the fertile flood plains of great rivers, the preconditions were in place to establish extensive irrigation schemes in which crop production per field worker was much higher and more reliable than in village agriculture. Laying down the infrastructure for such schemes required the organisation of massive amounts of labour, as did the ongoing maintenance of channels, headworks, etc. It was for the sustenance of the builders, managers and defenders of these undertakings that the new surpluses were destined.

Not that urban civilisations developed from village agriculture overnight. Just as the mammalian eye did not evolve as the result of a single mutation, urban culture did not flow from a single visionary purposive action. Neolithic culture was reshaped into urban culture by extended sequences of innovative activities such that each step in each sequence became a pre-adaptation which (unintentionally) established (some of) the conditions under which the next step could emerge.[69] If it were not to be resisted as a perceived threat to the established order, each step would necessarily have been small in terms of the amount of energy redirection it involved. We will take it on trust here that such sequences might be plausibly reconstructed.

The term *coevolution* can be usefully introduced here to capture the fact that adaptations in one type of technology will sometimes serve as pre-adaptations for

[68] Adams, R.N., 1975, *Energy and Structure*: *A Theory of Social Power*, University of Texas Press, Austin and London, p.281.

[69] Purpose: An end state that one plans to assist to eventuate (a) because it seems causally feasible and (b) which, for sufficient reasons, one wishes to see eventuate.

another type of technology, the obvious example being that the adaptations in the material technologies of food production, technologies which produced surpluses, were a necessary precondition for the emergence of social stratification, a social technology. In another clear example of coevolution, developments in agricultural and social technologies transformed natural ecosystems into agro-ecosystems; and when reigning technologies degraded the resource base (erosion, salinisation), niches appeared for ameliorative technologies. But whether this led to *directed* coevolution in the form of an active search for ameliorants we do not have the evidence to judge. More broadly, *diffusion* of technologies from one society to another (e.g. via trade, war) suggests as a plausible form of coevolution between Holocene societies.

Cultural evolution is here being likened to biological evolution wherein a sequence of 'short-sighted' adaptations, each selected for their immediate survival benefits, can lead to new species or, conversely, to the channelling of a species into an evolutionary cul-de-sac. In much cultural evolution, including the transition to urban culture, it is exploratory and playful behaviour by individuals which throws up *variations* on existing customary behaviour patterns, variations which, for our purposes, are technological innovations. An occasional such variation will be recognised as perhaps improving an existing technology and *selected* for further trial. If this perception of improvement persists under a range of conditions, the selected variant may be 'permanently' incorporated into the technology recipe and become widely used.

The degree to which such adaptations were conscious and purposive cannot be known, although that interpretation does seem doubtful for much of the Holocene prior to the Common Era, i.e. it is doubtful that people at that time could have said 'We are trying to improve this technology'. That sort of thinking would have been more characteristic of the first millennium BCE. It is probably more realistic to think of cultural evolution prior to, say, the axial age beginning about 800 BCE as a matter of people imitating their own and others' accidental successes; verbal instruction would have played a part too.

Sociologist Anthony Giddens' theory of *structuration*, while focussed on change in modern societies, is equally suggestive of how social structures and human agency might have interacted in the Holocene to produce cultural evolution: Repetition of their role-defined tasks by individuals reproduces the social structure—traditions, institutions, moral codes, and established ways of doing things—but these can be changed when people start to ignore them, replace them, or reproduce them differently.[70] This model recognises two-way causation, with humans having structuring power and structures having enabling and constraining power.

[70]Lloyd, C., 1993, *The Structures of History*, Blackwell Publishers, Oxford, pp. 42–43; Giddens, A., 1979, *Central Problems in Social Theory*: *Action*, *Structure and Contradiction in Social Analysis*, Macmillan, London.

Holocene Survival Strategies

One can think, metaphorically, of Holocene society as having been a single entity (call her Humanity) who was intentionally trying to develop 'what-to-do' survival strategies in the face of, first, large exogenous changes in her bio-physical environment and, second, (endogenous) survival threats caused, in part, by her own prior survival strategies. Coming into the Holocene, Humanity retained the hunter-gatherer strategy (social technology) of dividing into widespread geographically separated groups each capable of multiplying in the presence of a food surplus. This is a strategy which 'recognises' that environmental conditions vary from place to place and ensures that locally harsh conditions will only threaten a portion of the species. Comparably, the strategy of developing two very different food production systems—cropping and herding—might also be seen as a form of risk management insofar as global changes might impact differently on the two systems. Against that idea, different production systems, as well-argued by Diamond (see page 201), simply reflect adaptation to different local resource complements.

Early in the Neolithic the social technology of marauding—plundering the grain stores of neighbouring villages—was invented and while it may have provided a spike of cheap energy supplies to the raiders, marauding, on almost any reading, would have to be judged one of the great maladaptations of all time. First, it reduced total food supplies insofar as the marauders were temporarily unproductive. Second, it threatened, particularly during drought, the survival of the portion of the population being deprived of food reserves (although this does raise the suggestion that marauding functioned as a (very inefficient) method of population control in situations where carrying capacity limits were being approached). Third, it forced those being plundered to invest their energies in defending their reserves, by forming both armed forces and inefficiently large but more defendable villages-towns. Fourth, it killed off the able-bodied and, with the soon-to-be-invented technology of taking the defeated into slavery, further depleted the survival prospects of the 'losers' in such encounters; in a perverse way taking prisoners probably improved communication between village societies and hence opportunities to exchange technologies. Fifth, it led to a tit-for-tat mentality which would only be checked with the establishment of empires having the 'head-banging' coercive powers to stop marauding within their borders. We might also note that there is no reason to believe that cycles of plundering and being plundered imposed selection pressures which, genetically or culturally—even if they had persisted long enough—improved Humanity's longer-term survival prospects.

Overall, marauding, exacerbated by a drying climate after 5500 BP, led Neolithic society into a social trap where the species' survival prospects could not be further enhanced and where, despite its high external costs, there was no escape. That is, not until Holocene society self-reorganised around a new set of material, social and communicative technologies, notably extensive irrigated cropping and cities with populations stratified by socio-economic role. By diverting the energy of river flows into reliably delivering water and alluvium to grain crops, the new urban civilisations increased net energy yield per field worker markedly. One can only speculate as to what would have happened if Eurasia had had no great river valleys capable of supporting cities and large-scale irrigated agriculture. We are provided here with a good example of the contingent nature of cultural evolution.

Conversely, the relative decline of village agriculture illustrates how a successful survival strategy can exhaust the resources it draws from the dissipative system in which it is embedded (e.g. vacant habitable land); and also how a successful strategy can be threatened by parasitic behaviour from within (as well as by climatic, etc., shocks from without). Indeed, in the distinction between raiders and raided one can see the beginnings of the human equivalent of what biologists call *pseudospecies*, i.e. sub-populations of a species which, at times, behave as separate species (e.g. work together, breed together) including, perhaps, behaving in ways inimical to the interests of other pseudospecies. For example, Steven LeBlanc (2003) argues that humans have long been the main predators on the human species.[71] Alternatively, a pseudospecies is a group with a shared culture.[72] It is an idea to which we will return, along with the further idea that pseudospecies, as well as parasitising each other, can associate symbiotically, i.e. in mutually beneficial ways. William Catton's less emotive term for parasitism is *antibiosis* and Richard Adams' less biological term for pseudospecies is *operating units*.[73] However, rather than 'pseudospecies', I will adopt the more evocative term, 'virtual species', for this important idea.

In moving from a survival strategy based on village agriculture and herding to one predominantly based on extensive irrigated cropping and urbanism (plus urbanism's associated social technologies), Humanity was learning to convert accessible energy to more useful forms at a higher rate per field worker per annum. The size of the overall surplus was further increased by using poorly fed slaves and 'serfs' as field workers. However, apart from the use of river energy to transport water and materials, most of the energy being captured for human purposes still came from plants and animals. From a contemporary perspective, these were still low-energy societies.

Most of the modest surplus was used to energise the increasingly complex and diverse set of overhead activities—religious, military, engineering, trading—needed to maintain, protect and sometimes expand an increasingly complex production system. Recall Ashby's idea that an effective control system needs to be as complex as that which is being controlled. Central to the strategy was the emergence of political *states* as the dominant form of social organisation; each state had a *ruling class* with the capacity (technologies) to organise a *working class* into reliably providing the

[71] Le Blanc, S., with Register, K., 2003, ibid…

[72] Lorenz, K., 1963/1966, *On Aggression*, (First Edn.1963 translated by M Kerr Wilson 1966), Harcourt Brace, New York, p.80.

[73] Catton, W., 1980, *Overshoot*: *The Ecological Basis of Revolutionary Change*, University of Illinois Press, Urbana, p.101; Adams, R.N., 1975, *Energy and Structure*: *A Theory of Social Power*, University of Texas Press, Austin and London, p.54.

large amounts of labour, both manual and craft, needed to keep things going (reproduce the society) from season to season and year to year. Having control over food distribution, coercive powers and religious authority all played a part here. Whether it was seen as such we cannot know, but appropriating food surpluses also functions as a population control mechanism.[74] Effectively, a ruling virtual species had developed technologies which allowed it to 'domesticate' a labouring virtual species. It was an association which was mutually beneficial to the extent that each virtual species needed the other to survive but which also relied on 'exploiting' the working class to extract co-ordinated flows of human energy large enough to undertake collective works such as constructing religious monuments, protecting supplies of raw materials (e.g. wood, stone, minerals) and conquering neighbouring states/settlements to create empires.

While the practice of marauding at inter-village level was increasingly suppressed within individual empires and large states, it re-emerged, as the Bronze Age blossomed, in the form of frequent organised warfare between states and/or empires. In the mid-Holocene world, empires were as much virtual species as were classes within an empire, the difference being, perhaps, that the mainly conflictual relations between empires produced minimal mutual benefits. Trade was a limited exception possibly. White reflects that because of a tendency to romanticise the past, there is little awareness of the frequency of internal and external conflict in the great agrarian empires.[75]

Notwithstanding ambition, Bronze Age empires were restricted in size by not having technologies which allowed rapid communications (of commands, information, etc.) and transport (of people, materials, etc.) over long distances. Fred Cottrell points out that none of the Fertile Crescent civilisations could expand beyond limits imposed by the *relatively* high energy cost of transporting surplus energy to be used at distant frontiers.[76] The Egypt of the Pharaohs is a good example. Over time, these limits relaxed somewhat with the rise of a technology set which included horses large enough to ride, wheeled wagons, chariots and, most importantly, communication by writing. Hence, as the Common Era approached, most people in Eurasia lived in one of the four great empires.

The millennium before the Common Era also saw a succession of maritime trading cultures or sea powers, based on networks of coastal cities; most notably Phoenicia, Greece and Rome. Using sailed and oared vessels significantly reduced the energy costs of transporting goods and soldiers between coastal cities around and near the Mediterranean Sea. Putting this another way, societies which mastered maritime technologies were in an enhanced position to rule the seas, acquire colonies and slaves and monopolise the expanding gains from trade. For example, it can

[74] White, L., 1959, ibid., p.205.

[75] White, L., 1959, ibid., p.227.

[76] Cottrell, W.F., 1955, *Energy and Society*: *The Relation Between Energy*, *Social Change and Economic Development*, McGraw-Hill, New York, p.34.

be argued that the boundaries of the Roman Empire were set at the point where the extra costs of enforcing Roman rule at a distance balanced the extra gains from tribute and trade; and that it was maritime technologies that particularly allowed those boundaries to be extended. While oared war galleys remained in use till the eighteenth century CE, it was the efficient use of sailing technologies, with their ability to capture 'free' wind energy, which came to increasingly determine the wealth and strength of nations on the geopolitical stage.

Ready to Survive the Common Era?

Any notion that urbanised medium-energy societies of the post-Neolithic Holocene were in some way 'better' than low-energy village societies of the earlier Holocene must be rejected. Each developed and employed its own technology-mix in its own environmental context. The fact that medium-energy societies processed energy at a higher rate per capita through a more complex social structure does not imply that they had a greater intrinsic capacity to survive (self-reproduce), or that they offered the individual a higher quality of life. In principle, the advantage of having more decisions made by a ruling class is that this offers the possibility of adjusting a society's behaviour more rapidly than waiting for tradition and custom to respond to changed circumstances. In the event, both low- and medium-energy societies co-evolved with their total environments to the point where they were no longer recognisable as the societies described above. Having said that, to the modern eye, and given the choice, one might prefer to be a member of a low-energy village society offering something like liberty, equality and fraternity rather than being a member of a medium-energy society characterised by state power over the individual, a strongly stratified society and loss of the mutual aid provided in low-energy societies by strong kinship systems.

By the beginning of the Common Era, many of the broad elements of the survival strategy which Humanity would use for the next 2,000 years were well in place. To recapitulate, these included:

Growing the size of the human population and (a) spreading parts of that population into unoccupied or lightly populated niches as these become available and (b) concentrating parts of that population into cities

Using food-energy surpluses to support the political organisation of populations into geographically bounded and occupationally structured social pyramids, states and empires.

Using conquest and war between states/empires to expand the scale of and reap the benefits of activity coordination at a broader scale, e.g. ameliorating localised disasters, suppressing interstate conflicts

Using trade within and between states and empires to acquire resources for improving the efficiency with which production systems and production-support systems operate. Trade can lubricate a society by making a limiting resource more available.

Developing and adopting technologies (material, social, cognitive and communicative) which reduce the human effort needed to carry out the tasks through which society reproduces and protects itself from environmental and other variability.

The fact that humans have not died out means that this survival strategy (including its various elaborations) has not failed, either before or after the Common Era began. Perhaps this has just been luck in that if (e.g.) a slightly longer drought or more virulent pandemic had occurred, the species would have disappeared. Think how close to extinction the Mt Toba eruption brought humanity 70 kya. Alternatively, if they had occurred, Humanity may have survived disturbances much more threatening than those to which she was actually exposed. We cannot know.

Taking another tack, what if we imagine metaphorical Humanity to have been seeking to develop a *quality survival* strategy rather than one directed exclusively towards survival? Here, I mean a quality survival strategy to be one seeking to offer high quality of life to most members of the species. Many measures suggest themselves. One is how much exhausting and unrewarding physical work people have to do to survive. Another is how frequently and severely local and regional populations crash under the strategy. On both these measures Humanity's quality survival strategy seems to have performed badly, both before and during the Common Era. While war, famine and pestilence have not halted the upward climb in human numbers since the last glacial, countless regional and local populations have been depleted and disorganised by these and other associated scourges such as mass migrations and other flow-on effects of natural disasters. In between such disturbances, most people in most societies since the urban revolution have had their lives shortened by debilitating work.

While a survival strategy with the same broad foci (population, pyramidal societies, conquest, trade, technology) persisted through the Common Era, the particular technologies (including material, social, communicative and cognitive technologies) through which these focal concerns were recognised changed enormously. As consequential examples, the Common Era saw the emergence, although not necessarily the full flowering, of:

Markets for all factors of production, including land, labour and capital
Extraction and use of non-renewable energy
Technologies for systematically and deliberately creating new technologies, e.g. scientific research and development
Human rights
Global governance
Population control technologies
A global economy

In the next chapter we will consider a little of the Common Era's history, looking for trends, patterns and generalisations that provide context for understanding, and perhaps better managing the contemporary world. Here, we pause to bring together our accumulating understanding of the mechanisms underlying cultural evolution.

Explaining Change in Human Ecosystems

There are many perspectives from which one can view and begin to understand how human ecosystems change with time. In my book *Deep Futures* I find value in viewpoints from all of history, geography, sociology-anthropology, social psychology, systems theory, ecology and evolutionary biology.[77]

The biological disciplines are rather more concerned with changes among species in general—their interactions and their phylogenetic-ontogenetic paths—than with the human species in particular. Nonetheless, despite fierce debate over the specifics of biological change (at *all* space-time scales), and despite its many gaps, the biologist's story of how the human lineage became hunter-gatherers is plausible (no miracles) and wonder-full (Fancy that!). By the end of the last ice age, the species' capacity to adapt had equipped it with a phenotype (set of behavioural and physical characteristics) and a suite of cognitive, social, material and communicative technologies which, with or without any further evolution, was going to allow the species to survive and multiply under the markedly different conditions of the Holocene. In many ways, humans turned out to be pre-adapted to their new environment.

While the creation of biological adaptations by natural selection, symbiosis, self-organisation, etc., has never stopped, the additional contribution of such to the persistence of the human ecosystem declined relatively and (probably) absolutely after the emergence of modern humans (c.200 kya). Thereafter it was cultural evolution—treated here as much the same as technological evolution when the latter is broadly defined—which, *prima facie*, produced the adaptive behaviours that appear to have allowed humans to continue surviving. Thus, come the Holocene, it was cultural-technological evolution which was largely responsible for the Neolithic, urban and consciousness-cognition revolutions.

And, as argued earlier, cultural evolution is strongly analogous to the basic Darwinian process of natural selection through variation and selective retention—but with two exceptions. One exception is that variations in the pool of available technologies are not only generated by random exploratory behaviour but *purposively* in response to a perceived opportunity or challenge. More of that below. The other difference is that the process of selecting which new technologies will be adopted widely is more accurately thought of as a diffusion process based on imitation and learning, rather than as one based on relative reproductive success. Together, these differences convince some to describe cultural evolution as more Lamarckian than Darwinian.[78] Perhaps so, but what is more important is to recognise that both speciation and changes in human ecosystems exemplify the same process of universal evolution. It is the 'details' that are different.

[77] Cocks, D., 2003, *Deep Futures*: *Our Prospects for Survival*, University of New South Wales Press and McGill University Press, Sydney and Toronto.

[78] Hodgson, G.M., 1999, *Evolution and Institutions*: *On Evolutionary Economics and the Evolution of Economics*, Edward Elgar, Cheltenham.

With the arrival of the Holocene, the perspectives of the human-centred disciplines become increasingly relevant to the modelling of change in human ecosystems. This is particularly so as equilibrium-centred theorising about human societies has given way to change-centred theorising; that is, there has been a shift from seeing societies as basically unchanging to seeing them as always changing, sometimes rapidly, sometimes (very) slowly. Basic to the theorising of the human-centred disciplines is the idea of *agency*, i.e. of individuals and groups (virtual species, classes, states, interest groups, etc.) responding to changes in their circumstances by making *behavioural choices* according to various more-or-less rational criteria, including their beliefs and preferences. British philosopher, R.G. Collingwood was especially appreciative of the role played by thinking in determining historical phenomena: 'All history', he once affirmed, 'is the history of thought'.[79] Given this starting point, social change can be studied in terms of the cascading mutually causal interactions that are triggered by the behavioural choices of groups and individuals. But of course it was not until the Holocene that societies produced the social groupings and autonomous individuals which make such a conceptualisation possible. The view that people, individually and collectively, can act as change-agents in society is recognised explicitly in schemata such as Anthony Giddens' *structuration* and Christopher Lloyd's *structurism*.[80] What is being further suggested here is that behavioural choices can often be interpreted as decisions to apply some existing or, occasionally, newly created technology to what-to-do situations.

The idea that the evolution of human ecosystems—*eco-cultural evolution*—can be understood as a pageant of changing interdependent technologies is not at all new. The very naming of Holocene time-blocks after material technologies (Bronze Age, Iron Age, etc.) tells us that. Gordon Childe and Leslie White are two well-regarded pioneering students of Holocene societies who give technological change a central role in their histories, although both are working with a narrower, primarily material, understanding of the nature of technology than I am.[81] Sociologist Gerhard Lenski is another who sees sociocultural evolution as a process of technological advance with downstream consequences.[82] Lewis Mumford, a great historian, gets closer to the perspective being taken here when he suggests that large groups acting coherently, e.g. to build pyramids, have all the characteristics of large machines with human components, what he called *mega-machines*.[83] My perspective is that the 'recipe' for, say, building pyramids is a *social technology*. Another example: Graeme

[79] Collingwood, R.G., 1946/1994, *The Idea of History*, Oxford University Press, New York, pp. 214–215.

[80] Giddens, A., 1979, ibid.; Lloyd, C., 1993, ibid.

[81] Carneiro, R.L., 1973, A Reappraisal of the Roles of Technology and Organisation in the Origin of Civilization, *American Antiquity*, **39** (2), pp. 178–186.

[82] Lenski, G., and Lenski, J., 1974, *Human Societies*: *An Introduction to Macrosociology*, (2nd Ed.) McGraw-Hill, New York, p. 79.

[83] Mumford, E., 1983, *Designing Human Systems*, Manchester Business School, Manchester.

Snooks is the economic historian who sees war, population growth, trade and (material) technology as the main tactics employed in humanity's long-term survival strategy.[84] Without judging Snooks' insight *per se*, I group war, population growth and trade as social technologies. Even Marshall McLuhan's famous aphorism, 'the medium is the message', is saying that technology, directly or indirectly, drives change—once it is realised that for McLuhan *medium* means any extension of our bodies, minds or beings and that the *message* of any medium is the changes in scale, pace or pattern that it causes in a culture.[85]

Perhaps it needs to be pointed out before proceeding that what is being advocated here is not *technological determinism*, at least not in the simple reductionist ('nothing but…') sense of that phrase, i.e. the view that technology (alone?) determines history, or that spontaneous developments in technology are the (only?) triggers of social and cultural change. Or, more narrowly, that developments in a particular functional group of technologies (e.g. energy technologies) suffice to explain history. Such a view is unsatisfactory because it fails to capture the idea of *eco-cultural evolution*, i.e. that (material) technologies and institutions (which I am calling social technologies) coevolve both with each other and with the ecosystem-resource base.[86] Every widely adopted innovation creates niches (externalities) which may or may not evoke further innovations. For example, urbanisation created a niche for disease-control technology which was not filled till the arrival of public health reforms in Victorian times. Simple determinism does not capture the element of niche-identification and purposive experimentation which underlies much technological innovation.

Patterns of Technological Change

Unfortunately, modelling and understanding eco-cultural evolution in terms of coevolving technologies confers little capacity to predict future eco-cultural evolution. This less-than-encouraging conclusion is consistent with the view that social systems are true dissipative systems which self-reorganise spontaneously (although not necessarily rapidly) when energy flows through the system change sufficiently. A decision to adopt a technological change is a bifurcation (meaning, in physical terms, a small, critical energy fluctuation), under the influence of which the social

[84] Snooks, G.D., 1996, *The Dynamic Society*: *Exploring the Sources of Global Change*, Routledge, New York.

[85] McLuhan, M., 1962, *The Gutenberg Galaxy*: *The Making of Typographic Man*, University of Toronto Press, Toronto, pp. 43–44.

[86] By viewing cultural evolution in terms of the co-evolution of material and social technologies one avoids bruising arguments as to which of these leads and which follows in the development of culture. See Carneiro, R.L., 1973, ibid.

system moves into a new behavioural domain (basin of attraction). In this new domain the society still reproduces itself (cycles) in much the same way but, reflecting the use of new recipes, with some modifications to the ways energy is allocated to different functions. Accepting societies to be true dissipative systems does not preclude seeing them as systems of coevolving technologies. In appropriate context each perspective is valid and useful.[87]

While making specific predictions about future change in specific human ecosystems will always be fraught with uncertainties, there are, nonetheless, all sorts of patterns in the history of eco-cultural evolution and, if a specific situation matches any of these, a plausible scenario or two for that situation might thereby suggest itself. The modest value of this is that if any such unsurprising scenario implies a significant threat or opportunity, then it would seem sensible to act as though it were highly likely to occur.

Here we have space to mention but a few (overlapping) generalisations and patterns which illuminate how technologies, singly and together, rose, persisted and fell as threads in the tapestry of eco-cultural (co)evolution, both prior to and during the Common Era.

All Technologies Are Energy Technologies

While many threads can be extracted from the rich tapestry of cultural change in post-glacial societies, two stand out. One is the increase over time in energy use per capita per annum, and the other is the increasing complexity and size of social structures (more people in more groups, more interactions between groups). And, as suggested, the streams of technologies underlying these two trends can be seen to have coevolved. Cottrell suggests that the amounts and types of energy a society employs not only condition its way of life materially, but set somewhat predictable limits on how that society can and will be organised.[88]

More specifically, technologies which increase a society's rate of energy conversion (i.e. from one form of energy into entropy and other (useful) forms of energy), necessarily require additional social structures and relations to acquire and guide the flow of that additional energy through the society's technological processes, determining just where and when it is converted and what further energy conversions it might trigger. Complexification then is a natural correlate of increased energy use. Population growth is commonly a part of complexification too and particularly tends to occur when there is a sustained increase in the food energy available to a society. Increased pollution and resource degradation are other tendencies

[87] Abel, T., 1998, Complex Adaptive Systems, Evolutionism, and Ecology within Anthropology: Interdisciplinary Research for Understanding Cultural and Ecological Dynamics, *Georgia Journal of Ecological Anthropology*, **2**, pp. 6–29.

[88] Cottrell, W.F., 1955, ibid.

associated with increased energy use, particularly when a system's additional energy supplies come packaged with materials, e.g. food, wood. In this case, pollution is simply the material residues remaining after the potential energy has been stripped out. In other cases, resource 'degradation' is simply a rebadging of the fact of resources being diverted from a shrinking system (e.g. forest) to an expanding system (e.g. farming).

All technologies are energy technologies in the sense that they convert energy in one form to energy in another putatively more useful form. Jewellery making, to take an unlikely example, uses human kinetic energy to redistribute energy stored in the bonds of gemstones from one set of configurations to another. Spear-making produces a tool which allows human kinetic (movement) energy to be concentrated onto a small surface area. But technologies which, like these examples, use small amounts of energy per se are not for that reason unimportant. Many such are *trigger technologies* which are not directly useful but which inject sufficient *activation energy* into another more useful energy conversion process to allow it to proceed spontaneously. Verbal commands and signals which use small amounts of energy to convey, potentially, large quantities of information on which people then act, are good examples. Indeed, all conscious activity is triggered by the cognitive technology of decision-making. In some situations, a sequence of triggers may be required before the target technology is activated as when sparks are struck to initiate the energy-extracting technology of burning wood in a hearth.

In general, a trigger is an energy-dissipating perturbation that releases or inhibits the further dissipation of its own energy or that of other energy forms. Richard Adams nominates triggers as the key mechanisms that relate one dissipative event to another.[89] A trigger always has an energy cost and an energy yield and, to achieve efficiency in energy use, it is important that the ratio of yield to cost be as large as possible. For example, if human labour is the trigger which converts solar energy to grain, there must be a surplus of grain-energy output over human-energy input if this technology is to persist.

And, as discussed earlier, it is when that surplus is large that job specialisation and urbanisation become possible; the use of human energy to organise and increase control over human energy is a defining characteristic of civilisation. Even when it is not efficient in energy cost-yield terms, stratified societies may choose to co-ordinate and concentrate human energy to undertake tasks which would otherwise be impossible, e.g. manning galleys, building pyramids. The use of draft animals for ploughing is another example where the capacity to do work at a high rate during a critical few weeks of the year may be more important than being energy-efficient.

A society can only use more energy if it first extracts more energy from primary sources in the environment. Thus undomesticated plants and animals were almost the only primary energy source for hunter-gatherers; cultural evolution for them was

[89] Adams, R.N., 1975, *Energy and Structure*: *A Theory of Social Power*, University of Texas Press, Austin and London, p.49.

largely expressed in the form of better tools. At some stage, fire, a technology for releasing the energy stored in wood, appeared. Fire was a fundamental advance which opened the door to an intensification and geographic expansion of human society. In Neolithic and post-Neolithic times, undomesticated plants and animals were largely replaced by domesticated species as the primary energy source, along with a range of production technologies which increased the efficiency with which energy could be extracted from these sources, i.e. which saved human energy. Harvesting with sickles and ploughing are examples of energy-saving technologies. Sailing vessels were almost the only radically new energy-extraction technology to appear, and that in a minor way, in the Bronze and Iron Ages. Their time would come.

And, to complete a first simple functional classification of energy technologies, *energy-storage technologies* became possible once the technology-mix was able to reliably produce an energy surplus; granaries and domestic animals themselves are good examples.

So, it is being suggested, any individual technology in a society's changing mix of technologies can be interpreted as contributing to that society's energy security (stability of energy flows) in one or more ways as follows:

Energy extraction, e.g. fire-making, food-gathering, animal domestication, sails, marauding, enslaving
Energy release (triggering), e.g. verbal commands, signals
Energy saving, e.g. hand tools, water wheels
Energy conversion, e.g. cropping, food-sharing
Energy concentration, e.g. labour gangs, galleys, draft animals, hand tools and other prostheses
Energy storage, e.g. granaries, domestic animals

Now we have a vocabulary for understanding, with hindsight, the energetics of cultural change, i.e. a society's changing patterns of energy flows and its behaviour as a dissipative system. Any historically changing mix of technologies can be described in terms of changes in energy extraction, concentration, storage, etc. And, qualitatively at least, such changes can be evaluated in terms of their capacity to deliver stable or smoothly changing energy flows. For example, food-storage and food-sharing technologies allow a society to survive natural fluctuations in food production.

Many Technologies Are Combinatorial

Not all new technologies involve an upgrading of components in existing systems. Many are *combinatorial*. That is, components of established technologies are linked together to form a new composite technology.[90] Bronze production is a good

[90] Arthur, A.B., 2009, *The Nature of Technology*, Penguin, London.

example of a 'long chain' technology, requiring as it does the linking of mining technologies, transport technologies and smelting technologies. And while bronze production is a material technology, it would not be possible without adequate social technologies for co-ordinating the links in the production chain.

We might also note, in terms of coevolution, that improving one link in such a production chain can highlight a need to improve other links. More generally, as the stock of available technologies increases, the number of possibilities for combining existing technologies into new technologies increases even faster. In principle then (there are many barriers) it should not be surprising to see (fitful) *compound growth* in the pool of available technologies; what we might call the stock of *cultural capital*. Indeed, some writers, Hornell Hart being one, suggest that cultural capital accumulates at a compound growth rate which itself increases over time.[91]

Initial Conditions Shape Technology Opportunities

Another principle for understanding (but not predicting) technological change is that opportunities for introducing new technologies into 'unoccupied niches' are highly dependent on the configuration of the pre-existing environment, both natural and as socially constructed. The phrase *path dependency* captures the idea that a society's past choices of technologies constrain the choices available to it ('structure the alternatives') in the present and the future. Historical geographer Robert Dodgshon lists the types of constraints, what he calls *historical bindings*, which any new or replacement technology will have to satisfy. His list includes natural laws, physical limits and logical, technological, economic, ethical, psychological, cultural and political constraints.[92]

The importance of such *initial conditions* is well-evidenced by Jared Diamond's explanation of how cultures evolved differently in different regions according to the possibilities in each for domesticating local plants and animals. Thus, early Eurasians had access to plants and animals that were intrinsically susceptible to domestication, but this was less so in the Americas and even less so again in Australia. While Australian Aboriginals had little in the way of domesticable species available to them, Andean farmers could build a food production system around five local species: llama, alpaca, guinea pig, potatoes and a grain crop, quinoa.[93]

While the specifics of new technologies are unpredictable, can anything be said about what sorts of initial conditions are particularly likely to evoke new technologies? Certainly there is little to suggest, prior to the Common Era at least, that the

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[91] Hart, H., 1959, Social Theory and Social Change, In Gross, L. (Ed), *Symposium on Sociological Theory*, Harper an. Row, New York, pp. 196–238.

[92] Dodgshon, R.A., 1998, *Space*: *A Geographical Perspective on Change*, Cambridge University Press, Cambridge.

[93] Diamond, J., 1977, ibid.

idea of proactively seeking to improve existing technologies was part of people's thinking. The first exceptions to such thinking may have come in areas which had already accumulated a long visible history of technological change; the family of warfare technologies which had been evolving since Neolithic times is a good example.

More reactively, 'Necessity is the mother of invention', as the saying goes. Initial conditions which include threats to the ongoing smooth operation of an established society seem particularly likely to trigger innovative responses in material, social, communicative or cognitive technologies. The improvement in cognitive technologies in the chaotic times at the end of the Bronze Age is one dramatic example. So indeed are the Neolithic and Urban revolutions themselves.

Exhaustion of a widely used resource has ever been a common challenge to existing technologies. Running out of timber or building stone or, because of population growth, out of habitable land are obvious examples. As one particular pattern of human exploitation of the environment began to encounter difficulties, thanks to exhaustion of one or another key resource, human ingenuity had to find new ways to live, acquiring new supplies by trade or war or by finding replacement technologies. From a dissipative systems perspective, this is self-reorganisation.

Note that if a society has reached its capacity to acquire and use a particular form of energy, a new technology which uses that form of energy can only be taken up if the use of an existing technology processing that energy form is discontinued. The need to re-allocate a fixed labour force if a new form of social organisation is to be implemented is a good example. In more recent times, of course, many such re-allocations are made through markets. A corollary to this *re-allocation principle* is that technology development does tend to follow an *economising principle*, namely, to use as few resources as possible to satisfy society's needs, particularly those in limited supply.[94]

Technologies Come and Go

Why do technologies disappear? One reason has just been given but basically it has to be because the niches (needs) they are filling disappear or their niches can be better filled by other means. Weapons provide good examples of both processes. Sometimes one can track a technology as it is being adapted to a changing niche till, at some arbitrary point, it 'disappears' by morphing into a new technology. Sometimes there is genuine coevolution between the niche and the technology; pot-making is one example, writing is another.

And, between their birth and death, why do technologies persist? A promising new technology is not taken up rapidly unless it is imposed from above as may happen in a stratified society. Otherwise, it diffuses through and eventually saturates its

[94] Lenski, G., and Lenski, J., 1974, ibid., p 33.

niche as more people learn of, become aware of, its utility. And when it does disappear, it is more likely to fade away than vanish overnight; unless of course the society in which it is embedded suffers a collapse. Like many diffusion processes, the rates at which technologies spread tend to follow logistic or S-shaped curves, i.e. slowly at first, then rapidly, then slowly again. Truly fundamental technologies like language and writing seem destined to persist as long as their parent societies persist. More generally, new communication technologies have a special potential to increase the diffusion rates of other types of technologies.

In a general way it is *inertia*, society's tendency to resist change, which slows both the rise and fall of an emerging technology. Robert Dodgshon gives several examples.[95] The physical use of space in the past (e.g. structures erected, forests cleared) raises barriers against and reshapes opportunities for future change. His second example is institutional inertia. The standard analysis of institutional change sees ageing institutions becoming trapped in a performance crisis until a political crisis shifts the balance of power in a way which allows a radical overhaul of the 'rules of the game'.[96] Dodgshon's third example is 'knowledge inertia'. Societies transmit information in the form of cultural norms (how to behave, what recipes to use) from generation to generation and while there is a degree of selection and novelty in what is passed on, most is handed down unchanged.

Inertia is not necessarily irrational. For example, 'lock in' is the name given to the situation where an institution or organisation recognises that a new goal-seeking strategy would be more cost-effective than current strategy (equals initial conditions) if it were not for the investment cost involved in switching to the alternative. And, as suggested earlier (see page 121), risk of failure is another reason for inertia. For example, in hunter-gatherer societies operating near survival thresholds (e.g. the end of the last ice age), *technostasis* is the norm, i.e. the technology suite neither expands nor contracts. Why? The penalty for committing to a new technology which might subsequently fail is too high.

The obverse of inertia is stability. When technologies persist for a long time, they provide conditions, a nurturing environment, under which less stable technologies can evolve and adapt to the enduring technology. Adherents to a *cultural materialist* view of society are 'infrastructure determinists' who suggest that the entire structure (organisation) of any socio-cultural system rests on the way the society exploits its environment to meet the biological and psychological needs of the population.[97] That is, the (slow-changing) mode of production determines the forms of families, collectives and other group structures which in turn determine the behavioural and cognitive superstructure (social and cognitive technologies)

[95] Dodgshon, R.A., 1998, ibid.

[96] Visser, J., and Hemerijck, A., 1997, *A Dutch Miracle*: *Job Growth*, *Welfare Reform and Corporatism in The Netherlands*, Amsterdam University Press, Amsterdam, p.53.

[97] Elwell, F.W., 1991, *The Evolution of the Future*, Praeger, New York; Harris, M., 1979, *Cultural Materialism*: *The Struggle for a Social Science of Culture*, Vintage Books, New York.

of society. Infrastructure is given this leading role because it reflects the way a society adapts to its environment to meet basic needs—society's primary task. Group structure and mental and cultural superstructure must necessarily adapt to be compatible with the 'given' infrastructure (our values depend on the age in which we live). There is a clear debt in this thinking to Marx's basic idea that social life is shaped by the way people engage nature through production and that the mode of material production nurtures the forces which will guide social alignments such as class.

Cultural materialists nonetheless view societies as very stable systems with most changes in structural, infrastructural or superstructural technologies being resisted and dampened elsewhere in the system. Most successful social changes start with a mutual change in both the production system and its environment. Elwell claims that many of these reconfigurations have been changes that extract more energy from the environment, particularly where this favours the wellbeing of elite groups.[98] Intensification of the production system in this way leads eventually to some form of environmental depletion and then to either a sudden collapse of the cultural system or a shift to a new mode of production. If the culture shifts successfully, intensification starts all over again.

Fernand Braudel, the great French historian, had a comparable hierarchical view of social change. He saw geography as the enduring environment within which layers of institutional and psychological structures emerged and remained stable, often for generations, before crumbling away.[99] It is a view which equates with Eric Fromm's aforementioned observation that a society's social character will change readily to be compatible with its production system.

Confliction and Cooperation Have Long Shaped the Technology-Mix

Confliction and cooperation are pervasive behaviours in primate society (societies). Both can be regarded as 'umbrella' strategies (macro-technologies?) under which numerous social technologies for stabilising and/or expanding energy flows have evolved. Cooperation entails people working together to one end (e.g. a hunting party) and conflict entails people trying to thwart one another's behaviour (e.g. war). Both can be traced back to the primate trait of living in groups, each occupying a more-or-less fixed territory. This is, in several ways, an energy-efficient form of social organisation: being familiar with a territory means more efficient food-gathering and confers a knowledge of its danger spots. Living in groups, among other advantages, allows food-sharing, an early form of cooperation. Conversely, as an evolved 'technology' which differently helps to maintain this form of social organisation, primate groups attempt to aggressively expel trespassers, particularly

[98] Elwell, F.W., 1991, ibid., p.11.

[99] Braudel, F.,1972, *The Mediterranean and the Mediterranean World in the Age of Philip II*, (2 Vols), (Trans. S. Reynolds), Collins, London, Vol 1, p.16f.

of their own species—an early form of conflict. Aggression is behaviour intended to threaten or inflict physical injury on another. In tribal societies aggression is channelled and limited by customs rules, taboos, etc. It is further limited by the weapons available. Wesson makes the observation that, in tribal society, most aggression is initiated at the group level and most individuals simply conform, i.e. individuals are not particularly aggressive.[100]

By late Pleistocene times, aided by language as a coordination technology, hunter-gatherer groups had acquired well-developed social technologies for protecting and exploiting 'the leverage of collective action' within the group and, to some extent, between groups (e.g. intermarriage, trade). Within the group, behaviour would have been regulated by rules of co-operative conduct (e.g. gift exchange) which were partly instinctual and partly learned. Cooperation is best thought of as a strategy for amplifying the benefits of what can be achieved by individuals acting alone. Pooling of muscle-power, food, memory and artefacts are examples relevant to a tribal society. The kinship system can be thought of as a technology which, by creating an extended family, secures everybody's cooperation.

But, if it is to survive, cooperation has to be monitored to ensure that its dividends are fairly distributed. Cooperation based on direct reciprocity (immediate mutual aid) presumably evolved at some stage into a memory-dependent system of indirect reciprocity where cooperative behaviour could be legitimately rewarded at a later time and by people who had not benefited directly from the initial altruism. Indirect reciprocity is clearly an efficient rationale for cooperation but how, or if, it could have evolved through natural selection is a matter of some debate.

The role of aggression and hostility *within* the group is mainly to establish hierarchical standings and to protect the male–female pairing relationship, both behaviours which can be argued to have adaptive value. Having a leader is the extent of hierarchical organisation in tribal groups. A group with a courageous, skilled and aggressive leader stands to multiply and gain the security of greater numbers and a larger territory at the expense of other groups. Conversely, the efficiency of hunting and gathering for acquiring food declines beyond a certain group size. Tribal groups therefore tend to have upper an. lower limits on their size and much of our species' social behaviour is adapted to living in groups of, say, less than a hundred where all are known to each other.

The important conclusion emerging here is that a code governing cooperative behaviour and a code governing confliction (some would call it competition) were the twin foundations of tribal and intertribal social organisation. Indeed, both can be seen as aspects of an even higher-level strategy, namely interdependent decision-making. The further genetic role of these codes was in maintaining the system of small isolated groups which has been an ideal setting for rapid biological evolution. Both of these codes are elaborately adapted to the hunting and gathering mode of food production which hominids have followed for 99% of their history.

100 Wesson, C.B., 2010, *Introduction to Anthropology*: *Human Cultures*, Kendall Hunt, Dubuque, p.20.

But in the Holocene era, starting with a switch in the mode of food production to herding and cropping, these deeply engrained, largely unconscious, behaviour codes—probably what most people mean by 'human nature'—were increasingly required to guide behaviour in circumstances under which they had not evolved. As food surpluses per field worker increased, first under village agriculture and then within the irrigation 'civilisations', niches were created for both conflictual and co-operative strategies, both within and between societies.

While surpluses meant increased possibilities for communities to co-operate with each other through trade, stored food surpluses also became a new primary energy source for marauders (see page 150). Here was a novel way of extracting energy from the environment, one that yielded the human energy of slaves as well as food. Marauding was a conflictual technology which evoked countervailing technologies such as improved weaponry, static defences, larger settlements and, in time, standing armies. It was marauding which evolved in time into interstate and inter-empire warfare.

Simultaneously, the new surpluses were also evoking both cooperation and confliction within the growing communities themselves. Surpluses allowed a division of labour and skills between field workers and those who managed and protected the new production systems. This division of labour was an important co-operative or co-ordinating technology which allowed all participants to get more than they could alone or in smaller groups. But, over time, what had originally been a reciprocal exchange tended to become unbalanced with members of the management class accumulating more benefits than field workers, including economic and political power. Despite the risk of killing the goose that lays the golden eggs, it seems that once a group has obtained control over how surplus energy is used it is unwilling to return to a more equitable co-operative organisation of society.

By developing a suite of coercive, persuasive and belief-shaping technologies, ruling elites were able to extract maximum energy surpluses from their domesticated majorities for much of the Bronze Age. But while most people are accepting of authority in their lives they also have a limit to their tolerance of inequality and there was a high, but little recognised, level of resentment and revolt in many agrarian societies.[101]

Along with the invention by Bronze Age states of conquest and empire-building as a technology for acquiring food and human energy (slaves) came the scaled-up use of coercion to increase food production and to transfer maximal surpluses to the conquerors. Diverse technologies for the prosecution of war and the management of colonies emerged to support the use of conflict to secure energy supplies.

For further understanding of the roles of confliction and cooperation in shaping technology mixes across Eurasia in the millennia before the Common Era, it is helpful to think of *H. sapiens* as organised into virtual species, more commonly in

[101] Boyd, R., and Richerson, P.J., 1996, Why Culture is Common, but Cultural Evolution is Rare, *Proceedings of the British Academy*, **88**, pp. 77–93; Le Blanc, S., with Register, K., 2003, ibid.

conflict with each other than co-operating. Thus warring and trading states and empires were behaving as virtual species and, within individual states, powerful ruling classes and the masses they dominated also functioned as virtual species. Notwithstanding the waste and misery of all this, we have here a system of social organisation which was stable (i.e. persisted) for most of the Bronze Age. It was only for a brief time, starting with the axial age religions and limited democracy in the Greek city states, that post-tribal humans moved a small way past seeing societies as naturally divided into all-powerful rulers and masses with minimal rights.

Once a society has split into virtual species—groups with divergent interests—the tendency is for each virtual species to develop social, material, etc., technologies which further its own interests and, where they can, to suppress technologies which threaten those interests. For example, while new material technologies proliferated in the egalitarian societies of the early stages of the Neolithic Revolution such innovations were quite rare for much of the Bronze Age. Given a surplus of raw human energy (slaves and serfs) in the irrigation civilisations, it was not in the rulers' interests to encourage unsettling innovations which might have reduced workloads for food producers. On the contrary, social technologies for absorbing labour, building monumental structures for example, were developed. Such projects, like many social technologies are simultaneously cooperative (people working to a common end) and conflictual (enforcing cooperation). But whether such conceptualisations were consciously recognised at the time seems doubtful.

Recapitulation

A basic framework for understanding eco-cultural evolution can now be drawn together. It starts from a recognition that humans have long been organised hierarchically into 'larger' social groupings, each of which is made up of multiple 'smaller' groupings; and each smaller grouping is further divisible into even smaller groupings. Discussion above was limited to larger groupings called states-empires and smaller groupings of workers and elites within states, but could have been extended to a consideration of various categories of workers and elites or, indeed, to families and individuals.

Humans are all one species we know, but calling each grouping, large or small, a virtual species captures the idea that groups, as well as independently pursuing their members' security and quality of life, interact co-operatively and conflictually with other groups of not too dissimilar size and energy flows—just like species in canonical ecosystems. The result has been a kaleidoscopic history of groupings which, throughout the portion of the Holocene of present interest, have stagnated, stabilised, grown, regressed, branched, amalgamated, etc. Each virtual species persists for a time through the repeated use of a mix of technologies (material, social, cognitive, communicative) which more-or-less satisfies their material, social and psychological needs.

In parallel, each virtual species' technology-mix keeps evolving (sometimes by acquisition, sometimes by an endogenous process of variation and selective retention) as it attempts to adapt to the vagaries of the natural environment and to the threats and opportunities of its broader social environment as constituted by other virtual species. While we have canvassed a wide range of factors (energetics, inertia, initial conditions…) which play a part in determining what technologies, if any, might emerge in specific situations, none stand out as being strongly predictive of what will eventuate. The best we can say is that, retrospectively, one should be able to invoke these factors to plausibly explain particular innovations. Putting this more positively, a knowledge of their historical context is needed to understand and be unsurprised by contemporary events.

Coevolution of Virtual Species

How important is coevolution (mutual adaptation) between virtual species in this abstract descriptive model of eco-cultural evolution? Is there pattern in the way that relations between virtual species evolve over time? As stressed above, it is difficult to predict what will happen in specific situations but, provided that two (or more) interacting virtual species are embedded in a larger environment where energy flows are relatively stable, you would at least expect any ongoing interactions between those virtual species to 'grope' towards more coordination. And that will be so even when one has much more social (military, political, etc.) power than the other.

Being co-ordinated means that each virtual species has standardised, perhaps formulaic, responses to particular behaviours on the part of the other.[102] Because standardised behaviours (habits) are energy-conserving, even tacit coordination is a form of cooperation. Nor is coordination necessarily incompatible with conflictual relations. Even wars are loosely governed by rules which limit damage. Virtual species whose core behaviours are closely co-ordinated tend to become inextricably interdependent and therefore stand to be significantly disrupted by disturbances to their interrelationships. This is the downside of too much coordination; unforeseen disturbances readily threaten stability. Note the parallel to the short-sightedness of natural selection in biological evolution. In such situations, if decision-making were to be centralised under one controlling agent, individual virtual species, while losing some of their identity, might be protected from their own inflexibility. For example, if two warring states are integrated into a larger empire, they will be precluded from tit-for-tat war and given the opportunity to interact more productively. New forms of co-ordinated and centralised behaviour are discovered by experiment, either purposeful or playful. When such experiments produce 'improved' behaviours, these are retained—a process of trial and success. Societies stand to add a new hierarchical level each time newly centralised groupings of virtual species begin another round of coordination.

[102] Berger, P., and Luckmann, T.,1966, ibid.

A Sufficient Set of Ideas?

In this chapter we have reviewed, briefly and patchily, the eco-cultural evolution of human societies in Eurasia from the time of the hunter-gatherers who walked out of the last ice age through to the increasingly conscious civilisations that appeared in the wake of the Bronze Age in the centuries prior to the Common Era. This 10,000 year period saw three fundamental cultural shifts. One was the shift by Neolithic village communities to using domesticated plants and animals as their primary energy sources. The second, based on the achievement of regional food surpluses, was the further shift to a pattern of stratified urban societies in which surpluses were used to support populations of specialist workers, including priests and soldiers. Grafted onto this urban revolution was the widespread use by urbanised states of warfare, colonisation and enslavement to (it was hoped) secure, protect and enlarge their energy supplies.

The Bronze Age ended with the breakdown of what had become a shifting pattern of warring empires due, maybe, to both natural causes (climate change, earthquakes?) and, for what were still tribal minds, the unmanageable complexities of empire. The tribal mind had failed to cope with what it had created and, in its place, built on two coevolving technologies of the most fundamental kind, there emerged the modern mind. One was a form of writing which had symbols for vowels, a communicative technology which could capture and store speech. The other was the self-aware reflective mind, a cognitive technology embodying the skills to formulate and choose between alternative ideas and courses of action. This was the third revolution, what I earlier called the consciousness-cognition revolution. It was a revolution which strongly shaped the cultures of the Greek and Roman empires while they lasted but had somewhat less impact elsewhere. Nonetheless, the seeds of individualism had been sown, and sat quietly through the Dark Ages, ready to sprout during the Renaissance Spring.

The question we end on now is whether the coevolutionary processes that have been identified and developed as tools for explaining and understanding what happened to human culture in the Holocene, prior to the Common Era, will suffice to explain and understand cultural change thereafter. Our hypothesis is that the types of eco-cultural evolutionary processes identified in the Holocene-to-date also outline the possibility space within which those same processes could unfold in the Common Era. There is no reason to suppose otherwise, even though it is true that the last 2,000 years have seen massive and accelerating changes in population, energy-materials use, environmental impacts, human knowledge and relationships within and between virtual species. Cultural capital, meaning stocks of material, social, cognitive and communicative technologies has similarly grown. There have been revolutions galore including transport revolutions, fuel revolutions, the scientific revolution, the industrial revolution, the electronics revolution, the computing revolution, political revolutions, values revolutions, etc.

Many of these changes have been surprising to those living through them. Others have crept up on people. But, looking back, none are mysterious, not even consciousness if one can accept this cognitive technology as an expression of increasing language skills. A multiplicity of causal factors complicates understanding of some major changes and a simple lack of information draws a veil over others. Nevertheless, it has been possible to tell a rich plausible story about eco-cultural evolution up to the Common Era. As the next step towards building a *practical understanding* of the contemporary world, and taking a similar approach, we turn now to an overview, brief and patchy still, of eco-cultural evolution during the Common Era.

Chapter 4
The Road to High Complexity

This chapter continues our selective cultural history of *H. sapiens*, the animal species which, more than any other, has influenced the quantity of energy flowing through the global ecosystem and the paths which those flows take (war, population growth, monument building etc.). The best single indicator of the complexity of any energy-degrading system is the rate at which it processes free energy—as more and more energy flows through a system, degrading and converting to other forms as it goes, additional pathways made up of flow and storage structures are created and, usually, existing pathways are restructured. In the case of the human ecosystem, such thermodynamic changes come to be seen as cultural change—cultural evolution.[1]

Considering the human ecosystem as a whole, there has been a more or less monotonic increase (i.e. no significant reversals) in the amount of energy it has captured and processed in the last 12k years. Both the Neolithic and Urban revolutions can be viewed as having been triggered by the adoption of new more-productive technologies for acquiring food energy, technologies which appeared when the niches for previous technologies disappeared or degraded. Both revolutions relied (largely) on human and animal power to convert solar energy to food energy and both were accompanied by significant coevolution between food production and social and other technologies. The mid-Holocene's third revolution, the consciousness-cognition revolution, flowered only briefly in response to the failure of the 'cannibalistic' survival strategy of the Bronze Age.

Now we look to understand an era in which nonbiological energy sources start to play an increasing part in powering cultural evolution. Good examples, energy-extraction technologies which, over extended periods, have led to cascades of technology change elsewhere and to a changing cast of virtual species, include:

[1]Nils Bohr's Principle of Complementarity says two descriptions of nature are complementary when they are both true but cannot both be seen in the same experiment. In quantum mechanics, the wave picture and the particle picture of an electron or photon are complementary. Similarly, one can have a picture of cultural evolution couched in thermodynamic terms or in behavioural terms. Both may be true but descriptions from one perspective leave no room for the other perspective. But, as seems useful, one can switch between perspectives; also each description constrains what the other can say.

D. Cocks, *Global Overshoot: Contemplating the World's Converging Problems*,

DOI 10.1007/978-1-4614-6265-1_4,

Capturing wind energy using sailed vessels
Capturing the chemical energy contained in gunpowder
Capturing the chemical energy contained in fossil fuels
Of the biological sources of energy playing expanded roles in the Common Era (CE), horse power stands out (perhaps camel power too?)

More generally, my guiding principle for reducing what I know of the enormous history of the Common Era to an organised précis will be to try and identify trends, events, discontinuities and processes—such things as population growth, new technologies, human-made and natural disasters—which, on the back of trends in energy use, appear to have had the greatest consequences for the well-being of large numbers of people, either immediately or over time. Later, with the hope of getting a better idea of what we need to understand about contemporary societies if we are to pursue a social goal of 'quality survival', we will reflect on what has been selected.

The Last Two Thousand Years

> Away, for we are ready to a man!
> Our camels sniff the evening and are glad.
> Lead on, O Master of the Caravan:
> Lead on the Merchant-Princes of Bagdad.
>
> Have we not Indian carpets dark as wine,
> Turbans and sashes, gowns and bows and veils,
> And broideries of intricate design,
> And printed hangings in enormous bales?
>
> We have rose-candy, we have spikenard,
> Mastic and terebinth and oil and spice,
> And such sweet jams meticulously jarred
> As God's own Prophet eats in Paradise.
>
> And we have manuscripts in peacock styles
> By Ali of Damascus; we have swords
> Engraved with storks and apes and crocodiles,
> And heavy beaten necklaces, for Lords.
>
> James Elroy Flecker. The Golden Journey to Samarkand[2]

Trading Networks

One of the Common Era's first consequential cultural shifts was a sharp expansion in long-distance trade and communication between the four agricultural civilisations then containing a majority of Eurasia's (and hence the world's) people, i.e. the

[2]Flecker, J.E., 1913/1926, *The Collected Poems of James Elroy Flecker*, Secker, London.

Roman, Parthian (Persian), Kushan and Han empires. Movements, particularly of luxury goods, increased over both land and sea routes between east and west Eurasia. On land, the most famous of these trade routes was the Silk Road which split to skirt north and south of the hostile Tibetan Plateau. And at sea, ever-bigger sailing vessels plied the coastal waters of South and East Asia, venturing in time into the Indian and Pacific oceans. The regular seasonality of the north–south Monsoon winds was discovered some hundred years before the Common Era. Sailing vessels powered by wind energy would eventually supplant the technology of the pack animal (camels and dromedaries), and in the process change power relationships (Who controls trade?) between maritime and non-maritime states.

The linking of Eurasia's largest cities in a long-distance trading network brought material benefits primarily to consumers of high-value low-volume goods, i.e. to ruling groups. Trade is a technology which allows transport costs to be balanced against the benefits of regional specialisation and the savings which come from producing a product on a large scale. But that is only part of the story. Cities in the trading network became places where populations could and did grow, consolidating a trend towards urbanisation which continues to this day. Also, while trade provided the impetus, trade routes were increasingly conduits for the spread of learning, technology recipes, religions, art, genes and disease. Thus, an early consequence of this first drive towards a globalisation, a single world-system of commerce was epidemiological disaster as the separate disease pools of each empire (Plague, smallpox, measles, syphilis) mingled together. For example, drastic depopulation from disease in parts of the Roman Empire contributed to its disintegration. By the time the Western Roman Empire fell (476 CE), Buddhist missionaries, originally from north India, had already spread their influence as far as Japan and Java. Christianity too had spread, with the Roman Empire, through Europe and into Asia Minor where, in later centuries, Anatolia would become a shifting frontier between Islamic forces and Christian forces of the Byzantine or Eastern Roman empire. And, in India, Brahmanism and Hinduism were nurtured in the bosom of the Gupta Empire.

Northern Invaders

In the fourth and fifth CEnturies CE incursions of nomadic peoples from central Asia, possibly triggered by adverse climatic change, threw Eurasia's empires—Chinese, Indian, Persian and Roman—into disarray. The invaders were horse-riding pastoralists whose winning military technology was the use of mounted archers; they were mostly Mongoloids who spoke Turkish-family languages.

In Europe these nomad invaders were followed by Germanic-Turkic invaders (Goths, Vandals, Huns) from northern and CEntral Europe, peoples who had never been part of the Roman Empire. For 1,400 years from the sack and capture of Rome in 410 CE, Europe was a cauldron of constant war, pestilence and famine. Nonetheless, while the Goths sacked Rome, they respected and protected the Church which thereafter survived, albeit as a spiritually lifeless, dogmatic institution. The Western Roman Empire was replaced by smaller states, more self-sufficient but unstable and poorly coordinated; many with German kings. Urban populations shrank as people returned to village life. Indicatively, by the beginning of the sixth century, the numerous copper mines of western Europe had shut down, not to reopen till the tenth century. Brass, an alloy of copper an. zinc, seems not to have been made again till the fifteenth century.[3] Sea trade in the Mediterranean world, once it lost Rome's protection, was destroyed by pirates.

Without Roman legions to protect them, local populations across Europe turned to a feudal system of governance in which warlords and their mounted soldiers gave protection in exchange for loyalty and a life as a serf. Physical security and a subsistence existence were acquired at the price of individual freedom. Frightened and ignorant people submitted to the arbitrary and collusive authority of 'divinely ordained' monarchs, feudal lords, priests and a Pope whose infallibility was already being questioned. Economically, land was the basis of wealth. Socially, heredity was the determinant of position and opportunity. Intellectually, theological doctrine was the sole arbiter of truth. Greek ideas such as democracy and freedom of thought were suppressed by forces of religious and political absolutism, and would not reemerge until the fifteenth century. Europe's 'dark ages' had arrived.

In 535 CE, atmospheric dust and debris from a major natural event, perhaps a comet or asteroid, but most probably the eruption of Mt Krakatau in the Sunda Strait, initiated several years of low temperatures and reduced sunlight. This led to crop failures around the world, followed by some decades of climatic instability.[4] Plague (542 CE), droughts and floods which placed further pressures on social organisation and this period saw the collapse of societies beyond Europe, including the major civilisations of South-East Asia and South America. More generally, the sixth century, particularly after 535 CE, was a period of extensive political reorganisation right across Eurasia, e.g. the collapse of the southern Chinese empire during this time led to the consolidation of northern and southern China into a single empire, while the Indian Gupta Empire disintegrated in the face of invasions from central Asia.

Rise of Islam

In the century after the death in 632 CE of Mohammed, prophet of Islam, conquering armies from the Arabian Peninsula took their new religion as far west as Spain (711 CE) and as far east as northern India (713 CE). In Europe, classical learning now survived only in a Spain where Arabs (and North African Muslims) stayed to rule

[3] White, L., 1940, Technology and Invention in the Middle Ages, *Speculum*, 15 (2), pp. 141–159.

[4] Keys, D., 1999, Catastrophe: An Investigation into the Origins of the Modern World, Arrow, London.

for nearly 800 years. The Arabs had absorbed Greek culture when they overran Egypt and they presently established major schools and academies at Cordoba, Baghdad, Cairo, Damascus, Toledo and Seville. For some hundreds of years Muslim dynasties struggled to conquer the Byzantine Empire, succeeding when, marking the rebirth of the Ottoman Empire, Constantinople fell to the Ottoman Turks in 1453. Joseph Tainter argues that the Byzantine Empire survived as long as it did by simplifying—not complexifying as Rome did—the organisation of its army, government and economy.[5]

Europe Reorganises

Western Europe, in a period of increasing political integration under Frankish and Carolingian monarchies, began to recover from its dark ages in the eighth and ninth centuries. Charlemagne, king of the Franks from 768 to 814 CE, protected the papacy and, in time, gained legendary stature as 'the father of Europe'. His reign witnessed a shift in the centre of European civilisation from the Mediterranean to the plains of northern Europe, a shift that was later boosted by the occurrence of a 'medieval warm period' and by several new technologies. Dating of the medieval warm period is contentious but a reasonable estimate is that there was a core period from 950 to 1100 CE within a longer period of 900–1300 CE. One of the new technologies was a three-field rotation system which, through an understanding of how to exploit the spring rains of northern Europe, almost doubled crop yields. Another was the wheeled plough. And then, in the late ninth-early tenth centuries came three inventions for exploiting the strength of the horse—the horse-collar, the tandem harness and the horseshoe—which, taken together, to quote Lynn White, 'suddenly gave Europe a new supply of nonhuman power, at no increase of expense or labour'.[6] These inventions did for the eleventh and twelfth CEnturies what the steam engine did for the nineteenth CEntury. Horse power plus an increasingly widespread use of windmills and water-driven mills, allowed Western Europe to be, probably, the first-ever society to significantly replace human energy with nonhuman energy. Perhaps it was Europe's new energy surpluses which fuelled its 'twelfth century renaissance', a spectrum of developments in art, architecture, vernacular literature, law, philosophy, trading guilds, universities etc. For example, as early as 1210 CE theologians and natural philosophers at the illustrious University of Paris were debating the clash between revelatory knowledge and, following Aristotle, knowledge derived from the senses.[7]

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[5] Tainter, J.A., 2004, Energy and Sociopolitical Collapse, *Encyclopedia of Energy*, 5, (Ed Cleveland, C.), Elsevier, San Diego, pp. 529–543.

[6] White, L., 1940, ibid.

[7] Gaukroger, S., 2006, *The Emergence of a Scientific Culture*: *Science and the Shaping of Modernity*, *1210–1685*, Clarendon Press, Oxford.

Wind-Powered Trade

Elsewhere, from the eighth century, as Europe began to reorganise, a vibrant and dynamic Islamic culture entered a 'golden age', Sinic civilisation spread through Korea and Japan, and Indic civilisation spread through southern Asia. By 1000 CE, a complex network of trading routes linked the centres of manufacturing production in the Middle East, China, India and South-East Asia to each other and to underdeveloped suppliers of raw materials in Russia and Europe.[8] It was probably Arabs who, in the ninth century, invented the lateen sail which allowed tacking against the wind, extended traders' capacity to make sea voyages and allowed crew sizes to be reduced. The lateen was the forerunner of the fore-and-aft-rigs which would be the technologies behind the great ages of sail yet to come. By 950 CE the Mediterranean was virtually a 'Muslim lake'.

Spurred on by the Song-dynasty government and a rich merchant class, China was at the heart of this reinvigorated maritime trading system. Drugs, aromatics, textiles, base and precious metals were imported and exported. Ceramics, paper and prints were major exports, and sulphur for making gunpowder a major import. Some important exports were products of government monopolies. Foreign and domestic traders were taxed, as were their ocean-going ships. Duties were levied on imports. In a drive to monetise the Chinese economy, large quantities of copper coins were minted. Thomas Crump describes money as, after language, humanity's second most important invention![9] Metaphorically, it stores skill and labour and also translates one skill into another.

China's domination of global maritime trade continued even as, following the Song dynasty, it became a khanate (subdivision) of the Mongol Empire. The Yuan dynasty (1271–1368) was established by ethnic Mongols under Kublai Khan. In the fourteenth and fifteenth centuries China sent forth the largest ships and greatest fleets the world had ever seen, voyaging from the Arctic to the coast of Africa. Sending ships to London was well within China's technological capacities but after a few voyages Chinese shipping pulled back behind the Indian Ocean. For them, there was nothing tradable in Africa, and little in Europe. Nor was the Pacific of economic interest. Goods of value came mainly from the Middle East and India as they had for hundreds of years. Fortuitously, the monsoon winds in East Asia blow down the China coast and east from India, and then reverse with the shift of the seasons. This meant that ships from China, India and the Arab world could converge on Malacca and Aceh in south-east Asia, exchange cargoes there and sail home on favourable winds. From Korea and Japan to the Philippines, Chinese merchants built up a thriving maritime trade which lasted well into nineteenth century.

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[8]Goldstone, J., 1998, The Problem of the 'Early Modern' World, *Journal of the Economic and Social History of the Orient*, 41, pp. 249–284.

[9]Crump, T., 1973, *Man and His Kind: An Introduction to Social Anthropology*, Longman and Todd, Darton, p. 73.

The Islamic Empire

The 'golden age' of Islamic culture which began in the eighth century was a period in which the Islamic Empire, under the Abbasid Caliphate, not only grew to be the largest the world had yet seen but came to be the unchallenged world-laboratory for developments in science, philosophy, medicine and education. By 900 CE there were hundreds of shops employing scribes and book-binders in Baghdad, capital of the empire. It was an empire in which political control and cultural-religious influence followed the new dominance of Muslim over Chinese merchants along African-Arabian and Arabian-Asian trade routes. A widely accepted Islamic currency was created. To this day, western Africa and south-east Asia have large Muslim populations. Internally too, political power went with trading success rather than with land ownership. This was very much an urban civilisation. Already destabilised by a procession of crusading Christian armies from Europe (1095–1291) and by declining crop yields (due to soil salinisation), the empire's golden age came to an end when a Mongol Khan sacked Baghdad in 1258.

The Mongols

Who were these Mongols who conquered most of the Islamic empire as well as Song China? Indeed, their spectacularly successful cavalry also conquered much of Russia and eastern Europe. With horses in reserve, a Mongol army could advance 60–70 miles in a day. Driven by drought probably, they emerged from central Asia under the leadership of Genghis Khan in 1206 CE and by 1300 CE controlled most of the world's major cities. In 1405 CE, their empire held sway over more than 100 million people and covered almost a quarter of Earth's total land area—from the Pacific to the Black Sea and from Siberia to near-India. And by 1502 it had gone. The khanates into which it had been subdivided collapsed or were variously defeated and absorbed by neighbouring states. As much as anything it was Bubonic Plague (erupting in 1346) which was responsible for this rapid decline, a decline which included the closure of the great overland trade routes. Also, the spread of hand-held firearms allowed the once invincible mounted nomads to be repulsed. Remnant Mongol populations in the former eastern khanates became Buddhists and those in the western khanates became Muslims.

Gunpowder weapons had been in regular use in China from the early tenth century and their use had spread across Eurasia into Europe by the early thirteenth century. Cannon were regularly used in sieges of castles and cities from the early fourteenth century. The Ottoman Turks used large cannon at the final siege of Constantinople in 1453. Indeed, a factor in the decline of feudalism was that the castles of feudal lords were henceforth only temporary refuges. Small arms evolved rapidly from 1300 and by 1600 gunpowder weapons had revolutionised armies and warfare (e.g. reduced the role of cavalry) and an 'arms race' to acquire superior weaponry had taken off.

Islam's 'Post-Mongol' Empires

With the collapse of Mongol administration of the Islamic world in the fourteenth and fifteenth centuries, three new Islamic empires began forming across Asia: the Ottoman Empire in Asia Minor, the Safavid Empire in Persia, and the Mughal Empire in India. Together, these 'post-Mongol, post-plague' formations became the vehicle which carried the Islamic world from medieval to early modern times.

By 1529, the Ottoman Empire, first formed in the early fourteenth century, had expanded into Europe as far as the gates of Vienna. And in 1535, by taking Baghdad from the Safavid Persians, the Ottomans gained naval access to the Persian Gulf. One of the constraints on Ottoman expansion into the Indian Ocean was the difficulty of arranging supplies of naval timber for the Basra shipyard, which had to import suitable wood down the Euphrates from Anatolia. The Empire was already a dominant naval force in the Mediterranean and remained so until beaten at sea by the Holy League coalition in 1571. The Empire reached its peak influence around 1600, and then gradually declined, due to both internal disorganisation and to pressures from its enemies in Asia and Europe (e.g. the battle of Vienna in 1683). Economically, a huge influx of Spanish silver from the New World caused a sharp devaluation of the Ottoman currency and rampant inflation. Nevertheless, the empire survived till disbanded at the end of the First World War. Present-day Turkey is the remnant state.

The Safavid Empire started as a Shi'ite religious community which acquired the political and military strength to split from the Ottoman (Sunni) Empire in 1501. Its initial wealth came from its position on east–west trade routes but, to the Persians' disadvantage, these routes shifted in the seventeenth century. The Persians had to fight to protect their empire (something larger than present-day Iran) not only from the Ottomans but from their other Sunni neighbour, the Mughal Empire, and, from the north, Russians and Uzbeks. In 1722 the Safavid Empire fell to Afghan invaders. Out of its remnants grew the present-day theocratic state of Iran.

Mughal is the Persian word for Mongol. The Mughal Empire was established by descendants of Ghengis Khan in 1526 and, at the height of its power, around 1700, it controlled most of the Indian subcontinent and parts of what is now Afghanistan. The tolerance of its rulers towards the majority Hindu religion helped keep the peace. But, like the Ottoman and Safavid Empires, the Mughal Empire's power eventually declined, and it was absorbed by the expansion of the British Empire in India in the mid-nineteenth century.

Early Renaissance

From the twelfth century onwards, European feudalism began to decline and, by the late fourteenth century, following the ravages of the Black Death, was no longer a political and social force. Towns and cities, with their craft guilds and tradespeople, were growing in economic-political power and the lord-serf relationship was giving way to a monarch-subject relationship. The wool trade was becoming one important stimulus to development. But, of most significance here, a number of Italian cities (especially Venice, Florence, Milan, Naples) began to grow very rich in the late twelfth to thirteenth centuries through being intermediaries and bankers to the trade, particularly in meat-preserving spices, between central Europe and the Middle East. Wealth helped these cities, together with their hinterlands, acquire the status of autonomous city-states and, over the fourteenth, fifteenth and sixteenth centuries Italy's commercially active city-states were at the centre of a further revitalisation (renaissance) of European culture. Perhaps we can think of the Renaissance as beginning in the early fourteenth century with the publication of Dante's *The Divine Comedy*, possibly the greatest adventure story of all time? Italy's city-states competed with each other to be patrons of art, literature and philosophy and to establish academies for humanistic education.

But the early fourteenth century was also a calamitous time for Europe. The medieval warm period, a part-explanation for several previous centuries of population growth, was coming to an end. Winters were harsher, crop yields were down, grain prices soared and famine and war pruned populations heavily. Self-serving monarchs and callous landowners accentuated a general decline in living standards. And then came a pandemic of Bubonic Plague, a fatal disease spread by fleas which live on rats and humans. It started in Asia and travelled to Europe in rat-infested Italian ships trading goods across the Mediterranean. The 'Black Death', as it was known, reached England in 1348 and by 1351 had killed over a million people, one-third of Europe's already malnourished and susceptible population. Farm-labour shortages then further reduced food supplies.

It was not till the late fourteenth century that political order and levels of trading activities began to recover, not only in Europe but in Eurasia generally. Food became increasingly plentiful. In Europe, a trend towards developing strong stable monarchies became noticeable e.g. in England, France, Netherlands and Belgium as well as Spain and Portugal. A dynastic monarchy is a social technology with the potential to reduce succession tensions, inspire public obedience on the grounds that kings are divinely appointed and, through marital unions, create larger kingdoms.

The essence of Renaissance humanism was its rejection of the Church's obsession with the afterlife and its model of humans as poor sinful creatures whose only hope was to follow God's constraining and tyrannical edicts. Renaissance humanism preached confidence in people's ability to find the springs of right action within themselves. Its rejection of authoritarianism extended to looking at the natural world through one's own eyes (e.g. Leonardo, Vesalius), a perspective which we now recognise as *scientific*.

Following the capture of Constantinople in 1453, there was an exodus of Greek scholars to Italy, carrying a knowledge of Greek literature and other learning which the West had long lost; in part, the Renaissance blossomed in Italy because it was near Greece and had inherited Greek-influenced Roman traditions. Most importantly, the Renaissance had rediscovered the self-awareness and speculative capacity which had emerged with the great religions and in classical Greece—what I earlier called the cognition-consciousness revolution. Michel de Montaigne's *Essays* (1580) are, arguably, still unsurpassed as an example of a man finding self-knowledge.[10] As is so often the case in cultural evolution, ideas which had been long dormant came to life when conditions suited.

Printing

However, it was in Germany rather than Italy that a technology emerged which, fuelled by the Renaissance spirit, would set off a cultural explosion, a period of rapid, accelerating cultural evolution, across Europe and then the world. In 1436 Johannes Gutenberg combined a number of preexisting technologies (the wine press, paper, ink, replaceable wooden or metal letters) to produce the first (debatably) printing press. By 1501 there were 1,000 printing shops in Europe, which had produced 35,000 titles and 20 million copies of books, almanacs etc.

The great Dutch scholar Erasmus retranslated the New Testament in 1516 and within a year Martin Luther had initiated the Protestant Reformation. As bibles tumbled from the presses, ordinary people could, for the first time, study the Christian story for themselves. The market for books in languages other than Latin boomed and this had the side-effect of fostering feelings of regional unity and nationalism. People were now able to read, for example, the works of the literary giants of the Renaissance—England's Shakespeare, Spain's Cervantes and France's Rabelais. Nationalism did begin replacing religion as people's primary loyalty but, notwithstanding, religious bigotry and zeal would prove to be as important as trading rights and territorial ambitions in driving centuries of warfare between Europe's emerging nation-states, e.g. Protestant England versus Catholic France, Protestant Netherlands versus Catholic Spain.

There is another quite different way in which the invention of printing transformed the human mind. It can be argued that the invention of printing was also the invention of *standardisation*, an idea, a metatechnology (a technology for implementing other technologies), which is fundamental to the practice, *inter alia*, of bureaucratic organisation, industrial capitalism, scientific research, law, education and commerce. Like space and time, standardisation, the explicit adoption of and commitment to behavioural norms, is one of those generic ideas which are so big that, paradoxically, they are all but invisible. It is a background technology which, like custom, allows people to coordinate with each other.

Book printing was the world's first mass production process. It is a process in which standardised inputs are fed through a repetitive operation to produce standardised outputs. Henry Ford was a copycat! More than this, as books were produced in increasing numbers they became more standardised, more like each

[10]Montaigne, Michel de, 1580/1743, *Essais* translated into English by Charles Cotton as *Montaigne's Essays in Three Books*, B. and B. Barker, London.

other with respect to page layout, letter shapes, spelling, punctuation and word meanings. This loss in variety vis-à-vis the idiosyncrasies of manuscripts gave books a relatively greater usability.

In general, standardisation is a metatechnology which reduces the costs of communicating and implementing recipes for social, cognitive and material technologies. Provided the technology user understands the relevant standards, it does this by increasing his/her prior confidence as to what a recipe (really) means and in the likely qualities of the product. Once shown the way, the Renaissance mindset was to embrace standardisation, e.g. shipbuilding in sixteenth century Venice. It is not too much to say that, from the Renaissance to the twenty-first century it has been standardisation, including standardised money, which has allowed transactions and coordination between the specialist sectors of a multi-sectoral economy to take place.

Once they could be powered by coal and oil, standardised industrial technologies replaced, more than replaced, man and beast. Social organisation and values tagged along behind as Marx said they would. But the knowledge to keep the whole rambunctious show on the road was book knowledge, transmitted and updated from one generation to the next.

The Rise and Decline of Spain and Portugal

From the early fifteenth century until the early seventeenth century ships from several European countries on the Atlantic seaboard, traversed the world in search of new trading routes, new trading partners and particular trading goods, notably bullion and spices. In the process, they encountered peoples and lands previously unknown to them. Their initial goal, profit, was later expanded to variously include conquest, settlement and conversion of the heathen.

Portugal, resource-poor and small, but a nation with a long-established sea trade into northern Europe, led Europe's attempts to participate in a revitalised world economy, one dominated by the Ottoman and Chinese empires. Europe's problem was that its traders, particularly after 1453, were discouraged (e.g. by taxes) from using established land and sea trading routes to India, East Asia and South-East Asia. The Portuguese set out to find their own alternative sea route to India and beyond, namely a route circumnavigating the African continent.

Initially (c.1419) they explored some Atlantic islands and the west coast of Africa, the latter being where they established a profitable trade in slaves, gold, ivory, ebony and exotica. And then, in 1497, a Portuguese fleet rounded the Cape of Good Hope, sailed up the east coast of Africa and crossed the Indian Ocean to India. The long-distance sailing ships needed for such ventures were *carracks* and *caravels*, developed in Iberia (Portugal plus Spain) but drawing on Arab design features such as the lateen sail. They were seaworthy but small in comparison with the nine-masted junks of the Chinese merchant fleet of the time. And so began a Portuguese empire which would be largely financed by the spice trade. Around 1522, argues

Peter Trickett, the Portuguese may even have been the first Europeans to discover Australia (and New Zealand), charting the east coast and probably more.[11] By 1550 the Portuguese had 50 ports and forts in Asia and South America, many of which would become colonies in the nineteenth century and several of which were at strategic choke points (Aden, Hormuz, Malacca) in the global shipping network. As the sixteenth century progressed, the Portuguese navy increasingly dominated the Ottoman navy, and hence the spice trade, in the Persian Gulf, the Indian Ocean and around modern-day Indonesia's Spice Islands.

By 1492 Christian forces had recaptured the last of the Iberian Peninsula from the Islamic states there and Spain became free to belatedly begin competing with Portugal for a share of the spice trade. Under the sponsorship of the Spanish Crown, Christopher Columbus sailed west to (unintentionally) become the first (?) European to discover the 'new world' of the Americas. By 1533 the Spaniards, aided by guns, horses and disease, had subjugated the floundering Aztec and Inca empires and by 1549 sugar plantations, worked by slaves, had been established in Brazil by the Portuguese. Over several centuries. Spain extracted enormous quantities of silver from its growing American possessions, sufficient to finance a grand empire (and, as mentioned, destabilise the Ottoman Empire's currency in the process). It was an empire further boosted by Spain's annexure of an overextended Portugal and its possessions from 1580 to 1640. In 1571, it was a Spanish-led fleet which annihilated the Ottoman fleet at the battle of Lepanto and ended Ottoman naval hegemony in the Mediterranean.

Notwithstanding her trading and military successes, a combination of factors led to Spain's bankruptcy in 1576. These included a narrowly based economy, privateer attacks on her bullion ships, the costs of maintaining a large fleet and the costs of extended land wars in the Netherlands and elsewhere.

Spain and Portugal's successes in exploration, trade and colonisation encouraged the Atlantic seaboard countries of France, England and the United Provinces of the Netherlands (a 'league of city states' really) to follow suit. Already by the late sixteenth century a large share of the profits obtained from servicing intercontinental trade was accruing to Dutch (and, less so, English) merchants, shippers, bankers, brokers and insurers. In the sense of providing venture-capital, the Netherlands was the first capitalist state.

Spain continued to fight a debilitating series of land wars in Europe and to struggle against growing Dutch and (to a lesser extent) English power in the Atlantic and in European waters. From the second half of the seventeenth century she was forced into a series of treaties with the new maritime powers of Holland, England and France, treaties which broke her monopoly on trade with the Americas. Thereafter, much of the profit from this trade went towards financing the economic growth of these countries rather than Spain. Having failed to achieve the lasting economic

[11] Trickwett, P. , 2007, *Beyond Capricorn*: *How Portuguese Adventurers Secretly Discovered and Mapped Australia and New Zealand 250 Years before Captain Cook*, East Street Publications, Bowden, S. Aust.

strength which her American empire promised, Spain entered the eighteenth century as a second-class power.

As for Portugal, by the time her independence had been regained, her dominance over sea trade with the East had been lost to the English and Dutch. The country which had brought Europe into the wider world was proving too small to be able to defend her colonial possessions against intrusions by the English, Dutch and French. Perhaps the loss of Brazil to an independence movement in 1822 marks the effective end of the Portuguese empire.

European Imperialism and Mercantilism

Mercantilism is the belief that trade expansion will make a state strong, and therefore that the state and her traders should cooperate to strengthen each other. Mercantilist ideas were adopted enthusiastically by the emerging nation-states of Europe from the early sixteenth century and reigned through 300 years marked by religious and commercial wars until the coming of the Industrial Revolution and the perspective of laissez-faire (free market) economics. As the classical economists would later point out, 'successful' mercantilism stands to produce an oversupply of money and, with it, serious inflation.

Imperialism and *colonialism* are related social technologies whereby, going beyond 'free' trade, an individual state seeks to manage the export mix from particular overseas regions and/or to 'lock-in' exclusive access to exports from those regions. *World-system theory* suggests that, most commonly, both imperialism and colonialism involve the coercion-exploitation-domination of a weaker power or population by an economically or militarily stronger power.[12] While the age of overt colonialism is now over, imperialism, notwithstanding some rebadging, has continued as a favoured economic-political strategy by strong states till the present day.

From the early sixteenth century the north Atlantic kingdoms of France and England had sought to participate in the intercontinental trade which was making Portugal, and then Spain, very rich. The English-sponsored John Cabot landed in Canada in 1497 believing, like Columbus, that he had reached Asia. From 1524 the French were exploring the Atlantic coast of present-day Canada and the United States. In 1534 the Frenchman Jacques Cartier discovered the great inlet of the St Lawrence river and thought it could be the mouth of a channel through the continent to the Pacific. While that was not to be, permanent French Canadian settlements (New France) based on a profitable fur trade—a by-product of the *Little Ice Age* which followed the Medieval Warm Period—were in place there by 1608. Britain's first permanent overseas settlement (1607) was in present-day Virginia, but it was her later colonies in the West Indies which first provided healthy profits.

[12] Wallerstein, I., 2004, *World-systems Analysis*: *An Introduction*, Duke University Press, Durham and London.

These profits came from sugar plantations which depended on slave labour and on Dutch shippers who imported slaves and exported sugar.

The Dutch, rich from a herring boom, and equipped with superior ships, had begun to dominate intra-European sea trade, that is between Spain and the Baltic and North seas, from the late sixteenth century, Spain was not able to suppress Dutch trading efforts there as she had England's. Over the first half of the seventeenth century, seeking a monopoly of the Asian spice trade, the Dutch confronted the Portuguese, Spanish and Chinese empires and established a network of fortified trading posts, bases and plantations of their own in Asia, under the control of the Dutch East India Company, a state-sanctioned monopoly. The other component of Dutch commercial strategy (apart from their pervasive middleman activities) was to set up colonies across the Atlantic. Here they were not so successful. New Netherland, centre of a flourishing fur trade around the Hudson River (including present-day New York), was lost to the British in 1664. Further south, the Dutch West India Company colonised some small islands in the West Indies and part of the nearby mainland, but these served more as trading posts than as productive colonies. It was Britain's attempts (from 1651) to exclude Dutch ships from trading with her American colonies which led to the series of Anglo-Dutch wars (1652–1674) which would eventually strengthen England's position in the Americas at the expense of the Dutch.

More generally, the seventeenth and eighteenth centuries was a period when existing economic and political linkages between European, North and South American, East Asian, Indian and African states, colonies and coastal trading enclaves were strengthened and extended. For example, the trans-Atlantic slave trade which had grown quietly through the fifteenth and sixteenth centuries expanded sharply in the seventeenth and eighteenth centuries. Silver, spices, sugar, slaves, coffee, tea, tobacco, ceramics and textiles were traded around the world. The energy of the winds, harnessed by sailing ships, had made the creation and maintenance of a global commercial system possible.

Wars, civil wars and lesser conflicts such as piracy, revolts and uprisings continued unabated on land and sea.[13] For example, the Dutch strategy for acquiring a monopoly of the cloves trade was to control clove-growing in one region and then, by warring against clove traders and producers in other regions, eliminate clove-growing elsewhere. History of course has assigned particular significance to the American and French revolutions of the late eighteenth century.

Of the Eurasian empires not yet directly affected by European intrusion, the seventeenth to eighteenth centuries saw territorial expansion in the Chinese, Russian and Mughal, and, even, the Ottoman empires. Muscovy (the Russia-to-be) expanded across northern Eurasia to cover a sixth of the world's land surface by 1795 and, through marriage, claimed leadership of the Eastern Christian church. Europe however remained unconsolidated. War there, commonly religious war, was endemic because no state had clear superiority. One consequence of this was an 'arms race'

[13] http://www.warscholar.com/WarScholar/Year/1600.html (Accessed 14 Jan 2008).

improvement in weaponry which was to later ensure the military dominance of Europe over the rest of the world. Also, there was greater scope for market-driven behaviour in Europe than elsewhere because capital could move between countries when the command system in any one of them became too demanding. Because mercantile wealth could not be readily appropriated by bureaucratic authority, private and, subsequently, state wealth began to accumulate rapidly, feeding on itself. The new wealth accumulated preferentially in metropolitan areas at the expense of the rural peripheral peasantry who remained subject, not to market forces, but to feudal control over their lives

At sea, Europe's mercantilist era of quarrelling states came to a virtual end at Trafalgar in 1805 and, on land, a decade later at Waterloo. Nelson's crushing defeat of the French and Spanish navies established Britain as the dominant world naval power for a century. Similarly, Napoleon's defeat at Waterloo destroyed French dominance of continental Europe and ushered in 70 years in which Britain rather than France would become the hegemonic power in the world system, just as, according to Immanuel Wallerstein, the Dutch had been in middle half of the seventeenth century.[14] In retrospect, mercantile capitalism and Protestantism proved to be forces which could create states and empires independent of feudalism and the Church of Rome.

Fossil Fuels and Industrial Capitalism

The distinctive characteristic of the *Industrial Revolution* was the progressive replacement of human and animal muscle power, and then water and wind power, by inanimate energy. For a long time, the technology which made this substitution possible was the coal-fired steam engine, first invented before the Common Era but coming into wide use (reinvented?) in England when it was realised that the important task of draining flooding coal mines could not be successfully tackled by muscle-powered machinery. Coal, which England had in abundance, was widely used for domestic heating (trees had become scarce) but, more consequentially, was in high demand from industrial iron smelters. Subsequently, by the end of the eighteenth century steam engines were introduced in the textile industry to drive the ever-larger looms etc. which allowed labour to be more productive and the size of the labour force to be reduced. Other industries which started benefiting from cheap coal were sugar refining, soap boiling and the manufacture of glass, pottery and bricks. The builders of coal colliers were indirect beneficiaries.

And, by mid-nineteenth century in what can be seen as a second phase of the Industrial Revolution, steam power was being used to mechanise both transport and agricultural operations.

[14]Wallerstein, I., 1983, The Three Instances of Hegemony in the History of the Capitalist World-Economy, *International J. of Comparative Sociology*, XXIV (1–2), pp. 100–108.

A third and more complex phase of the Industrial Revolution was being driven by two families of technologies by the early twentieth century. One family developed around the use of fossil oil for powering internal combustion engines, including, particularly, those in automobiles and farm machinery; the farm tractor released enormous quantities of land from the production of horse feed. The other was the generation of electricity in commercial quantities by coal-fired power stations. Each family spawned clusters of new industries including oil production, petroleum and petrochemicals, automobile production and, based on electricity, communications, domestic applications and entertainment. A fourth phase, post-World War 2, was based on a cluster of developments in the aviation, aluminium and electronics industries.

At this point we might introduce the useful idea of a *techno-economic system*, i.e. an interrelated set of technologies with which are associated particular sets of raw materials, sources of energy and infrastructure networks. The idea that the history of industrial capitalism can be broken into phases dominated by successive techno-economic systems can be usefully linked to another powerful idea, that of *Kondratieff cycles*. These are named for the Russian whose massive study of social and economic time-series data first identified them.[15] His empirical observation was that, from the early eighteenth century, many innovations and processes have diffused through society over time in a way which can be described by an S-shaped (sigmoid) curve, i.e. slow growth at the beginning, followed by accelerating and then decelerating growth culminating in excess capacity and market saturation, e.g. mainframe computers 'saturated' around 1995.

Phases of global growth and expansion in economic activities last 50–60 years under this model and are punctuated with phases of fundamental change in the structure of the economy, the technological base and many social institutions and relations, i.e. change in the techno-economic system. Towards the end of each techno-economic phase in the economy, many markets saturate, inflation accelerates and growth (in real per capita gross national product) slows. Brian Berry has concluded that whereas *growth rates of prices* swing up and down in, approximately, 54-year cycles (Kondratieff waves), *rates of economic growth* oscillate with 25–30 year rhythms, averaging 27 years and called *Kuznets cycles*. That is, each Kondratieff long wave of price changes has two Kuznets cycles of economic growth nested within it, one on the upwave of price changes from trough (marking deflationary depression) to peak (stagflation crisis) and one on the downwave of prices from peak to trough.[16] The search by entrepreneurs for revitalised profits induces a cluster of new technologies which slowly at first, and then more rapidly, penetrate markets.[17] Why 55 years? We don't know although, suggestively, Berry finds

[15] Kondratieff, N.D., 1926, *Die Langen Wellen der Konjunktur*, Archiv für Sozialwissenschaft und Sozialpolitik, (German translation of Russian original), *Band*, 56, pp. 573–609.

[16] Berry, B.J.L., 2000, A Pacemaker for the Long Wave, *Technological Forecasting and Social Change*, 63, pp. 1–23.

[17] Grubler, A., and Nakicenovic, N., 1991, Long Waves, Technology Diffusion and Substitution, *International Institute for Applied Systems Analysis Review*, XIV (2), pp. 313–342.

economic activity strongly correlated with a lunisolar cycle of that length, one which affects crop production regularly and just sufficiently to nudge (entrain) various aspects of economic activity into step with each other and with the lunisolar cycle! J.D. Sterman attributes these long oscillations to the interaction of various sorts of lags in the economy's responses to changing conditions, especially lags in the buildup of capital required to lift output levels.[18]

Cesare Marchetti nominates 1940 and 1995 as the ends of Kondratieff price-growth cycles.[19] The data supporting such a precise cyclical view of socio-techno-economic history is quite impressive but cannot 'prove' that the world economy is indeed entering a new growth phase that will slow, accelerate and then slow again towards 2050. Nonetheless, there is a cluster of new technologies currently beginning to generate products for growing world markets. These centre around computer and communication technologies and, to a lesser extent, biotechnologies, nanotechnologies, new energy technologies and new transport technologies.

Looking for inflection points in the way humanity has historically used technology and energy, it is possible to see the second half of the twentieth century as the effective end to what is widely known as the Industrial Revolution—if we see that revolution as one in which humans learned to extend their physical capabilities by using energy-processing machines as prostheses for completing both large- and small-scale tasks, or to complete tasks more rapidly. While technologies for manipulating physical *materials* (e.g. in war, extractive industries, engineering, chemical synthesis) have continued to emerge, technologies for manipulating and communicating *information*, building on printing, telegraphy, radio and television, became increasingly important with the invention and utilisation of computers in the second half of the twentieth century. At the risk of overusing the word, we have moved on to an *information revolution*.

The trend towards European dominance of trade and capital accumulation under mercantilism was only reinforced by the Industrial Revolution. After the eighteenth century as Britain's Industrial Revolution spread to other countries, European states were able to use both cheap manufactured goods and military superiority to dominate and extract economic surpluses from peripheral states around the world in a frenzy of colonisation, most notably in the 'scramble for Africa'. And in this they were helped by the decaying of the gunpowder empires that had arisen in the fifteenth and sixteenth centuries. Overseas investment became an outlet for surplus capital which could not be profitably invested in saturated home markets.[20] Also, the opening up of the farmlands of the 'New World' colonies of North America and Australasia boosted world food supplies and, in time, the rate of world population

[18]Sterman, J.D., 1989, Nonlinear Dynamics in the World Economy, In Christiansen, P. , and Parmentier, R.D. (Eds), *Structure*, *Coherence and Chaos in Dynamical Systems*, Manchester University Press, Manchester.

[19]Marchetti, C., 1987, Infrastructures for Movement, T*echnological Forecasting and Social Change*, 32, pp. 373–393.

[20]Heilbroner, R.L., 1953, The Worldly Philosophers: The Lives, Times And Ideas of the Great Economic Thinkers, Simon and Schuster, New York, Ch. 7.

growth. This was on top of a lift in world food supplies that had already been triggered by the introduction of productive American crops—potato, sweet potato, maize and cassava—into Europe and West Africa.[21] Substantial cities began to appear after 1700 and grew with amazing speed in the nineteenth century. By now, *industrial capitalism*, based on entrepreneurs investing in the production of standardised manufactured goods, had replaced mercantile capitalism as the paradigmatic economic system. In the nineteenth and twentieth centuries, this form of economic organisation became the main, but not only, means of achieving industrialisation throughout much of the world.

Social and Political Change Under Industrial Capitalism

Turning from the economic to the social, the structures, experiences and perspectives of ordinary people's lives were transformed by the Industrial Revolution. Displaced rural families who had lived their lives in a world of subsistence agriculture, cottage industry (e.g. wool spinning), barter, fairs and market towns now worked under inhuman conditions in ghastly factories and lived in terrace houses in and around large cities. While their housing was quite often an improvement on rural hovels, infant mortality increased under the dense, cramped living conditions accompanying rapid urbanisation. During the early Industrial Revolution, 50% of infants died before the age of two.[22] Children as young as eight were sent to work in factories and mines. Mortality amongst children older than two started falling from about 1870, but a major decline in mortality for younger children came only with rising incomes and improved public health measures after the turn of the century.

Most factory workers came to uncomplainingly accept their lot for, as Eric Fromm points out, 'Every society shapes the energies of people in such a way that they want to do what they must do in order for society to function. Social necessities become transformed into personal needs, into social character'.[23] Notwithstanding, worker disenchantment grew and fomented as the Industrial Revolution progressed. One virtual species, the factory owners was accumulating great wealth while another, the working class, remained impoverished. It was an environment in which the political philosophy of socialism emerged to challenge the reigning ideas of individualism and laissez faire, the ideas (see below) which gave legitimacy to the callous norms of industrial capitalism. While British society was never restructured along socialist lines, a series of Factory Acts which slowly reformed working conditions was enacted from 1833 onwards.

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[21] Wright, R., 2008, What Is America?: A Short History of the *New World Order*, Knopf Canada, Toronto.

[22] Stearns, P. , and Schwartz, R., 1991, *World History*: *Tradition and New Direction*, Addison-Wesley, New York.

[23] Fromm, E., 1964, The Heart of Man: Its Genius for Good and Evil, In Ashen, R.N. (Ed.) *Religious Perspectives*, 12, Harper Row, New York, p. 93.

Changing Perceptions of Nature, People and Society

Full tribute has been paid to the Greek contribution to the development of consciousness, writing and cognitive skills. Notwithstanding, the Greek genius was one-sided in that they reasoned deductively from what appeared to be self-evident, not inductively from what had been observed.[24] Not always of course. Aristotle, pupil of Plato, could be an acute observer but many of his looser speculations were later adopted as dogma by the Roman Catholic Church. For example, the Aristotle-Plato view that the Earth is at the centre of the universe (geocentrism) was a self-serving Church dogma from the third century to the 1500s and scientists who, like Galileo, disagreed were regarded as heretics.

The powerful Church philosophers of late medieval-Renaissance times (Scholastics) had never retained the Greek realisation that the truth is something to be discovered. Rather, to quote Alasdair MacIntyre, they had 'allowed themselves to be deceived about the character of the facts of the natural and social world by imposing an Aristotelian interpretation between themselves and experienced reality'.[25] Conversely, the post-Renaissance humanist philosophers of the seventeenth and eighteenth centuries, led by Rousseau, Voltaire and de Montesquieu, saw themselves as stripping away interpretation and speculative theory and confronting fact and experience just as they are. They saw themselves as throwing light on what Aristotle obscured. It was thus an Age of Enlightenment.

Consider science. The seventeenth century is commonly regarded as a time of 'revolutionary' growth in scientific knowledge and 'revolutionary' changes in research methods and principles. And it is true that many key ideas from the Aristotelian tradition were transformed at this time by such great scientists (then called natural philosophers) as Isaac Newton and Robert Boyle. Thus, the *mechanist* natural philosopher René Descartes struck down Aristotle's 'final cause', the idea that Nature's way is purposive, instead likening her processes to those of a mechanical clock in which inert particles of matter are moved by direct physical contact. Where Nature had previously been imagined to be an active entity, the mechanist philosophers viewed Nature as following natural, physical laws. However, while less so than in physics, chemistry and biology still find it helpful, albeit metaphorically, to see Nature as goal-directed. And Descartes' clockwork world has given way to one where much of Nature is seen in terms of complex energy-processing systems populated by unruly feedback relationships.

An empirical or experimental approach to scientific discovery was boosted and slowly adopted through the influence of, particularly, *Novum Organum* (1620), Francis Bacon's direct challenge to Aristotelian method.[26] Notwithstanding, it is salutary to note that the Persian (Arab?) polymath Ibn al-Haytham (965–1039)[27]

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[24] Carothers, J.C., 1959, Culture, Psychiatry and the Written Word, *Psychiatry*, 22, pp. 308–320.

[25] MacIntyre, A., 1981, *After Virtue*: *A Study in Moral Theory*, Duckworth, London, p. 78.

[26] Fowler, T., (Ed), 1878, *Bacon's Novum Organum*, Clarendon Press, Oxford.

[27] http://en.wikipedia.org/wiki/Ibn_al-Haytham (Accessed 31 Jan 2008).

formulated a quantitative, empirical and experimental approach to physics some 600 years before Bacon. His approach included the use of mathematical methods to describe and generalise measurements of physical phenomena, something that European scientists arrived at in the sixteenth and seventeenth centuries.

Despite its many successes, and great expectations, the new approach to science was slow to yield results that, translated into technology, stood to benefit industrial capitalism (pottery was an exception). That was a 'payoff' which only began to flow copiously in the second half of the nineteenth century when, in particular, the science of metallurgy permitted the matching of alloy steels to industrial specifications, the science of chemistry permitted the creation of new substances like aniline dyes, and electricity and magnetism were harnessed in the electric dynamo and motor. As this perceptive quote from Hanbury Brown[28] shows, science depends on technology as much as technology depends on science:

> At the time Bacon wrote—the early seventeenth century—scientists were making rapid progress largely due to the new scientific instruments—the telescope, microscope, thermometer, barometer, pendulum clock and the air pump. Histories of science are often written in terms of outstanding people like Newton and Einstein, so that they give the impression that the progress of science depends largely on the development of new theories. It would be nearer the truth to say that it depends on the development of new instruments and hence on new materials and new ways of making things … our knowledge of the real world is limited by the tools which are available at the time.

Science, Capitalism and Democracy

Robert Heilbroner nominated 'the promise of science' as one of three widespread changes in perspective that emerged from the eighteenth century *European Enlightenment* and noted that all three spawned powerful secular trends which are still being worked through worldwide.[29] His other nominations were:

Confidence in capitalism's capacity to utilise resources (land, labour and capital) to produce goods and services in great quantities.

The legitimacy of the will of the people as the source of their own collective direction.

We can note that all three shifts in perspective have their origins in that active willingness to challenge philosophical, political and religious authority which resurfaced during the early Renaissance. This heightened confidence itself rested on an expanded faith in what can be accomplished through *reason*, where reason is that ability which helps people decide what is true.

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[28] Brown, H., 1986, *The Wisdom of Science*: *Its Relevance to Culture and Religion*, Cambridge University Press, Cambridge.

[29] Heilbroner, R., 1995, *Visions of the Future*: *The Distant Past*, *Yesterday*, *Today*, *and Tomorrow*, Oxford University Press, New York, p. 112.

It would have been hard to not recognise the productive potential of industrial capitalism in the face of the Industrial Revolution's clear demonstration that entrepreneurs had learned to combine fossil energy with land, labour and capital to produce standardised manufactured goods and services in quantity. What may not have been recognised though is that for entrepreneurial industrial capitalism to develop on any significant scale, entrepreneurs had to be able to buy land (a catch-all for *natural resources*), labour and capital (both capital goods and funds) in competitive markets which reflected the value and availability of those inputs for producing saleable commodities. Without such markets, coordinating or even initiating industrial ventures becomes very difficult and inefficient.

As explained by Karl Polanyi (1944) in *The Great Transformation*: *The Political and Economic Origins of our Times*, it took many hundreds of years, from feudal times onwards, for effective markets in land, labour and money to come into being in Britain.[30] But, by the early Industrial Revolution British entrepreneurs could buy and sell land, labour-power and capital in 'free' markets, meaning markets subject to few socially imposed rules and influences. For example, the abandonment of the Speenhamland system of poor relief in England at the end of the eighteenth CEntury marked the last gasp of a social order that had accepted a degree of collective responsibility for the welfare of its members. Thereafter workers had little choice but to accept the working conditions offered by monopsonistic employers, commonly unwilling to offer more than subsistence wages. In line with a pervasive acceptance by entrepreneurs and their parliamentary supporters of a self-serving version of Adam Smith's case for the virtues of competitive markets,[31] land and capital markets were similarly unregulated. It was a laissez-faire economy, an expression, in today's terms, of neoliberal values. More generally, British society was, for a time, engulfed by the idea of individualism, meaning, basically, that everyone is responsible for themselves and, obversely, that society has few responsibilities towards its members. The post-feudal rise in free labour and the idea of status based on acquired wealth (not land) had both provided opportunities for the emergence of individualism. Output advanced dramatically with the nineteenth century, but so did social instability and political conflict.

Polanyi argues that the threat of major disruption to British society declined only when a significant degree of social control over the use of labour, land and money had been restored through the creation of new institutions, such as trade unions and a central bank, and the emergence of a body of legislation that established legal limits in areas such as wages, working conditions and the use of land and other natural resources. He further argues that this perception of early industrial capitalism illustrates the absolute necessity of having such a politically defined national framework of laws and institutions to set the constraints within which markets must

[30] Polanyi, K., 1944/ 2001, *The Great Transformation*: *The Political and Economic Origins of our Time*, Beacon Press, Boston.

[31] Smith, A., 1776/1893, An Inquiry into the Nature and Causes of the Wealth of Nations, Routledge, Manchester, Ch. 8, Book 1.

operate if their tendencies to destroy nonmarket values (e.g. the family, the natural world) are to be effectively contained. Even money markets require central banking and the management of the monetary system to protect manufacturers and other producers from the unpredictable dynamics of unfettered monetary operations.[32]

Given the support for unregulated markets by the rich and powerful, how then did social control over markets come about in the industrialising countries of Europe in the nineteenth century? The answer lies in the establishment of parliamentary democracies in Europe during the Enlightenment, these being a practical expression of Heilbroner's third major change in perspective—recognition of the sovereignty of the people. To quote Marvin Harris on this putatively surprising development[33]:

> In anthropological perspective, the emergence of bourgeois democracies in seventeenth- and eighteenth-century Europe was a rare reversal of that descent from freedom to slavery which had been the main characteristic of the evolution of the state for 6000 years.

The mind turns here to the French Revolution of 1789. This was not so much a revolution against the external effects of industrial capitalism as a revolution against malnutrition, unemployment, fierce taxes and privilege. The group which came to power was dedicated to the proposition that government had the right to and should, in the name of 'the people' who were 'sovereign', impose radical change on the social system. Furthermore, these two ideas—that reformist political change is a 'normal' process and that it is the 'people' who are sovereign—spread rapidly throughout the world and, indeed, have never since gone away.

These two ideas were not new of course. Their classical roots have been noted but, more immediately, and for example, Tom Paine's tracts fuelled both the French and American revolutions. His *Rights of Man* became the cornerstone for thinking about one of humanity's truly great social technologies, namely human rights.[34] Thus, printed books were continuing to act as agents of cultural change because of the ideas they contained and the ease with which they could be accessed. Indeed, Edmund Burke in England and Joseph de Maistre in France were soon to publish 'reactionary' books that fundamentally challenged the whole doctrine of parliamentary democracy and reasserted the enduring social and moral value of 'traditional' authorities.[35] The *Counter-Enlightenment* had begun.

Reverting to a longer view, the advent of parliamentary democracy was the culmination of a process of gradual change in the principles that governed the distribution of power in European society. Coming out of feudal times, an oligarchy empowered by military strength, God's support for church and monarchy, aristocratic breeding and land ownership gradually lost power to a commercial class of wealthy merchants. The parliaments of the first stage were congresses of feudal lords.

[32] Polanyi, K., 1944/ 2001, ibid., p. 132.

[33] Harris, M., 1977, *Cannibals and Kings*: *The Origins of Cultures*, Vintage Books, New York, p. 264.

[34] Paine, T., 1791/1950, *Rights of Man*, Kurt. H. Volk Inc., New York.

[35] Burke, E., 1790/1793, *Reflections on the Revolution in France*, Printed for J. Parsons, London; de Maistre, J., 1797/1994, *Considerations on France*, Cambridge University Press, Cambridge.

The parliaments of the second stage were increasingly inclusive of and dominated by rich traders. Perhaps ironically, the idea of 'universal' human rights (e.g. voting rights) for all citizens, irrespective of their social roles, and the *freedom* to exercise those rights, which is nowadays used to justify democracy was first used to justify a redistribution of power to the commercial class.[36]

Around the world, a modest trend towards accepting, recognising and expanding citizen rights, opportunities and protections, albeit marked by numerous reverses, has continued ever since. Certainly lip-service is paid to the idea of parliamentary democracy in most contemporary nation-states. It is a trend which has almost always been confronted by and resisted by advocates of market deregulation and by supporters of traditional authority. When confined within the crucible of parliamentary democracy of some sort, the struggle between the groups (virtual species) that these two trends speak for has expressed itself as an uneasy oscillation of power between a spectrum of fuzzy political ideologies (What is the role of government?) which differ foremost in their beliefs about the rate at which power should be transferred to the citizenry. *Conservatives* want slow or no change. *Liberals*, while favouring a return to free markets (economic liberalism) and individualism (political liberalism), have, historically, been willing to accept a moderate rate of political change. The liberal concept of individualism emphasises the idea of *personal freedom*, meaning that the state guarantees certain rights to the individual citizen in hir dealings with those in authority. *Socialists*, more radically, have wanted markets, the arbiters of what is produced, to be replaced by more collective processes of decision-making.

An important part of the struggle to control the parliamentary process and the outcomes of participatory democracy has always been around the question of who is a citizen. Who is a member of the political community? Who is to have influence on the political process? Before the Enlightenment, full citizenship was a privilege, an elevated status limited by class, race, creed, gender, age, income etc.[37] While many of these constraints have been relaxed in advanced contemporary democracies, no nation-state has as yet offered full citizenship to every resident who wants it. Indeed, governments with Counter-Enlightenment leanings (and not just Fascist states) have regularly seized and created opportunities to downgrade the citizenship status of groups designated as threats to the nation-state.

The idea of the nation-state was itself a product of the Enlightenment. In Western Europe and the Western Hemisphere, since the late eighteenth century, humanity has been perceived as divided into groups called *nations*, people sharing a common identity and history. A state is a political structure with effective coercive power within a geographic area. While a nation is not identical to a state, the people of a nation-state consider themselves a nation. *Nationalism*, a doctrine which has had an enormous influence on modern world history, holds that the people of a nation have

[36] Website for International CEnter for Peace and Development http://www.icpd.org/about_us.htm (Accessed 7 Feb 2008).

[37] Woolf, L., 1931/1937, *After the Deluge*, Pelican, London, Ch. 2.

the right to democratically govern themselves without outside interference; most nationalists believe the borders of the state should be congruent with the borders of the nation; most nationalists regard the nation-state as the paramount instrument for realising the social, economic and cultural aspirations of its citizen-members.

Counter-Enlightenment forces continued to wield often-repressive political power in most of Europe for most of the 70 years after the French Revolution. But, coinciding generally with the spread of the Industrial Revolution, a tide of French-inspired nationalism was rolling in. Greece, for example, achieved independence from the Ottoman Empire in 1829.

By 1848, population growth and a series of poor harvests in the 1840s produced an industrial slump and a doubling of food costs. These triggers, along with nationalist awakenings and short-sighted repression help explain why that pivotal year saw a wave of attempts at revolution (by French (again), Poles, Czechs, Hungarians, Balkan Christians) and the beginnings of German and Italian unification. While none of these ventures was immediately successful, they emphatically signalled that all-powerful monarchies would no longer be a legitimate or feasible form of government and that nationalist sentiment (patriotism) would become the primary source of their own legitimacy for many states. Over following decades, a number of 'enlightened conservative' governments, following the British example, accepted the necessity of 'concessions' in order to forestall worse unrest. Notwithstanding, the nationalist aspirations of these and other peoples and their desire to form nation-states independent of the empires from which they sprang remained an important element in the brew of processes that, in 1914, exploded into World War 1.

World Wars

Precursors

Despite presenting as a kaleidoscope of internal revolutions, unrest and shifting boundaries around emerging states, Europe, in terms of wars *between* nations, remained largely at peace from 1815 to 1914. This felicitous state of affairs is usually attributed to the formation of the *Concert of Europe*, an informal political integration of the *great powers* of Europe (initially United Kingdom, Russia, Austria, Prussia and France) that met from time to time to solve, in concert, problems that threatened peace between European nations. Given Europe's global hegemony at the time, the Concert of Europe can be seen as an early attempt at global governance, a forerunner to the League of Nations (1920–1946) and the United Nations Organisation (1945–). To the extent that it was successful for a century, the Concert of Europe relied, first, on the 'no outside interference' principle of state sovereignty as the cornerstone of inter-nation law and order, a principle going back to the Westphalian treaties which, in 1648, marked the end of several long European wars. Second was an acceptance of the *balance-of-power doctrine*, i.e. the need to prevent any one nation from becoming strong enough to impose its will upon the rest. The further notion of 'general war' prescribed that all states should band together against any 'rogue state' that aggressively attacked another.

Now, following Polanyi, the participants in what, by the nineteenth century, had become a worldwide capitalist system of extraction and production (thanks to imperialism, the spread of industrialisation and cheap coal-fired ocean transport) recognised that, if they were to reliably earn good profits, they needed a world of nonaggressive and internally stable sovereign states, perhaps not all states but certainly the great and near-great powers.

> The fact was that the market economy could flourish only in societies able to define a relatively coherent national economic space within which it was possible to achieve a viable political compromise regarding the 'limits of the market'. Moreover, the links that such national economies forged with the outside world always had to be managed and controlled in ways that could be reconciled with that domestic political compromise, but this would always be a source of friction that could escalate into a crisis at any time, because unforeseen changes in the international economy could always transform a manageable set of external linkages into a quite unmanageable one, thereby 'requiring' a degree of domestic adjustment that was incompatible with the existing domestic political compromise, or indeed with any potential compromise.[38]

And this is what happened. Towards the end of the nineteenth century, the world's economic system was not working to the benefit of most people, thanks largely to the widespread adoption of a monetary system called the *gold standard*, one in which the standard economic unit of account was a fixed weight of gold. Under the gold standard, each nation's currency issuers guaranteed to redeem each unit of paper money, upon demand, with a specified amount of gold. This had profound expansionary effects on international trade and investment, a sphere dominated by and dependent upon a relatively few powerful international financiers such as the Rothschild family. In particular, because exchange rates between currencies were constant, decisions to buy, sell or invest in foreign markets became less risky; funds could always be withdrawn at a guaranteed rate of exchange. Also, nations on the gold standard could borrow at lower interest rates.

The downside of this monetary system, because of linkages we need not explore here, was that many nations found that, to maintain a guaranteed exchange rate, the domestic economy had to be contracted periodically, basically by raising interest rates or reducing the amount of money in circulation. For example, recessions severe enough to prompt protectionist measures hit Europe and United States in the early 1890s. Such contractions hurt domestic producers, consumers and workers, e.g. through more unemployment, lower wages. But, because these groups lacked the political power of the international investment community, central banks were free (were directed?) to do whatever was needed to maintain exchange rates—without fear of the domestic consequences, economic or political. In the longer term, it would be the rise of European labour movements that would kill off the gold

[38] Bienefeld, M., 1989, The Lessons of History and the Developing World, *Monthly Review*, 41(3), pp. 9–41.

standard; political elites would be forced to share power with broadly elected parliaments containing influential parties representing labour and agrarian interests, parties which didn't care for contraction, deflation, and high interest rates. Meanwhile, apart from a relative decline and slowing in the previously dominant British economy, world economic activity and trade picked up in the two decades before the Great War. Globalisation as measured by the ratio of trade to Gross World Product was in fact higher in the period 1870–1914 than in the period 1914–1950.

While exchange rates between a core of industrial countries remained stable for some decades prior to the Great War, the gold standard functioned less successfully in the *peripheral countries* of the global economy—basically, those supplying raw materials to the industrialised economies. Such economies were subject to large economic shocks as the prices of their exports rose and fell. Countries at the periphery were also subject to large shocks as British investors' willingness to loan capital abroad went through unpredictable cycles. Latin countries, for example, were repeatedly forced off of the gold standard and into devaluation by financial crises.

As emphasised by world-system theorists[39] the distinction between core, semi-peripheral and peripheral economies persists till the present day. Extractive economies, as they 'develop', use up their reserves and become impoverished, while the productive economies of the core zones, as they develop, increase their power to dominate and exploit the extractive economies. As a generalisation, the chief mechanism by which the surplus value generated by core-periphery trade gets consistently transferred from peripheral to core countries is that peripheral exporters have to accept low-profit 'competitive' prices for their primary products while industrial exporters can impose a degree of monopoly (high profit) pricing on their secondary products. Stephen Bunker argues convincingly that this core-periphery mechanism produces uneven development within states just as it does between states.[40]

Unleash the Dogs of War

When war came it was at the end of a decade-long series of diplomatic clashes between the great powers, clashes which drove tensions to near breaking point. In turn these diplomatic clashes can be traced to changes in the balance of power after 1871, the year of German unification. By the dawn of the twentieth century, United States (after its civil war), Italy and Japan (after the Meiji Restoration) had become great powers, even as the Romanov empire (Russia) and the Habsburg empire (Austria-Hungary) were declining (notwithstanding, or perhaps for this reason, there was a 'will to war' in both Russia and Austria-Hungary). Japan became the first East Asian country to transform itself into a modern nation and to win a war against a European power (the Russo-Japanese War of 1905). Despite a complicated

[39] Wallerstein, I., 2004, ibid.

[40] Bunker, S., 1985, *Underdeveloping the Amazon*: *Extraction*, *Unequal Exchange*, *and the Failure of the Modern State*, University of Illinois Press, Urbana, Ch. 9.

set of military treaties between Europe's great powers, and given a situation exacerbated by various 'arms races', the balance of power was unravelling. British hegemony was coming to an end. For many, war seemed an attractive way out of cumulating domestic and foreign problems. Europe in 1914 was surely a nonequilibrium system which, having adapted as far as it could to increasing energy throughputs from trade and industrialisation, was triggered into a massive restructuring—the Great War (World War 1) and its aftermath—by a single political assassination.

In the event, it was an outcome of the Great War that various nationalist aspirations came to fruition. With the toppling of the ruling dynasties in Germany, Austria-Hungary, Russia, and the Ottoman Empire, a number of new nation-states appeared in central and eastern Europe. These included Finland, Estonia, Latvia, Lithuania, Poland, Czechoslovakia, Hungary, and Yugoslavia-to-be. Even then, many of the new nation-states contained national minorities who demanded independence or changes to frontiers. For example, the conflicting claims of German and Polish nationalists became the nominal reason for the outbreak of World War 2.

Outside Europe, World War I, together with the spread of Western ideas, stimulated the rise of nationalism in Asia and Africa. Some examples. After defeating the Western allies (1922–1923), the Turks, led by Mustafa Kemal (later Atatürk), were able to remodel their state along European lines. During the same period the leader of the Indian National Congress, Mohandas Gandhi, was stirring the aspirations of the Indian masses for national independence. And in China, Sun Yat-sen the leader of the Kuomintang (Nationalist People's Party), inspired a successful national revolution against the last (Qing) dynasty. Because these various movements were directed against European capitalist powers, they were supported by the Soviet-communist state.

On the economic front, the chronic instability that characterised the global economy prior to the Great War only worsened in the period between the first and second world wars. The gold standard was reintroduced in 1925 but the worldwide economic downturn of 1930–1939, known as the *Great Depression* was approaching and the gold standard was abandoned, country by country, from 1931. The longer a country stayed on the gold standard, the more overall deflation it experienced. The Keynesian (demand management) and social-democratic reforms that were introduced into the world-system's core of industrial states during and after World War 2 reflected the lesson drawn by most observers at the time, namely, that an unregulated economy in which investment is driven by private capital markets is inherently unstable and inefficient. Once again, ideas spread by a book (J.M. Keynes' *The General Theory of Employment*, *Interest and Money*) would shape the world.[41]

Geopolitically, the postwar interwar period (1918–1939) saw the appearance of totalitarian regimes in Russia, Germany, Japan, Italy and Portugal. Whether fascist as in Germany or communist as in Russia, a totalitarian system of government tolerates only a single political party, one to which all other institutions are

[41] Keynes, J.M., 1936, *The General Theory of Employment*, *Interest and Money*, Harcourt, Brace and Co., New York.

subordinated, and which demands the complete subservience of the individual to the State, including their thoughts! Communism, at least in its Soviet form, is a totalitarian version of socialism. The rise of fascism in Hitler's Germany appears to exemplify the willingness of a people battered by their rapid descent into poverty and a humiliating postwar loss of national identity to put their future in the hands of a nationalist demagogue, a future from which they could not escape as Germany turned into a militaristic police state.

An alternative perspective is that aggressive fascism offered a way forward for both Germany and Japan, two highly industrialised countries which, unlike Britain, France and America, had no territorial base from which to draw raw materials.

A New Order

A victory in World War 2 (1939–1945) by an alliance of capitalist and communist states over an axis of fascist states produced a new world order, a 'cold war' between a 'western' bloc of capitalist powers led by the United States and an 'eastern' bloc of communist powers led by the Soviet Union. It was surely the threats of all-destructive nuclear war and high civilian casualties which prevented direct hostilities between these blocs as they competed across the world for military and economic superiority; and proselytised for converts to their respective ideologies of communism and capitalism. With the collapse and dismemberment of the Union of Soviet Socialist Republics in 1989, the United States became, for a moment, the world's unchallenged hegemonic state.

Elsewhere, the growth of nationalism in colonial countries was quickened by World War 2. The British, French, and Dutch empires in eastern Asia had been overrun by the Japanese, an axis power that widely disseminated the nationalistic slogan 'Asia for the Asians'. The colonial powers were weakened further by the military and economic consequences of the war and by the expansion of Soviet influence. In its propaganda, the Soviet Union emphasised the right of colonial countries to national self-determination and independence. Britain granted independence to India, Pakistan, Ceylon (now Sri Lanka), Burma (known as Myanmar until recently) and Malaya (now part of Malaysia). The United States granted independence to the Philippines. The Netherlands relinquished control of the Netherlands Indies, which became the Republic of Indonesia. France lost possession of its colonial empire in Indochina. By 1957 nationalism had triumphed throughout Asia, and the colonial empires there, with the exception of countries tied to the Soviet Union, ceased to exist.

Similarly, in Africa and the Middle East, nationalist movements developed postwar and, in many cases, succeeded. By 1958 newly established nation-states included Israel, Morocco, Tunisia, Libya, Sudan, Ghana, Iraq and the United Arab Republic (Egypt and Syria). In the 1960s and 1970s, Algerians, Libyans, and many formerly British, French, or Belgian colonies in black Africa became independent.

Europe itself experienced an enormous amount of ethnic 'unmixing' following a postwar movement of the boundary of the Soviet Union westward into Poland.

Millions of Germans, Poles and Ukrainians were forcibly resettled. An exchange of populations took place between Czechoslovakia and Hungary, with Slovaks transferred out of Hungary and Magyars sent away from Czechoslovakia. A smaller number of Magyars also moved to Hungary from Yugoslavia, with Serbs and Croats moving in the opposite direction. Later again, the decline of Communist rule in Eastern Europe unleashed separatist forces that contributed to the dissolution of the Soviet Union, Yugoslavia, and Czechoslovakia. The 1990s saw a number of former Soviet satellites, including the Central Asian republics, joining the United Nations.

Nationalism remains a potent force in world affairs. Competing Jewish, Arab, and Palestinian nationalist aspirations continue to generate political instability in the Middle East. Elsewhere, separatist movements are commonly ethnically based (e.g. amongst indigenes and minorities) and tend to be found in economically backward (peripheral) regions of postcolonial societies, e.g. Aceh and Irian Jaya in Indonesia. Separatist movements in industrial states (e.g. Scots, Walloons, Bretons) tend to be in underdeveloped regions of those states.

The worldwide wave of post-1945 decolonisation is sometimes attributed to a belated recognition by colonising powers of the democratic rights of colonised peoples. This may well be part of the story but, as J.K. Galbraith notes in *A Journey through Economic Time*, there were economic reasons also.[42] Domestic economic growth and trade between the advanced industrial countries had come to be seen as far more important than any gains from colonial trade. In cost-benefit terms, ex-colonisers shake off any obligations, financial or otherwise, to their ex-colonies. Nonetheless, ex-colonisers can still access their ex-colonies' cheap goods and labour and, where necessary to their purposes, exert financial, military and political pressure. Territory *per se* is of no value under this *neo-imperialist* perspective. What had been a system of European core states, each with its own colonial empire in Asia, Africa and the Americas became a global system of sovereign states.

Trade, particularly between industrialised nations, grew rapidly in the post-1945 world. While the gold standard never returned in classical form, the *Bretton Woods international monetary system* which was negotiated by the Allies in 1944 and lasted till 1971 was another attempt to maintain stable exchange rates. This time it was only the American dollar which was made freely convertible into gold. Capital flows were largely restricted and room for a nation to manoeuvre in the case of a persistent imbalance of payments was achieved through the introduction of contingently adjustable exchange rates. So, following an 'age of catastrophe' from 1914 to the aftermath of the Second World War, the world experienced 25–30 years of a 'sort of golden age' of extraordinary economic growth and social transformation.[43]

[42] Galbraith, J.K., 1994, *Journey Through Economic Time*: *A Firsthand View*, Houghton Mifflin, Boston.

[43] Hobsbawm, E., 1994, *Age of Extremes*: *The Short Twentieth Century*, 1914–1991, Michael Joseph, London.

The Postmodern Era

Vaclav Havel defined the modern world as the almost five centuries from the discovery of America to the moon landing in 1969.[44] The *Postmodern Era* is thus a convenient name for the period from the early 1970s to the present and near-future.[45] How, from the perspective of a brief world history of the Common Era, might this era be described? What have been the recent and ongoing changes—economic, political, social, ecological, environmental and psychological—that have the greatest potential to change quality of life for large numbers of people, now and into the indefinite future? That is what we are looking for.

Economic Well-Being

These have been decades in which capitalism, as well as communism, has failed global society in important ways—as evidenced by mass unemployment, cyclical slumps, increasing divergence between wealth and poverty and between state revenues and state expenditures. Consonant with the Kondratieff model, the growth rate of the world economy dropped from five per cent per annum in the 1960s to two per cent in the 1990s. An increasingly integrated and deregulated world economy has undermined the economic independence of all regimes. As in the period prior to World War 1, the last 30–40 years have again seen the increasingly free movement of capital make it difficult for countries to maintain stable exchange rates and full employment. In their efforts to survive, many regimes replaced the Keynesian economic ideas which ruled in the golden age with neoliberal and laissez-faire ideas. The intention has been to create domestic environments favourable to the owners of globally mobile capital, including such policies as antistrike laws and low taxes on capital. But followers of the 'deregulation' path have done no better than others and a swing back towards interventionist thinking is now appearing, e.g. towards new ways of regulating global capital flows.[46]

All economic activity requires materials and energy and growth in economic activity has now brought the world to a point where, according to the World Energy Outlook 2007, published by the International Energy Agency (IEA), it faces an unsustainable energy future if governments do not radically change their energy policies in the next 10 years.[47] If governments hold to current policies, the world's primary energy needs will grow by 55% between 2005 and 2030, the report says.

[44] Havel, V., 1994, *The Need for Transcendence in the Postmodern World*, Liberty Medal acceptance speech at Independence Hall, Philadelphia, Pennsylvania (4 July 1994).

[45] http://en.wikipedia.org/wiki/Postmodernity (Accessed 4 Apr 2008).

[46] Quiggin, J., 2001, The Fall and Rise of the Global Economy, In Sheil, C., (Ed.) *Globalisation: Australian Impacts*, UNSW Press, Sydney, Ch. 2.

[47] International Energy Agency, 2007, World Energy Outlook 2007, Paris.

This growing demand will mostly be in developing countries and will be overwhelmingly (84%) met by fossil fuels. While crude oil production has probably peaked, coal and uranium are still readily available. But, be clear, the 'scramble for energy' is on. Greenhouse gas emissions will rise by 57%, with the United States, China, India, and Russia contributing two-thirds of the increase. Renewable energy technologies (particularly wind, solar and geothermal) have enormous potential but the size of the 'capital hump' which has to be climbed over if these are to be implemented on a sufficient scale to replace fossil energy is not widely appreciated.[48] Energy-hungry technologies (e.g. fertilisers, aircraft, mass media) have allowed the capabilities of the world's food, transport and communications systems to grow enormously, thereby accelerating the processes by which formerly separate societies are coming to function as a single society, economically, socially and culturally.

Nourished by ever-expanding scientific knowledge, new technologies have appeared in droves and continued to squeeze human labour out of the production of goods and services, without necessarily providing suitable work for those jettisoned, or a rate of economic growth sufficient to absorb them. Very few observers seriously expect a return to the full employment of the golden age in the West—but a shortage of workers as populations age could change that. Demand in Western mass markets will continue to decline insofar as transfer incomes (social security etc.) fall.

The global capitalist system, increasingly the province of large transnational corporations, including state-owned 'sovereign wealth funds', remains under threat from several directions. One is the volatility of increasingly deregulated global financial markets which, seeking to reduce risk in various elaborate ways, have grown perhaps twice as fast as the dollar value of world trade. More general is the ongoing resistance to the global capitalist system from those virtual species who perceive its outcomes to be, above all, inequitable, and who increasingly operate on an international stage. The so-called 'world revolution of 1968' when groups in many countries protested at the slow rate of redistribution of economic benefits post-1945 is a primary example.[49] The activities of the World Social Forum and protests against the World Trade Organisation are more recent examples. Such movements are better not dismissed as trivial, especially when viewed as part of a broader push for the formation of a global state.

Global Governance

Despite widespread doubts in recent decades as to the legitimacy and effectiveness of nation-states, the people of the world have persisted with and continued to adopt the nation-state as their basic form of political organisation. And, to the extent that

[48] A capital hump occurs in the manufacturing sector when there is an intermediate demand for machines needed to produce the machines in final demand.

[49] Wallerstein, I., 2004, ibid., p. 84.

people from different parts of the world come together to take collective action of some sort, it is still nation-states which most commonly represent people's interests in such fora. What might be termed transnational social movements are one growing exception to this generalisation, e.g. movements concerned with status of women, environmental protection, human rights, democracy, antiglobalisation, and world economy (Davos).

The most inclusive of international political organisations is of course the United Nations (UN). That inclusiveness gives the UN a legitimacy such that, despite being currently dominated, quite undemocratically, by the US hegemon and the core Allied powers from the Second World War, a reformed UN (more checks and balances, more resources, less bureaucracy) could yet become a true federation of the world's states. Meanwhile, reflecting the perceived benefits of targeted cooperation, there are ever-more examples, at a smaller scale, of more or less successful multi-state organisations. Thus, I judge the European Union to be quite successful. The International Monetary Fund, on the other hand, appears to have lost credibility.

Notwithstanding, while a world war is not on the horizon, it is a disordered world in many ways, a world in which there are no institutionalised procedures for dealing with a multitude of international governance issues. Consider how dozens of new territories have emerged without any independent mechanisms for border determination. Consider climate change. Consider nuclear proliferation. Consider the management of warfare as a social technology. We live in a world where industrial states can win battles against peripheral and semi-peripheral states but not wars, not in the sense of being able to control the conquered territory after 'victory'. The privatisation of the means of destruction means that it is now quite possible for small groups of political or other dissidents to disrupt and destroy anywhere. Concurrently, the cost of keeping unofficial violence under control has risen dramatically. Max Singer and Aaron Wildavsky are two who, like Eric Hobsbawm, see the world as dividing into two parts. One part is characterised by peace, wealth and democracy. The other by zones of war, turmoil and slow development, zones where a century of disruption can be expected. Note though that the short lives of the twentieth century's totalitarian and ruthlessly dictatorial regimes reinforce the idea that sheer coercive power has its limits.[50]

State of the Nation-State

Wallerstein has charted the changing legitimacy of *states* over the past 500 years, i.e. the degree to which such are accepted/ supported by their citizens.[51] Initially weak, the cement of nationalism and the rise of the concept of the sovereignty of the people, particularly after the French revolution, created strong nation (cf. city) states

[50] Singer, M., and Wildavsky, A., 1993, *The Real World Order*: *Zones of Peace/Zones of Turmoil*, Chatham Publishers, New Jersey.

[51] Wallerstein, I., 1995, *After Liberalism*, The New Press, New York.

although class struggles (e.g. Disraeli's 'two nations'), did threaten to delegitimise states in the nineteenth century. However, support from both left wing and right wing forces, the right emphasising unity against external enemies and the left holding out the possibility of the people taking control of the state apparatus, strengthened the state and permitted the taxes which funded more services and hence more legitimacy.

Legitimacy declined again in the first half of the twentieth century with the failure of popular movements once in power, and with massive casualties in patriotic wars. Support for the state revived on the back of post-1945 welfare-statism, only to decline yet again in the last 30 years.

Why? Reasons suggested for this most recent decline in the power, role and legitimacy of the nation-state include:[52]

Power is being passed upwards to supranational bodies via treaties and international regulations and standards. Transnational arrangements such as the European Community and North American Free Trade Association are already overriding parts of traditional national sovereignty, e.g. in social and environmental policy.

Power is being passed downwards to regional authorities.

World financial markets set limits on domestic fiscal and monetary policy for most countries.

Nations have limited scope for any actions that reduce their international competitiveness.

Transnational companies determine investment partly on the basis of tax treatment and hence there is a limit on any country's capacity to extract tax from foreign businesses.

The talented are becoming more mobile and can choose to live where life is good and personal tax rates are low.

Business is increasingly participating in public policy making through lobbying aimed at influencing policy decisions.

States are finding it increasingly difficult to provide public goods such as law enforcement (hence the rise of private security services), property and environmental protection, regulatory structures etc. The state's natural monopolies, postal services for example, are eroding. Indeed, the ideal scale for providing many services is changing, under globalisation, from national to international.

Nevertheless, the 'territorially rigid' nation-state continues to exist. Patrick Kennon foresees a continuation of the current division of nations into a first, a second and a third world, perhaps with some limited movement of nations between these categories, such as, for example, post-Franco Spain joining the first world.[53] First World countries, mostly liberal democracies as in the Organisation for Economic Cooperation and Development (OECD), are politically stable without

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[52] McRae, H., 1994, *The World in 2020*: *Power*, *Culture and Prosperity*: *A Vision of the Future*, Harper Collins, London.

[53] Kennon, P. E., 1995, *The Twilight of Democracy*, Doubleday, New York.

having to depend on police-state methods or foreign support. They are economically advanced in terms of such indicators of a modern economy as GDP per head, price stability, inflation rate etc. They are socially developed in terms of education, life expectancy public health and other social indicators of well-being.

Second World countries are commonly in disequilibrium because they have powerful and unrelenting internal enemies whom they control with loyal and effective police forces. The more authoritarian second world regimes put security above principle and make no claim to higher abstractions, e.g. Myanmar. Others justify and legitimate themselves on ideological grounds or on the basis of economic success (e.g. the newly industrialising countries of Asia).

Third World countries, sometimes called the South because so many are in the southern hemisphere, are those unable to enforce their will throughout their national territories. Many are overwhelmingly burdened by foreign debt—having to make debt repayments to first world countries ensures that schools and hospitals cannot be built and that ever-more resources will be sold off, exacerbating the problem further.

The quintessence of liberal democratic government is 'restrained' majority rule, that is, majority rule restrained by culture, law, custom, 'natural' rights to protect minorities and the power of a range of countervailing institutions (such as churches, unions, business, the public service, academia).[54] It allows the individual an effective say in running the state through a process of free election of representatives under broad suffrage to make laws and carry out policy. The will of the people is the legitimate source of their own collective direction. Geoffrey Gorer emphasises that not only *is* majority rule restrained by a range of values ('whatever is taken to have rightful authority in the direction of conduct') in a democracy, it *must be* if democracy is to survive; that the attitude of 'winner takes all' is fatal to democracy.[55] Government must have the consent of all the governed. Yet many first world countries contain a growing underclass that feels that the political process has failed it. Certainly many unemployed feel betrayed by a society that says 'If you try hard enough you will get a job'. So how has this happened?

Democracy's greatest strength, having to maintain the approval of the voters, is also its greatest weakness, namely, having to get reelected every few years by pandering to short-sighted and greedy voters and not take account of future voters, nonvoters etc. Single-issue parties can exert a disproportionate influence. Liberal democracies seem incapable of preempting (anticipating? forestalling?) or even seriously debating problems and, moreover, tend to overreact when they do eventually respond. The reason has been neatly diagnosed as 'pluralistic stagnation' wherein competing interest groups continually nullify each other: whatever is proposed by one group is commonly against the interests of some other organised group and therefore vigorously opposed.[56]

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[54] Dahl, R.A., 1999, *On Democracy*, Yale University Press, New Haven, Connecticut.

[55] Gorer, G., 1966, *The Danger of Equality and Other Essays*, Cresset Press, London.

[56] Lindblom, C.E., 1965, *The Intelligence of Democracy*: *Decision Making through Mutual Adjustment*, Free Press, New York, Ch. 9.

Contributing to the 'log jam' in many cases is the built-in unwillingness of contending parties to compromise, to moderate their demands. It is proposals which threaten only a diffuse and unorganised public interest which best stand to succeed! Mancur Olson talks about *distributional coalitions* or *special-interest groups* that are willing to sacrifice large national gains to obtain small gains for themselves.[57] Still, while liberal 'representative' democracies have become increasingly vulnerable to sectional interests in recent decades, they face little internal threat of being taken over through the ballot box by nondemocratic groups such as religious fundamentalists or US-style 'patriots'. The numbers of such are too small.

Of more concern is the prospect of some liberal democracies becoming authoritarian police states—as a response to deepening intractable divisions within the society, along with the loss of both sovereignty and legitimacy. Where such divisions are geographic (e.g. Quebec in Canada, Scotland in the United Kingdom), dissociation might be the way forward, but where, say, 20% of the community forms a diffuse underclass, Rio de Janeiro-style 'war' and terrorism in the cities is foreseeable.[58] Beginning signs can be seen in Liverpool, Manchester and Newcastle in the United Kingdom and in Los Angeles and New York in US.

But even where democracies are not deeply and intractably divided to the point of being threatened by violence and its repression, or not threatened at the ballot box by antidemocratic minorities, they are still threatened by 'creeping bureaucratisation'. Kennon sees the rise and fall of nation-states as dependent on the interplay between the political sector, the bureaucratic or managerial sector and the private sector.[59] The political sector is essentially confrontationist and that is inefficient. He notes that economically successful states of recent times are those where the bureaucracy and its specialists are able to concentrate on facilitating the activities of the private sector and solving 'technical' problems. He conjectures that first world countries intent on retaining that status, but bedevilled by pluralistic stagnation or gridlock, will gradually turn more and more decisions over to bureaucrats and specialists. The increasing role of economists is a good example of the erosion of authority by technical competence. Interest groups would not then be able to play the same role as they do now in influencing government decisions. Concurrently, the core business of government stands to move from the provision of services to the administration of service provision.

The political sector would not disappear in such a 'post democratic world', nor would it cease to have important functions: it would legitimise bureaucratic actions just as a monarchy can legitimise parliament; it would act as an ombudsman for individuals and as umpire for disputes between bureaucracies; it would channel violent tendencies into harmless theatre (as sport does); and, if things went really wrong, it could reassert itself as an authority of last resort.

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[57] Olson, M., 1982, *The Rise and Decline of Nations*: *Economic Growth*, *Stagflation and Social Rigidities*, Yale University Press, New Haven, Connecticut.

[58] Van Creveld, M.L., 1991, *On Future War*, 1st UK Ed., Brassey's, London.

[59] Kennon, P. E., 1995, ibid.

Ecological and Social Well-Being

The most recent decades of the Common Era have also been the time when the potentially catastrophic ecological consequences of economic growth have begun to emerge, e.g. climate change, fisheries depletion, deforestation, soil degradation, species loss, air and water pollution. Economic growth is an abstraction and, more concretely, the environmental and ecological impact of human society is largely a function of population size and rate of energy use per head of population, both of which have been increasing rapidly since the Industrial Revolution.

It is widely accepted that even though total fertility rates are falling in many countries, world population is likely to rise from 6.7 billion to more than 9.2 billion in 2050. Notwithstanding, declining fertility rates in all parts of the world now make it likely that human population growth will come to an end over the course of this century.[60] So, while world population is growing, it is now doing so at a much slower rate (1.2% per an.um) than in the mid-twentieth century (2% per an.um) and, because of increasing longevity and decreasing fertility, the world's population is ageing. The average age of the world's people will rise from the present 28 to 41 years old in 2100, with the proportion of people over 60 years old increasing from 9.2 to 25.5%.[61]

As well as growing and ageing, the world's population is urbanising and moving. The percentage of the world's population living in cities will rise from 50 per cent today to 70 per cent in 2050 according to UN projections. More and more cities will be *megacities* of over ten million residents, most with a majority living in dystopic slums. One threatening consequence of increased urbanisation and increased interactions between societies is that the world community becomes one big disease pool. While being a 'global village' means that there are no longer susceptible unexposed local populations waiting to be drastically reduced by diseases new to them (e.g. the Australian Aborigines after white settlement), it also means that a virulent new disease could drastically reduce the world population.[62] Or, less apocalyptically, pandemics of cholera, yellow fever and plague are ever-present possibilities.

The large migrations that took place between the core countries of the First World after World War 2 seem to have come to an end. The twenty-first century stands to be one of movement of people from poor to rich countries and, indeed, the first wave of peripheral (Third World) peoples has already arrived in the First World. Differences in population growth rates are already generating strong migratory pressures, especially between proximate rich and poor countries such as China and Japan or eastern and western Europe. Under the combined influences of population

[60] Lutz, W., and Qiang, R., 2002, Determinants of Human Population Growth, *Philosophical Transactions of the Royal Society B*, 357 (1425), pp. 1197–1210.

[61] Lutz, W., Sanderson, W.C., and Scherbov, S., (Eds), 2004, The End of World Population Growth in the 21st Century: New Challenges for Human Capital Formation and Sustainable Development, Earthscan, London.

[62] McNeill, W.H., 1979, *Plagues and People*, Penguin, London.

growth, the disruptions of climate change and competition for basic resources, it is not difficult to foresee population movements more massive than the world has ever known. There can be little doubt that friction between natives and foreigners will be a major factor in the politics, global and national, of the next decades. Eventually, the problem of how to keep world population stable will have to be faced.

Global energy use continues to climb in step with increasing Gross World Product per capita and increasing population. Since 2000 there has actually been a cessation or reversal of earlier declining trends in the energy intensity of GDP (joules of primary energy use per dollar of GDP) and the carbon intensity of energy use.[63] In the First World, it is increases in the per capita supply of usable energy which allow people to make use of an ever-growing suite of social, material, cognitive and communicative technologies in their personal lives and in their social roles. Thus, technological advances in transport and communications have 'virtually annihilated time and distance'. Technologies which allow fossil energy to be substituted for human labour have dramatically increased productivity and reduced workforces in food production and manufacturing industry; and allowed the service industries workforce to grow. World agriculture has become highly dependent on artificial fertilisers that are produced by energy-intensive methods. Computer-based information technologies have amplified our ability to access and manipulate information. And so on.

The ecological consequences of ongoing economic growth will not make the world uninhabitable for humans but will change the everyday environments in which people live and perhaps reduce the carrying capacity (numbers that can be supported) of the globe considerably. Many societies will have to be fundamentally reorganised. In the long run, a balance will have to be struck between humanity, the (renewable) resources it consumes and the effect of its activities on the environment. Nobody knows, and few dare speculate how this is to be done, and at what level of population, technology and consumption such a permanent balance would be possible. One thing however is undeniable: such a balance would be incompatible with a world economy based on the unlimited pursuit of profit in capitalist economies of the type now existing.

Changes in Social Character and Identity

If a Cro-Magnon baby from 20,000 years ago were to materialise in a First World maternity ward tomorrow, there is no reason to think that s/he would not grow up to be a more or less 'normal' member of the community. Equally, today's 50-year olds could have fitted into their parents' or grandparents' society, provided that they were socialised and educated from birth in that earlier society.

[63] Raupach, M.R., Marland, G., *et al*., 2007, Global and Regional Drivers of Accelerating CO_2 Emissions, *Proceedings of National Academy of Sciences*, 104 (24), published online at http://www.pnas.org/content/104/24/10288.full.

If a well-informed young adult from the First World urban middle class were to 'time travel' from 1970 to 2010, they would be struck immediately by changes in the product mix, the job mix and the technology mix. Equally, recognising continuity as well as evolution, they would appreciate that the physical economy could still be described in terms of such 'mixes'. They would note the increased use of capital and energy-intensive technologies (transport and farming are good examples), the growth of sophisticated service industries (medicine and pharmaceuticals are good examples), the further disaggregation and specialisation of worker tasks, the pervasiveness of new information-communication technologies, the relative decline of 'wet and heavy' industries, the emerging of new 'knowledge' industries based on, for example, alternative energy, biotechnologies, manufacturing nanotechnologies. They would be overwhelmed by the ever-growing range of elaborate consumer products being produced by 'footloose' industries scattered around the world. On matters less economic, one might guess that our time-traveller would be greatly surprised by the collapse of Soviet communism and the ubiquity of the perception that climate change is upon us. And they would feel at home with perennial worries about world population growth, pollution and violence (although not with the contemporary fear of terrorism). A list such as this gives no more than the flavour of a culture which, by historical standards, is changing at unprecedented speed.

But, what if we are looking for insights into how people's minds, their 'mental capital', may have altered during these same feisty decades—such things as their attitudes, values, norms, beliefs, sense of identity, their 'objective' knowledge? Where do we start? Has there been little change? Have past trends simply continued, or have there been abrupt shifts? Is 40 years too short a time to detect changes anyway? Are generalisations even possible?

A good place to start is with Eric Fromm's previously mentioned idea of *social character*.[64] Fromm was a cultural materialist who, 60 years ago, argued that it is *character* that leads a person to act according to the dictates of practical necessity and also, of equal importance, it is what gives him/her psychological satisfaction from so doing. That is, people develop the very traits that make them desire to act as they have to act if they are to function as members of their society. Social character or 'the socially typical character' is an extension of the idea of individual character, namely, that in a slowly changing culture, a majority of people come to acquire a common set of character traits, a 'collective mentality'. As with individual character, social character internalises what is externally necessary and thus harnesses willing human energy to the tasks of a given economic and social system, tasks that reflect how that society is organised to meet the needs of its members.

Here, in ground that has been regularly tilled by psychologists, sociologists and others, we have space but to comment, speculatively and impressionistically, on a few aspects of the dialectical interplay between socioeconomic organisation and

[64]Fromm, E., 1942, Character and the Social Process, Appendix to *Fear of Freedom*, Routledge and Kegan Paul, London; see also MacCoby, M.,2002, Toward a Science of Social Character, *International Forum of Psychoanalysis*, 11 (1), pp. 33–44.

social character; and to indicate something of the process by which social character has changed historically and is changing now.

Fromm's protégé, David Riesman, focussing particularly on the United States, detected a shift there in the mid-twentieth CEntury from an *inner-directed* social character, guided by strongly internalised values and a sense of direction towards an *other-directed* social character guided by a search for the approval of others.[65] He finds little place in American society for his third category, *tradition-directed* social character. People in tradition-directed societies are largely guided by custom and habit and share a somewhat-limited range of similar ideas and perceptions. Decision-making in traditional societies is not adaptable and the viability of such societies declined (for example) under the unstable conditions and turmoil of the late Bronze Age. This is, partly, why, in the 'axial age' of the first millennium BCE, traditional societies began to be replaced with societies where decision-making was guided more by new religions and, in the case of Greek society, by rational self-consciousness. People of the time began to recognise and actively develop their own individual identities (I am a …), a process of *individuation*, differentiation from the group, which soon stalled but which resumed again with the coming of the European Renaissance and Reformation.

European society became more complex as it emerged from feudalism and the Middle Ages. And with that complexification came a corresponding increase in the number of ways that individuals could be identified, i.e. distinguished from each other in terms of their socially relevant characteristics. Across Europe, blocks of individuals became increasingly distinguishable from each other in terms of, particularly, occupation, nationality, language, religion, education and political beliefs.

Nonetheless, identity had not thereby become a matter of choice and individual identities were certainly not unique. People of all classes had little choice but to accept the identities bestowed on them by society and most played their part in reproducing their societies. Social character found its expression in a largely uncritical acceptance of 'our' nation-state, monarchy, established religion, cultural practices, mercantile capitalism etc. All such had become associated with positive emotions. There was widespread respect for the authority of these institutions and, because a majority had similar values, social solidarity and cohesiveness were high. From a psychological perspective, being among people of similar social character satisfies the individual's need to belong.

Equally, there was a leavening minority who, from the Reformation onwards, wanted these core institutions reformed to become less authoritarian, less constraining, more participatory, more equitable, more reasoned. Political liberals and religious freethinkers were seeking the autonomy and the right, within limits, to order their lives and express their beliefs in ways that seemed good to them. And this is what eventually happened. Despite the resistance of conservative and reactionary established-interests, the eighteenth century was a century of enlightenment and revolution, both political and industrial. The spread of political rights at this time

[65] Riesman, D., 1950/1961, *The Lonely Crowd*, Yale University Press, New Haven.

can be viewed as the ‘invention’ of a social technology for ameliorating the danger of society’s identity-conferring institutions igniting social unrest.

The eighteenth century was also one in which, reflecting the commercial interests and deep influence of industrialists, the economic doctrine of *laissez faire* (‘free’ markets) and the related social doctrine of *individualism* came to be widely accepted. Social character was again following the ‘requirements’ of the economy. The perspective of individualism is that the state, rather than being seen as a means for collectively pursuing the common good (*collectivism*), is to be limited to guaranteeing conditions under which the individual can pursue hir own self-interest and make of hirself whatever hir talents and abilities will allow (sometimes called self-actualisation). It is further assumed that those requisite conditions are minimal. The conundrum for a society seeking to be adaptable yet stable is that while individualism promotes individual initiative, innovation and responsibility, there is, without a concept of the common good, nothing to bind the body politic together, nothing to underwrite cooperation. Thus, a seesawing struggle for political dominance between individualism and collectivism in some form remains the central feature of politics to this day. And an individual’s attitudes towards this duality remain an important dimension of hir identity.

In the nineteenth century most aspects of most people’s identities, whether they lived in a core society or a peripheral society, continued to be structurally imposed. That is, short of alienation and rejection, people had little or no choice as to their nationality or religion or occupation, notwithstanding that these sometimes changed haphazardly, e.g. finding oneself a citizen of a newly formed nation-state or a conscript in an old one. The spread of unregulated labour markets did little to expand employment options for the working class. Most industrial workers and peasants had neither the income nor the discretionary time nor the social space to individuate in any significant way. Indeed, for most, individuation would have been a concept with little meaning.

However, for the urban middle classes in the industrialising countries, genuine identity-defining choices were beginning to appear. Males could aspire to a white collar or even professional career. Within the confines of Christianity one could choose between Catholicism and a variety of Protestant denominations. People were somewhat freer to make their own choice of spouse. Politically, one could be a socialist, a liberal or a conservative. Post-school education was often available to those wanting it. Informed by newspapers and a proliferation of books, one could take a position on big issues like evolution, the abolition of slavery, child labour, poverty, the class system, votes for women. And there was a modest space for a variety of hobbies and pastimes. People were free to migrate to the New World; or just move to another city. The right, and even the need, to individuate in a ‘free’ society where so much was changing was accepted, albeit reluctantly by those seeking to protect traditional values.

In practice people’s choices were strongly correlated with and restricted by their parents’ identities, e.g. there was little mobility between social classes. Notwithstanding, Western society in the nineteenth century was differentiating into ever-more virtual species or ‘tribes’—blocks of people with similar identities and matching social characters. While tribes routinely fulfilled their economic and social obligations, it was becoming increasingly recognised that, in a liberal democracy, there is also scope, inside and outside the parliamentary system, for such social-identity groups to protect their members' interests and, sometimes, rework society to better meet members' needs. The formation of labour parties to protect and promote working class interests within the parliamentary system is a primary example. An era of pluralistic politics, with all its possibilities for further fragmentation of social characters and elaboration of social-identity groups was beginning.

Coal provided the primary energy surplus which allowed/ precipitated the diversification and complexification of nineteenth century Western society, and hence of social character and identity. It was a surplus which, starting as profits in manufacturing industry, filtered down into a range of new technologies that restructured the product mix and the job mix. Apart from industrial technologies *per* se, and the social technologies that were restructuring governance and capitalism, there were several technologies which seem to have been of generic significance in allowing/ encouraging an expansion in the spectrum of personal identities and lifestyles observable in ordinary people. These were telegraphy, the rail network, the typewriter, paper made from wood pulp, cheap postage and the lighting, by gas and electricity, which made night life possible. Positive attitudes towards these innovations easily became part of social character in the Western world.

The invention of the telephone in the 1880s and radio broadcasting in the 1890s introduced radically different ways of projecting speech through space. The gramophone allowed speech to be projected in time but it was a mechanical invention rather than electronic like the much-later tape recorder. Television was a prosthesis which allowed both speech and bodily presence to be projected in space and time (and allowed an extended field of vision). Marshall McLuhan has argued that these new technologies effected a major shift in the way people think and behave, that we are returning to the oral-aural culture of traditional societies.[66] We are spending much more time talking to each other and relatively less time reading and writing. More than that, he says, the world has become, in his famous phrase, a 'global village' where radio and television have created a shared mythic structure (Hollywood?) and a collective mind, a global-wide social character.

But, we might ask, has electronic technology changed the *way* we think by changing the way we read-write? The answer is probably No. There is no doubt that word processors, hypertext, voice recognition technology, searchable electronic libraries etc. have ramped up the efficiency and the reach with which we both read and write. But it is hard to see that our thinking processes differ from those of our grandparents. Just to be clear here, what we think *about* is obviously different—we live in a different world.

Fossil oil joined coal as a primary energy source in the twentieth century. Internal combustion engines transformed a range of industries, directly and indirectly, and,

[66]McLuhan, M., 1962, *The Gutenberg Galaxy*: *The Making of Typographic Man*, University of Toronto Press, Toronto.

for many people, their employment, their social character, their lifestyle and their identity. As noted, one particularly important reason why coal remained an important primary energy source was its increasing use in coal-fired power stations for generating electricity, a highly flexible form of secondary energy. For example, the spread of telephony and broadcasting in the first half of the twentieth century and computer-based information processing and the Internet in the second half has depended on the availability of reticulated electricity; as have many other domestic and industrial technologies to which people have adapted.

The rate of cultural-technological change, while not directly measurable, has surely been increasing since the start of the cultural eon, and has probably been increasing at an increasing rate with the increasing use of, first, coal, and then oil. New technologies have emerged and diffused and coevolved to the extent that they have been found useful. Particularly in the last hundred years, the product-technology mix in First World economies has relentlessly self-reorganised into paths that use more energy.

What has this ‘long century’ of oil and electricity meant for social character and for the individuation of identities? In general people have, more or less willingly, done what has been necessary to reproduce (maintain) the society they find themselves in, i.e. the concept of social character remains broadly valid in the twentieth twenty-first century as in earlier times. First, people have learned, and updated as necessary, the multitude of skills demanded by an economy producing an ever-changing basket of goods and services. Second, they have been willing to use their incomes to purchase the basket of goods on offer, thereby keeping supply and demand in approximate balance. And when there has been a mismatch between production and consumption needs, during recessions for example, social character has not broken down. In practice of course the basket of goods on sale is changing ‘dialectically’ in response to business perceptions of what will be profitable and consumer perceptions of what will satisfy their ‘needs’.

This high-energy period has also been one in which, through opportunity and necessity, populations have become more finely divided in terms of both social and personal identities. There are more ways to be different, both in terms of the groups people can see themselves belonging to and in the activities which they might undertake as individuals. Individuals create a multifaceted social identity for themselves by identifying with and accepting roles within various social groups which have their own established attitudes, norms etc. Depending on social context, the individual moves amongst this suite of roles.

The group which has most notably attained social identity (as well as richer personal identities for its members) in the last century is women. An increased role for women in the labour force has coevolved with the product-technology mix, particularly with the decline of manual work and the rise of service work. From the fifties, innovations like processed food and the contraceptive pill have given women more options for balancing a domestic role and paid employment. Improvements in the status and independence of women have in turn redefined role and identity for many males, e.g. around parenting. Other categories of individuals who have acquired a public social identity, and are recognised as having a collective political voice (voices) include ethnic groups, sexual-identity groups, disabled people, sufferers from various diseases, sporting groups, cultural groups, consumer groups…the list goes on.

Postmodern People

Societal change can always be seen as standing in a dialectical relationship to the 'history of ideas'.[67] When the ideology governing the management of most first world economies lurched from Keynesian interventionism to something much closer to 'free market' liberalism in the early 1970s, it triggered cascades of substantive change in the technology-product-job mix, income distributions, the distribution of economic activity around the world and employment conditions. In terms of impact on social character, this ending of the postwar 'golden age' saw the revival, rapid spread and acceptance of two perspectives—nineteenth century individualism and economism. *Economism* is the philosophy that, because people are primarily strivers after material gain (sic), governments should give priority to economic considerations when making policy decisions. *Neoliberals* make the further assumption that material gain will be higher in a fully commodified economy and society than under any other form of social organisation. *Commodification* occurs when an activity involving production, exchange, saving, or borrowing is newly monetized and, consequently, becomes tradeable—just as the commodification of land, labour and capital made industrial capitalism possible. In post-1970 markets, where there have been a declining number of societal constraints on what commodities can be traded, commodification, because it promises profits, has grown in many, often-new, areas, e.g. producing children. *Privatisation* is a form of commodification in which governments sell publicly owned assets such as land, physical infrastructure and service agencies to profit-seeking private corporations.

The enthusiastic assimilation of these perspectives by individuals, governments and corporations since, say, 1970, has had major impacts, positive and negative, on the quality of life and psychosocial well-being of citizens of Western 'post-industrial post-modern' societies. In terms of material well-being there has been a 'hollowing out' of the middle class, meaning increasing proportions of rich and poor, but with the incomes of the poor declining in relative rather than absolute terms.[68] As the willingness and ability of the state to provide people with proper education, health services, security, transport, housing etc. has been declining, social character has, for a large group, been responding by becoming entrepreneurial, hard working, information-rich, socially apathetic, apolitical, self-promoting, socially interactive and self-sufficient. These are traits well suited to finding a role in a commodified society and to reaping material benefits therefrom. For those with sufficient income,

[67] Berger, P. , and Luckmann, T., 1966, ibid. p. 128.

[68] Dollar, D., and Kraay, A., 2001, *Growth is Good for the Poor*, World Bank Policy Research Working Paper No. 2587, Washington, DC.

a market society offers a multitude of painless and enjoyable ways to be different from others, i.e. to individuate. Many goods and services formerly provided through the state can be bought in a market society.

But what of the ‘cultural laggards’ who have resisted or have not been adaptable enough to take on a postmodern, market-oriented social character? One such group is those older people who, having previously adapted to or grown up in a more collectivist society, have found themselves unwilling to accept the thin social contract implied by a society committed to individualism and economism. Another group left behind in what has become a runaway society is the slow learners, particularly those who cannot acquire the increasingly specialised knowledge and skills that contemporary employment so often demands. A third group has not so much resisted adapting but rather has been excluded *a priori*, either deliberately (e.g. prison inmates) or through lack of opportunity, e.g. minority groups, the socially disadvantaged.

Isaiah Berlin is known for his observation that ‘the history of thought and culture is …a changing pattern of great liberating ideas which inevitably turn into suffocating straitjackets, and so stimulate their own destruction by new emancipating and, at the same time, enslaving concepts’.[69] There are signs that this reflexive, dialectical process is already operating on the ideas that captured First World thinking in the 1970s, namely, that individualism and free markets could rescue the stagflating economies of the time and produce high quality of life for most people. Now, thirty-plus years later, there is a widening conviction that neoliberalism has been given a generous opportunity to rise to this promise but has significantly failed. The perception is more than one of failure to achieve what might have been; it is a rediscovery of Karl Polanyi’s conclusion (see page 226) about an earlier era, namely, that by its very nature, an unregulated marketised society cannot offer high quality of life to the bulk of its people. Consider some of the spreading perceptions which have helped to reinforce this awakening disillusion:

A market society strikes a hard bargain. For many, it takes too much time (a) to earn the money and then (b) to choose and buy the goods and services they have come to expect or which they see as ‘normal’. ‘Choice fatigue’ is a reality. For many, because of the way work is structured, they have to spend long hours earning money to pay for services they would otherwise have provided themselves. Many couples feel they do not have the time to raise a family. There is little discretionary time for recreation and personal development.

The demands of an individualistic marketised society lead, in several ways, to a decline in *social capital*, i.e. to a weakening of social networks and amicable relationships of practical and emotional importance to the individual. For example, the need for people to be mobile, if they are to find and keep employment, fragments and fractures families and communities. The market’s presumption that one’s responsibilities to others are set by contractual arrangements alone seeps into interpersonal relationships and militates against altruistic, reciprocal and dutiful

[69] Berlin, I., 1980, *Concepts and Categories*: *Philosophical Essays*, Oxford University Press, Oxford, p. 159.

behaviour.[70] People become more selfish. Participation in community life declines. The contractual perspective diminishes loyalty between employee and employer.

Even for people with money, their choices within the market are muddied, in the name of competition, by dishonest, uninformative and manipulative advertising. Poor people and people with offbeat demands are ill-served by the market system. Too often, it seems that 'competition' does not improve the quality, price or range of genuinely different goods and services on offer.

Economics becomes the dominant discourse in a marketised society. For example, politics is no longer the crucible in which people struggle to define and control their destinies; politics is more a debate amongst the few on how to manage society to facilitate the flourishing of the economy. Indeed, an economic metaphor is used to understand politics as a 'market' for the votes of narrowly focussed, and largely selfish, interest groups (virtual species). In the public arena, science, the arts and education are most commonly viewed through a cost-benefit prism. To the extent that people have to reduce themselves to 'saleable personalities', and nothing else, to compete for employment, they are forced, metaphorically, to become commodities. In similar vein, individuality is increasingly shaped by the commodities one purchases.

Because money matters so dominate public and private discussion, a market society is a BORING society—a bit like someone who has only one topic of conversation. More significantly, this monologue squeezes many important issues off the public agenda, e.g. from newscasts.

A market society is a *risk society*, i.e. one where people recognise that they have to be increasingly self-reliant in relation to the contingencies which lurk around employment, health care, higher education, personal safety etc. Examples include health insurance, borrowing to finance one's education. Many people find they do not have the income, the information-acquisition skills, the family-community support or the access to trusted advice which would allow them to feel confident that they had adequately protected (insured) themselves against life's contingencies. People with specialist skills are as vulnerable to unemployment as the unskilled in a rapidly changing market economy.

For many, the result of feeling that they are not coping is anxiety, a fear of the freedom which an individualistic, marketised society offers and demands (Durkheim's anomie[71]). In turn, anxiety frequently leads to disabling depression. Consequently, there is a degree of support for the idea that the social contract needs to be rewritten to ensure that the state carries more of each individual's life risks. Presumably this means more than revisiting the postwar welfare state and more than the push for individualisation of responsibilities so characteristic of neoliberal governments.[72]

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[70] Lévi-Strauss, C., 1957/1980, Reciprocity: The Essence of Social Life, In Coser, L.A., (Ed.), *The Pleasures of Sociology*, New American Library, New York.

[71] http://en.wikipedia.org/wiki/Anomie (Accessed 28 Jan 2011).

[72] Giddens, A., 1991, *Modernity and Self-Identity*, Polity Press, Cambridge; Bauman, Z., 1992, *Intimations of Postmodernity*, Routledge, London.

The aggressive individualism of the Postmodern era has in part been an understandable reaction to people's postwar fears of being swamped in a mass society.[73] But it has led to a loss of faith in collective action. Notably, people have lost faith in the state's capacities, including its ability to deal with big problems which affect the individual's life but about which the individual can do little, e.g. war, climate change. Partly because of the state's ready support for business interests over the public interest, there is a loss of faith in the state's willingness and capacity to pursue social justice. The rhetoric of market ideologists emphasises the competitive aspects of capitalism and overlooks its equally important cooperative aspects. People translate their experience of this perspective in their economic life into their social relationships, i.e. these become rivalrous and dominative. In many spheres, an intensely competitive ethos is wasteful, suspicious and destructive; and, also, it is often unfair in the sense that 'winners' are lucky as often as they are clever or industrious.

Trust in the honesty of others tends to decline in an individualistic society, e.g. not trusting strangers, politicians, spokespeople for institutions, media stories, and bureaucrats. This is a natural consequence of the idea that individuals have few responsibilities to others. Regular exposure of corrupt practices and of people not playing by the rules, further undermines trust.

Erosion of authority is another feature of increasingly individualistic societies. People have become less willing to be guided in their behaviours and beliefs by the judgements, assertions, wishes and commands of 'authorities', particularly the traditional authorities of church, state, family, community and 'experts'. A general consequence here is that people become less able to predict the other's behaviour and hence the 'other' becomes more threatening. Social cohesiveness is lost. In the family, parents are less able to successfully hand on knowledge of social behaviours; other-directed adolescents are learning more from their peer groups. Traditional religion has lost its capacity to mobilise large segments of society through its systems of real and perceived rewards and punishments. People do not listen to politicians. Ironically, the collapse of the Soviet state and its threat to the West probably weakened the internal authority of Western states.

Declining faith in most sorts of experts in the Postmodern era has coincided with a rise in *postmodernism*, the aesthetic, literary, political or social philosophy, as the case may be, whose central feature is suspicion of all claims and a wariness about making any claims at all. *Caveat emptor*! Postmodernism is based on the recurring anti-Enlightenment, anti-reason idea that knowledge can come only from personal experience, not from deductive or abductive reasoning (sic). Expertise in science, this being the search for universal knowledge, has come under particular attack, e.g. evolutionary biology. More generally, this loss of faith in expert knowledge has led to a decline in people's awareness of the ideas that have shaped contemporary understanding of the world. Among other consequences, that further erodes people's confidence in who they are.

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[73] Gleason, P. , 1983, Identifying Identity: A Semantic History, *The Journal of American History*, 69 (4), pp. 910–931.

Clearly, it is not easy to make generalisations as to how the mentalities of First World people have changed through the Postmodern Era. It is being suggested here that, since the early 1970s, many have taken on a social character, a body of attitudes and beliefs, which has helped them to participate willingly and successfully in societies which became more marketised and individualistic than the slower-moving, more sociable mixed economies of the postwar ‘golden age’. But, it is also being suggested that during the last decade or so a perception has been growing that individualistic and weakly regulated market societies threaten individual and social well-being in important ways, viz. the points above.

You Are Here

This then is where we are now. While the First World’s dominant paradigm is not under immediate threat, one might ask whether these perceptions of its weaknesses are spreading at an increasing rate. Has support for the dominant paradigm peaked? Has there been an increase in antipathy towards those questioning the dominant paradigm? Conversely, are the disillusioned already alienated and actively hostile? Are any antithetic alternatives to the dominant paradigm emerging? Are people behaving differently as they come to recognise various weaknesses in the dominant paradigm?

Such questions can only be answered impressionistically here. A society’s belief systems tend to change only when they clearly fail and when, as well, there are plausible alternatives to hand. It may be that the confluence of climate change, peak oil, religious fundamentalism, nationalism, resentment of exploitation, economic instability, species extinctions, pollution, stubborn poverty, loss of sociality etc. will destroy the individualistic marketised societies that have characterised the First World for decades. But, to date, the only alternative being envisaged at global and national scales is a gentler, more-regulated capitalism, a tamed capitalism, a less dynamic capitalism. Socialism is discredited for the moment and there are no plausible scenarios for a return to much earlier forms of governance and economy. Examples of the sorts of marginal changes being canvassed within existing political structures include the protection/expansion of political and other rights (e.g. who is a citizen?) and, in general, check-and-balance constraints on the capacity of the more powerful to exploit the less-powerful, e.g. consumer protection legislation.

But elsewhere, in their personal and interpersonal lives, more and more people are making adjustments they see as promising to better meet their priority needs. The reference is to psychologist Abraham Maslow’s theory of *human needs* which sees people as striving to satisfy received physiological and psychological needs for life, safety and security, for belongingness and affection, for esteem, for respect and self-respect and for self-actualisation (personal development, realisation of latent potentialities).[74] As more basic needs (e.g. food) are met, attention switches, in a hierarchical fashion, to satisfying higher needs (e.g. for creative activity). A need, in

[74]Maslow, A., 1968, *Toward a Psychology of Being*, Van Nostrand, New York.

general, is 'that which persons must achieve if they are to avoid sustained and serious harm'.

The notion of a *needs hierarchy* leads directly to the idea that a person enjoying high quality of life is someone who is largely able to satisfy his or her higher needs. This complements the suggestion, from ecologist Charles Birch, that quality of life is measured by a person's feelings that their potentialities for creative activities and relationships with others are being satisfied.[75] As a general and uncontroversial assertion, most contemporary individuals, tacitly or overtly, have the enjoyment of a 'better' life, as an umbrella goal. Within the opportunities and constraints inherent in the societies they live in, people make more or less rational choices as to how to satisfy their needs.

People of the Postmodern era who are seeking to ameliorate stresses that come with trying to live out the social character required for full participation in a marketised individualistic society are adjusting their behaviours and attitudes in various ways, several of which we can note:

Downshifting is a response to the challenge of balancing income, work and leisure. It involves moving to a lower-paid job where hours are shorter or the work more meaningful or the lifestyle possibilities more attractive/ less expensive. Or it could involve early retirement. Downshifting implies a reduced willingness to compete for status and its symbols and an increased determination to take greater control over the construction of one's life story (self-actualisation) and the formation of one's identity (Who am I?). For example, downshifters are less likely than others to use consumer goods as markers of their identity.

Joining nontraditional, nonfamily groups and networks. In societies where relocation is common, joining can be viewed as people creating new 'tribes' to replace the lost tribes of family and community. Also, new communications technologies allow geographically dispersed people to form interest groups. Joining can satisfy a need to belong to a supportive group of like-minded people. Also, being a member of a group becomes part of one's identity. Some groups, particularly ethnic groups, strengthen their sense of identity by actively rejecting outsiders. Joining groups with antisocial tendencies (e.g. street gangs) may reflect alienation from or a rejection of mainstream society. Joining 'activist' groups may be a conscientious response to matters of social concern, e.g. joining environmental groups, human rights groups. Outside formal organisations, people apparently benefit from joining crowds (e.g. at sporting events) and participating in episodes of mass emotion, e.g. mourning Princess Diana.[76]

Because they represent 'authorities' that have lost legitimacy, or that have already been rejected in an expression of individualism, it is becoming less popular for lonely, other-directed people to join 'traditional' institutions like national political parties and mainstream churches. Instead, there is a trend towards becoming

[75] Birch, C., 1975, *Confronting the Future: Australia and the World: The Next Hundred Years*, Penguin, Melbourne.

[76] le Bon, G., 1947, *The Crowd: A Study of the Popular Mind*, Benn, London.

politically active at a local rather than at some higher level and a tendency to join new and splinter religious organisations. These latter include fundamentalist congregations, cults and new-age religions. For the many people who have found they feel increasingly alone and without guidance under the freedom of an individualistic society, these new religious forms offer strong authority, strong support, strong structure and a strong sense of belonging.

There is a joke which says that when you give people freedom to be themselves they promptly imitate others! This is particularly true of the young in a permissive, ever-changing society where parental guidance is weak. Adolescents and immature adults, not having a developed knowledge of their real identity options, and deeply wanting to belong, are strongly influenced by their peers and by media celebrities.

Rethinking individuation is a more fundamental adjustment to postmodernity than downshifting or joining if we think of these as strategies for treating *symptoms* of stress in contemporary society.

Even within the constraints of being a willing and conforming member of a market-oriented individualistic society there is adequate scope for people to individuate, at least in the superficial sense of being readily distinguishable from each other. For example, people differ in employment classification, specialist knowledge, general knowledge, purchases, family arrangements, hobbies, belief systems…as well as the basics of gender, age, ethnicity and nationality. Everyone is different under any such dissection.

But, having a unique identity compatible with compliant membership of a society whose values are oriented to marketisation and individualism does not provide sufficient individuation for many people. Even with the adoption of ameliorating strategies, many (particularly the better-educated?) find that their spectrum of needs is not adequately met. Or, indeed, is actively frustrated. In particular, given individualism's nihilistic tendency to question all external authority, it is ironic when it is perceived that an ideology built on individualism and marketisation is just as much an authority-source waiting to be questioned as any religion, world view, social contract or expert opinion.

Amongst those who do not lose their nerve when they realise that there is no external authority that can legitimately tell them how to live their lives, those whose character is more inner-directed than other-directed perhaps, the option exists to impose one's own order on life. This is the *existential challenge* and various responses to it are possible. An increasingly common response is to conceptualise one's identity, not as a 'given', but as a life story, a biography, which is under continuous construction. Under this thinking, self-actualisation becomes a series of tasks for which one takes responsibility and undertakes to learn to perform competently. The aim is to consciously mould yourself into a person with a life story, a character and a personality. Satisfaction comes from the feeling of having done your best to meet your needs, subject to your life circumstances.

Notwithstanding, a significant part of any life story lies in how one has negotiated the everyday pit-traps of a risk society. And it is here that First World governments, faced with increasing numbers of people who are not amenable to guidance from the state or who are not competent risk-managers, have been experimenting with more actively creating environments in which people can learn to be self-reliant and want to contribute to their marketised society. One approach, epitomised by the British Labour Party's 'third way', is through the use of a tacit social contract, based not on duty or morality, but on quasi-contractual rights and responsibilities.[77] People are expected to engage with society (e.g. to work) and to look after themselves while government is expected to provide the resources which people can use to upgrade their survival skills. It is a social contract which is still very much under negotiation. That is to say, both government and governed are open to adjusting their behaviours. Indeed, prominent sociologists, including Zygman Bauman and Anthony Giddens, are seeing collective action as increasingly mediated through and by the needs and demands of individuals.[78]

Now, with relations between the collective and its members still coevolving, our quick trip through the last 2,000 years is complete. We have come to a point where we have accumulated sufficient historical material to think about the Common Era more broadly.

Understanding and Reflecting on the Common Era

In the previous chapter, which took us to the beginning of the Common Era, it was suggested that the evolution of human ecosystems, call it *eco-cultural evolution*, can be understood as a narrative or play (including plays within the play) in which a changing cast of interacting virtual species (populations of humans with common interests) uses changing suites of interdependent technologies (material, social, communicative and cognitive) to secure their survival and well-being in a changing environment. It was also flagged that several functional groups of technologies already in use at the beginning of the Common Era would continue to be widely used, up till the present day. These included the growth and spread of population, urbanisation, trade, warfare and systematic technological innovation.

This simple qualitative model of cultural evolution, a conceptualisation based largely on the idea of coevolution between virtual species, technologies and environments, has worked well for contemporary anthropologists studying stability and change in traditional societies such as the horticulturalists of Papua New Guinea's highland valleys.[79] Many traditional societies are simple enough and historically stable enough to allow the chains of effects of recent technology-introductions such

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[77] Giddens, A., 1998, *The Third Way*: *The Renewal of Social Democracy*, Polity Press, London.

[78] Bauman, Z., 1992, ibid.; Giddens, A., 1991, ibid.; *Beck*, U., and Beck-Gernsheim, E., 2002, Individualization: Institutionalized Individualism and its Social and Political Consequences, Sage, London.

[79] Abruzzi, W.S., 1996, Ecological Theory and the Evolution of Complex Human Communities, *Advances in Human Ecology*, 5, pp. 111–156; Lenski, G., 2005, *Ecological-Evolutionary Theory*: *Principles and Applications*, Paradigm Publishers, Colorado.

as, in Papua New Guinea for example, shotguns and steel axes, colonial administration and Christianity, to be traced piecewise through time. What is being suggested here is that the evolution of the global human ecosystem over the Common Era has followed, but more complexly, and more grandly, the same coevolutionary model.

In concrete terms, new technologies or novel applications of existing technologies or shifts in environmental parameters or the emergence of new virtual species will, sometimes, initiate sequences of adaptive changes which have major consequences for (and this is what we are interested in) the well-being of large numbers of people, either immediately or over time. These are the turning points of history. Mostly though, such disturbances are quickly absorbed into the ongoing cyclical flows of material-energy in the society where they originate; they come to nothing. In the present chapter, the macro-history of the Common Era has been condensed to a score of discontinuities (bifurcations) and extensive reorganisations which have each been judged to have had or to be still having momentous consequences for global society, e.g. by shifting centres of wealth accumulation. Two fundamental recurring themes pervade this family of pivotal reorganisations. One is globalisation and the second is the accumulation of cultural capital.

Globalisation

At the beginning of the Common Era most of the world's land surface was already occupied by communities of *H. sapiens*, a genetically homogeneous species whose biology has barely changed since. From a systems perspective, the world of the time could be divided into a *core* set of somewhat-interconnected Eurasian civilisations—the Roman, Persian, Indian and Chinese empires—and a set of *peripheral* societies in Oceania, the Americas, Africa and the margins of Eurasia itself. These latter had almost no interactions amongst themselves or with the Eurasian core. To reduce the history of the Common Era to a phrase, it has been a story of increasing interactions and exchanges within and between those initial sets of peripheral and core societies. Today, this process of individual societies coming together to function as a single society, not just economically, but socially and culturally, is referred to as *globalisation*.

From the perspective of complex-systems science, Common-Era globalisation is, arguably, an example of a dissipative (open) self-organising system—namely the Eurasian core societies—growing, differentiating (specialisation of parts) and complexifying (adding more internal and external linkages) in synchrony with an uninterrupted increase in the rate at which that system has been capturing free energy, i.e. energy available for doing useful work. Any nonlethal increase in the free energy entering a dissipative system both permits and demands complexification.

Dissipative systems such as the global (i.e. human plus natural) ecosystem require stable energy gradients on which to feed, persist and evolve. For most of the Common Era, the major source of energy warming the Earth and sustaining-constraining the global ecosystem has been the Sun. It is a source which has changed and is changing extremely slowly by the measure of human history. Until the industrial era, global temperatures, and their variability, remained remarkably constant and benign, the modest exceptions in absolute terms (and they may have been regional rather than global) being the ‘medieval warm period’, the ‘little ice age’ and several ‘volcanic winters’. Measured by their impacts on food supplies, population sizes and well-being, these phenomena were of course far from modest.

Against this slow-moving backdrop, and until the Industrial Revolution, most of the energy captured by the Eurasian core societies was solar energy which had been transformed into food energy stored in plants and animals. Over centuries, the small surplus achieved by each food producer increased slowly with the spread of each lasting advance in energy-saving (input-reducing) or yield-increasing technology. In each society, these surpluses were collected together by the ruling virtual species and, after feeding themselves, used to feed workers who could be directed into projects and activities anticipated to enrich, protect, glorify or further empower the ruling virtual species, at home or abroad—all with little concern for the well-being of the majority. Notwithstanding, populations did zigzag slowly upwards. Aggregating small surpluses under centralised control is a social technology which makes otherwise-impracticable large-scale social technologies feasible. Such include standing armies to manage unrest, wars to acquire resources (including energy), building religious and civil infrastructure and producing-exporting tradeable goods.

Most trade across Eurasia in the early part of the first millennium relied on the diversion of surplus food energy into assembling trains of pack animals for land transport and oarsmen for sea transport. But, later in the millennium, trade between Eurasia’s main cities grew, and grew increasingly profitable, in line with major improvements in technologies for capturing ‘free’ wind energy to transport trade goods in sailing ships. The sailing ship, like the computer, became an *enabling technology*, i.e. one which changes the cost of completing some widespread generic task; computers process information cheaply and sailing ships transport trade goods cheaply. Sail was the technology which would underpin globalisation until the late nineteenth century when steam ships and electromagnetic forms of communication emerged. It allows large volumes of goods etc. to be transported over great distances, at speed and in comparative safety. More than that, trade routes spread diseases, religions, technologies, genes and information about foreign lands and world events. Just to emphasise the path-dependent nature of history, we might note that if globalisation had occurred in a world without ocean-going ships it would have been massively different.

Chinese merchants, and to a lesser extent Muslims, dominated world maritime trade (which meant in and around Eurasia) from the eighth to the fifteenth century. Thereafter, it was Europeans who, relying increasingly on sail, sought (as if) to incorporate other continents into the Eurasian economy. In particular, sailing ships played a central role in the explorations and colonial ventures of Portugal, Spain, Netherlands, France and Britain. From an energetics perspective, the relatively small amount of energy captured by sails was sufficient to trigger large and valuable flows of goods back to Europe from outposts and colonies in the peripheral world.

Indeed, so valuable was this trade that the European nations fought each other, again and again, for its control. The critical weapons used in these struggles, as were those used to subdue peripheral societies who did not like their 'terms of trade', were guns, a technology which is effective because it can trigger the rapid conversion of concentrated chemical energy (gunpowder) into the kinetic energy of a speeding musket- or cannon-ball.

In ecological terms we can think of the Europeans as a virtual species that, early in the Modern Era, discovered resource-rich new niches (new lands) where, by virtue of their preexisting material and social technologies, they were preadapted to out-compete and displace the indigenous virtual species—Amerindians, Aboriginals, Africans etc. Natural ecosystems too were increasingly replaced with imported agro-ecosystems. After initial losses from conflict and imported diseases, colonial populations started to grow again, partly as a result of importing slaves and settlers. In tandem with increases in food imports, Europe's population grew also.

These extensions of the European segment of the core Eurasian society into other continents were the beginning of what Catton calls an 'an age of exuberance' for the human community, a two-stage development enabled first by wind power and then by tapping the world's 'once only' stocks of fossil energy, primarily coal and oil.[80] In this 500 year era, now rapidly approaching its end, an ever-increasing throughput of 'outside' energy has permitted and demanded an ever-faster coevolution (mutual adaptation) of virtual species, technologies and environmental components of the global human ecosystem. Additional energy increments have been stored and circulated and dissipated in emergent flows and structures, e.g. new industries, new customs, new consumption patterns. At the same time, preexisting flows of materials, energy and information have been expanded, subdivided and further interconnected. In short, in line with humanity's accelerating use of primary energy, the human ecosystem has probably complexified at an increasing rate throughout Havel's Modern Era. The contemporary world contains an infrastructure of 'temporarily persistent' links, both physical and institutional, which allow people everywhere to interact (communicate, visit, learn, trade, intermarry, fight, spread pandemic disease etc.) in a coordinated way with unprecedented ease.

This global infrastructure is organised hierarchically in the sense that, even now, not all parts of the world are equally well connected into the greater human ecosystem. Some parts are hubs or nodes which support a more intense exchange of materials, energy and information than elsewhere. Principally, these energy- and information-intensive nodes are the core societies of the day, particularly the larger cities therein. But it is not a static hierarchy. The suite of core societies and global cities has evolved over time, e.g. North America, Japan, Germany and Russia emerged as core industrial societies in the late Modern Era. In fact, on a rising tide of energy flows, most ongoing societies, even the most peripheral, have increased, albeit at different speeds, the amount of energy-information they process.

[80]Catton, W.J., 1980, *Overshoot*: *The Ecological Basis of Revolutionary Change*, University of Illinois Press, Urbana.

The Koalas of Kangaroo Island

Despite their relatively low fertility, mammalian populations are still liable to outgrow and permanently destroy their food resources. Often however, before this happens the stimulus of overcrowding produces behavioural and physiological responses such that the population declines, of its own accord, to a more sustainable level.[81] Thus parental care and cooperation are increasingly replaced by competition, dominance and aggressive violence. Females and infants, the foundation for future population growth, are disproportionately the victims of these stress-generated behaviours.

In the 1920s, a small group of endangered Koalas (*Phascolarctos cinereus*) was released on Kangaroo Island off the South Australian coast. They munched their way steadily through the stock of leaves on the island's Eucalypts and multiplied. Today, with their food supply nearly gone, the island's now-large population of Koalas is on the brink of crashing, of dying of hunger and disease. If, in the absence of intervention, that happened, both Koala and Eucalypt populations would probably recover in time. It is a common story in natural ecosystems for the population of a species to overexpand, to *overshoot* the level which can be supported by the ongoing flow (cf. stock) of recurrent food supplies—fresh leaf growth in the Koala case. Thomas Malthus (1798) famously foresaw something similar for humans, namely, population growing much faster than food production.[82] That has not happened to date.

Is this Koala story a metaphor for the human situation in 2010 CE? Are oil and coal reserves our Eucalypt woodlands? Will high population density trigger population decline?

Humans have created a global society of 6.8 billion people (and rising) which depends ineluctably on mining the world's stock of fossil energy, not just for food production, but to meet a broad spectrum of human needs. Considered as part of an adaptive strategy, this reliance on coal-oil-gas has several problems. One is that fossil-energy stocks, oil in particular, are being depleted so rapidly that a major restructuring-destructuring of global society within a generation or two seems certain. You can't make bricks without straw! Either energy supplies will fall or consumption will have to be slashed to fund a massive investment in renewable energy production. The other problem is that even if we weren't running out of fossil energy, it still seems inescapable that we have to curtail its use. This is because by-products and unintended side-effects of using fossil energy at today's rates are threatening to trigger long-lasting global changes which will disrupt the lives of most of the large number of people affected. Sea-level rise and climate change and its consequences (e.g. for the distribution of ecosystems) are well recognised here but, more generally, as a rule of thumb, environmental modification or disruption

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[81] Russell, C., and Russell, W.M.S., 1999, *Population Crises and Population Cycles*, The Galton Institute, London, p. 1.

[82] Malthus, T., 1798, An Essay on the Principle of Population, Johnson, London.

(e.g. chemical pollution, species extinctions) is roughly proportional to the rate of energy use (whatever its source). We would appear to be entering a period of increasing instability (sensitivity to disturbance) and potential for conflict between virtual species, one in which the physical environment, the technology mix and the size-geography of populations are in a coevolutionary transition.

The global-change situation we are in deserves a special name; I suggest the *Overshoot Crisis*.[83] And, to survive it, my working assumption (nothing is certain) is that we will have to pass through a contractionary *bottleneck* of some sort, i.e. a disorganisation and reorganisation which will surely involve social disorder and personal trauma for many.[84] History is crammed with examples of societies in which population has grown for a period and then, for various reasons, declined rapidly, invariably associated with a disruption of the social order.[85] What is different about the present situation is its ubiquity.

In the overall story of anatomically modern humans, globalisation is the first great theme of the Common Era. Let us now review the Era's second stand-out theme, what I will call the *accumulation of ideas*.

An Ongoing Accumulation of Ideas

Meanings are perceptions of relationships between concepts-percepts. Thus, the meaning of 'the expansion of meaning' is that, over the Common Era, humans have accumulated ever-more perceptions of how more and more concepts can be spoken of together in grammatical sentences, e.g. light is wave-like. And, to the extent that concepts and relationships are abstracted from actual experience, meanings are mental models of reality. You *understand* when you perceive meaning. An *idea* is the expression of a meaning in words. Ideas operationalise meanings by putting them in a form where they can be communicated to others. And an idea which reduces the recipient's uncertainty about a meaning (narrows the range of possibilities) is *information*. In particular, *knowledge* is information deemed useful for some purpose. *A narrative* or *story* is an extended chain of meanings connecting and ordering a series of events, facts, concepts etc.

Each individual holds a *stock of meanings* which collectively constitute his or her understanding of the world and from which he or she draws to help answer 'what's happening' and 'what-to-do' questions. Humanity's stock of meanings at any time is its *cultural capital*, the sum total of meanings held by all individuals plus all the retrievable meanings stored in books and other repositories. Many meanings are

[83]The term is adapted from William Catton's *Overshoot*: *The Ecological Basis of Revolutionary Change*, University of Illinois Press, Urbana, 1980.

[84]Turner, G.M., 2008, A Comparison of The Limits to Growth with 30 Years of Reality, *Global Environmental Change*, 18, pp. 371–411.

[85]Russell, C., and Russell, W.M.S., 1999, ibid.

shared of course and it is because people share meanings (as ideas) that they can communicate (e.g. transfer information) and coordinate their activities. Equally, many meanings are contested. Dialogue and dialectical discussion are technologies which can harmonise and align contested meanings.

As discussed earlier (see page 85), all meanings and ideas carry a positive or negative emotional 'charge' which triggers or inhibits potential behaviour based on that meaning. In what-to-do situations the mind searches for a plan of action, an imaginary experience, which is consistent with its understanding of relevant cause-consequence relationships and, as well, is emotionally acceptable. It is by way of this process that ideas shape the larger themes of history, as well as individual lives. Thus, when an emotionally powerful chain of ideas, a 'grand narrative', spreads through a virtual species, it can trigger and energise large shifts in collective behaviour. For example, Islam, a simple but promise-filled new religion, gave the Arab peoples the emotional energy, the confidence perhaps, to conquer much of Eurasia in the eighth century. Indeed, religious narratives, along with national 'origin' myths (e.g. Hitler's myth of an Aryan master race, America's myth of 'manifest destiny'), have consistently, throughout the Common Era, energised and legitimised wars and the colonisation of indigenous peoples.

Once people acquire stories that explain who they are and how they should live, they cling to them. Nonetheless, like social character, such stories do change over time as circumstances change. For example, Jack Miles argues that Christianity represents a pacifist revision of the Jewish myth of Yahweh, the warrior God, at a time when violence had become an inappropriate response to the threat of oppression.[86]

The fact that national and religious origin-myths commonly have a limited grounding in reality, is not the most important point to be made about them. Rather, have they helped their adherents to survive? It is a point I take from *Darwin's Cathedral: Evolution, Religion and the Nature of Society* by David Sloan Wilson[87]:

> …people who stand outside religion often regard its seemingly irrational nature as more interesting and important to explain than its communal nature. Rational thought is regarded as the gold standard against which religious belief is found so wanting that it becomes well-nigh inexplicable. Evolution causes us to think about the subject in a completely different way. Adaptation becomes the gold standard against which rational thought must be measured alongside other models of thought. In a single stroke, rational thought becomes necessary but not sufficient to explain the length and breadth of human mentality, the so-called irrational features of religion can be studied respectfully as potential adaptations in their own right rather than as idiot relatives of rational thought (pp. 122–123).

Some would-be adaptive myths contain a thinly disguised what-to-do model as well as evoking positive emotional signals. For example, Kipling's idea of 'the white man's burden' was a self-serving characterisation of Victorian imperialism as

[86]Miles, J., 2003, The Self-disarmament of God as Evolutionary Pre-adaptation, *Midwest Studies in Philosophy*, XXVII, pp. 153–165.

[87]Wilson, D.H., 2002, Darwin's Cathedral: Evolution, Religion and the Nature of Society, University of Chicago Press, Chicago.

a noble enterprise.[88] Many Americans and a few Australians still live by the myths of their frontier origins. Aboriginal myths which, through Dreamtime stories, accurately represent the landscape and its behaviours exemplify, in a different way, religion as a technology for improving survival prospects.

Impact of the Scientific Attitude

The essence of the *scientific or objective attitude* is its recognition of the provisional nature of knowledge and the need to keep correcting meanings in light of growing information. It extends to the further idea of *scientific method*, to wit, that such information can and should be actively and systematically collected. This attitude, which began to spread rapidly from the sixteenth century, has increasingly had the effect of undermining powerful religious and national myths, including some associated with the consequential historical shifts identified earlier in this chapter. What happens is that ideas and narratives which are not compatible with empirical data begin to trigger negative rather than positive emotions, irrespective of the authority of their source. The paramount example is the impact of Darwin's *On the Origin of Species*… on the Judaeo-Christian creation myth. More recently, historical research has challenged many national origin myths.[89]

But the contribution of the scientific attitude to the growth of meaning has been far wider than its role in a slow world-wide trend towards replacement of supernatural and other fanciful models of reality with objective-scientific views. For some hundreds of years now, science or, more generally, evidence-based scholarship has been creating whole domains of meaning—disciplines—replete with new concepts and new relationships between such. While all disciplines, but particularly those of the type found in universities, contribute to the collective stock of meanings, the meanings, relationships, concepts and vocabularies within disciplines are of course available only to small groups of specialists.

The contribution of the scientific attitude to the growth of humanity's stock of technologies—meaningful recipes—has been similarly far-reaching. Generally speaking, technologies are retained until something sufficiently better comes along, a rare event in pre-Modern societies. And when a 'technologist' is creating something better, s/he is often building on the results of past scholarship. This is as correct for what have been the slower-growing stocks of social, communicative and cognitive technologies as it is for the faster-growing stock of material technologies.

While medieval minds were lively enough, they did not have the cognitive technologies to assess the quality of an explanation. To quote Herbert Muller, medieval people 'inferred things too easily'.[90] For them, one swallow did make a summer.

[88] http://en.wikipedia.org/wiki/The_White_Man's_Burden (Accessed 17 June 2008).

[89] For example, Geary, P. J., 2002, *The Myth of Nations*: *The Medieval Origins of Europe*, Princeton University Press, Princeton, NJ.

[90] Muller, H.J., 1952, The Uses of the Past: Profiles of Former Societies, Mentor, New York, pp. 244–250.

Neither did the medieval mind actively seek to upgrade ideas to help it better answer 'what's happening' and 'what-to-do' questions, even in problematic circumstances. The very idea that an idea might be wrong or right or improvable is unimaginable to someone who has only ever been exposed to one 'world view'.

In recent centuries the Modern-era mind, equipped with a more objective and exploratory attitude, has begun to replace the uncritical medieval mind. Why? Because, so far, such has proved more adaptive. That is to say, societies in which people have actively and objectively searched for evidence-based meaning have been able to respond creatively to change and opportunity. Such societies have generated and trialled a succession of models of reality and recipes for social etc. technologies, some of which have been selected to persist because they have satisfied perceived needs/goals of their inventors and adopters. For example, in the world's core societies industrial technologies have continued to increase the wealth and power of elites even as the social technology of democracy has erratically improved the well-being of ordinary people. In peripheral societies, where the mindset tends to be more medieval, the available stock of meanings has still grown, but more slowly.

In what sense is the vast expansion of meaning that has occurred during the Common Era an evolutionary process? Any entity is said to have evolved if it exhibits piecewise change over time, e.g. a biological species in which the percentage of individuals carrying a particular version of some gene changes. And while we do not have the data or the concepts to measure them, the world's stock of meanings is an entity which has clearly changed in terms such as number, categories and distribution across virtual species and individuals. That is, it has evolved.

But is there anything in the evolution of cultural capital corresponding to the mechanism underlying much biological evolution, namely, the 'selective retention of ongoing variation'? During biological evolution of a species, random variations (e.g. mutants) are immediately tested against the reality of the bio-physical environment—is this variation stable enough to persist here? Yes or no? There are no second chances.

In cultural evolution the starting point is another sort of variation, a variation in an agent's[91] mental model of an idea or recipe. Any such variation is tested *in imagination* for its likely success in terms of goal achievement—any relevant goal, not just immediate reproductive success. If it passes, and is also emotionally acceptable, it can be used or held ready for future use. If it fails, there is a second chance. The failed idea can be deliberately reworked and rapidly reevaluated, perhaps several times, before being put to use. It may still fail when actually trialled of course but, as an adaptive process, sequential innovation and testing in the mind is quicker, more energy-efficient and more flexible than gene-based evolution. It can also, to some extent, focus purposively on filling gaps, empty niches, in a stock of meanings, e.g. as the world complexifies under globalisation, the number of 'meaning' niches

[91] Sterelny, K., 2001, *The Evolution of Agency and Other Essays*, Cambridge University Press, Cambridge. Having evolved from instinct, an impulse to act is associated with every thought.

grows. Metaphorically, the difference between the two ways of selecting variation (biological and cultural) is like the difference between selecting from a hand of cards versus dealing cards, one at a time, till a suitable card turns up.

Progress, the God That Failed

Progress means going in a particular direction but, in discussions of sociocultural evolution it has come to mean ‘going in a particular direction which is also a “good” direction’. In Victorian England, Charles Darwin saw evolution as continually redirecting and morally neutral, but for Herbert Spencer, his influential rival, evolution, including social evolution, was progressive. ‘Civilisation’, said Spencer, ‘is a part of nature; all of a piece with the development of the embryo or the unfolding of a flower’.[92]

As a result of its successes in creating new technologies (e.g. in public health, in manufacturing) and finding evidence-based meaning in the natural world, the scientific attitude, and natural science in particular, came to be viewed very positively in the world’s core societies by late nineteenth century. The troika of scientific method, capitalism and democracy was seen as a guarantee of sustained human progress. The perception was that these umbrella technologies had improved and would continue to improve the human condition. But, from about the middle of the twentieth century, the prevailing attitude towards the future became more one of ‘postmodern apprehension’.[93] Negative aspects of these three change-agents, previously unknown or unrecognised, are now perceived to be as important as their undisputed positive effects.

Considering science specifically, it is ironic that its characteristically sceptical attitude, that which undermined religious narratives and nationalistic-ideological beliefs, has now spread to the point of bringing science itself into question for many people. Perceptions of the ‘failures’ of science–technology include:

Its failure to tell a human origins story with the same emotional appeal as religious origin-stories. While science provides a lofty, impersonal, nonjudgemental perspective from which to regard humans, it does not encourage a view of humans as noble beings fashioned in the image of God; or, indeed, of fallen angels.

Its close links to evils such as nuclear, biological and chemical weapons, the world arms trade, technologies for torture and oppression.

Its failure to solve such global problems as poverty, hunger, injustice, energy shortages, environmental degradation, mental illness.

Its inability to predict natural disasters such as earthquakes and tsunamis.

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[92] Spencer, H., 1851/1969, *Social Statics*, Augustus M. Kelley, New York, p. 65.

[93] Heilbroner, R., 1995, *Visions of the Future*: *The Distant Past*, *Yesterday*, *Today*, *and Tomorrow*, Oxford University Press, New York.

Its failure to foresee the 'biteback' effects of new technologies, e.g. DDT, new rice varieties produced by the green revolution.

Its role as a frequent bearer of bad news, e.g. climate change, lifestyle risks.

The unwillingness of most scientists to work on problems that straddle disciplinary boundaries, or on bringing disciplines together (consilience) or on synthesising divergent knowledge bases.

The apparent inability of science to definitively 'prove' anything.

The failure of many scientists to live up to their image of being honest truth-seekers. Perceptions of scientific corruption range from miscreants who fake data to dissemblers who are employed to peddle misinformation and doubt and muddy debate on, mainly, health and environment issues.

Failure to lift humanity's capacity for understanding and managing complexity in an increasingly complex world. Managing the planet seems to be getting harder, not easier.

Science's failure to save itself from becoming just another service industry in a capitalist world

Its failure to dispel an image of science as an elite, hubristic and ultimately boring activity.

Failure to ameliorate people's feelings of inadequacy and resentment in face of their ignorance of science.

The Ecology and Coevolution of Ideas

The rise of scepticism (and relativism) and its impact on the credibility of the search for evidence-based meaning and, earlier, on traditional beliefs is a telling example of the way in which ideas (verbalised meanings) coevolve. But can we say anything more general, anything more than has been said, about how the ideas comprising the global stock of ideas-meanings have coevolved with each other?[94] Or, how coevolution between the material globalisation process and the global stock of nonmaterial ideas-meanings has taken place?

As a starting point, it helps to hypothesise that the globe's ever-changing stock of ideas-meanings is a self-organising energy-processing system—a *global meaning-system* in which each person is a separate node and energy source for transmitting (e.g. by voice, letter), processing and storing ideas. Despite being distributed across the world, with nodes wherever there are people, the global meaning-system can still be thought of as (and not just metaphorically) a single open system in which small energy flows associated with speaking, thinking and memorising are dissipated along with the larger energy flows associated with using prosthetic communication technologies.

[94] Bateson, G., 1972, Steps to an Ecology of Mind: Collected Essays in Anthropology, Psychiatry, Evolution, and Epistemology, University Of Chicago Press, Chicago.

Nodes in the global meaning-system are connected by direct speech in the case of small localised groups and by a variety of communications channels across longer distances. Some channels, like semaphore, email and telephony, are two-way (transmit and receive) and others, notably mass media, are one-way. In principle, ideas can flow, perhaps circuitously, between any two people. In practice, flows and exchanges of ideas among people who already have relationships and similar sets of ideas (e.g. within a cultural group or virtual species such as a tribe a guild, a nation…) predominate over flows between virtual species. Against that, flows of ideas tend to be greater between virtual species that are in cooperative or competitive relationships, e.g. dialogue, trade. Structurally then, the global meaning-system is made up of many variously interconnected local meaning-systems.

Transmitted ideas may or may not be processed or stored in the recipient's memory. Most transmissions within a virtual species are routine and habitual, serving to reproduce (maintain) the day-to-day organisation of the group and its coherence, i.e. its coordination and capacity for cooperation. They help answer 'what-to-do' and 'what's happening' questions and, to the extent that they are acted upon (e.g. are commands), small information flows can trigger much larger flows of motor energy. Indeed, an *organisation* is a self-maintaining system in which the behaviour of each component depends on the presence and behaviour of other system components, especially the information they transmit. In a traditional society, the implementing of habits, rituals and customs will routinely trigger the exchange of established ideas. It is language, the verbal exchange of meanings, which creates that common world of ideas in which every individual lives. And it is the expressing of one's thoughts that makes one's own subjectivity accessible.[95] As the saying goes, people must talk about themselves until they know themselves.

But is the world of exchanging ideas a true ecosystem? The defining characteristic of any ecosystem is that it can be described as a persisting web of interdependent populations, each necessary (well, there are exceptions) for the survival of all. In biological ecosystems, each population is made up of members of a species, subspecies or virtual species. In a stable ecosystem, each individual reproduces itself before dying. Viewing meaning-systems as ecosystems, all nodes where a particular idea is *understood* constitute a population. That is, there is one population per established idea.

What then is the process by which populations of ideas rise and fall? Come and go? Are 'species' of ideas interdependent in the same sense that the food web makes populations interdependent in a biological ecosystem? That is the key question. A transmitted idea does not directly provide sufficient energy to maintain the ideas in a recipient's mind but, provided it is not ignored, it triggers in-body flows of nervous energy which result in ideas being stored or processed or transmitted.

If the global meaning-system is a true ecosystem, a transmitted idea, X, will result in further transmissions which, immediately or eventually, and before the

[95] Berger, P. , and Luckmann, T., 1966, ibid., p. 37.

recipient dies or forgets X, trigger another transmission of X. Each transmission of X has to eventually produce one further timely transmission of X into a mind where it is understood—if the population of X in the global meaning-system is to be maintained. If each transmission of X produces, on average, less than one further successful transmission of X, the X idea will eventually die out in the sense that it will no longer be widely understood. If each transmission of X produces, on average, more than one subsequent transmission of X, the number of nodes where that idea is understood will grow. A group's shared ideas (e.g. its values, ideology, archetypes, norms, even words) probably need to be circulated periodically to reinforce and keep them from being displaced by new or recovered ideas and falling into 'memory holes'. where they can no longer guide collective or individual actions. Dictionaries illustrate the ecosystemic nature of meaning-systems. Think of individual words as ideas. A dictionary defines words in terms of other words. A word-idea will go 'extinct' if the words used to define it go extinct, i.e. are no longer understood. Words fall out of use when they are no longer task-relevant, e.g. the name of a defunct technology. If a word becomes fashionable, e.g. the name of a blossoming technology, then the words used to define it will become more widely understood.

New ideas, whether generated internally or imported from others, are first tested for emotional acceptability (e.g. compatibility with group ideology or values) and then processed for information content, i.e. for their contribution to the individual's stock of potentially useful meanings. Note that a new idea must come with sufficient context (explanation, definition) if it is to be meaningful; and, like an antibody locking onto a virus, there must be a 'niche' for it in the preexisting meaning-system. For example, you cannot add a word to your vocabulary if you do not understand the words used to define it. Ideas judged acceptable and task-relevant are committed to memory.[96] From there, they may be communicated, more or less accurately to others, depending on how rewarding this is foreseen to be. If it is accepted that the essence of evolution in open systems is 'selective retention of variation', the incorporation of new ideas into a meaning-system is an evolutionary rather than an ecological process.

There are various ways in which communicating a new idea might be rewarded, e.g. it might create an emotional bond; it might engender gratitude; it might change another's behaviour; it might change your group's meaning-system. The idea of *memes* is relevant here. To use Daniel Dennett's phrase, memes are 'distinct memorable ideas' which, for whatever reason, spread easily from person to person in the community.[97] They can be as frivolous as a pop tune or as serious as a political ideology. *Memetics* is the study of the diversification, compounding, replication and spread of memes through society, conceived of as an evolutionary process analogous to Darwinian evolution, with memes being the counterparts of genes.

[96] Sperber, D., and Wilson, D., 1987, Précis of Relevance: Communication and Cognition, *Behavioral and Brain Science*, 10, pp. 697–754.

[97] Dennett, D., 1995, *Darwin's Dangerous Idea*: *Evolution and the Meanings of Life*, Simon and Schuster, New York, p. 344.

Proponents of memetics consider that, like genes, memes are replicated with reasonable accuracy when transmitted from one person to another. They further suggest that the self-organising processes of diffusion, modification, complexification and accumulation of memes and the behaviours they induce lie at the heart of changes in society, e.g. religious or patriotic fervour.[98]

This is a view which brings us to the edge of *historical idealism*, the notion that history is propelled by ideas, ideals, values and norms that manage to achieve mass appeal and reorganise the thinking of whole societies. It is to be contrasted with *historical materialism*, the notion that it is systems of production or industrial-military might which steer history.[99] Max Weber can be said to have given an idealistic explanation of the growth of capitalism by linking it to the emergence of a 'Protestant ethic'. And as J.M. Keynes famously noted:

> The ideas of economists and political philosophers, both when they are right and when they are wrong, are more powerful than is commonly understood. Indeed, the world is ruled by little else.[100]

Conversely, in earlier discussion, Fromm's *social character*, the way in which people think about their roles in society, was presented as being directly moulded by the production system and the demands it placed on workers.

As usual in debates about causation there is a middle way. The middle way here is coevolution: changes in social organisation create niches (e.g. uncertainties) in the meaning-system, i.e. places where ideas that give meaning to those changes can form. Equally, imagining changes in social organisation is a precursor to making those imagined changes real. The history of slavery and its abolition is a good example. Each step towards abolition produced ideas for taking a further step.[101] Stepwise developments in material technologies provide other neat examples.

The History of Ideas

According to Peter Watson, the idea that ideas have histories is comparatively recent, perhaps as recent as Francis Bacon in the late sixteenth century.[102] Studies in the history of ideas have tended to focus on developments in the foundation domains of philosophy, science, social organisation and religion and this book too has something of the same foci. Here, our aim is to identify and give examples of several different ways in which ideas, as well as evolving within such domains, have coevolved with ideas from other domains.

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[98] Blackmore, S., 1999, *The Meme Machine*, Oxford University Press, New York.

[99] Polak, F., 1973, *The Image of the Future*, Elsevier Scientific Publishing, Amsterdam, p. 14.

[100] Keynes, J.M., 1936, *The General Theory of Employment*, *Interest and Money*, Harcourt, Brace and Co., New York, Ch. 24.

[101] Whitehead, A.N., 1933, *Adventures of Ideas*, Free Press, New York, Ch. 2.

[102] Watson, P. , 2005, *Ideas*: *A History from Fire to Freud*, Weidenfeld and Nicolson, London.

The most prominent of these processes, seen particularly clearly in struggles between scientific and religious ideas, and between political ideologies, is *competition*—the battle for minds—between incompatible belief systems. Each side not only searches purposively for the ideas that will make its view of reality more plausible but actively struggles to destroy the credibility of the other side's ideas, e.g. belief versus disbelief in the supernatural. Adversaries in such debates are commonly self-interested to the point where they are willing to resort to lies, disinformation, emotional appeals and other antirational technologies to persuade.

Debates within philosophy and science do not touch whole communities as political and religious debates do. In science, competition between incoming and outgoing *paradigms*, to use Kuhn's term,[103] is robust but, largely, remains principled. One reason for this is that many scientific hypotheses can and will be tested empirically. Another reason is that scientists do not so much *believe* their hypotheses as presume that they will be corrected and improved over time.

A second way in which ideas coevolve is through analogical and metaphorical thinking. That is, ideas which have been accepted as reliably describing aspects of what happens or what exists in one domain are imaginatively used to describe aspects of what exists or what is happening in a second domain. The coevolution of consilient ideas in physics, socio-economics and biological evolution provides a good example.[104] Economics began as an adjunct to the natural sciences. It emerged through the efforts of Hobbes, the physiocrats and Adam Smith to extend the concepts and methods of seventeenth century nature-philosophy into understanding people and society. That is, it was a development of scientific materialism.[105] Subsequently, nineteenth century physics imported several important ideas from the social sciences, including system-equilibrium ideas (from economics) and, in thermodynamics, the idea of the statistical distribution (itself a spinoff from eighteenth century probability theory).[106] Economics later reimported these ideas after they had been further developed by mathematical physicists. Darwin, as is well known, drew on Malthus' *Essay on Population* for the idea of natural selection.[107] Subsequently, a variety of attempts to understand social evolution have turned (back) to biological metaphors, e.g. the idea of society as a developing and differentiating 'super-organism'; the 'survival of the fittest' ideology of social Darwinism; the emergence of *evolutionary economics* as a discipline.[108]

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103 Kuhn, T.S., 1970, *The Structure of Scientific Revolutions*, University of Chicago Press, Chicago.

104 *Consilience*, in the sense being used here, is the idea that generalisations invented to account for one set of phenomena often account for others as well. See Whewell, W., 1847, *The Philosophy of the Inductive Sciences*, John Parker, London.

105 Gare, A., 2000, Philosophy, Civilization, and the Global Ecological Crisis: the Challenge of Process Metaphysics to Scientific Materialism, *Philosophy Today*, 44(3), pp. 283–294.

106 Ball, P. , 2004, *Critical Mass*: *How One Thing Leads to Another*, Heinemann, London, pp. 83–87.

107 Malthus, T., 1798, ibid.

108 For example, Nelson, R.R., and Winter, S.G., 1982, *An Evolutionary Theory of Economic Change*, Belknap Press, Cambridge, Mass.; Spencer, H., 1864, *Principles of Biology* (Vol. 1), Williams and Norgate, London.

Perhaps the most important factor favouring the coevolution of ideas located in different domains of a culture is that because all new ideas have to be compatible with that culture, in harmony with it, if they are to survive; they will necessarily be in harmony with each other. That is, all have to conform, more or less, to the one cultural straightjacket. The constraints which impose in-common limits on all of a culture's shared ideas include:

Values (those abstract qualities of an idea which trigger positive emotions).
Emotional taboos (ideas which trigger negative emotions stand to be rejected).
Cognitive structures (how ideas are grouped).
Cognitive technologies ('rules' for thinking).
Syntactic-semantic structure of the language (ways in which things can be said).
Acceptance of root metaphors underlying world views of the era (e.g. 'the market' in the postmodern era).
When a culture's 'idea-space' is firmly constrained, niches in different domains can be connected by small (imaginative) leaps across domain boundaries; and thus are more likely to become connected.

Is the Global Meaning-System Sufficiently Adaptive?

We humans have achieved an understanding of ourselves and our world which, in many respects, is orders of magnitude greater than that of, say, classical Greece. And, in many respects that understanding (perception of meaning) continues to increase at unprecedented rates. The best single indicator here is the number of words available for verbalising meanings. For example, English, the richest of the world's 2,700 or so languages, has grown from about 50,000 words in Old English to about a million words today, if half a million or so uncatalogued scientific and technical words are included.[109] The world's largest library, the Library of Congress, contains over 18 million books. If all texts in this library were digitised, their totality would comprise 20 terabytes of data (a terabyte equals a thousand times the content of the Encyclopaedia Britannica).[110] By 2001, the Internet archive already had 100 terabytes of online data! Yet, it was only as recently as the eighteenth century that Denis Diderot edited a seventeen-volume encyclopedia that aspired to be 'a compendium of all valuable knowledge'.[111]

Other rough indicators of growth in humanity's total understanding suggest themselves: the sheer number of people in the world, each with a different meaning-system; the range of overlapping virtual species, each with a shared suite of ideas;

[109] McCrum, R., Cran, W., and MacNeil, R., 1992, *The Story of English*, Penguin, New York.

[110] http://www.loc.gov/index.html (Accessed 28 July 2008).

[111] Diderot, D., (Ed.), 1751, *Encyclopédie, ou Dictionaire raisonné des sciences, des arts, et des métiers pars une société de gens de lettres*; http://www.etss.edu/hts/hts3/info5.htm (Accessed 28 July 2008).

the number and reach of mass media outlets; and the voluminous technological expertise that keeps the world's societies functioning from day to day.

Notwithstanding, even as new ideas have been boosting the global stock of meanings through the Common Era, extant ideas have been disappearing. Many, probably most, ideas are short-lived because they are tools for understanding or responding to fast-changing local situations, e.g. weather conditions, group dynamics. As immediate conditions recede into the past, so do the ideas that are modelling those conditions (at least till such conditions reoccur, as they tend to do in traditional societies).

But, given that our interest here is macro-historical, what of bigger questions, questions of 'what to do' and 'what's happening' on the scales of continents and generations? Regional-scale overshoots have been common in Holocene history and now we appear to have a global-scale Overshoot Crisis with the potential to affect every human, now and for generations into the future. Is the global meaning-system coevolving with the globalisation process in ways which might allow humanity to pass through a bottleneck without too much disorder and personal trauma? Are we learning fast enough? It is concerning that humans have rarely been able to respond to looming threats of overshoot in time to save the resource base.

There is a conventional understanding of what is happening here. It takes the form of a world view which, while recognising the emergence of environmental constraints, believes market forces will evoke restructuring and technological change at a rate sufficient to forestall environmental and social problems and resource shortages. This economistic paradigm is widely accepted because it has worked in the sense of having delivered ongoing consumption increases for many; warnings of bottlenecks lack credibility because they have been ignored in the past without disastrous consequences following. And influential interest groups argue for continuing the current market-dependent strategy.

Still, whether it turns out to be a misunderstanding or not, the very acknowledgement of a global-scale Overshoot Crisis is an important achievement for the global meaning-system. It evidences the fact that humans are increasingly able to think about, not just human-scale processes, but micro and global-millennial processes. But how well? How deep an understanding of causal processes behind Global Overshoot can we hope for? Is the global meaning-system delivering a sufficient understanding of conditions necessary for ongoing survival of global society? Is that system sufficiently developed to see how understanding can be translated into practice? Such questions are prompted by the casual perception that the world's problems seem to be not only increasing but getting harder to solve.

Several Reasons for Gloom

> In the beginning was deception….First Adam, ashamed of his own act, tries to deceive God: he hides with Eve amongst the trees of the Garden of Eden. Discovered, however, he admits before God the betrayal of the promise not to touch the forbidden fruit. What Adam then tries is to escape the blame by accusing Eve of having seductively offered him it. Eve, in her turn, responds to the divine questioning by pointing the accusing finger at the serpent: it had

> deceived her and persuaded her to try the fruit. But what did the serpent say? It told Eve that the threat by God was a deception—they would not die when they ate the fruit, but their eyes would be opened and they would become like God in the ability to discern good and evil (Eduardo Giannetti 1997).[112]

Global Overshoot is a big complex problem caused, in large part, by energy-intensive globalisation. It is presenting itself in the form of multiple, pervasive, linked challenges associated with, *inter alia*, population growth, species extinction, climate change and oil depletion. Because it is a qualitatively different problem from anything that has gone before, we might ask if there are reasons why the global meaning-system might, intrinsically or extrinsically, be incapable of providing sufficient understanding to allow the 'human collective' to make rational choices about how to respond to Global Overshoot.

The first of these reasons is complexity itself. It is always difficult to predict the behaviour of open complex systems, characterised as they are by lagged feedbacks, negative and positive. For example, a postwar baby boom can lead to high unemployment 20 years later; the time taken for the oceans' expansion to come to equilibrium with a given level of greenhouse warming is several centuries. Prediction becomes even harder when the system in question is changing (rapidly) in terms of its material and energy inputs. Given the complexity of global society, and our ignorance of many of its linkages (what affects what), we can safely say that the global meaning-system will not be able to produce a quantitatively accurate model of the globalised world. When a system is largely unpredictable because it cannot be modelled, the consequences of attempting to 'correct' its behaviour will also be unpredictable over anything but short periods into the future. Even if some legitimate decision-making agent called the human collective (e.g. a world parliament) were to attempt to make rational decisions comparing the consequences of comprehensive alternative responses to Global Overshoot, it could not be done. Furthermore, as well as embodying a prediction problem, the global meaning-system yields no plausible criteria for rating multifaceted consequences, adding apples and oranges if you like. Given then that a rational or *synoptic* approach, to use Lindblom's term,[113] is out of reach, the default challenge to the global meaning-system, one we will address presently, is to devise 'second best' methods of conceptualising the Global Overshoot problem and how it should be addressed.

But, even if there were progress on these intrinsic difficulties, there would remain extrinsic reasons as to why the global meaning-system is as yet unable to create the understanding required to address Global Overshoot. If there is to be a coordinated, comprehensive and effective response to the Overshoot Crisis it will necessarily involve the active and willing participation of a large majority of the world's people (as Ashby's *law of requisite variety*[114] tells us, a successful control system needs to be as diverse in its possible settings as the system being controlled).

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[112] Giannetti, E.,1997, Lies we Live By: The Art of Self-deception, Bloomsbury, London, p. 21.

[113] Lindblom, C.E., 1965, ibid., Ch. 9.

[114] Ashby, W.R., 1960, *Design for a Brain*: *The Origin of Adaptive Behaviour*, (2nd Ed.) Chapman and Hall, London.

However, global society has no established institutions, no collective agent, for planning and coordinating global-scale activities from the top down, e.g. identifying what each nation-state is to do.

More to the point, thinking 'bottom up' and idealistically, few individuals have an unambiguously positive emotional response to the proposition that Global Overshoot is a major threat to human well-being and must be addressed vigorously. But, unless such an attitude does spread, global society will not see a widespread shift towards 'post-material' values and behaviours, and no reshaping of the predominant social character towards one where people want to do what they have to do to play their part in managing Global Overshoot.

The first very obvious reason for this situation is that most people in the world, certainly in the peripheral world, are either poor or desperately poor and concerned only with local issues that affect their immediate survival. They probably will not have heard of the Overshoot Crisis or, if they have, they probably will not have the education to understand what is, after all, a many-layered issue. And even if they do understand the issue and think it important, they may be fatalistic, i.e. assume themselves to be helpless to do anything.

There are similar good reasons why the idea of a global-overshoot project is not as yet strongly supported by the people of the world's core societies. In these rich societies the individual is bombarded with ideas, some intended to inform, others to persuade or deceive. In this cacophony, well-tagged 'information overload', the idea that Global Overshoot may be a paramount problem has only just begun to spread as and is a long way from becoming an 'idea in good currency'.[115] Even then, many people will not hear because their minds have been closed by their religious or political beliefs.

Those who are consciously listening struggle to choose between competing arguments as to why such a project should or should not be supported. They have learned that they live in cultures where propaganda and deception are commonplace, a world where, more than likely, advocates are not seeking to convert you to a truth as they see it, but to make you behave in a way advantageous to them. What to do? What to believe? Researching the overshoot issue for oneself may be an option for a few well-educated people with access to today's electronic information systems. But most have little choice other than to accept the judgement of an authority figure they are prepared to trust or, failing that, pluck a few snippets of 'evidence' from the arguments that they encounter (e.g. the Arctic is melting) and jump intuitively to a conclusion.

Just to be clear here, the routine corruption of meaning by self-serving interests is a much bigger and wider problem than any muddying of the overshoot issue. While deceit has long been with us (Homer's *Odyssey* is about little else), the resources, psychological insights and communications channels available to contemporary deceivers and persuaders raise, as a serious question, the possibility that

[115] Schon, D.A., 1971, *Beyond the Stable State*: *Public and Private Learning in a Changing Society*, Penguin, Melbourne.

we have savagely compromised global society's capacity to tackle its many challenges, just one of which is the Overshoot Crisis. For example, being able to trust that, mostly, one is not being deceived is fundamental to the functioning of a market economy, contracts notwithstanding. Perhaps deceit has become the Achilles' heel of language, the master technology?

Self-deception may be as important as deception in thwarting rational debate about the case for a global-overshoot project. As Giannetti demonstrates at length, humans are marvellously adept at coming to honestly believe in propositions which, conveniently, are compatible with their immediate self-interest.[116] For well-off people in the industrialised world, any comprehensive response to the Global Overshoot Crisis is likely to demand the self-discipline of foregoing short-term gain in return for long-term gains to, primarily, others. How sensible then to be sceptical of a 'bad news' scenario of a world in deep trouble! How easy to see that one's own responses must wait on the responses of others!

So, putting together the technical difficulties of devising a rational response to the Global Overshoot Crisis and the psychosocial barriers to widespread participation in any such response, it will be a bloody miracle if humanity squeezes through its coming bottleneck without massive wounds.

Continuities and Discontinuities

Two more or less unbroken *continuities*, namely the trend towards globalisation and the ongoing accumulation of cultural capital, have been suggested as interdependent processes which together offer an initial understanding (What's happening?) of the evolution of the human ecosystem over the Common Era. Slotting into these 'umbrella' trends are other long-term homeorhetic trends which, at any time, both reflect what has gone before and strongly shape what can/does happen subsequently. These include growth in:

Usable energy captured by humans
Number of human beings alive
Number and size of cities and, more generally, of collectives
Stocks of available technologies—social, material, communicative and cognitive
Stocks of physical infrastructure
Trade and communication between geographic regions
Natural, social and human scientific knowledge

Each of the score of momentous *discontinuities* selected as punctuation points, as turning points, for this chapter's story of humanity's journey through the Common Era appears to have triggered extensive reorganisation, but without dislocating the Era's underlying continuities. Declines in such measures in one part of the world

[116]Giannetti, E.,1997, *Lies we Live By*: *The Art of Self-deception*, Bloomsbury, London.

have been soon recovered elsewhere. The various highlighted shifts in such things as territorial boundaries, population patterns, trade relations, technologies, mental models and climate have not deflected a broader pattern of growth and increasing connectivity in global society. In the language of dissipative systems the *global* system has not (yet) been pushed, by an ever-increasing throughput of energy, past its resilience threshold, past its homeostatic limits, into a new and unpredictable behaviour regime.

The same 'dynamic stability', meaning the global system's capacity to hold to an extended (2,000-plus years) trajectory, does not hold for individual regional-scale subsystems within the globalising system, particularly those regions where history's 'momentous discontinuities' were born and from whence they spread. In these subsystems, being small relative to the global system, an initial discontinuous shift (bifurcation) in the flow-paths, flow rates of energy, materials or ideas commonly proved to be sufficient to trigger a major reorganisation in the region's activities, institutions, production system etc. From a human point of view, such reorganisation might be catastrophic or rewarding. Thereafter, depending on the particular changes occurring in the 'seed' region, 'knock-on' or 'domino' effects (these are thermodynamically open systems) spread to adjacent or otherwise connected (e.g. via trade routes) regions. Some such transfer-effects soon peter out while others travel across the world. Think of the Plague, triggering a wave of drastic social reorganisation as it spread across Eurasia; or the Industrial Revolution wherein a discontinuous shift in manufacturing and energy-extracting technologies in Britain was imitated around the world and, in time, boosted the contribution of trade to most of the world's economies, and hence to the global system; global-scale continuities arise through the alignment of similar regional-scale effects.

Homeostatic Limits and Self-Reorganisation

More generally, regional societies are always evolving, singly and together, sometimes abruptly and discontinuously as in these examples and sometimes in ways better described as smoothly and continuously. Every society is faced with the challenge of persisting in an environment where access to stocks and flows of energy, materials, ideas is always changing because of the activities of neighbours, trading partners, enemies, Nature etc. And, within certain limits, societies do adapt to such changes and persist. But, if the absolute change or rate of change in a society's inputs, whether up (positive stress) or down (negative stress), exceeds some threshold level, the society will collapse, i.e. lose nearly all structure. For example, regions experiencing sharply reduced throughputs cannot continue to service their prior degree of organisational complexity and have to reorganise to something simpler. Thus, in a country destructured by war—a high-energy disturbance—people flee or return to low-energy village life (deurbanisation).

Regions which are subjected to moderate changes in their input regime initially absorb such changes smoothly and homeostatically, i.e. without changing their structure, simply altering flow rates along existing links or adding/subtracting from their existing stores of materials and energy. However, there are always limits to how much change can be absorbed in this continuous way. When those limits are reached, the region either collapses from overload (or underload) or it reorganises towards something more (less) complex, e.g. more links, more structures, more reserves, more layers of organisation, different technologies. The ways in which regions respond to changing terms of trade provide everyday examples: When prices for their products fall, exporting regions economise and struggle to carry on. But, if prices stay low, the export industry, and then the regional economy collapse. If export prices rise, exports rise only slowly until a reorganised production system allows a discontinuous jump in production.

When a region has responded homeostatically to an ongoing environmental overload without collapsing or reorganising, it will normally continue to survive as long as there are no further increases in input flows from the environment. It will tend to settle down in a steady state with input and output flows in balance. Nevertheless, any region being pushed towards its homeostatic limits has inescapably lost *resilience*, this being its capacity for absorbing further change without being triggered to de- or restructure. This loss of buffering capacity, this vulnerability to any further change in a system which is close to its homeostatic limits, can alternatively be thought of as *homeostatic weakening*.

On the other hand, when a regional society responds to an ongoing environmental overload (e.g. a rise in energy throughput) by reorganising into a more complex structure, it reacquires a capacity for absorbing a further similar change. This is because the homeostatic limit on further throughput gets shifted outwards in accordance with the system's new structure. Unfortunately, the society's homeostatic limit on input reduction also rises. This means that if energy supplies (say) now decline 'permanently' the system will be more prone to collapse or simplification into minimally connected 'bits' than if it had not reorganised. In short, a system which responds structurally to what is only a temporary change in input flows will become less resilient as flows revert to 'normal'. This is the *Overshoot challenge* identified previously as facing the global system as a whole and now being identified as a potential threat to the continuity of individual regional societies as well. While the time scales on which global and regional systems reach overshoot are very different, the processes operating are analogous.

History records that, at most times, some regional societies will be complexifying and moving towards overshoot while others will be simplifying or collapsing; the world always unravels as it is built anew. For example, some regional populations will be growing through in-migration and natural increase while others will be declining through out-migration; some regions will be accumulating wealth and capital while others are losing it. The continuities exhibited by the global system are the resultant of the various regional changes.

Global and Regional Life Cycles

Whether global or regional, systems which keep increasing in complexity can be thought of as passing through the growth stage of a *life cycle* which, in time, will become a senescence stage and, ultimately, end in collapse or significant simplification.[117] Given enough time, all open dissipative systems simplify-collapse, basically because the larger slower dissipative systems in which they are embedded and on which they rely for input flows eventually reorganise or even collapse. For example, the warm conditions of the current interglacial period will come to an end and energy flows into the human ecosystem will probably plummet.

But even without massive change in the ecosphere which feeds and protects the human ecosystem, complexifying systems become increasingly vulnerable to relatively small fluctuations in the surrounding environment's mass-energy flows. The process which more or less guarantees this is as follows: Each successive reorganisation (usually an elaboration) confers less-and-less resilience on the system as it approaches senescence, i.e. the system's homeostatic limits keep retreating. This means that ever-smaller fluctuations in the environment are sufficient to precipitate a further reorganisation or, if a suitable reorganisation, one matched to the changed flows, is not available, the system will simplify or collapse.

Why does a regional system lose resilience as it complexifies? There are various reasons. One is that as a system complexifies its resources get increasingly 'locked up' in processes and structures which require a large pulse of 'activation energy' to divert them into novel processes which are more energy intensive (dissipate more energy). Inertia in regional land use patterns is a common example: land accumulates in the hands of conservative owners who see no benefit to themselves from changing their established land uses. Putting this another way, an unresponsive system is probably not generating enough options, enough variety from which to select new behaviours.

Another way in which a complexifying system loses resilience is that adding extra links, nodes and flow-paths to an open system reduces the average intensity of energy flows through the system's network of paths. The significance of this is that reducing average flows through a system's paths makes that system more vulnerable to disruption from typical environmental fluctuations. It might be also noted that it becomes increasingly difficult to find niches in a complexifying system such that the benefits of an additional flow path are not outweighed by an associated loss of function in existing paths—the phenomenon known to economists as diminishing marginal returns.

[117] Holling, C.S., 1973, Resilience and Stability of Ecological Systems, *Annual Review of Ecology and Systematics*, 4, pp. 1–23.

The Deep Processes of Eco-Cultural History

In the broad sense in which the word is being used in this book, history-writing is a technology, a recipe with a purpose. More than one recipe of course; historians use a variety of approaches to the interpretation and organisation of historical material for creating coherent stories about the experiences and accomplishments of peoples over time. The present chapter is an exercise in 'big' history—the story of humankind over the last several thousand years. It is not and cannot be comprehensive.

Historiographically, its starting point is the recognition that all histories, human or nonhuman, are histories of open dissipative systems. These are chunks of space-time which can always be described in terms of flows of energy and materials entering, leaving and circulating within them. Dissipative systems behave in characteristic ways. They are always changing, sometimes extremely slowly and sometimes rapidly, sometimes smoothly and continuously and reversibly (homeostatic change), sometimes convulsively and discontinuously (self-reorganisation). When dissipative systems are interconnected, meaning that energy and materials flow between them, they coevolve, i.e. change in one system leads to change in others, outputs from one system become inputs for another. While there is no 'correct' way of disaggregating a dissipative system into a population of subsystems in order to follow its inner history, it is usually more illuminating and tidier to look for its 'natural' subsystems—those parts which are more densely connected within themselves than they are to the outside world. In the case of the human ecosystem, that means the bio-physical environment plus a population of social groupings which, depending on what is being investigated, might be virtual species, classes, societies, nation states, empires…

While all dissipative systems have similar general characteristics, each recognisably separate type of dissipative system is normally analysed using its own experientially based frame of reference. For example, different vocabularies have been developed to describe historical changes in physical, biological and social systems even though homeostasis, and self-organisation. might be common to all. The point being made is that while dissipative processes are all-pervasive, they present themselves differently in different types of systems. Humans have learned to think about different types of systems without necessarily recognising their same deep structure. It was not until the twentieth century that the widespread applicability of, first, *systems thinking* and then *complex-systems thinking* began to be recognised.

In this spirit, the present chapter idealises the Common-Era history of the human ecosystem as an articulated story of evolutionary and ecological changes in and around an evolving population of human social groupings. The convenient simplifying assumption which allows the story to keep moving forward is that each social grouping (virtual species) acts as a single-minded *collective agent*. In the present context, an agent is a goal-seeking entity which is constrained to keep making rational choices; that is, an agent, before acting, compares alternative possible behaviours in terms of their consequences for goal achievement. An agent's mental model of the world, the basis for its rational behaviour, is founded on its beliefs and preferences as well as causal understanding of what is happening in its environment. Rational decision-making is always bounded (limited in what it can take into account), but note also that being rational does not preclude behaviour which is, to outsiders, short-sighted, ignorant, prejudiced, superstitious etc. Notwithstanding, agency is the motor of history!

Obviously there are many reasons why it will always be difficult for the historian to model the rationality behind an historical agent's actual decisions and behaviours. Why did Germany attack Russia in 1941? What a complex question. Commonly, one can do little more than interpret agent behaviour in terms of a few conventionally recognised goal-seeking/ problem-solving strategies such as trade, conquest, new technology and growth; and perhaps get some sense of past values. This may or may not be enough to convey understanding. Nor is it particularly helpful to know that, in principle, an agent's decision-making processes are a dissipative system like any other.[118]

The historical discontinuities identified in this chapter were periods of rapid cultural evolution, times at which particular virtual species started to behave in markedly different ways—ways which soon triggered large behaviour shifts in other virtual species. Some such shifts were reactive responses to changes in the bio-physical environment (e.g. warming or cooling of the climate, disease outbreaks) or in the social environment, e.g. trade options, invasion, the spread of ideas including religions and technologies. Other more proactive shifts were triggered internally, e.g. after the invention of new social and material technologies; after resource depletion; applying existing technologies opportunistically. As noted earlier, the reason for tagging humanity's Common Era history as *eco-cultural* is to emphasise that changes in the natural world are as important for understanding what has happened as changes in behaviour within and amongst social groups. The term *eco-cultural* also reminds us that evolutionary change in recent millennia and longer has been cultural and behavioural rather than genetic.

Evolutionary Ecology

What are the respective contributions of evolutionary and ecological processes to a macro-history of the Common Era, written as it is here around momentous discontinuities separated by slow-changing ongoing reorganisation—periods of relative stability? Broadly speaking, evolutionary change in a virtual species' behaviour or in relations between multiple virtual species involves more or less irreversible structural change such as the introduction of new structures or the reorganisation of existing structures. In biology one thinks of a genetic change in a species and in

[118] Pagels, H., 1988, *The Dreams of Reason*, Simon and Schuster, New York; Sperber, D., and Wilson, D., 1987, Précis of Relevance: Communication and Cognition, *Behavioral and Brain Science*, 10, pp. 697–754.

human societies one thinks first of a new or newly introduced technology (material, social etc.). Conversely, ecological change, within one or between several virtual species, is more reversible, involving fluctuations in flows along preexisting links and in stock levels in preexisting storage nodes, e.g. working longer hours to meet a surge in export demand, reducing stockpiles, population growth.

The inference here is that history's periods of major discontinuous change are more evolutionary and its periods of continuous change are more characterised by ecological processes. That is to say, after a burst of rapid evolutionary reorganisation involving multiple virtual species the rate of reorganisation slows and, in the subsequent period of relative stability, each surviving virtual species will be learning to reliably reproduce itself in what amounts to a 'new' niche. Survival and, to use Holling's term,[119] renewal is likely to rely heavily on the virtual species' homeostatic or ecological adjustment capacity. Survival means that, staying within their respective homeostatic limits, all interconnected virtual species will have found mutually compatible ways of exchanging materials, energy and information amongst themselves.

Notwithstanding, every virtual species' adaptive responses during historically quiet periods are likely to also include ongoing incremental reorganisations as the group trials novel behaviours which promise to improve goal achievement. Self-reorganisation does not have to be transformative; in fact, it will most commonly involve the adjustment of a few links and nodes at a time. And, because this is happening to all the interacting virtual species simultaneously, each virtual species can be thought of as coevolving with its *niche* where its niche is, to a large extent, defined in terms of those behaviours in other virtual species which, for survival's sake, need to be recognised.[120]

So, while cultural evolution never stops, it might be expected to proceed relatively quickly during discontinuities and relatively slowly in between. More concretely, periods of rapid change disrupt the existing organisation of societies while longer in-between periods of gradual change are likely to produce developmental changes such as population buildup, capital accumulation and stable relationships with neighbours. A clear-cut recent example is provided by the demise and tumultuous aftermath of the Soviet Union. Twenty years later, its former satellites have become 'new' virtual species and are groping their way towards political stability and economic development.

All this raises the question of 'speciation' amongst virtual species, these being social groupings of individuals with shared interests, commonly having their members breeding and working together. Virtual species in the human ecosystem function like plant and animal species in 'ordinary' ecosystems, and that includes *speciating*, the formation of new species from existing species.

While cataloguing virtual species is a subjective and context-dependent matter, the list has clearly changed dramatically over the Common Era. Empires, nation-states,

[119] Holling, C.S., 1973, ibid.

[120] Odling-Smee, F.J., Laland, K.N., and Feldman, M.W., 2003, ibid.

religious, economic and political groupings, alliances, classes etc. have come and gone in what is probably history's best recognised processional. New virtual species come into recognisable existence, and vice versa, in a variety of ways. Sometimes an existing society transforms itself from within by adopting radical technologies, e.g. Turkey before and after Kemal Atatürk. Conversely, societies can be destroyed by natural disasters or self-destruct as a result of holding grossly maladaptive beliefs.

At the global scale, new social forms most commonly emerge as a result of competition/cooperation between existing societies.[121] War and conquest can see a virtual species destroyed and its remnants assimilated into an updated version of the conquering virtual species. Conversely, any cooperative alliance (trade, military, economic etc.) between virtual species creates a new virtual species which has a degree of control over the preexisting component virtual species. Relationships in which some virtual species have a degree of power to control, constrain or coordinate the behaviour of others are *hierarchical*, a type of arrangement that characteristically appears in dissipative systems as they become more energetic and more complex, e.g. supranational organisations in a globalising world.

At the scale of the nation-state, Common Era populations have usually been organised hierarchically around two umbrella virtual species, jointly playing out an ongoing struggle between authority and freedom—a powerful ruling minority and a ruled (dominated) majority. In relations with the outside world, the ruling elite is the agent which makes decisions on behalf of the whole population. Against the persistent backdrop of this broad structure, the elite and the subordinate virtual species have continued to evolve and coevolve. Both are hierarchical and it is amongst the populations of lower-level virtual species (a) within the elite and (b) within the subordinate population that speciation takes place. Virtual species within elites, call them *factions*, have been notorious throughout history for engaging in their own power struggles as energetically as they have sought to exploit the subordinated majority. New factions equate to new virtual species. Subordinate virtual species too have comprised an ever-changing suite of interest groups based on, for example, political affiliation or changing economic roles.

Cultural speciation, as presented here, is a much sloppier process than biological speciation which can always be modelled in terms of changing gene frequencies in a population. Changes in any number of a group's characteristics, including such things as demographics, technologies, home territory, external links and beliefs, might be sufficient, depending on the context, to trigger a judgement that a virtual species has emerged or disappeared. Virtual species exist in the eye of the beholder and the beholder is not in a position to model their formation; only to recognise some of the classes of virtual species that do regularly emerge and some of the situations conducive to emergence and disappearance of virtual species (particularly, but not exclusively, rapid change of one sort or another).

[121] Quigley, C., 1966, Tragedy and Hope: A History of the World in our Time, Macmillan, New York.

The Uses of History

Historiography is, before all else, a technology for imposing greater meaning on one or another aspect of the past and near-past. It does this by identifying historical 'facts' and clarifying or finding relationships between those facts; or between those facts and things more contemporary, or of particular interest to the historian. The relationships which confer meaning might be purely chronological, a mere ordering of historical facts in time. Or they might be inductive generalisations about co-occurrences between types of facts, e.g. identifying causal relations of the 'post hoc ergo propter hoc' form, or searching for the 'laws of history'. As noted (see page 201), an excellent example of what is possible is Jared Diamond's realisation of the importance of certain initial conditions, most notably the possibilities for domesticating local plants and animals, in shaping the very different courses of history on different continents. What the historian finds depends not only on what evidence is available but on the conceptual framework and world view he or she brings to the task; and the available evidence will in turn depend on the historian's conceptions and preconceptions.

Implicitly or explicitly, all histories have a higher purpose. Thus, like this book, much history is exploratory—e.g. testing to see if the facts are compatible with a received higher idea ('progress' for example). In the present case, the facts do seem to be compatible with the hypothesis that history can be interpreted as a hierarchy of evolutionary and ecological processes in dynamic open systems. Such a conclusion is by no means unique. In their own ways, various macrohistorians, including David Christian, Immanuel Wallerstein and William McNeill have accepted this perspective.[122]

The present exercise, again like others, also has a normative intention. Can we, despite Hegel's firm No, learn from history? Is it true that those who do not understand the past cannot understand the present or think productively about humanity's long-term future? Or, more specifically, does a long-term history of humanity from an evolutionary-ecological perspective give any insight into what we might want to learn from history and what might be possible within that constraint? Does the present history, or indeed history in general, clarify the limits of agency and how an individual or collective agent might better approach the quality survival task? These are questions to be addressed in the next chapter.

[122] Christian, D., 2003, ibid.; McNeill, W.H., 1980, ibid.; Wallerstein, I., 2004, ibid.

Chapter 5
Confronting Global Overshoot

The Warm Glow of Understanding

> The unbroken history of the human lineage can be traced back to the origins of the universe but more recently, meaning the last few million years, we have become, and remained, animals called mammals, then primates, and then a branch of the great ape family. Primates evolved to live in groups in territories from which they attempted to exclude trespassers, a behavioural tendency which persisted as the first humans evolved into modern humans and spread across much of the planet. During the last Ice Age, as *Homo sapiens*' rate of biological evolution (e.g. increasing brain size) slowed down, its rate of cultural evolution (e.g. tool-making skills) speeded up. That is, humans began to create and use an expanding and selectively changing range of behavioural 'recipes' (what I have adventurously called technologies) which through learning and imitation within and between groups, could remain available from generation to generation. By making the further assumption that groups and individuals are purposive agents (i.e. constrained to behave in an emotionally acceptable and rational way) when choosing between technologies, one can, in hindsight and in principle, construct a plausible story (a scenario) of how the species has survived, multiplied and thrived (or not) since, say, cultural 'liftoff'. The fact that technologies have become more elaborate and collectively more energy-intensive over time does not change the basic process; nor does the fact that the rate of cultural change has varied over time.

Before contemplating the future and its difficulties let us bask a moment in the warm glow of understanding that a knowledge of history's interweavings confers. The cameo recapitulation above is a confident assertion that, subject to accepting several methodological premises (groups as purposive agents, the species' capacity for technological innovation), and assuming a sufficiency of raw historical facts,[1] an

[1] 'By facts we usually just mean "data", that is, everything we count as not part of the particular problem before us, but as what is safe enough to be taken for granted in solving it, and needed to do so. But facts are never confined to the raw data of sense, and seldom to "physical facts" (the kind that can be stated in terms of physics). It is a fact that this is food or poison, that it is dangerous, dirty, unique, or legal, that it is an ancient totem pole or the flag of my country. Yet standards quite alien to physics must be grasped before we can "see" these facts. They are thus never logically isolated from some kind of "evaluating"'. From Midgley, M., 1978, *Beast and Man*, Cornell University Press, Ithaca, p. 178.

D. Cocks, *Global Overshoot: Contemplating the World's Converging Problems*,

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abductively plausible world history should be possible, i.e. a history which is consistent with the facts. To make this happen, one has to not only assume that individuals are rational, albeit subject to emotional taboos, but that they have a fairly standard mix of motivations[2]: for material gain, access to women,[3] power, acceptance, self-preservation, etc. Virtual species too have to be understood by assuming them to be selecting behaviours (what Graeme Snooks calls dynamic strategies[4]) which are variants on a few generic social technologies such as trade, conquest, colonisation, etc.

In the event, every history, from world to local, is limited by factual gaps and a necessarily imperfect understanding of protagonists' mental models. There is also the inescapable limitation that the historian has to find a way of simplifying the warp and weft of the historical tapestry, its many parallel and cross threads, so that it can be presented as a linear narrative of a size that can be absorbed. Thus, the perspective of the present exercise is that history can be viewed as a succession of fundamentally important turning points or discontinuities. These are clusters of events which start wherever and which trigger (cause) extended chains of events, of ongoing and spreading adjustments, many of which will themselves be 'minor' discontinuities.[5] The challenge in applying this approach is to identify a manageable number of major discontinuities such that one can yet say something of where each came from and where it led. The complexity of history comes with the interweaving of multiple cascades of adjustments to multiple diachronic discontinuities.[6]

The present exercise centres on a macrohistory which culminates in the beginnings of a major discontinuity. It purports to explain how the human lineage went from being a small population of well-adapted tree-dwellers in Africa to being an erupting worldwide population relying on fossil fuels and an ever-elaborating suite of material, social, communicative and cognitive technologies for meeting people's material and other needs, albeit with starkly varying degrees of success. Whatever that success, it is hard not to feel a sense of wonder (fancy that!) at how these 'hairless apes' have created, survived, exploited, absorbed, magnified and built on history's environmental, biological and cultural discontinuities. Think of ice ages, the Toba eruption, language, cultural liftoff, the Holocene climate shift, agriculture, cities, writing, consciousness, sail, plague, printing, industrialisation and the list goes on.

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[2]Midgley, M., 1978, ibid., p.14 suggests that 'we badly need new and more suitable concepts for describing motivation'.

[3]Gottschall, J., 2008, The Rape of Troy: Evolution, Violence, and the World of Homer, Cambridge University Press, Cambridge.

[4]Snooks, G.D., 1998, *The Laws of History*, Routledge, London and New York.

[5]Minor discontinuities in macrohistory become the major discontinuities of microhistories.

[6]Salthe, S.N., 2010, Maximum Power and Maximum Entropy Production: Finalities in Nature, *Cosmos and History*, 6 (1), pp. 114–121.

Wonder Is Not Admiration

Having said that, wonder is not necessarily admiration. People tend to admire (approve of) contemporaries with talents and character traits they would like for themselves, talents and traits which are believed to enhance quality-survival prospects in today's world. By imitating parental behaviour, children learn what to admire and what to disapprove of. Furthermore, discretionary behaviours which are consistently admired (or denigrated) acquire a *moral character* which goes beyond approval-disapproval, i.e. non-conformity incurs physical or psychological (e.g. shame) punishment.

To the extent that people admire-denigrate other life forms, and that includes their own ancestors, it comes from projecting contemporary human qualities onto such, e.g. the tree that, metaphorically, 'strives' to reach the sky, the 'faithful' dog. Similarly we are tempted to admire and denigrate, and to pass moral judgements on what appear to be contemporary traits in our ancestors. But ancestral behaviours which we judge to be cruel, honest, honourable, cooperative, combative, exploitative, and so on may not have existed in the sense that, at that time, the *concepts* of cruel, honest, etc. may have not yet emerged. After all, cruelty (say) is an idea which had to be invented and given a name. Or, they may have existed but not had any moral character.[7]

So, we can say that the cruel conduct of, say, the Bronze-Age Assyrians was immoral by contemporary standards, but does anything useful follow from that observation? It is, potentially, more useful to ask if the Assyrians made an adaptive mistake by choosing to be cruel. Did they even perceive that they had a choice, consciously or unconsciously? Would they have achieved more of what they valued if they had chosen not to use the social technology of cruelty to produce conforming behaviour? Certainly their victims would have been better off. But, would the quality of life and survival prospects of today's humans be better if the Assyrians had foregone cruelty? These are unanswerable questions. If we are to reserve admiration for discretionary behaviours we judge to have improved the achievement of, and prospects for, quality survival, then much of history will be beyond that judgement.

In the event, scholars have found it more productive to study the history of values, i.e. how people in the past have thought about values. What did historical peoples value in terms of ends and means of behavioural standards? Answers here have contributed, first, to understanding how it really was to live in, say, times of global transformation and, second, to understanding the diversity of people's values, not only in the past but, by extension, in the present, e.g. today's fundamentalist Christians appear to exhibit a religiosity comparable to much of medieval Europe.[8]

[7]Williams, B., 2006, *Philosophy as a Humanistic Discipline*, (A.W. Moore Ed.) Princeton UP, Princeton, Ch. 8.

[8]Muller, H.J., 1952, *The Uses of the Past*: *Profiles of Former Societies*, Mentor, New York, pp. 244–250.

Some Ineluctable Realities

Contemplation of the macrohistorical record yields several foundational conclusions about humans and the world they now face which cannot be forgotten if we are to think realistically about the quality survival task; recall the suggestion in the Preface that a suitable peak goal for humanity might well be one of seeing its lineage surviving, and surviving well. The three realities to be now recapitulated as impediments to achieving quality survival are the what-to-do problem, the virtual-species problem and the global overshoot problem.

Purposive Behaviour Is Necessarily Experimental: The What-to-do Problem

Cultural and genetic evolution over millions of years has produced, in the modern human, a layered behavioural guidance system under which, depending on the information being received, activates particular biological, cognitive or emotional responses. Thus an immediate direct threat might trigger a genetically programmed *instinctive* response of greater or lesser specificity. A more nuanced what-to-do situation might trigger an emotionally directed response in the form of an impulsive choice from a limited range of previously learned behaviours. And then, late in the evolutionary story, came the choosing brain, as we earlier called it. Here, the brain imagines the consequences of alternatives to impulsive behaviour and chooses the first imagined alternative to generate sufficiently positive feelings. That is, feelings act to limit the enormous range of alternatives that would otherwise have to be explored cognitively before a behavioural choice is made.

Language-based conceptual thinking was the technology which dramatically increased the range and effectiveness of cognition for guiding behaviour. In reasonably stable environments humans learn to behave in accordance with the slowly evolving customs, habits, roles and traditions of their own societies. But in non-routine, and hence stressful, situations, leaders and other decision-makers have come to increasingly rely on mental models of reality to guide their choice of what to do. And in some areas, most notably in science, people have learned how to upgrade such models in the light of experience.

Having said that, it needs to be recognised that all attempts to make rational decisions (those based on ends-means thinking) in what-to-do situations are less than ideal for reasons which include limited time, limited knowledge, pervasive complexity, illogicalities and misperceptions. Given the difficulties of thinking critically and comprehensively, decision-makers commonly resort to using ‘short cut’ heuristics or seeking the advice of authority figures.

What the above means is that all behaviour, whether instinctive, emotionally directed or highly rational is, to some degree, experimental. The outcomes of an individual’s decisions, particularly in novel situations, are never certain—hence the ‘law’ of unintended consequences. So, when trying to solve a what-to-do problem rationally, one must be routinely prepared to respond further as one’s actions prove inadequate for the problem as initially conceived. Unfortunately, many what-to-do problems are also ‘wicked’, an eye-catching word meaning that they have no definitive formulation (What sort of problem is this?) and no criteria for identifying a conclusively ‘best’ solution. For example, over what time horizon does one compare the costs and benefits of alternative actions? Moreover, the family of issues that underlies each problem is itself likely to be evolving. It is easy to conclude that most problems will never be solved, only managed by cautiously ‘muddling through’, or overtaken by events. Notwithstanding, these difficulties are poorly recognised.

There Is No We: The Virtual-Species Problem

From early hunter-gatherer times, human groups have used the technologies of division of labour and territory-protection for improving their security and productivity. It was through the evolution and elaboration of these technologies—plus their coevolution with some related adaptations and with environmental changes—that the species came to be organised into a loosely connected and dynamic (ever-changing) network of hierarchically stratified, territorially based societies.

Unlike better-armed group-living species such as wolves, Palaeolithic humans were never strongly selected for a capacity to self-inhibit aggressive behaviour towards trespassers of their own species. This is consistent with the perception that before developing energy-concentrating weapons—and then it was too late—human groups had little capacity to inflict lethal violence on each other. Thus, the untrained fighting style of (modern) humans consists largely of shoving and overhand blows to the bony head/shoulders/ribcage area.[9] While few individuals are highly aggressive, most conform when their group or society initiates aggressive behaviour; ordinary soldiers can be trained to kill when ordered, but most are still reluctant. In brief, humans tend to be aggressive towards strangers but, without weapons and appropriate training, rather ineffectively so.

In those Holocene societies that learned to produce surplus storable food, both population size and task specialisation increased, as did the use of social dominance (e.g. by coercion, manipulation, deceit) far beyond that which had existed in subsistence societies. And it is from these times that it becomes increasingly useful to describe humanity as being organised into virtual species, meaning coherent groups that engage in periodic competition, conflict and cooperation. In the broadest terms, these groups were, and still are, political states and, within each state, a ruling class and a working class. Beyond that breakdown, the hierarchy of virtual species extends upwards to associations of states and downwards to factions and functional groups within classes. In complex hierarchical societies, each individual is normally associated with multiple virtual species and may move between such, e.g. social classes, political parties, professions and football clubs. In particular, ruling elites

[9]Morris, D., 1977/2002, *Peoplewatching*, Vintage, London.

are almost always divided into vigorously competing virtual species with shifting memberships.[10]

Every virtual species behaves, in several respects, like a separate hunter-gatherer group. In particular, group members are predisposed to feel friendly towards those within and enmity towards those outside the group (not just trespassers). And from Palaeolithic to modern times, the sharing of amity and enmity emotions has repeatedly been at the heart of the individual's success in satisfying his or her psychic needs, notably for bonding (the need to 'belong'[11]), for identity (being an autonomous individual) and for meaning in one's life (being part of 'something larger than oneself'). For example, I am a Greek and proud to be a Greek, not a thieving Trojan. We Greeks will conquer the Trojans, no matter how long it takes.

This amity-enmity dichotomy is also the source of the dual standard of morality which most people unconsciously hold, namely judging 'strangers' differently (moral alchemy!) from one's own 'tribe', be it a gang, class, ethnic group, nation or football club. In extreme form it leads to a failure to recognise other virtual species as conspecifics, as fellow humans; abominations such as ethnic cleansing, mass extermination and unimaginable cruelty follow easily. Somewhat less immoderately, other virtual species are seen as humans but, because of their 'dangerous' beliefs or their presumed past behaviour, they are humans who have 'foregone the right' to be treated as 'we' aspire to treat our own.

Armed conflict between groups or societies is a commonplace of history[12] but aggression, or hostility at least, between virtual species *within* hierarchical societies has been equally pervasive. Thus, the majority of humans have been oppressed by their own ruling classes for most of post-glacial history. A society of any complexity requires that some of its members coordinate and direct the activities of the majority. With few exceptions, these elite minorities have used their power to advance and protect their own interests at the expense of majorities. Reforms and concessions which have improved quality of life for the majority have most commonly come only in response to the threat of civil unrest from the 'dangerous classes'. During quieter times the elites seek to reclaim such concessions. The prime example of modern times is the creation of welfare states after the Second World War as a response to fascism and communism, and their winding back with the demise of communism.[13]

From Neolithic times, elites (soldiers, priests, bureaucrats, politicians, etc.) have regularly taken their peoples to war in search of resources coveted by the elites themselves—land, slaves, women, converts, bullion, tribute, etc. Notwithstanding this coercion, a state's elites and its masses generally come together to temporarily form one virtual species in times of war or external threat.

[10] Hassan, F., 2005, The Lie of History: States and the Contradictions of Complex Societies, *Dahlem Workshop Reports*, MIT Press, Cambridge, MA.

[11] Koestler, A., 1967, *The Ghost in the Machine*, Arkana, London.

[12] Le Blanc, S., with Register, K., 2003, ibid.

[13] Wallerstein, I., 1995, *After Liberalism*, The New Press, New York.

Burdened with rising populations or falling food supplies, elites have often been willing to let their people slowly and surreptitiously starve (Let them eat cake) or, indeed, to use war and conquest as technologies for culling their own populations. The link between hunger and attacking the neighbours weakened with the coming of hierarchical societies. It is only in the last few thousand years, starting with limited democracy in the Greek city states, that humans have moved somewhat from seeing societies as naturally divided into all-powerful rulers and masses with minimal rights. In some modern industrial nation states, elites have managed to convince the majority of ordinary people that their political decisions do not favour elite interests. But, even in a strong democracy, every new issue of concern spawns a new mix of self-interested virtual species and a what-to-do problem that cannot be solved in a demonstrably efficient and equitable manner.

Nonetheless, in societies where people are not hungry, think they are being treated reasonably fairly (justly) and feel reasonably secure psychologically, amity and sociality come to displace enmity and sociopathy (regarding others as enemies to be mistrusted and exploited if possible). People develop an expectation that their interests will be favoured acceptably often. Decisions get made and coordinated activity proceeds; people do what is expected of them. The so-called competitive societies, those where egoism is admired (greed is good!), run the risk of squandering those putative reserves of goodwill and helpful friendliness which might buffer against social unrest.

This brings us to the point of accepting that there is a *virtual-species problem*, namely the difficulty that autonomous virtual species have in collectively agreeing (we agree…) to work in a coordinated way towards ends judged to be mutually beneficial, and ends which could not be achieved by one group acting alone—the amplification effect.

Often, it is the virtual-species problem which becomes the major impediment to the inventing of a new social technology. It may be of course that not every relevant virtual species construes the proposed behaviour as beneficial to them or they see it as less beneficial than some other more-independent behaviour (its opportunity cost). Or doubts may be felt as to what exactly is being agreed and what exactly will be achieved. This last is where the virtual-species problem and the what-to-do problem intersect. As discussed above, outcomes of proposals for addressing what-to-do problems are always uncertain and carry the risk of unintended consequences. It is understandable that groups already living on the edge of survival might be averse to risking experiments with novel behaviours, no matter how promising, and prefer to continue with 'safe' traditional behaviours.

The virtual-species problem is more conventionally known among political scientists as *agonism*, a term borrowed from biologists. For biologists, agonism is that combination of aggressive, defensive and avoiding behaviours which allow members of a species to regulate its spatial distribution and, probably, access to food and mates. Among political scientists, agonists are sceptical about the capacity of politics to eliminate, overcome or circumvent deep divisions within societies, e.g. of class, culture and gender. They find many models of political behaviour, including liberalism and communitarianism, to be far too optimistic about the possibility of finding a harmonious and peaceful pattern of political and social cooperation.[14] Agonists prefer to start their theorising by asking how societies might first deal with such irreducible differences. It is a question to which we shall return.

In most circumstances, it is much harder to achieve the benefits of coordination when the virtual species involved are large collectives such as nation states. Compared with domestic agreements, there are several reasons why this should be so. First of all, trust is scarce in international relations where, for centuries, 'realist' doctrines have prevailed, namely, that the essence of foreign policy is to make yourself as militarily powerful as possible, alone or through alliances.[15] Cooperation becomes even more difficult between nations that are already in conflict or have a history of conflict. Negotiators from different countries are more likely than negotiators from the same country to misunderstand each other's values and to disagree about 'facts' and about what is a fair distribution of costs and benefits.

Notwithstanding, states have been forming military alliances and making trade agreements for millennia. It is in situations where the shared threat or opportunity is not immediately obvious, or where the flow of benefits is not immediate, that international cooperation proceeds slowly. Examples are plentiful in the fields of international law, financial institutions and protection of the environment.

To claim 'There is no We' is just an extravagant way of making the point that it is normally difficult, and often impossible, for two or more virtual species to find and take coordinated actions that will benefit all. Part of that difficulty is the same difficulty as that facing a single virtual species, or an individual for that matter, in any what-to-do situation—all intentional behaviour is inescapably experimental. This is why virtual species that see themselves in an ongoing cooperative relationship must be prepared to revise their joint plans frequently. Even then, even when a degree of trust has been achieved, all such relationships are probably best recognised as intrinsically fragile.

Cooperation within the existing system of virtual species is but one strategy for a virtual species to advance its own interests. Conflict and coercion are other possibilities which, in their own ways, are as problematic as cooperation. Sometimes there is a place for competition in the sense of different virtual species seeking access to the same resources but without trying to thwart each other's efforts directly. Another less direct strategy, one which does not take the prevailing order for granted, might be to try to reshape the attitudes of 'neighbouring' virtual species so that the level of goodwill between virtual species is more conducive to future cooperation, e.g. through cultural exchanges, gifts and arms reduction.

Overall, the ineluctable realities we have identified as the what-to-do problem and the virtual-species problem are major constraints on what humans can achieve through collective action. They greatly reduce the range of options from which a choice of (joint) actions might eventually be made.

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[14] http://en.wikipedia.org/wiki/Agonism (Accessed 27 Nov 2008).

[15] Morgenthau, H., 1948, Politics Among Nations: The Struggle for Power and Peace, Alfred A. Knopf, New York.

Overshoot: The Accumulation of Spillovers

We come now to recapitulating the third of the ineluctable realities which, it is being suggested, must be viewed unblinkingly, not forgotten or bypassed, if one is to think critically about the quality survival task as it presents at the beginning of the twenty-first century of the Common Era (and that is what we hope to do).

In my earlier book, *Deep Futures*,[16] the twenty-first century was foreseen to be a difficult century for humanity, one in which the successful pursuit of quality survival would require the species to work doggedly to ameliorate the problems of war, poverty, injustice, environmental degradation and sociopathy or, more positively, pursue the goals of peace, material well-being, social justice, environmental protection and sociality. The virtual-species problem (pervasive disagreement) was assumed to be soluble (e.g. through a strong United Nations) and, while the presenting problems were great, they too were not to be treated as insoluble.

I am now convinced, just a few years later, that this scenario, call it *strong intervention*, is highly implausible. That is, one would be surprised in the extreme if it came to pass. For me, it is a much more plausible scenario that this will be not just a difficult century, but a disastrous one! Almost irrespective of anything that large numbers of well-intentioned people might do, the existing problems of war, poverty, injustice, inequity, environmental degradation and sociopathy will grow, not shrink. Under the combined effects of drought, famine, war, mass migration, poverty, disease, resource exhaustion and economic disruption, the world's population will start falling well before current estimates that global population will peak 'naturally' around 2070. Many indicators of quality of life, including life expectancy, will slump. In all countries, but especially in an increasing number of failed and war-torn states,[17] it will become much harder for most people to meet their everyday needs. Women and children, the old and the sick will be most affected. Jobs will be few. Supply chains for basic commodities (e.g. food, fuel, medicines) will break. Barter will become normal. Inflation will escalate. Health, education, transport and police services will degrade. Power and water supplies will become unreliable or worse. Roads and other infrastructure will be poorly maintained. Crime and group violence will escalate. Violent protest and looting will be commonplace. Ordinary people will live in fear. Mental illness will be endemic. People will turn to authoritarian regimes for respite. In brief, cities everywhere will struggle to avoid becoming giant lawless slums. Rural populations will be vulnerable to marauders and incursions from displaced persons. Life will be an exhausting wretched struggle.

Such a dark-age 'future' has already arrived in parts of the world—most obviously in parts of East and West Africa, the Middle East and South America. But it is also appearing in parts of large cities in first world countries, e.g. France, Britain

[16] Cocks, D., 2003, *Deep Futures*: *Our Prospects for Survival*, University of New South Wales Press and McGill University Press.

[17] Stewart, P., 2007, 'Failed' States and Global Security: Empirical Questions and Policy Dilemmas, *International Studies Review*, 9, pp.644–662.

and USA. The further questions surrounding this basic scenario of a world descending into Hobbesian dystopia, a shambles, are how far and how fast? And what makes it plausible?

But How Far? How Fast?

If quality of life is going to degrade globally, one might expect it to degrade more slowly in first world countries with their established institutions and the technological skills to divert resources being used for discretionary purposes into essential services. On the other hand, first world societies have directed very large, and now problematic, energy flows into the construction and ongoing maintenance of networks of relationships between virtual species. Resources such as labour and capital have been progressively locked into specialised functions (tasks) on which other functions are highly dependent, so-called long-chain dependency. This means that if the material-energy-information flows along a link gets disrupted, and there are no contingency plans for restoring that link's function (as in a competitive just-in-time economic system), the disruption spreads to other links. Just how far such malfunctioning spreads depends on the architecture of the network, its patterns of connections between nodes of activity. In general, as networks of functions become ever more tightly connected, they move towards transmitting shocks rather than absorbing them, i.e. they become unstable. If a highly connected node, a 'hub', a power grid for example, is knocked out abruptly, whole populations stand to suffer dramatic falls in their quality of life. If the same power grid degrades slowly, people may have time to adapt and the impacts will be less dramatic, but still ultimately destructive of people's options. The 2008 global credit crisis, and its subsequent transmission to the real economies of many countries, is a text book example of how disruptions can spread in a highly connected (globalised) system. Russia's descent into chaos in the winter of 1991–1992 did not spread globally but did illustrate how an organised, albeit repressive, society can break down in just months.[18]

In the world's rich countries, where most people have a high standard of living compared with second and third world (less developed) countries, people rely largely on markets, including the employment and stock markets, for satisfying their daily needs; and they rely on government to provide personal and property security. When markets and governments fail to meet normal expectations, not only does quality of life drop for most people, but they do not have coping and survival mechanisms and skills for meeting their needs in more basic ways, e.g. using more labour, simpler technologies and less capital and energy to grow food. More than that, their societies are not organised to facilitate extra-market adaptations (e.g. providing vegetable plots in cities) or, indeed, to switch to providing goods and services appropriate to changed lifestyles, e.g. wind-up radios and more public transport.

[18] Ferguson, N, 2010, Complexity and Collapse: Empires on the Edge of Chaos, *Foreign Affairs*, March–April, PDF Reprint, http://www.foreignaffairs.com/issues/2010/89/2 (Accessed 21 Jan 2011).

By contrast, people are more self-sufficient, less dependent on markets, in poorer countries. The exception to this is that the urban poor in such societies are particularly vulnerable to rising food prices. Poor people's lives invariably contain more hardship and physical labour, more disease and early death, more hunger and violence; but the collapse of markets around them does not cause them to fundamentally restructure their lives, not if their only purchases are, say, cooking oil, salt and matches. Having said that, the current global recession-depression is already hurting poor countries in several ways, including falling capital inflows (including aid), falling commodity prices and job losses in both export industries and in numbers of overseas guest workers.[19]

The happenings which do have relatively greater impact on the poor than on the rich are natural disasters, epidemics and organised violence. When they are spared such shocks, subsistence farmers, gardeners, fishers and herders can usually keep their societies intact, as evidenced by, for example, the maintenance of habits, customs and rituals. It is when such imposts turn people into refugees and displaced persons, or, indeed into marauders and pirates, that their quality of life plunges. Forced migration, including the return of desperate slum dwellers to their villages, is doubly bad. Not only are the migrants traumatised, but the areas they descend on become instantly overpopulated, with all the possibilities which this creates for conflict between migrant and resident virtual species. As evidenced by the late Bronze Age, such 'knock on' discontinuities can spread over thousands of kilometres.

But none of the above constitutes evidence that, as of now, dystopic bottleneck conditions are festering and spreading across more of the world. Indeed, two important direct indicators of average (species-wide) quality of life, life expectancy at birth and under-five infant mortality, continue to improve, even as global population is rising by some 70 million per year. Nonetheless, while life expectancy at age 15 has increased by 2–3 years for most regions over the last 20 years, there are exceptions. Life expectancy in Africa decreased by nearly 7 years between 1980 and 2001, and for the transition countries of Eastern Europe, in the same period, by 4.2 years for males and 1.6 years for females. On the other hand, the global child mortality rate declined by almost one quarter between 1990 and 2006, partly as a result of campaigns against measles, malaria and bottle-feeding, and partly from improvements in the economies of most of the world outside Africa. Gross World Income per head, which correlates strongly with health status, increased by 47% between 2000 and 2007. Prior to the 2006 food crisis, living standards in the developing world had been rising dramatically for some decades. The proportion of its population living in extreme economic poverty—defined as living on less than $1.25 per day (at adjusted 2005 prices)—fell from 52% in 1981 to 26% in 2005.[20]

While such global trends conceal marked differences between regions, and the quality of the underlying data is questionable anyhow, they are *prima facie* evidence

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[19] Anon, 2009, The Toxins Trickle Downwards, *Economist*, 14 Mar 2009, pp.54–55.

[20] http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTPOVERTY/EXTPA/0, content MDK:20153855~menuPK:435040~pagePK:148956~piPK:216618~theSitePK:430367,00.html (Accessed 22 Dec 2008).

that, world-wide, quality of life is probably still rising. The UN Human Development Index for the world, which is a crude amalgam of indices for income, literacy and life expectancy, has risen monotonically over its 20-year history.[21] Having said that, and recognising that falling child mortality is a major contributor to rising life expectancy, one suspects (there is no direct data) that the species-wide figure for *years of healthy life expectancy at age 15* might be stagnant or declining. The word 'healthy' here means 'without disabilities that constrain core activities'.

But, consider the debit side of the quality-of-life ledger:

Between the start of 2006 and 2008, the average world price for rice rose by 217%, wheat by 136%, maize by 125% and soybeans by 107%.[22] Suffering among those who spend the bulk of their income on basic food has been immense and food riots have occurred in dozens of the world's cities. Concurrently, these soaring *grain prices* have forced a sharp reduction in food aid, putting the 37 countries that depend on the World Food Program for emergency food assistance at risk of social breakdown. The UN Food and Agriculture Organisation's (FAO) provisional estimates are that, in 2007, 75 million more people were added to the total number of undernourished relative to 2003–2005.[23] This represents an increase in the proportion of hungry people in the world from 16 to 17%. It is true that over the past half-century grain prices have spiked from time to time because of weather-related events (e.g. the 1972 Soviet crop failure) but the situation today is entirely different.[24] New and established trends are coming together which make it probable that real food prices will keep rising in coming decades, and keep rising faster than real incomes.

Demand for grain will continue to increase as a result of population growth and, less probably, as a result of the diversion of grain crops to ethanol production and meat production. On the supply side there is little new cropland coming on stream to balance ongoing losses to urban land uses and land degradation. In this century, irrigated agricultural land per capita has been falling by 1% per annum. This will accelerate if Eurasia's glaciers continue to melt. Climate change, as currently foreseen, may allow cropping to expand in Canada and Russia but this stands to be offset by crop area contractions in the 'breadbasket' countries of the Southern Hemisphere. A trend that may not be permanent but is worth noting is that grain consumption has exceeded production in 7 of the last 8 years; the world's stock of carried-over grain (2008) has fallen to 55 days of world consumption, the lowest on record. The world's grain markets are only one poor harvest away from panic.

Between 1950 and 1990, energy-dependent technologies (fertilisers and machinery) and new plant varieties allowed the world's farmers to increase *grain-land productivity* by 2.1% a year, but between 1990 and 2007 this growth rate slowed to 1.2% a year. Technological advances, encouraged by higher grain prices

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[21] UN Human Development Report, 2010, http://hdr.undp.org/en/countries/ (Accessed 5 Nov 2010).

[22] http://en.wikipedia.org/wiki/Food_crisis#cite_note-cyclone-5 (Accessed 12 Dec 2008).

[23] UN Food and Agriculture Organisation, 2008, *The State of Food Insecurity in the World 2008*, United Nations, Rome.

[24] http://www.Earth-policy.org/Updates/2008/Update72.htm (Accessed 12 Dec 2008).

but discouraged by higher oil-energy prices, could reverse this slowdown. However, there are no obvious candidates for this role at the moment.

In 2009, with the economic crisis impacting most societies, the Global Peace Index, as calculated by the Institute for Economics and Peace,[25] has actually slipped. However, contrary to popular belief, the world in the last 20 years has become more peaceful. The frequency and lethality of wars has been declining since the end of the Cold War in 1989. Since 1990 more wars have ceased than have started and the number of negotiated settlements has steadily increased.

Notwithstanding, according to one source,[26] there were 31 significant military conflicts in the world in 2008 compared with 25 in 1998. Apart from the direct suffering caused by civil and international conflicts, these, along with hunger, are a major cause of *forced migration*, a further indicator of declining quality of life. One partial measure here is the number of people under the care of the UN High Commissioner for Refugees (UNHCR), including both internally displaced people and international refugees. In 2007 this number rose by 2.5 million to 25 million.[27] Refugee numbers dropped dramatically when people returned home after the Balkans conflicts of 1992–1995, but have been rising again since then.

Environmental degradation in the forms of drought, desertification, erosion, deforestation and, most recently, sea level rise has become an increasingly important source of the hunger that triggers migration. One might guess that the proportion of the world's people experiencing a reduction in quality of life as a result of being forced to relocate is continuing to rise but data to support that hypothesis is not available. While they are suppositional and not factual, scenarios have been imagined which foresee a massive increase in the number of environmental refugees in coming decades. For example, one of Gwynne Dyer's climate change scenarios[28] has Italy being overwhelmed by environmental refugees from a blighted North Africa by 2036.

Living in a society where civil and political rights are poorly established and protected is a pervasive obstacle to the achievement of high quality of life. Between 2004 and 2007, some 43 countries, or more than 20% of the world total, saw their scores for freedom-of-association decline—according to the calculations of Freedom House, a somewhat-conservative non-government organisation.[29] While the number of *people in prison* worldwide is a relatively small nine million, the rate per 100,000 people jumped from 117 in 1992 to 154 in 2004.[30] In quality-of-life

[25] *Peace, its Causes and Economic Value*, 2009, Discussion Paper, Institute for Economics and Peace, www.visionofhumanity.org (Accessed 3 June 2009).

[26] http://www.warscholar.com/Year/2000.html (Accessed Dec 11 2008).

[27] UNHCR, 2008, *Global Trends: Refugees, Asylum-seekers, Returnees, Internally Displaced and Stateless Persons*, Annual Report.

[28] Dyer, G., 2008, *Climate Wars*. Scribe, Melbourne.

[29] Freedom House, 2010, *Freedom in the World 2009*, http://www.freedomhouse.org/template.cfm?page=363&year=2009 (Accessed 22 Dec 2010).

[30] World Bank, 2008, World Development Indicators, *Development Review*, http://www.world-bank.org/…/YR07_CH2_RP02_AFR.pdf (Accessed 24 Jan 2010).

terms, these figures are more likely to be indicative of declining social cohesion than anything else. Authoritarianism does seem to be on the rise again following the post-Soviet remission.

Mental and behavioural disorders affect more than 25% of all people at some time during their lives. They are present at any time in about 10% of the adult population. They are also universal, affecting people of all countries and societies, individuals of all ages, women and men, the rich and the poor, from urban and rural environments. They have insidious economic impacts and crippling impacts on the quality of life of sufferers and their families. The World Health Organization estimated that, in 1990, mental and neurological disorders constituted 10% of total *disability adjusted life years* (DALYs) lost due to all diseases and injuries. This rose to 12% in 2000 and was projected to further rise to 15% by 2020, partly due to a decline in the incidence of childhood infectious diseases.[31] Common disorders causing severe disability include depressive disorders, substance abuse disorders and schizophrenia.

Data is not available for judging whether a global citizen's lifetime risk of developing a mental disorder is increasing or decreasing; some predisposing factors are declining (e.g. incidence of poverty) and others are increasing, e.g. the per capita use of psychoactive substances, including opioids, stimulants, tobacco and alcohol. Suicide rates would seem to be a good partial indicator of mental illness and, globally, from 1950 to 1995, suicide rates increased by approximately 35% in men and approximately 10% in women in all age groups.[32] The reasons for the differences in rates among different age, sex, and ethnic groups, as well as the change in rates since 1950 are not known. A pointer from one study is that, across 27 nations, alcohol consumption predicts suicide rates.[33]

Over the last three decades, longstanding communicable diseases such as tuberculosis, malaria, and cholera have spread geographically and more than 30 previously unrecognised communicable diseases, such as Ebola, HIV, Hantavirus and SARS, have emerged as new threats to quality of life.[34] The slow-moving HIV/AIDS pandemic has already killed more than 20 million people and sickened between 34 and 46 million; it is on the way to becoming the worst pandemic in history. A wide range of disease-producing microbes are becoming increasingly resistant to antimicrobial drugs, e.g. drugs for malaria, tuberculosis and pneumonia.

Given such predisposing conditions as globalisation, population growth and urbanisation, it can be argued that, for the fourth time in history, humanity is encountering a 'great wave' of epidemic disease.[35] The first of these came with the domestication

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[31] World Health Organisation, 2001, *The World Health Report 2001*, Ch. 2 http://www.who.int/whr/2001/en/index.html (Accessed 22 Dec 2010).

[32] World Health Organisation Statistics *www.who.int/whosis* (Accessed 17 Dec 2008).

[33] Lester, D., 2001, Association of Alcohol Use and Suicide in 27 Nations of the World, *Psychological Reports*, 88 (3), p.1129.

[34] Worldwatch Institute, 2005, *State of the World 2005*, http://www.worldwatch.org/node/1044 (Accessed 22 Dec 2010).

[35] Worldwatch Institute, 2005, ibid.

of wild animals (10 kya) and the second with the linking of East and West Eurasia by trade routes (2.5 kya). The third 'great wave' began during the era of transoceanic exploration and trade expansion in the fourteenth and fifteenth centuries, when Bubonic Plague arrived in Europe from Asia, and European explorers and settlers brought smallpox, measles, influenza, and other diseases to indigenous populations across the Americas and Australia.

The last decade has witnessed a decline in the share of the world's working-age population (aged 15 years and older) that is in employment (known as the employment-to-population ratio). It stood at 61.4% in 2006, 1.2% points lower than 10 years earlier.[36]

At the time of writing, many of the world's major economies are contracting, i.e. they are producing goods and services at a lower rate than in the recent past. For very large numbers of people, this world-wide *recession-depression* is having a direct impact on their quality of life and, also, on their expectations or hopes for an improving quality of life. Not only does unemployment rise as economies contract, but government revenues (e.g. from taxes) fall, making the provision of government services (e.g. schools, hospitals, police forces) more problematic.

There are other whole-of-world statistics which could be included here as partial indicators of how quality of life has been changing in the last decade or so for the average global citizen (e.g. air quality data, work hours data, data on the psychological impact of species extinctions and ecosystem destruction), but, on the basis of the grossly imperfect indicators presented, are there tentative conclusions to be drawn?

Yes. With the exceptions of clear improvement in child mortality rates, and a possible ongoing improvement in healthy life expectancy for adults, the selected indicators are all consistent with a subjective judgment that, on a decadal timescale, the (hypothetical) average global citizen is experiencing slowly declining quality of life. As a whole, the species is experiencing more hunger, violence, mental illness, dislocation, communicable disease, political restrictions, unemployment and deteriorating collective services. The burden is not being equally shared of course. Behind the average experience, a small fraction of the world's population is probably experiencing rising quality of life, even as others are bearing a disproportionate share of the burden of these imposts. It is in populations where people's ability to meet their physical and socio-economic needs is already low that the present decline is most easily seen.

Four Juggernauts

While our discussion is suggesting that gross quality of life is slowly declining rather than improving, it makes no claim that this deterioration will continue, even though I believe (nothing more) that it will. We have already concluded that

[36] International Labour Organisation, 2008, *Global Employment Trends 2008*, http://www.ilo.org/global/publications/WCMS_090106/lang--en/index.htm (Accessed 22 Dec 2010).

predicting the future behaviour of complex dissipative systems is a vanity. We cannot see how far and how fast the present decline will go. Nevertheless, there is little to suggest that the *percentage* of the world's people that is hungry, traumatised, mentally ill, displaced, infected, fearful, unemployed or dying young will decline in coming decades.

On the contrary, there is considerable agreement that a number of global-scale processes, *endogenous trends* as unstoppable as *juggernauts* it would seem, are in train and which, if not reversed, will, at some 'tipping' point, push the human ecosystem past its resilience limits and trigger major reorganisation or disorganisation, perhaps on the scale of the Neolithic and Industrial Revolutions. These 'tectonic stresses',[37] these ongoing high-momentum processes, which, on balance, stand to make life harder, not easier, for most people include:

Population growth
Depletion of renewable (e.g. fisheries) and non-renewable (e.g. oil, phosphorus) resources
Global warming
Complexification of world society and the global economy (carrying with it the threats of ungovernability, long-lasting global recession-depression and the further impoverishment of poor, but resource-rich countries[38])

It is this perception of an impending disorganisation, an unravelling, a bottleneck with pervasive quality of life implications which is being termed the Overshoot Crisis. However, the difficulty of seeing how soon and deep this bottleneck might become is emphasised when one appreciates how internal driving processes can amplify or quieten each other, commonly in unintended ways. For example, the current (2008–) global recession-depression is probably slowing population growth, global warming and resource depletion. Conversely, oil depletion is likely to slow economic activity and global warming; an indication here is that five of the last six global recessions were preceded by an oil price spike.[39] And, of course, contingent episodes such as pandemics, wars and mass migrations add further complication. It was in recognition of a similar perception—that the world faces, not so much a set of large free-standing problems, but a 'metasystem' of global-scale interacting problems—that the Club of Rome coined the useful term *global problematique*.[40]

Where though, the question remains, did these juggernauts come from? One answer is to see them as *spillovers* or *externalities*, as the cumulative unintended

[37] Homer-Dixon, T., 2006, *The Upside of Down*: *Catastrophe*, *Creativity*, *and the Renewal of Civilization*, Island Press, Conn.

[38] Bunker, S., 1985, Underdeveloping the Amazon: Extraction, Unequal Exchange, and the Failure of the Modern State, University of Illinois Press, Urbana.

[39] Rubin, J., 2009, Just how Big is Cleveland? http://research.cibcwm.com/economic_public/download/soct08.pdf (Accessed 24 Dec 2010).

[40] Meadows, D.H., Meadows, D.L., Randers, J., and Behrens Jr., W.W., 1972, *The Limits to Growth*: *A Report for the Club of Rome's Project on the Predicament of Mankind*, Potomac Associates, London.

consequences of the efforts which every virtual species, from individuals to nations, makes to improve its own quality-of-life prospects. Each virtual species chooses the technologies it will use to this end, usually taking little account of the quality-of-life implications for other virtual species. We might call Global Overshoot the tragedy of the invisible hand! It is the consequence of numerous individual virtual species choosing technologies which generate spillovers (or precursors to spillovers) in the form of population growth, resource depletion, complexification and global overheating. For example, an extra child might help the family but not the village. Narrowly rational people do not ensure a rational society.

Three Ways of Reacting to an Overshoot Scenario

> The history of philosophy is to a great extent that of a certain clash of human temperaments. Undignified as such a treatment may seem to some of my colleagues, I shall have to take account of this clash and explain a good many of the divergencies of philosophers by it. Of whatever temperament a professional philosopher is, he tries when philosophizing to sink the fact of his temperament. Temperament is no conventionally recognized reason, so he urges impersonal reasons only for his conclusions. Yet his temperament really gives him a stronger bias than any of his more strictly objective premises. It loads the evidence for him one way or the other, making for a more sentimental or a more hard-hearted view of the universe, just as this fact or that principle would. He trusts his temperament. Wanting a universe that suits it, he believes in any representation of the universe that does suit it. He feels men of opposite temper to be out of key with the world's character, and in his heart considers them incompetent and 'not in it,' in the philosophic business, even tho (sic) they may far excel him in dialectical ability (William James 1907, *Pragmatism*,[41] Ch 1).

My scenario of an *Overshoot Crisis* with a dystopic prognosis provides a reference point for developing and critiquing several contrasting attitudes (habitual ways of regarding issues) towards global change. This 'baseline' starting point is a loose acceptance that the world is indeed experiencing resource depletion, global warming, population growth and ramifying interdependencies; and that the paramount indicator, species-wide quality of life, is more-or-less stagnant, moving up a little perhaps, or down a little, depending on one's values. The several attitudes to be now explored accept this description of the contemporary world, but differ in the significance they attach to it in terms of where it might lead and what, if anything, should be done about this potentially overwhelming issue.

In the above quotation, William James is recognising that his fellow philosophers tend to come to beliefs that are compatible with their inherent temperaments. This insight, plus his famous distinction between two temperaments—tough-minded *Empiricists* and tender-minded *Rationalists*—provides a basis for understanding the sharp differences in attitudes towards the Overshoot Crisis which are to be found in

[41] James, W., 1907/1981, *Pragmatism*: *A New Name for Some Old Ways of Thinking*, Hackett Publishing, Indiana.

today's public and academic discussions of these matters. From the many possibilities lurking therein, I have selected three contrasting sets of attitudes for comparison and have given them the colloquial names of:

Don't panic
Stop fiddling
Rise like a phoenix

While these alternative viewpoints span the spectrum from tough- to tender-minded, as will be explained, I have avoided perspectives which overtly draw their inspiration from religious beliefs, political ideologies, rent-seeking agendas or Panglossian technological optimism.[42]

Don't Panic

'Don't panic' is the tongue-in-cheek advice on the cover of *Hitchhiker*'*s Guide to the Galaxy*[43] by Douglas Adams. It is hard for Adams' hero not to panic when he realises that ours is an insignificant planet blocking an inter-galactic freeway in an unfashionable part of the galaxy. Notwithstanding, the advice is good. One is likely to think more clearly and find a way out of trouble if the mind is not racing from one knee-jerk response to another.

The tough-minded Empiricists, whose response to my dystopic scenario is 'Don't panic', are sceptics who find it hard to believe in anything other than well-established facts. In this, they are the heirs to a long line of thinking which goes back to the Greek sophists and leads eventually to such great empiricists as Locke, Berkeley and Hume. Unlike tender-minded Rationalists, they are slow to use induction, deduction and abduction to create bold working hypotheses, spurs to significant action. They are wary of conceptualisation and speculation, and that includes formal models. Their reason for warning against panic is that they cannot understand how the tender-minded can confidently foresee an ineluctably growing problem that must be tackled vigorously and at once. Indeed, they have little faith that humans have the cognitive ability or data to plan solutions to large what-to-do problems or to muster the cooperation this will normally demand. For some, this means that empiricists are pessimistic and fatalistic as well as sceptical. They would reply that they do not 'cross their bridges before they come to them'. That is, they are generally not too concerned about anything that is not an obvious threat.

[42] Lefroy, E.C., and Hobbs, R.J., 1993, Some human responses to global problems, in *Nature Conservation 3*: *Reconstruction of Fragmented Ecosystems* (Saunders, D.A., Hobbs, R.J. and Ehrlich, P.R. (Eds.)), Surrey Beatty, Chipping Norton.

[43] Adams, D., 1980, *Hitchhiker*'*s Guide to the Galaxy*, Harmony Books, New York.

Other tendencies which James finds in empiricists are that they tend to think analytically (look inwards rather than outwards) rather than synthetically and materialistically rather than idealistically. Among other things, the latter means looking to new technologies rather than new ideas as drivers of history.

What Is the Evidence?

More specifically then, given these tendencies, how might the tough-minded be expected to view the four global processes suggested above as having the potential, singly or together, to drive the human ecosystem towards a major reorganisation.

Global population growth is a well-studied process for which reasonably reliable and current data is available. Fertility rates and death rates change slowly and smoothly most of the time which means, other things being equal, that future population numbers can be predicted, decades ahead, more successfully than most other social indicators. Both Empiricists and Rationalists accept this and, on the basis of documented declines in fertility rates, accept that the rate of global population growth is steadily declining, meaning that world population will peak in 40–50 years. The Empiricists' perception is that there is little evidence that the world is coping any less effectively with each passing year's population increment (70 million but declining) and that there is therefore little reason to try and lower the rate of population growth below what is happening naturally. In any case it is not easy to see how that might be achieved, other than through making better birth control methods freely available.

Depletion of renewable and non-renewable resources is well enough documented and not to be denied per se. For discussion purposes, consider the non-renewable resources, oil and phosphate; and the renewable resources, native-forest timber and ocean fisheries. The available data is not incompatible with the idea that global production of both oil and rock phosphate has peaked and will now begin to decline, failing major discoveries. Indeed, prior to the current global recession, prices for both were beginning to rise and will again rise as the global economy recovers (but see below). Such price rises, provided they are not too sharp, provide timely and manageable signals to the economy to reorganise. In the case of oil, which is important to all sectors of the economy, it is fortunate that a number of substitute fuels and industrial feedstocks (biofuels, natural gas, coal-seam gas, tar sands, etc.) exist and are already being produced in increasing quantities. In time, as supplies of carbon-based fuels (and fossil uranium) peter out, the energy sector will again have to reorganise, probably around renewable energy technologies such as wind, wave and solar power (there are a number of others).

The phosphate situation is somewhat different. Phosphorus is an essential plant nutrient for which there is no substitute. Global agriculture is massively dependent on phosphatic fertilisers. Current reserves of rock phosphate will last many decades at current rates of mining but, at some stage, triggered by rising prices, large-scale technologies for recycling the phosphorus being dissipated in sewage, soil erosion and runoff will have to be introduced. While that transition will further raise food prices (recycling is energy intensive), the tough-minded, while hoping that this will not cause widespread pain, accept that this is a transition which, in the longer term, cannot be avoided.

Over the 15 years from 1990 to 2005, the world lost 3% of its total forest area through clear-felling for logs and woodchips and agricultural uses. In the same time, timber and woodchips from single-species short-rotation plantation forests have increasingly replaced the supply of these products from native forests. While plantations now provide wood products more cheaply than native forests, the clearing of forests (tropical forests in particular) to grow crops remains a matter of concern to those who regret the loss of biodiversity that this entails. However, apart from the direct impact of forest clearing on a small number of indigenous people, there is no data to suggest that forest clearing affects, or will affect, quality of life for any significant proportion of the world's people. Conversely, the meat, palm oil and other products produced on cleared forest lands meet people's needs on world markets.

Ocean fish stocks have been massively depleted in recent decades with many fisheries around the world collapsing. Nevertheless, as a result of more intensive technologies, harvests of ocean fish have remained at around 85–95 million tonnes. Meanwhile, global production of farmed fish and shellfish has more than doubled in value and weight (29 million tonnes in 1997). Aquaculture now supplies more than one-fourth of all fish that humans eat. Notwithstanding, pressure on wild fish stocks has not declined with the introduction of aquacultural technologies. First, demand for fish has grown in line with population growth. Second, the farming of carnivorous species, salmon and shrimp for example, requires vast quantities of wild-caught fish to feed confined stocks—indeed, the norm is that 2–5 kg of wild-fish biomass (fishmeal) is required to produce 1 kg of these high-market-value species.[44] Even if the wild-fish harvest can be maintained, a further change in technology will have to occur eventually—from farming carnivorous fish to farming herbivorous fish such as carp.

Global warming, meaning a permanent increase in the temperature of the global atmosphere and oceans, may or may not be happening and may or may not be anthropogenic, i.e. be caused by human activities which result in a net emission of greenhouse gases into the atmosphere. Certainly the upward trend in atmospheric CO_2 since, say, the beginning of the Industrial Revolution is real enough, but whether this change in the atmosphere's composition is responsible for the large proportion of years in recent decades with temperatures well-above 'average' is not obvious. Perhaps this 'cluster' of warm years is simply a statistical fluctuation of the type which appears in all time-series of measurements of natural variables? Or, perhaps the world is experiencing a real upward trend in global temperatures, but not one due to the greenhouse effect? For example, have global temperatures been

[44]Naylor, R.L., Goldburg, R.J., Primavera, J., et al. 2001, Effects of Aquaculture on World Fish Supplies, *Issues in Ecology*, No.8.

simply rebounding since the (ill-defined) end of the Little Ice Age towards those of the Medieval Warm Period?

The modelling work that has supported the conclusion, reached by the International Panel on Climate Change (IPCC) for example, that global warming is real and largely caused by human activity, is rich and commendable[45] but nonetheless contestable.[46] Some Empiricists are open-minded as to the truth of this conclusion, while others seize on recognised conceptual flaws and database deficiencies in the main models as grounds for rejecting those models' conclusions.

Empiricists who accept the reality of global warming may still be doubtful as to whether anything can or should be done about it. For those who cannot additionally accept that greenhouse gases are the cause and that reducing these will 'solve the problem', there is not much that can be done. For example, alternative ways of cooling the planet, such as loading the atmosphere with aerosol particles or putting reflectors in space, have been suggested but, if anything, such are more problematical for sceptics than emissions reduction.

Those Empiricists who can accept that the greenhouse gas hypothesis is plausible, albeit 'unproven', may still be reluctant to advocate action to curb greenhouse gas emissions. This could be for any of several reasons. One is the difficulty of assembling a comprehensive range of alternative countervailing action plans for consideration, together with the further difficulty of associating each plan with a reliable estimate of its costs and benefits or, more generally, its quality of life consequences. If attempted, such a study might even find the 'do nothing' option to be superior! And then there is the virtual-species problem. Global warming has to be tackled at a global scale. It would not suffice for Americans and Europeans to agree on what to do; the views of Chinese and Indians would have to be considered. To date, neither China nor India accepts that proposals for controlling global warming take sufficient account of their interests as major industrialising societies.

But there is a response to the perception of global warming, and its potential to disrupt billions of lives, which is compatible with tough-minded empiricism. Rather than attempting to ameliorate, to forestall the avalanches of change which would occur if 'worst case' models of climate change turned out to be correct (e.g. by reducing emissions), people might be able to cooperate sufficiently to monitor and give early warning of the emergence of shocks and abrupt impacts and help those affected to adapt to them, e.g. help people move to higher ground or relocate as sea level rises. While it is true that this reactive or adaptationist approach would still require large-scale cooperation if large-scale impacts were to occur, the practical problems to be addressed, and responses to them, would be clear, and hence more readily agreed. The adaptationist approach has the further advantage that it does not require massive 'up-front' investment to ameliorate changes which may not even be

[45] United Nations Intergovernmental Panel on Climate Change (IPCC), 2007, *Climate Change 2007*, *Fourth Assessment Report*, United Nations, New York, Synthesis Report.

[46] For example, http://en.wikipedia.org/wiki/Richard_Lindzen (Accessed 27 Dec 2010).

the cause of global warming and its consequences or to ameliorate changes which may never occur. It should not be taken as derogatory to label the adaptationist approach to global warming as 'muddling through' or reactive.

Global recession-depression is the fourth of the dark horsemen hypothesised to be presaging dystopia. The reality of the abrupt unravelling of the highly connected global financial system and the global 'real' economy which began in 2008 has been plain to the tough- and the tender-minded alike. It was of little surprise to the tough-minded that there was a near-total failure of 'experts' to foresee the onset of this bifurcation and equally unsurprising that there is much disagreement as to its causes and its prognosis. Historically, depressions have led to output falls of the order of 10–15% over several years, but could the present reversal be much deeper and much more prolonged? The possibility that the global economy-financial system might never return to anything like its present size and structure is barely contemplated. What happens if the American dollar continues its 30-year slide and there is no 'lender of last resort'? Could international currency markets collapse? The plethora of what-to-do remedies and rescue operations being tried by weakly cooperating individual governments in their efforts to restore the *status quo ante* attests to the limited understanding humans have of the monstrous non-linear system they have created.

Empiricists too have little confidence that the course of the current recession-depression can be predicted, nor do they have much confidence in the ability of the global community to slow or reverse the present recession-depression. Indeed, they have doubts as to whether this is even desirable. As pointed out by Joseph Schumpeter, with his ideas of 'creative destruction', the death of old enterprises releases 'locked up' resources for the establishment of new enterprises, better-adapted to an ever-changing world.[47] The same idea is found in Buzz Holling's thinking about the processes of destruction, simplification and renewal in natural ecosystems.[48] If allowed to run its course (e.g. no bailouts), the present recession-depression will cleanse the economy of numerous activities with high opportunity costs. Notwithstanding, Empiricists who value the idea of high quality of life for most people will still see it as important for governments to support people who have lost access to employment and publicly funded services as this downturn spreads.

Summing Up Tough-Mindedess

In terms of responding to a scenario of Global Overshoot ending in total social breakdown, the tough-minded are likely to have a reactive or wait-and-see attitude towards the four global-scale processes suggested as ineluctably increasing the

[47] Schumpeter, J.A., 1942, *Capitalism*, *Socialism and Democracy*, Harper, New York.

[48] Holling, C.S., 1973, Resilience and Stability of Ecological Systems, *Annual Review of Ecology and Systematics*, 4, pp.1–23.

probability of such an outcome. Reluctant as they are to generalise, the tough-minded have learned that when large complex systems are subjected to disruptive forces they tend to self-reorganise in ways which counter or negate the impacts of those disruptions. The tough-minded believe in closely monitoring these global-scale processes so that people know what is happening at any time and, if and when quality of life can be seen to have been impacted, practical steps can be taken to redress those impacts. First put out the 'spot fires'. Their 'early warning' and 'first aid' attitude to the global problematique is understandable in light of their lack of confidence in the global community's ability to understand and manage population growth, resource depletion, global warming and economic complexification. They note the irony that a global-scale social breakdown will at once halt the very juggernauts that have supposedly caused that disorganisation. It worries Empiricists that many (perhaps most) of the relationships implicit in the reference scenario cannot be investigated via the methods of experimental science.

Two Ways of Being Tender-Minded

In terms of William James' distinction, a tender-minded rationalist is one who, in the spirit of the Enlightenment, is able to accept the Overshoot-diagnosis as a plausible working hypothesis. That is, in the absence of effective intervention, the unfolding consequences of global population growth, resource depletion, global warming and complexification of global networks will be, indeed, already are, highly threatening to species-wide quality of life. Rationalists, more so than Empiricists, have learned, from others, or from experience, to trust reason as a basis for action. More strongly, they *want* to use their reason to guide their behaviour. They are readier to come to inductive generalisations and to accept abductive explanations, i.e. those that are consistent with the facts. Compared to Empiricists, they are willing to accept lower levels of proof. Sometimes, because no reasoned position can ever be fully justified, Rationalists can be tempted to retreat into dogmatism when confronted with scepticism and accusations of naïveté. Normally though, Rationalists will recognise that their mental models of what is happening and what to do are likely to be wrong and likely to need correcting in light of experience and changing circumstances.

More generally, the 'how-to-intervene' problem is enormously challenging and has no truly convincing answer. In principle, Rationalists want the global community to address both causes and consequences of Global Overshoot. This means, firstly, that they will be looking for ways to slow, reverse, modify or adapt to one or more of the 'big four' global trends.[49] Secondly, they will be looking to forestall or,

[49] Füssel, H-M., 2007, Adaptation Planning for Climate Change: Concepts, Assessment Approaches and Key Lessons, *Sustainability Science*, 2(2), pp.265–275.

if that cannot be achieved, mitigate (from mitigare: to soften) the adverse quality-of-life consequences, the suffering, lurking in these trends. In that last they are at one with the Empiricists.

This is the point where it is necessary to make a distinction between Rationalists who believe that effective intervention at the present stage of the Overshoot Crisis is possible and Rationalists who believe that the Overshoot Crisis is going to run its course, irrespective of the efforts of well-intentioned, knowledgeable humans, i.e. Rationalists who are 'Immediate-Interventionists' vs. Rationalists who are 'Post-Bottleneck Reconstructionists'. The latter group's somewhat different perspective is that a well-prepared, forward-looking global community has reasonable prospects, after passing through an inevitable dystopic bottleneck, a great contraction, in which quality of life plunges, of rising, like a phoenix from the ashes and reconstructing a long-lasting human system in which quality of life steadily improves for most people. We will discuss these contrasting tender-minded attitudes under the admonitory headings, 'Stop fiddling' and 'Rise like a phoenix'.

Stop Fiddling

Popular legend has it that Emperor Nero played the fiddle (lyre) while the Great Fire of Rome burned in 64 CE. The admonition of the Immediate-Interventionists to 'Stop fiddling and try to prevent the fire from spreading' is a metaphor for an attitude which sees the unfolding consequences of Global Overshoot as highly threatening to species-wide quality of life; and, furthermore, as a matter of urgency, the global community (the global 'fire brigade') should (and can) intervene vigorously to slow or reverse these processes.

Those who are looking to intervene at once to ameliorate or prevent a dystopic collapse over coming decades include governments, inter-government organisations, non-government organisations, enterprises and individuals. While each of these has its own capacities for intervention and its own sense of priorities, governments have a collective responsibility and inevitably carry much of the load. Our purpose here is not to discuss the many particular recommendations for immediate intervention that have been made. Rather, it is to highlight a handful of principles and priorities that might or should be guiding the making of such more-specific choices; and to ask what the proponents of immediate intervention hope to achieve in the longer term.

For a start, it is clear that a comprehensive approach, a 'grand plan', will never be possible and that a mixture of partial, heuristic and instrumental approaches will have to be used. At first sight, there is a body of ideas that has been developed to assist with making multi-faceted decisions under non-certainty.[50] That methodology would suggest searching for the mix of interventions with the highest expected

[50] http://en.wikipedia.org/wiki/Decision_theory (Accessed 24 Dec 2010).

quality-of-life benefits into the future and then regularly revising one's plans as circumstances change. Unfortunately, the time, data, probabilities, values, resources, etc. for taking such an approach are not available. The rationalist ideal is again found to be constrained.

Just as comprehensiveness is not possible, its opposite, 'tunnel vision', needs to be avoided, i.e. avoid addressing just one dimension (the global economy, say) of the global problematique while neglecting its other dimensions (e.g. resources, population, climate). Here, it is helpful to ask of any policy developed to address issues in one dimension what its implementation might mean for issues in other dimensions (all problems exist in the context of other problems). Or, more proactively, one should be looking for interventions which address multiple issues simultaneously. This can, in fact, be observed in current discussions on how to use government funding to revive a flagging global economy. Beyond lubricating the financial sector, government funding can play a useful role in, for example, improving infrastructure, and hence resource flows; or, supporting research into the mechanisms of climate change and population change; or improving quality of life directly by improving health and education services.

For the purpose of developing a suite of 'high priority' interventions, it is necessary to recognise which unwanted aspects of the juggernaut processes are mitigable and worth mitigating and which can be adapted to and are worth adapting to; the logic is that of medical triage. For example, sea level rise is one consequence of global warming which, given the high proportion of the world's population living near the tidal zone, has major quality-of-life implications for the species; mid-latitude droughtiness is another. Many Interventionists think that the rate of sea level rise would be mitigated (slowed) if greenhouse gas emissions were to be reduced 80% by 2050. Or, more adaptively, those living in the coastal fringe can move to higher ground—if such is nearby and relatively unpopulated. But those so 'invaded' will simultaneously lose some of their quality of life, an illustration of how all mitigatory and adaptive responses to the stresses of overshoot produce both winners and losers. Such conflicts of interest between virtual species have to be resolved politically, often with great difficulty, or unsatisfactorily. That is why technological solutions, which are imagined to create fewer conflicts of interest, are so commonly promoted by politicians, e.g. building dykes against rising seas; capturing and storing carbon emitted from coal-fired power stations.

As the Overshoot Crisis broadens and deepens, conflicts of interest stand to consume much of the available political energy and that is dangerous for quality of life in the longer term—innovation becomes very difficult. More than that, Robert Heilbroner points out that in times of social crisis people often turn towards authoritarianism in the belief that it will be better able to cope than democratic structures can.[51] People will not tolerate a society where they are subject to periodic upheavals. A good example is fascism. In the 1930s fascism brought stability to fluctuating economies by reducing freedom at a time when there was a stalemate between

[51] Heilbroner, R.,1993, *21st Century Capitalism*, Norton, New York, p.113.

democracy and what is nowadays called neoliberalism.[52] Stability of expectations is clearly an important part of quality of life. Even in quieter times, many are willing, with help from the state, to sacrifice freedom and democracy for security. With the highest priority, the authoritarian threat must be held at bay. But how? Because the social technologies for strengthening democracy cannot just be taken off the shelf, it is important that adequate resources be found for generating and trialling ideas for improving democratic processes, e.g. making them less adversarial and more dialogic.

As a general principle, people can often adapt to large changes if such do not happen too quickly. So, even if the juggernaut processes cannot be stopped, all interventions which might delay their impact need to be evaluated. Moves to protect national economies from the vagaries of the global economy (e.g. via job creation schemes) would be an example. Using some form of taxation or rationing to slow the rate of depletion of oil and other minerals would be another. Measures to slow the rate of population growth, educating women for example, might take decades to bite but could mitigate social unrest in countries with high birth rates, e.g. in east Africa.

What of other principles for helping identify priority interventions? Some are self-evident, like attempting to mitigate-adapt to changes directly reducing quality of life for large blocks of people, especially those already disadvantaged, e.g. food and water shortages. Equally, attempts should be made to pre-empt 'high impact but low probability' contingencies such as large-scale resource wars, 'runaway' global warming and permanent global-scale depression.

A Scenario for Optimists

The more optimistic advocates of immediate intervention, subscribers to the dominant paradigm, usually (see page 303) seem to think the global community can go a long way towards slowing, reversing and adapting to the juggernaut processes underlying the Overshoot Crisis and towards ameliorating the accompanying negative impacts on quality of life. A scenario which would not surprise them might run something like this:

> Global warming and its downstream consequences will be mitigated and adapted to, albeit belatedly, using a mix of energy-saving measures, strategic retreat, renewable energy and carbon capture and trading. The global economy will recover from recession-depression more rapidly than otherwise through the use of public investment, redistribution programmes and fiscal-monetary measures. Once recovered, the global economy will be reformed and proofed against further runaway disturbances through the use of measures for slowing capital transfers between currencies, stabilising exchange rates and regulating risk-taking market behaviours.[53]

[52] Polanyi, K., 1944/2001, *The Great Transformation*: *The Political and Economic Origins of our Time*, Beacon Press, Boston.

[53] Solow R.M., 2009, How to Understand the Disaster, *New York Review of Books*, 56 (8) http://www.nybooks.com/articles/archives/2009/may/14/how-to-understand-the-disaster/ (Accessed 24 Dec 2010).

Interventionists recognise that they can do very little about global population growth and, in any case, it is a juggernaut that is already slowing. Notwithstanding, there will be regions of the world where intervention to improve quality of life and to lower birth rates might be judged a priority, i.e. regions where rapid population growth has spawned hunger, disease and war. For example, outlawing the international arms trade would make war a smaller problem than it is. There will also be regions where mass movements of people will need to be managed. In the developed world, intervention to promote acceptance of simpler lifestyles will not slow global population growth but might be encouraged on the grounds that this will make it an easier task to feed the billions yet to come—the philosophy of 'live simply that others might simply live'.

As resources are depleted, the real costs (energy, labour, etc.) of delivering supplies to users rise which, if the economy is operating at capacity, means fewer goods and services will be available for final consumption. For example, if the energy required to extract and market a barrel of oil increases, that additional energy, etc. is now lost to the rest of the economy. Alternatively, as such real costs rise, market forces which mitigate and adapt to this loss are likely to emerge. If the supply schedule of a resource rises, its market-clearing price will rise and ration what is available. Also, users of the resource will begin looking for cheaper substitutes, e.g. gas for oil. Recycling may increase where this is technically possible, e.g. for metals and phosphate. Technologies for improving resource-use efficiency (resource input per unit output) may be sought, e.g. fuel-efficient cars. In general terms, depletion of resources triggers a self-reorganisation of the product mix and the technology mix being used. If this self-reorganisation takes place fairly slowly, it will not necessarily be obvious that the reorganisation has reduced—or improved for that matter—quality of life.

If however a reorganisation takes place rapidly by human standards, people's lives will be disrupted and their quality of life will probably fall. In such situations Interventionists may look to introduce public programs which slow depletion (e.g. extraction quotas) or which speed up and improve the adaptive and mitigative responses generated by market forces, e.g. labour market programs, subsidies for recycling and for research into substitutes and efficiency measures.

Resource extraction can trigger other side effects (spillovers) which Interventionists may seek to mitigate or adapt to. Pollution in its many forms is a good example, e.g. air pollution from burning fossil fuels for transport and electricity generation. Resource use of itself can lead to resource depletion, e.g. loss of biodiversity through land clearing and degradation of poorly managed arable land.

Finally, in the case of renewable biological resources such as fisheries and forests, Interventionists will probably seek to avoid depletion by having harvesting regulated to levels below maximum sustainable yields.

Managed Markets

The tender-minded Rationalists who want the global community to 'stop fiddling' and intervene decisively in the Global Overshoot process have a characteristic approach to the how-to-intervene problem, namely a *managed markets* approach.[54] Under this perspective, the ordinary market processes of the economy are expected to spontaneously counter the advance of the various juggernauts to a considerable extent, e.g. bringing profitable new technologies to market. But it is equally recognised that a variety of collective actions will still be needed to address problematic aspects of the Overshoot process which are external to the market economy. For example, unmanaged markets will not provide goods and services for which there are no effective buyers, e.g. health and education services for poor people. Thirdly, the managed markets perspective recognises that some major threats to quality of life cannot be ameliorated by either governments or markets, at least not in the space of a few decades, e.g. global population growth.

Perhaps because it is too far off to have triggered consideration, it is not clear how Interventionists think the human ecosystem will be evolving and functioning after it has passed through a much less disruptive bottleneck than would have been the case without strong intervention. Implicitly, once effective measures have been taken to mitigate and adapt to the juggernaut processes of Overshoot, much of the human ecosystem's pre-existing structures and processes will still be intact and poised to evolve further, free from the overhanging threats associated with economic complexification, resource depletion, global warming and the fallout from relentless population growth. While the evolutionary trajectory of this post-bottleneck ecosystem cannot be foreseen, it might well present as a world where fewer people are using less energy and social–cultural change is taking place more slowly than in today's world—a reformed world rather than a transformed world. It stands to be a more sustainable world, but one which would still seem quite familiar to postmodern people.[55]

We have now identified two contrasting attitudes towards the proposition that the human ecosystem has entered a global Overshoot Crisis which is funnelling into a dystopic bottleneck where quality of life will plummet for a large fraction of a much-reduced global population. One is a tough-minded 'wait-and-see' attitude whose advocates are empiricists. They are willing to implement adaptation and mitigation measures but feel they must wait till problems and damaging trends are (more) clearly evident.

The second attitude is a form of tender-minded rationalism whose advocates believe that, in the absence of massive immediate reforms, the reference scenario

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[54] Harris, J.M., 2009, Ecological Macroeconomics: Consumption, Investment, and Climate Change, *Real-world Economics Review* # 50, http://www.paecon.net/PAEReview/issue50/Harris50.pdf (Accessed 13 Sept 2009).

[55] Raskin, P., Banuri, T., Gallopín, G., et al., 2002, *Great Transition*: *The Promise and Lure of the Times Ahead*, A report from the Global Scenario Group, Stockholm Environment Institute, Boston; Mulgan, P., 2009, After Capitalism, *Prospect*, Issue 157, http://www.prospect-magazine.co.uk/article_details.php?id=10680 (Accessed 28 April 2009).

with its vision of a rapid descent into 'tohu-bohu' is all too likely to come to pass. These Immediate-Interventionists are optimistic in the sense of being willing to act as though the global community, using a managed markets approach to intervention, can ensure that the dark future of the reference scenario will be briefer and less disruptive than would otherwise be the case. They have a level of confidence that the global community, governments and markets together, will mostly be able to make rational decisions on how to mitigate/adapt to foreseeable and emerging problems associated with overshoot. A depopulated, deurbanized, deindustrialised, deglobalised world awash with displaced people can be avoided. And they do not see the virtual-species problem, the difficulties that interest groups have in working cooperatively, as a towering barrier to successful intervention; theirs is not a world ruled by thugs and macroparasites.

Rise Like a Phoenix

We come now to our third selection from various possible attitudes towards the reference scenario, i.e. towards the idea of an *Overshoot Crisis* with dystopic consequences, including currency wipe-outs, depopulation, deindustrialisation and deurbanisation. It too is a rational tender-minded attitude, like that of those who would intervene strongly to minimise the entangled impacts of various juggernaut processes on quality of life for the world's peoples over coming decades. Differently though, it is an attitude which regards Immediate-Interventionists as far too optimistic, believing as they do that the global community can reform slow, mitigate and adapt to the momentous processes that are already reshaping and redirecting many elements of the human ecosystem. The alternative perspective now to be considered is that it is already too late to stop a massive disorganisation and simplification of the human ecosystem from occurring, more-or-less as the reference scenario suggests.

However, while deeply pessimistic about the immediate trajectory of the world system, this attitude, tagged here as *Post-Bottleneck Reconstructionism*, is ultimately optimistic. How is that? The metaphorical admonition to 'Rise like a phoenix' is a reference to the mythic phoenix bird which self-immolates every 500 years only to rise anew, reborn from its own ashes. The implication is that after passing through an inevitable dystopic bottleneck, a great contraction in which quality of life plunges, it might be possible to reconstruct a long-lasting human ecosystem in which quality of life steadily improves for most people.

Is it totally preposterous, this scenario of a world experiencing a collapse in the social processes that allow daily life to continue meeting people's basic needs? It has happened before on a regional scale many times but perhaps not globally since the volcanic winter following the Mt Toba eruption 70 kya. Under the threat of a superpowers nuclear war, fear of such a scenario was widespread during the mid-twentieth century. Today, many respected scientists and academics, including James

Lovelock, Martin Rees, Thomas Homer-Dixon and Ronald Wright,[56] and respected science journalists, such as Howard Kunstler and Paul Roberts,[57] have concluded that they would not be surprised by the eventuation of some version of such a scenario. And to further help us to imagine what this looming bottleneck could be like, there is a long tradition of science fiction that explores life in apocalyptic and post-apocalyptic worlds.[58]

Having made the working assumption that the world system is sliding into an inescapable dystopic bottleneck, and given that the proponents we are talking of are tender-minded Rationalists who want to facilitate and expedite a post-bottleneck recovery in quality of life, what might Reconstructionists advocate? What is their strategy for helping global society rise like a phoenix? There are many possibilities, but let me elaborate one based on the 'Noah's Ark principle'. Faced with an inundation he could not prevent, the mythical Noah built a large boat which safely housed a variety of animals until the floods retreated. The animals were then released to repopulate the Earth. Transposing this 'be prepared' principle to the prospect of Global Overshoot, Reconstructionists argue that, before pervasive collapse arrives, there is a *window of opportunity* during which the global community should do as much as possible to prepare for reconstruction.

As with the Immediate-Interventionists, there is an elephantine assumption here that the global community's various virtual species (governments, enterprises, non-government organisations) will be able to agree on what should be done, and be able to cooperate to attempt it. It would help here if Reconstructionists could convince people at large that an extreme-case scenario is plausible, although one imagines that most people will find it impossibly frightening to contemplate the destruction of their civilisation. And yet, a society that cannot and will not even consider the possibility of such a collapse cannot organise to better survive it. It would be ironic if collective action were to become an idea in good currency only after the organisational structures that would allow collective action had become dysfunctional!

Just as Noah conserved biological capital, the Reconstructionists' task can be viewed as one of conserving and/or constructing an appropriate endowment of 'capital' to leave to the survivors of the bottleneck experience. This is where difficult questions start to suggest themselves—what to try to bequeath will depend on what the survivors' situation is assumed to be. For example, when will stable new patterns of social organisation begin emerging from the disorder of the bottleneck period? Are we talking decades or centuries? What form will those emerging societies take?

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[56] Lovelock, J.E., 2006, *The Revenge of Gaia*, Allen Lane, London; Rees, M.J., 2003, *Our Final Century*, Heinemann, London; Homer-Dixon, T., 2006, *The Upside of Down*, Island Press, Conn.; Wright, R. 2004, *A Short History of Progress*, CBC Massey Lectures, House of Anansi Press, Toronto.

[57] Kunstler, H.J., 2005, *The Long Emergency*: *Surviving the Converging Catastrophes of the Twenty-first Century*, Atlantic Monthly Press, New York; Roberts, P., 2004, *The End of Oil*: *On the Edge of a Perilous New World*, Houghton Mifflin, Boston.

[58] http://www.empty-world.com/book_index.html (Accessed 10 Mar 2009). A fine example is Stewart, G. 1949/1999, *Earth Abides*, Millennium, London.

Will they be anarchic, tribal or hierarchical? Will nation states exist? How will societies be energised? Will there be mechanical power, electric power, and animal power? Irrespective of Reconstructionists' efforts, what cultural and physical capital will survive the bottleneck?

The Aftermath: Rolling Backwards Through History

While it is largely unpredictable, the behaviour of the global system as it is pushed into self-reorganisation by population growth, resource depletion, economic complexification and global warming is not unbounded in its possibilities. For example, if people are to survive, and we can assume some will if there are no nuclear wars and winters, they will need to keep producing food by cropping, herding, fishing, hunting or foraging. If people persist, so must technologies for food consumption (e.g. fire, cooking) and production. It can also be assumed that people will try to live in intentional communities of some sort to secure the benefits of cooperation, e.g. physical security and food sharing. If so, language will also survive, perhaps with a degree of splitting and simplification, depending on which communicative and cognitive technologies also survive. However, other than supporting small populations of scavengers, large cities will not survive extended disruption to their food, water and energy supplies. And, as recently demonstrated in Baghdad, recommissioning degraded infrastructure is an enormous task, even with outside help.

It only takes a few such circumscriptions to create a space where one can think about the post-bottleneck world in a concrete way. For example, let us suppose that, come the twenty-second century, our great-grandchildren or beyond have survived the worst of the bottleneck and are beginning to lead lives which are more settled and routine but still highly precarious. The Ecumene (inhabited world) might be somewhat smaller than it is today, but not dramatically so. Mid-latitude deserts may have expanded and coastal plains lost to rising seas but, elsewhere, one can imagine a thin smear of small subsistence villages distributed across the continents in patterns not dissimilar from today's food-growing regions; in total, the human, mostly rural, population is likely to be very much smaller. Crop yields per worker stand to be low and variable for reasons which include more climate variability, no mechanisation, no artificial fertilisers, no well-adapted management skills and plant varieties poorly adapted to new climate patterns. As in the early Neolithic period, or the early Middle Ages, any food surpluses will be insufficient to reliably support unproductive soldiers, priests and city-dwellers. Some villages might be able to support a blacksmith; others would need to trade precious surpluses for iron-tipped tools. With an anvil and a hammer a blacksmith can make everything else he needs; then he can make items needed for farming, building, cooking, etc.

There will of course be some favoured areas, *refugia*, where food surpluses come easily. For example, as coastal waters penetrate inland they will become nutrient-rich and support larger fish populations. In general, renewable resources will be recovering from their pre-bottleneck exploitation; foraging prospects will improve.

Communities capable of producing surpluses will have to trade-off the security offered by stored food against the risks of attracting marauders and displaced people; or the risks of allowing their own populations to grow; or the risks associated with becoming a hierarchical society.

Creating an Inheritance

Whether or not it actually guides their behaviour, these village communities could not but benefit from knowing how past societies have made these sorts of choices and what the consequences were. Indeed, just knowing that their forebears had to make similar choices is likely to boost a community's sense of identity. However, it is doubtful if the significance of surpluses and what happens to them would be appreciated by post-bottleneck villagers, at least not without assistance; few enough contemporary people understand how food surpluses have influenced history. Here then is a first task for the Post-Bottleneck Reconstructionists—write a potted ecological-evolutionary history of the species, specifically for bottleneck survivors and with a focus on the adaptive consequences of major innovations in material, social, cognitive and communicative technologies. Perhaps an update of Gordon Childe's classic *Man Makes Himself* would suffice.[59] However imperfectly, we know much of potential value to our descendants—if we can but transmit knowledge to them across the discontinuity we are probably entering.

More generally, many ideas about what to try to bequeath flow from the modest starting assumption that the human ecosystem, as it emerges from bottleneck times, will be reorganising into numerous small communities of peasant farmers. Today, nearly half the world's people still live in villages of one sort or another. Given the Phoenix scenario, one can imagine most of these becoming dysfunctional, or even abandoned, under impacts such as crop failures, loss of government services, waves of refugees and loss of markets for selling cash crops and buying simple manufactures. Nevertheless, depending on how long the bottleneck lasts, sites of existing villages are likely to become the loci around which post-bottleneck societies begin to reorganise, places where people, extended families perhaps, come together for mutual protection, to share knowledge and meaning, to undertake collective enterprises, to feel a sense of belonging, etc.

Assistance to these bottleneck survivors might be most useful if structured around the goal of helping them solve their immediate (cf. long-term) problems. Here, it seems plausible that these will be not dissimilar to the sorts of problems that modern scholars infer to have faced village-based farming societies as they have emerged around the world from the early Holocene onwards. For example:

Managing food production and distribution under uncertain weather conditions
Managing population size and composition
Managing relations with neighbouring villages

[59] Childe, G., 1936/1981, *Man Makes Himself*, Moonraker Press, Bradford-on-Avon, England.

Protecting themselves from marauders in search of food, women, slaves, valuables, etc.
Protecting themselves from coercive self-serving leaders
Improving technologies for routine tasks
Creating meaning and identity for themselves

These then are the sorts of problems the Reconstructionists might want to help with. Let us assume so for present purposes. If, and it does not seem very probable, Reconstructionism were to become an idea in good currency, resources might become available for assembling technology recipes and physical capital, either existing or imaginable, for the present generation to transmit to post-bottleneck generations; and for setting up 'time tunnels' for transmitting them. That is, Reconstructionists would be using the lull before the storm to create-document technologies and create-conserve artefacts specifically for the benefit of the present generation's (great?) great-grandchildren.

It may well be of course that, after living through several generations of increasing disorganisation, our descendants will have lost all understanding of a science-based world view and reverted to animism or theism. After all, look at how little impact Enlightenment thinking has today on a large majority of the world's population. Perhaps our descendants might conclude it sensible to reject any help from those who triggered their discomfort!

It would be premature to make lists of specific technologies, artefacts, etc. which a Reconstructionist initiative might decide to transmit to post-bottleneck survivors. Ideally, the selection and construction of such a bequest's components would emerge from an extensive programme of dialectical discussions, consultancies and research involving numerous historians, contemporary villagers, anthropologists, sociologists, psychologists, technologists, scientists, sci-fi writers, futurists, etc. (Why not degrees in post-bottleneck studies?). The best candidate institution for managing such a programme might be something like a UN-based *World Commission for Post-Bottleneck Reconstruction*. Or, in the absence of an international initiative, countries could still plan for the long-term survival of their own people.

What can be done here is to note, in relation to each of several challenges to post-bottleneck village life, a few of the suggestions and observations likely to appear in discussions on just what cultural and physical capital has a good claim to be made available to the bottleneck survivors. These points represent the merest flavour of the many that might be raised.

The Food Problem

Urban refugees, in particular, will have little idea of basic agronomic practices including seedbed preparation, watering, weed control, plant nutrition (including recycling) and harvesting techniques. Well-designed implements, including wheelbarrows, will help. Making allotment gardens available to city dwellers now might help preserve cropping skills.

Growing food without the help of draft animals or machinery is physically demanding and for much of the year, totally time-consuming. Using draft animals increases output but such have to be fed and husbanded.

Survivors will need ways of diversifying and stabilising food supplies, including the use of mixed plantings, some hunting and gathering, trade with neighbours, and raising domestic livestock. Any experimentation (e.g. plant breeding) will have to be on a small scale. Although survivors will need to supplement crops by foraging and hunting, it would seem almost impossible to transmit such landscape-dependent skills through manuals.

Technologies for sharing and distributing food can smooth out minor fluctuations in food supplies. Such practice will also contribute to group cohesion.

Survivors will need simple technologies for protecting stored food, including tubers and root crops, grain, flesh, fruit and nuts, from rodents and insects and decay. Good rat traps protect grain and capture food. Survivors will need technologies for protecting growing crops from birds and animals, e.g. birdlime, traps and fences.

The Population Problem

Depending on the productivity of the local environment, villages with populations smaller than, say, 50 or larger than, say, 150 are likely to encounter problems of, among others, achieving peaceful governance, sufficient defence capability and coordination of collective actions.

In principle, the population of an aftermath village and its surrounding farmland and other territory—the *stocking rate*—needs to be well below the long-run carrying capacity of that territory. A low stocking rate confers resilience and security in the face of fluctuating food supplies. In practice, identifying that carrying capacity will be difficult, if not impossible, when local experience is limited and the local climate is not only variable but still changing perhaps.

Although it can be argued that quality of life is likely to be higher when numbers are more-or-less stable, history suggests that it is extremely unusual for human communities, whatever their size, to avoid population growth in good times and swift decline, through death or out-migration, in bad times. One reason is plain ignorance of population cycles. Reasons for a community allowing or encouraging population growth include fear of enslavement or massacre by a more-numerous enemy or, conversely, an ambition in the community's own leaders for territorial expansion through military conquest. A large population may be seen (probably wrongly) as insurance against epidemic disease. For the individual, a large family offers some insurance against deprivation in old age.

Because optimal population size will always be context-dependent, Reconstructionists can do no more than warn survivors of the dangers of over-estimating carrying capacity and suggest a cautious approach to changing community numbers, whether up or down. More concretely, Reconstructionists should perhaps give high priority to bequeathing social and material technologies with the potential to ameliorate causes of population growth. Three of these causes, those stemming from the problems posed by marauders, coercive leaders and difficult neighbours, are dealt with separately below. Here, we can recognise the value for population management of technologies for reducing unwanted births and technologies for raising healthy life expectancy at birth. Remember, we are talking of informing people who will have little historical memory of today's medical knowledge.

For a number of reasons, contraception is preferable to abortion and infanticide as a tool for population stabilisation. Unfortunately, condoms and sophisticated prophylactics such as contraceptive pills, emergency contraceptives and spermicides will not be available to post-bottleneck villagers. Research is needed now to locate and evaluate (and even breed) effective herbal abortifacients. The ancient Greek colony of Cyrene at one time had an economy based almost entirely on the production and export of Silphium, a powerful abortifacient in the Parsley family.[60] Research is similarly needed to develop intra-uterine contraceptive devices simple enough to be made by post-bottleneck villagers. It may also be possible to simplify and improve the accuracy of fertility awareness methods (e.g. presence of cervical mucus) of avoiding pregnancy.

Reconstructionists may also be able to suggest behavioural guidelines which, along with more material technologies, might help survivor communities to keep their numbers stable. For example, women are more fertile and better milkers when well fed; the old can expect to be poorly fed when the stocking rate is too high; food rationing might improve survival rates in bad seasons; and cannibalism is an option. An appreciation of the slow march of population dynamics would help.

Like people today, bottleneck survivors will want to lead long healthy lives. Simple technologies for raising healthy life expectancy at birth include awareness of preventive behaviours such as avoiding contaminated water and washing hands with soap (which can be made from wood ash and animal fat). If large numbers of people could be trained to treat common illnesses and injuries ('barefoot doctors') before the world becomes too disorganised, theirs would be the sort of knowledge having a reasonable chance of being passed on till it became available to post-bottleneck villagers. As a bonus, to be able to understand the training manuals studied by these nurses would be a powerful incentive for people to continue learning to read. Ways of making simple medical instruments (e.g. tweezers, needles) would need to be developed too.

The Neighbour Problem

Throughout pre-history, humans and their extinct near relatives lived in small groups in more-or-less fixed territories which they came to know well, and from which they attempted to expel trespassers. But, as noted earlier, lethal inter-group violence and

[60] http://en.wikipedia.org/wiki/Abortifacient (Accessed 12 Mar 2009).

dispossession was probably a common response to overpopulation and hunger caused by runs of poor seasons.[61]

Under the phoenix scenario, it is easy to see how a culture of inter-group violence might grow up in a region as bottleneck survivors struggle to choose sites for villages, manage their group numbers and come to an understanding about boundaries with strangers in neighbouring villages. And it would not necessarily be an advantage to have this process of reconstruction being overlaid on a past pattern of occupied villages, not if the remnant prior populations wanted to cling to outdated practices and old enmities.

Once started, tit-for-tat violence seems almost impossible to stop. Still, while more than likely fruitless, it is important that Reconstructionists make a special effort to communicate this truth to post-bottleneck villagers. There may be a place for posturing and spear-shaking to clarify boundaries between territories but the risks of escalation need to be made crystal clear. A culture of inter-group violence has many costs and few benefits. Apart from the diversion of valuable resources into security operations and the creation of a permanent climate of fear, the big danger when fighting between neighbours becomes institutionalised is that it might trigger a push for population growth. Warring can then become a routine activity for culling excess population! What a trap.

Relations between neighbouring villages are more likely to be cooperative and friendly where villages are small and stocking rates low, and in frontier situations where new villages are founded by emigrants from nearby villages. Such arrangements are also conducive to 'balance of power' solutions to the problem of aggression, i.e. several of a region's villages can collaborate to discipline any single village which becomes aggressive.

When there is a degree of trust and interaction between the villages of a region, they will come to share a common disease pool (and hence similar immunities) and enough of a common language to be able to communicate on trade and other matters of common interest. Trade has the potential to improve life in many ways, allowing the acquisition of, for example, medicinal herbs, abortifacients, pottery, cloth, jewellery, pack animals, large and small domestic animals, seeds, minerals and scavenged metals.

History shows that intermarriage between people from neighbouring groups can promote cooperation and alliances between those groups. When those groups are extended families or clans, incest conventions can also serve as a technology for population control.

History reveals other ways in which neighbourly relationships can be improved, including inter-village gatherings to celebrate natural events (e.g. the passage of the seasons), song-and-dance 'corroborees', feasts and sporting contests. Knowing others makes them less threatening, but such social technologies take time to evolve, even under stable conditions.

[61] Le Blanc, S., with Register, K. 2003, ibid.

The Marauder Problem

The marauder problem is somewhat different from the neighbour problem. Like the Vikings and Scottish border peoples of history, these are mobile groups which descend unexpectedly on sedentary peoples, take what they want by force and then depart the region. If a village's grain stocks, including grain reserved for planting, are stolen, the villagers might well starve—or turn to marauding themselves. In a post-bottleneck world, there could be hordes of displaced wanderers reduced to marauding to survive. It is clear that, above a certain level of successful marauding, a society organised into small villages could not survive and people would have to revert to a hunter-gatherer existence. An alternative would be for villagers to come together for protection in urban centres. Historically however, this 'consolidation' solution was only possible in special situations where output per field worker could be increased markedly by setting up large-scale irrigation projects, as in ancient Mesopotamia. Another solution, in situations where modest surpluses could be consistently achieved, would be *warlordism*, i.e. marauders become protectors in return for a share of each harvest.

It seems plausible that the Reconstructionist movement might judge it important to try passing down technologies which could help aftermath villages survive marauding. Of the many suggestions that might be considered here, we will note (a) some preparations that rely on a high degree of cooperation between neighbouring villages, (b) some preparations that make a village's assets less reachable, and (c) some preparations that increase a village's capacity to physically resist invasion.

Provided they are not too far apart, cooperating villages could warn each other of the presence of marauders using long-distance drums or gongs. Homing pigeons are another possibility. Research on the re-design of such signalling devices could be undertaken now. Agreements to come to the aid of a village being attacked are a possibility. Part of each village's food reserves could be stored in other villages, making it less likely that all would be stolen in a raid. If they could be developed, such arrangements might lead, in time, to a form of local government.

A village's food reserves and other portable valuables will be harder to steal if they are dispersed and hidden and protected with booby traps (more research needed). A few caches could be poisoned. Food reserves in the form of live animals can be dispersed too. Hideouts for women and children and, perhaps, men can be established away from the village.

An alternative to evasion, depending on the size of the marauding group, is physical resistance. While Reconstructionists might want to help aftermath villagers protect themselves, transmitting technologies for better weaponry is problematic in that most defensive weapons can also be used offensively, and therein lies the prospect of arms races and endless war. Still, as Neolithic villagers found, palisades and ditches are (non-portable) structures which give defenders an advantage. It sounds strange but perhaps the design of palisades and ditches needs researching; or, given that there will be no cannon to bring them down, stone walls may repay the effort of constructing them.

If marauders are to be confronted, the value of dogs needs to be recognised. Not only do they have the senses and the instinct to be brilliant natural sentries, most dogs of reasonable size can be trained to become frightening, fearless attackers on command. In peaceful times, aftermath villagers will learn, as their forebears did but with some help from the Reconstructionists perhaps, how useful dogs are for hunting, carrying, protecting livestock and crops and, indeed, for eating.

The Bully Problem

The primate trait of being willing to conform to emerging dominance-submission relationships within the social group has adaptive value in terms of helping to maintain order without constant fighting and as a technology for coordinating group activities such as hunting, migrating and provisioning. It is a trait which perhaps coevolved with the capacity of the young to accept parental authority in species where learned behaviour (culture) had become central to survival. While modern humans, primates all, are generally willing for their beliefs and behaviour to be guided by legitimate authority, they are less willing to submit to being frightened and coerced by bullies. For example, democracy is a recent social technology which derives its authority from the principle that each person has equal political power within a political unit that has a monopoly on coercive force.

In a post-bottleneck world, where technologies for conferring legitimate authority will have to be rebuilt, there will be space for violent bullies to emerge and claim the authority to make collective decisions on behalf of the community. Such developments have to be resisted because thugs generally make bad leaders. They tend to have poor impulse control and to be socially irresponsible, imposing selfish and self-interested decisions on the community. It is important that Reconstructionists attempt to convey this perspective to bottleneck survivors.

History shows that, once in control, sociopathic leaders are difficult to dislodge. They tend to form a virtual species around themselves by making decisions which favour an elite few (e.g. access to food) and by restricting access to weaponry.

There are various social technologies which, where they have become customary, help protect against the rise of coercive self-serving leaders. Thus, in many tribal societies, collective actions are agreed by reaching a consensus or agreed by tribal elders. Or, rather than a single leader, it might be customary for a duo or triumvirate of leaders to be selected by consensus (or by lot) and allowed to lead for a fixed period. The 'invisible hand' principle suggests the importance of harnessing self-interest to the pursuit of the public interest, e.g. leaders who are acclaimed as having served the public interest well might be invited to lead for a further period. These traditions have been traced back as far as Mesopotamian city states c.2500 BCE.[62]

[62]Bermant, C., and Weitzman, M., 1979, *Ebla: A Revelation in Archaeology*, Times Books, New York.

It is important that the powers of leaders be circumscribed in clearly defined ways. While hereditary leadership offers social stability at times of succession, the risks of getting a mad, bad or incompetent heir make this an unacceptable social technology. The group must be willing to kill or exile a bad leader or one who stays too long. Apart from an understanding of what leaders can decide, it is equally important for the powers of others in the group to be agreed, e.g. who is to predict the weather. In this way, doubts as to where a particular responsibility lies can be minimised. Leadership is an effective social technology in many situations (e.g. simplifying communication and negotiation) and should not be abandoned just because it is so often abused.

Now is the time to do more research on the bullying personality. Are bullies treating people as they were once treated? Do leaders who are bullies inspire more confidence than others in times of conflict? Perhaps something of use to aftermath villagers can be discovered and bequeathed, along with what is already known.

The Identity Problem

Many post-bottleneck villages are likely to contain *ad hoc* assemblages of traumatised refugees with little sense of history of family, or the pre-bottleneck world or the human lineage. Without such knowledge, it is hard for people to acquire a strong sense of identity, meaning a feeling of belonging to various entities larger than oneself, such as one's family, village, region, species or, for some, the biosphere or the universe. Apart from each individual's psychic need for identity, villagers with a common or shared sense of identity will be able to more readily trust, communicate, collaborate and compromise with each other. It is obviously important for post-bottleneck villagers to understand the value of shared identity and hence for Reconstructionists to develop and transmit understanding of how shared identity can be fostered, e.g. through story-telling or simply through shared experience.

One can imagine that, within a few generations of 'the great breakdown', people will have only a hazy idea of the history of the great cities that, for them, exist only as ruins to be mined for useful materials which are no longer being produced. If, as suggested above, the survivors can, with the help of the Reconstructionists, have access to a technological history of the species, it might help them understand something of what worked and what failed for their ancestors, and hence might improve their own choices. Rationality is a delicate plant and it is important that aftermath villagers do not revert to 'pre-critical' thinking.

It would not be possible, even for well-resourced Reconstructionists, to prepare and transmit a history of every local area which could become a site for a post-bottleneck village. What then might they be able to do to help post-bottleneck people to identify strongly with their local territories and communities? Not much probably, but one possibility would be to encourage localism and communitarian values at the expense of liberal values among today's rural communities. The hope here would be that these values might survive through any future social disorganisation. *Localism* (also called *regionalism*, *bio-regionalism*) is the movement to have more of people's needs, economic and social, satisfied within a local area (up to, say, half a day's travel) which, politically, enjoys significant autonomy under the nation state. The bio-regional variant of localism looks for self-sufficiency for the residents of a bio-physically defined area such as a river catchment. Authority needs to be set in place now for future villages to assume emergency powers should higher levels of governance disappear.

A more concrete idea for creating a lasting sense of place would be to delineate today's local government boundaries with permanent markers and take the children out to 'beat the bounds'. Maps may well become rare, so knowing your territory's former place name and shape might be useful when negotiating boundaries with neighbours.

Humans tend to think in terms of binary divisions. But aftermath villagers must avoid identifying their communities by negation, i.e. by focussing on differences between 'them' and 'us'. This way lies prejudice, fear and, often, violence; shared enmity encourages a form of bonding that is ultimately self-defeating.

Identity through negation stands to be problem within communities as well as between communities. If and when village societies start to become more hierarchical, with a ruling virtual species and a labouring virtual species, differences between virtual species are more likely to be recognised than commonalities. Traditionally, ruling virtual species have developed a range of social technologies for suppressing the potential for conflict. These include physical coercion, food rationing and the propagation of religious ideas which convince the underclasses to accept their lot in life. Such technologies work only up to a point before revolt emerges. The question for Reconstructionists is whether they can help aftermath villagers understand the importance of minimising differences between virtual species.

Technology Issues

Darker versions of the reference scenario imagine a world of primitive subsistence villages where the elaborate manufactures and services (including electronic communications and motorised haulage) and food markets of today's urban industrial civilisation are no longer available. More than this, even in a world which has been disorganised for just several generations, it is likely that many of the skills which might have helped survivors to improve their quality of life will have been lost; along with physical capital such as buildings, tools, drainage systems and fences; and those inputs which are themselves made from the end products of various long chains of manufacturing processes (wood screws provide a simple example).

In a post-bottleneck world it will take time and luck to reconstruct village communities which have the material, social, communicative and cognitive technologies to survive the 'normal' range of threats to be expected from nature and various fellow humans. This is because complex technologies have to be built up from simpler technologies which are already established. You can't weave before you can spin, so to speak. The best that today's Reconstructionists can hope for is to speed up the rate at which some simple ideas, recipes and artefacts are 'discovered' by bottleneck survivors. There is no point in trying to transmit elaborate technologies through a time of rapid technological simplification.

Even as they learn to master village life, survivors will need to keep devising and modifying technologies for better dealing with changing conditions, if they are not to become increasingly vulnerable to disturbances. Apart from attempting to transmit various selected technologies, it might be just as important for any phoenix project to project and reinforce the optimistic perspective that humans have a long unbroken history of inventing new and improving old technologies.[63]

Equally, and it cannot be known in advance, survivors might benefit from being warned that most promising new technologies have a latent ‘biteback’ or ‘fishhook’ potential if adopted too enthusiastically, i.e. after a lag period, they come to be seen as having caused new problems. The outstanding examples are better weapons, rapid population growth and task specialisation leading to privilege. Recognising such ‘technology traps’ may be insufficient reason for not entering them of course.[64]

A technology which reduces inputs (e.g. a better plough) rather than increases outputs has several advantages. While saved resources (e.g. work hours) can be used to increase output, they may be better used to increase leisure time or to implement public works such as improved defences, or to improve social cohesion through group activities such as festivals. It is particularly important that time be found for educating the young in reading and writing, wherever these communicative technologies have survived.

History suggests that mutually beneficial trade is commonplace between the simplest of societies. Equally, post-bottleneck communities should probably be seeking technologies that produce tradeable goods. Apart from its direct benefits, trade can bring new ideas, an understanding of the outside world and improved relations with neighbouring communities. It is important however for communities to avoid becoming too specialised in the production of a few goods; outlets can disappear and specialisation often leads to exploitation.

Shouting Down the Time Tunnel

Trying to transmit a message to one’s great-grandchildren has all the uncertainties of shouting down a metaphorical ‘time tunnel’. One has to decide what to shout about and how to shout it; and then wonder Will anyone hear it? Will they listen? Will they understand it? Will they find it useful? Being a one-way tunnel, they can’t shout back and tell you.

The Phoenix strategy can be thought of as having several prongs. One is to invest at once in the targeted development of new social and material technologies, which, if they survive the bottleneck tumult, promise to prove useful to post-bottleneck

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[63] Childe, G. 1936/1981, *Man Makes Himself*, Moonraker Press, Bradford-on-Avon, England.

[64] Heidegger, M., 1977, *The Question Concerning Technology and Other Essays*, (Trans. W. Lovitt), Harper an. Row, New York.

villagers. Another is to make contingency plans for 'mothballing' a small number of 'heritage' sites which incorporate vast amounts of concentrated information, especially the great libraries and museums. Remembering the fate of the ancient Library of Alexandria and, more recently, the Baghdad Museum, such entities have to be recognised as vulnerable to social unrest. The third prong, as discussed above, involves collating a body of contemporary insights and procedural information and seeking to actively transmit this aggregate across a period of massive social disorganisation into the hands of post-bottleneck peoples. The thinking here parallels sci-fi writer Isaac Asimov's idea for an *Encyclopedia Galactica*, a vast compilation of the knowledge of a dying galactic empire, or Douglas Adams' *Hitchhiker's Guide to the Galaxy*.[65] Here, we consider some obstacles to and ideas for successfully transmitting an Earth-bound *Collation*.

One obvious principle is to use a diversity and redundancy of channels to deliver a Collation to as many post-bottleneck village sites as possible. Electronic media will be unsuitable because they do not store well and become increasingly difficult to read. More to the point, the infrastructure which carries today's Internet (computers, servers, transmitters, fibres, etc.) will have been irreparably degraded by then. And, like other machinery from the industrial age, electricity generators will have disappeared.

What about books? Yes, the Reconstructionists' Collation can be thought of as a library of a few hundred books, manuals, etc. But they will have to be special books in a number of ways. Physically, they will need to be printed on some durable, fire-resistant medium (aluminium?), cheap enough to produce millions of copies in a number of contemporary languages. Their fonts will have to be large to allow reading by candlelight. In terms of presentation, they will presumably have to be written as though for people with a basic 800-word vocabulary and, like children's books, with lots of pictures. Also, they will have to be written as though for people with limited cognitive skills with respect to causation, induction, deduction, abduction, etc. It is well known that, without practice, people tend to forget how to read and it probably has to be assumed that people who have been living precariously for several generations will also have trouble in making longer-term plans and investments when conditions begin to stabilise.

Much imagination will be needed to create a distribution system which has any prospect of reliably delivering Collations to post-bottleneck villages. How can each village's 'library' be protected from pilfering and wanton destruction until it needs to be accessed? Most suggestions have obvious flaws. One possibility is to house each village's collation in one or several shipping containers. But should these be padlocked or left open to be protected by local people? Would their contents be attractive to marauders? Should each village have multiple libraries? And so on. Perhaps each shipping container's walls could be covered, inside and out, with

[65] Asimov, I., 1995, 1996, *The Foundation Saga* (Foundation, Foundation and Empire, Second Foundation), Paperback editions, Harper an. Collins, London; Adams, D., 1980, *Hitchhiker's Guide to the Galaxy*, Harmony Books, New York.

useful permanent inscriptions—like Hammurabi's Bronze Age steles which proclaimed the law for all to see.

Religious communities played an important role in keeping the flame of learning alive through the European dark ages. Might it be possible for the Phoenix project to encourage the establishment of ongoing communities of secular religious committed to, first, surviving the bottleneck and, second, mastering and passing on the Collation? For example, a contemporary group whose members might have perspectives and ideals suited to such a mission is the *deep ecology* movement founded by Arne Naess.[66] Simple agrarian societies are ecologically benign. And, continuing this high speculation, as more-orderly agrarian societies emerge from the bottleneck, these 'secular monks' could leave their 'monasteries' and become wandering story-tellers and teachers, helping villages make use of their inherited Collations. Plus ça change…

Discussion

This chapter is organised around a dystopic scenario, an imagined future in which, world-wide, quality of life drops sharply over the next few decades. It is imagined that people in both rich and poor countries will find it much harder to satisfy their everyday needs and to remain functional. Unthinkably large numbers will die from hunger, violence and disease. At the collective scale, nation states will see the abandonment of cities, the disappearance of many industries and institutions and currency failures. It is argued that such a scenario is a plausible expression of ongoing cumulative change in four highly consequential attributes of the human ecosystem—people numbers, stocks of natural resources, mean global temperature and the interconnectedness of the global economy-society. History certainly shows that human societies change markedly when any of these 'control parameters' shift. In a situation I have described as Overshoot, these four attributes have now, putatively, reached threshold levels, i.e. levels beyond which the global human ecosystem can only continue to function as a complex dynamic system if it spontaneously self-reorganises into a structure which is better adapted to such changes.

It is because self-reorganisation is inherently unpredictable in speed, scope, onset, etc. that different people can, quite legitimately, have quite different beliefs as to whether and how this reference scenario might eventuate, and different ideas as to what the collective's response to such a scenario should be. The chapter suggests that, among those concerned for the well-being of the world's people, it will be common to find tough-minded wait-and-see Empiricists and tender-minded Interventionists. The former have open minds as to when and how disorganisation might set in and spread but are willing to see generous aid offered to victim groups

[66] Fox, W., 1990, *Toward a Transpersonal Ecology*: *Developing New Foundations for Environmentalism*, Shambhala Publications, Boston and London.

when it is clear that their quality of life is in decline. However, they have little interest or confidence in efforts to manage the juggernaut processes (resource depletion, population growth, global warming, economic complexification) lying behind declining quality of life.

Those I have labelled as (immediate) Interventionists are convinced that, if nothing is done, the reference scenario could very well come to pass. But, they also believe that, if there is strong coordinated intervention to manage the juggernaut processes and their impacts, average quality of life will decline but slowly for a generation or so and then begin to monotonically improve again. This is the idea that a 'soft landing' is possible.

As presented here, what is remarkable about the advocates of both these widespread attitudes, perhaps more so for the Interventionists because they are more ambitious, is that they are not overawed by either the virtual-species problem or the what-to-do problem. In claiming to have a realistic perception of the reference scenario and how to best respond to it, they are equally claiming to have a reasonable working knowledge of the what-to-do options that are available, and their consequences, and whether or not the cooperation and coordination each option calls for can be achieved.

In addition to the Interventionist (Stop fiddling) and reactive (Don't panic) responses, the chapter elaborates a third possible response to the reference scenario, that of the Reconstructionist or Preparationist. Here, the radical perception is that the reference scenario, or something much more dystopic, is not only totally plausible but largely unstoppable. That is, humanity needs to look to the future on the assumption that quality of life will plunge everywhere in coming decades, but most painfully in communities where there is a high dependence on trade and elaborate manufactures, where population density is high and where food and water are already scarce and further threatened by global warming. The Reconstructionists take this new dark age as given and ask what can be done now to help the village-scale communities that will be forming and looking for security and improved quality of life once the uncertainties of the bottleneck period begin to pass, in two or three generations perhaps.

As with the Interventionist and reactive responses, but probably more so, the ineluctable realities of the virtual-species problem and the what-to-do problem would make it very difficult for contemporary Reconstructionists to create and successfully deliver a genuinely useful inheritance to our post-bottleneck descendants. That is, an inheritance that would help them rebuild a technology mix and quality of life more quickly, while avoiding the reintroduction of some of the maladaptive technologies (behaviours) which have helped to create the present Overshoot Crisis.

Unfortunately, these descendants have no voice in today's world and diverting resources towards their interests in the face of today's pressing needs seems unlikely, nor can one imagine players in today's political processes admitting that their working hypothesis is to assume an approaching massive breakdown of global society. So, as with the Interventionist and reactive strategies for responding to Overshoot, the Reconstructionist strategy is unlikely to evoke significant collective action.

A Broader Context

There are various other responses to the reference scenario which this chapter could have explored, but those selected, based on differences in respondent temperament, probably constitute a reasonable sample of the possibilities. Responses based on ideology, superstition or despairing nihilism were deemed unlikely to lead to productive discussion. Similarly, I could have selected a different reference scenario, one in which the speed and extent of breakdown in global society were either more or less than in the chosen scenario, or a scenario squeezed out of a different set of global-scale processes. Notwithstanding these matters of judgement, I will take my perception of the attitudes and responses outlined as a starting point for putting the Overshoot Crisis, and people's conceivable responses to it, into a broader context.

Despite the observably relentless progression of momentous juggernaut processes which appear to be more threatening than opportune, we will not know if we are now entering the early stages of a major discontinuity in the organisation of planetary society until hindsight allows us to look back at what happened, particularly what happened to average quality of daily life. If the Reconstructionists are making the right assumption, we have indeed entered a major discontinuity, but if the Interventionists' working assumptions are right, the global community will be willing and able to avert what would otherwise be such a breakdown. This would leave the global community free to resume building a more sustainable civilisation. So, unlike the tough-minded Empiricists, both groups of tender-minded Rationalists—the Interventionists and the Reconstructionists—agree that global society is approaching a major discontinuity; they disagree as to whether it can be averted.

Some Reconstructionists might further disagree as to whether it 'should' be averted, i.e. should a potential discontinuity, a sharp drop in average quality of life, be converted into a gentler transition to a post-overshoot world? Or, should global society be allowed to go through a harsh bottleneck so that it can be 'born again'? If there really were such a choice, history suggests that permitting or encouraging a sharp drop in quality of life in order to allow a more progressive replacement society to emerge would probably be a mistake. How many successful revolutions against oppression have quickly led to renewed oppression? In similar vein, starting from the assumption that average quality of life is about to drop sharply, it is a knowledge of history which suggests that Reconstructionists' attempts to help post-bottleneck villagers should focus, not on improving their quality of life per se, but on helping them to avoid being brought down by various perennial threats.[67] More generally, it might be observed that the real tragedy of the Overshoot Crisis is that it has already redirected the global community's attention from the challenge to

[67] Fagan, B., 2008, *The Great Warming*: *Climate Change and the Rise and Fall of Civilisations*, Bloomsbury, New York. Fagan argues that village-based societies have, historically, been particularly resilient in face of climate and other change.

steadily improve quality of life for most people to the challenge of preventing a decline in average quality of life from present levels. People of goodwill are asking how much will quality of life decline in coming decades. They are not asking how much will it improve.

If the Reconstructionists' working hypothesis is correct, global society is entering a period of reorganisation at least as far-reaching as any associated with past periods of major reorganisation, including the flowering and transformation and disappearance of civilisations; and reorganisations triggered by climate shifts, natural disasters, shifts in cognition-consciousness and the emergence of transformative social and material technologies.

One thing that stands to be different about this twenty-first century bifurcation, if it is that, is that it could engulf the whole world, something not experienced since the global warming at the end of the last ice age. Even the few remnant hunter-gatherer societies could be disrupted by climate change. More than this, apart from the sheer numbers standing to be killed or dispossessed, disruption could spread very quickly because of the density of high-energy links—economic, political, social, and environmental—between large and small regions everywhere. When disruptions are being initiated in a variety of ways (through resource depletion, global warming, population shifts, economic linkages, etc.) at multiple locations across the Ecumene, the potential for inter- and intra-regional domino effects, positive feedbacks, chain reactions, oscillations, destructuring, etc. is enormous. Breaking a link which carries or just directs a large energy flow (e.g. capital movements) is necessarily highly disruptive. Historically, endogenous and localised disruptions were more-or-less self-limiting in a world of loosely connected regions; and, when it was a single region being disrupted, surrounding regions, being still organised, could both absorb the spill-over effects and initiate reorganisation in the disorganised region, e.g. the absorption of failed states by neighbouring states.

While the current Overshoot Crisis has the potential to be the most disruptive of the Holocene epoch, it pales beside various geophysical perturbations which scientists have flagged as plausible possibilities for the distant future. As discussed in my earlier book, *Deep Futures*, these include 'permanent total drought' in about 900 million years, large differences between daytime and night-time temperatures, and the extinction of the Sun in 5–7 billion years.[68] Also, once we begin thinking about futures measured in millions rather than thousands of years, scenarios such as volcanic winters, asteroid strikes and the loss of the geomagnetic field become plausible possibilities as distinct from possibilities which would be highly surprising if they occurred in the next millennium. Based on today's knowledge, it is reasonable to assume that the human species, or a successor species, will be snuffed out at some time in the far future. We emerged from stardust and to stardust we will return.

In the nearer future, much less threateningly, the species will have the next ice age to contend with. Already, at 11,000–12,000 years, ours is the longest inter-glacial

[68] Cocks, D., 2003, *Deep Futures*: *Our Prospects for Survival*, University of New South Wales Press and McGill University Press, Sydney, Ch 2.

on record and, well within a thousand years, we could be plunged into a world where, as in the last ice age, average temperatures are up to 10° lower than today (although the cooling process commonly has taken much longer). Current greenhouse warming could delay this somewhat but is unlikely to permanently stall a process which, driven by recurring variations in the Earth's orbit, axial tilt and axial wobble, has operated with a basic regularity for a million years. In that cold, perhaps CO_2-deficient, dry, windy world, wheat could not be produced in the breadbaskets of Ukraine, North America and Australia and, in the absence of revolutionary technology, world population would plummet, if it had not plummeted already.

What Will Happen? Piecemeal Intervention?

What has been achieved by having this discussion of various ways of reacting to a dystopic reference scenario? Are we any closer to knowing what will happen to global society over coming decades? The answer of course is No, once it is accepted that the global human ecosystem is a dissipative system which has been continually reorganising because it has been capturing energy at an increasing rate.

On the other hand, the possibilities as to what could happen or could not happen to the human ecosystem may be a little clearer, albeit wide-ranging. Thus, it seems highly unlikely that any of the three strategies suggested in the chapter on behalf of Empiricists, Interventionists and Reconstructionists respectively will be adopted explicitly by the global community. Reconstructionists in particular would find it difficult to convince people or governments, who would prefer to not be convinced, that the reference scenario is plausible to the point where the species should act as though it will eventuate. Empiricists run the risk of being labelled 'just sceptics' and of being captured by those beneficiaries of the *status quo* who are advocating inaction in their own short-term interests.

On the other hand, the Interventionist position is likely to get a degree of support, but in a piecemeal way. That is, as early warning signs of particular threats to the quality of ordinary lives or the functionality of states appear in particular locations, those who stand to be directly affected will promote precautionary efforts to adapt to or mitigate the foreseen harm. Indeed, in a variety of ways this is already happening, from Kyoto to kerbside recycling and from bank bailouts to wind farms. A few of these efforts stand to be global in scope, tackling the juggernauts directly, but most will be national, regional, local or personal. Poor and failing states though will not have the resources to protect themselves or their people from Overshoot's shocks; and international assistance to such will be very limited.

But, to repeat, there is little chance of the Overshoot Crisis being tackled comprehensively. The understanding being suggested here is that the evolution of the global human ecosystem, and quality of life for many, are already being noticeably influenced by a process of *piecemeal intervention* in an Overshoot Crisis of unpredictable speed, size and duration. Like other wicked problems, the Overshoot Crisis is exhibiting itself as an evolving set of interlocking issues, constraints, objectives and options for action. Ends and means overlap. There are multiple protagonists, what I call virtual species, and each will take various actions, various actions, each of which is intended to be a partial solution, i.e. to improve some aspect of the total problem.

Faced with this emerging unscripted interplay between juggernaut trends and a patchwork of virtual-species' responses, it takes little to imagine that a sharp shift in community psychology, in social character, is also taking place. Recall that a society's social character is to be seen in the way that most people internalise, accept and support the cultural values implicit in their society's social and economic systems. But history shows that a society's social character can change quickly once it is commonly perceived that its socio-economic system is failing to deliver the values it professes to foster. As and if a failing socio-economic system is replaced by one seen as more progressive, so will the previous social character be replaced by one supportive of the incoming system. More precisely, this replacement process is coevolutionary in that change in either social character or the production system will induce further change in the other; social character both leads and follows social change. For example, Leonard Woolf's *After the Deluge* is largely concerned with the way in which, in nineteenth century Europe, the idea and practice of democracy replaced an unquestioned acceptance of inherited privilege as society's main organising principle.[69]

So, what is happening to social character now in, for example, First World countries? As noted in Chap. 4, support for the values and ideas underpinning economism and neoliberalism has declined in recent decades, in line with the perception that the economic growth which these beliefs have fostered (at least until very recently) has failed to deliver increased prosperity and improved quality of life for the many. While there is no clearly apparent successor to either the capitalist system of production-consumption or a besieged belief system, there is evidence of both being 'reformed'. Thus, the recent spread of 'interventionist' social-democrat governments in place of neoliberal governments is best interpreted as a movement to reform, but not to replace, the dominant paradigm. That is, markets are still being seen as the core institutions of Western post-modern societies, but intervention to 'correct' widely acknowledged widespread market failures has acquired a renewed legitimacy.

Much of that legitimacy rests on a growing approval within the community for the idea that *Sustainable Development* is an appropriate umbrella goal for the global human ecosystem. Building on the environmental movement that began in the 1960s, Sustainable Development is based on the proposition that all of the global community's projects can and should meet standards for environmental protection, economic development and social development in a balanced way.[70] Just as neoliberalism was waiting in the wings to replace Keynesianism in the 1970s, Sustainable Development has been emerging as the strongest aspirant to displace neoliberalism as the centrepiece of First World social character. Support for this

[69] Woolf, L., 1931/1937, After the Deluge: A Study of Community Psychology, Pelican, London.
[70] http://en.wikipedia.org/wiki/Sustainable_development (Accessed 26 Dec 2010).

transition seems to have accelerated as the growing perception that there is a global Overshoot Crisis has joined the perception that economic growth alone did not and cannot provide high quality of life to most people. In this vein, *piecemeal intervention*, with its emphasis on managed markets as primary instruments for responding to Overshoot, presents as a canonical example of the Sustainable Development philosophy.

Presumably, if this chapter's dystopic reference scenario does eventuate in the next few decades, the ideas of both Sustainable Development and neoliberalism as grand organising principles will be consigned to the dustbin of history. People will then develop a new social character consonant with the society in which they find themselves. For example, if urban societies revert to a village-based mode of social organisation, one would be unsurprised by the emergence of a social character which is appreciative of the qualities of village life and supportive of customary approaches to addressing the problems that villages encounter.

Very Sobering

To conclude, this is a very sobering chapter. It is suggesting that, while humans will survive their human-made Overshoot Crisis, it won't be because of any remarkable capacity to adapt to major challenges in ways that protect quality of life. It will be because the Crisis wasn't as bad as some thought it could have been; that is, the species was not really tested. Or, it will be that while the crisis was highly destructive of quality of life for most, it spat out a post-bottleneck population which, scattered and much-reduced, retained sufficient social and material technologies to begin rebuilding stable sedentary societies and improving quality of life once again, nor does our analysis find any global collective will to consciously avert extended crises or to work systematically towards achieving high quality of life for most people into the indefinite future.

So, it has to be asked, if this is cultural evolution in action, is it a dead-end process, limping along until a somewhat bigger shock than the present crisis drives the species to extinction? For example, global warming during the Permian extinction produced sufficient deadly hydrogen sulphide gas to kill off 50% of animal families and 95% of marine species (see Chap. 1). This is a largely unrecognised possibility which could happen again if, in a warmer world, the oceans' heat-transferring currents stop flowing.

For those hoping for a human ecosystem where prospects for long-term quality survival will continue to improve—call them *Ecohumanists*—a better question to ask is whether cultural evolution is producing social, cognitive, communicative and material technologies which, other things being equal, could help this to happen. Growing out of our ever-increasing ability to conceptualise the world and its component processes, we have acquired a profusion of technologies, but no accompanying sense that prospects for quality survival are thereby improving. It may be that the quality survival challenge is not recognised as important by enough people, or is actively opposed by too many people or is just too difficult under present levels of cognitive skills and scientific knowledge, e.g. our limited understanding of the dynamics of complex systems and our inability to solve the virtual-species problem.

If Ecohumanists want to convince enough people to believe in and progress the idea that quality survival is humanity's primary goal, they have to explain the world view (system of fundamental beliefs that describe reality) which leads them towards this conclusion. Thus, a great many Ecohumanists view the world, including the human ecosystem, in terms of evolutionary and ecological processes, and find this to be a philosophy, a model of reality, which gives them a sense of meaning (What's been happening? Why are things the way they are and not otherwise?) and a sense of belonging—to the universe, the world and the human family. It is the feeling that all people, present and future, are one's 'brothers and sisters' or, at least, one's 'neighbours', that brings one to regard quality survival as a matter of ultimate importance. It is the Ecohumanists' belief that feelings of loyalty to and solidarity with the 'other' blur differences between virtual species, foster cooperation and refocus the search for new technologies away from market reform and towards quality survival.

When a dominant world view emerges in a society it provides a set of constraints and guidelines within which both social character and social organisation will evolve, i.e. both will continue to change, but in ways which are not incompatible with the overarching world view. Because world views usually change much more slowly than social character and social organisation (centuries vs. decades often), they are, most of the time, like a *medium* within which social evolution takes place. For example, if a world view inclines people to believe that humanity has been just plain lucky to have survived both large natural events and its own selfish, short-sighted behaviours, it may also incline them to behave with more concern for others and more presbyopically.

Unlike traditional societies where a single world view is the norm, today's connected world is one where alternative world views—religious, scientific, political, economic, psychological, etc.—struggle for dominance, in the sense of each having their advocates, e.g. Samuel Huntington's 'clash of civilisations', CP Snow's 'two cultures'.[71] What then is the likelihood that a world view based on a scientific understanding of reality will become widespread? And what are the shortcomings of such a perspective? Perhaps there are other world views which also constitute belief-environments where quality survival is readily seen as being humanity's paramount goal? Where concern for people everywhere is highly valued?

This then is where our project to understand the origins, nature and possible trajectory of the Global Overshoot Crisis has finally led us, namely, to a conclusion that the ways in which societies respond to existential opportunities and problems are broadly determined (macro-determined) by the world view or views prevalent in

[71] Snow, C.P., 1959/1965, *The Two Cultures and a Second Look*, Cambridge University Press, New York; Huntington, S.P., 1996, *The Clash of Civilizations and the Remaking of World Order*, Simon and Schuster, New York.

the society. This is a simple but important conclusion which, in the next and final chapter, to round out our analysis, we will look at in more depth. In particular, I will argue that *Ecohumanism*, understood as a science-based and humanistic world view cum philosophy, offers both a shareable understanding of the long trajectory of the human ecosystem and a variety of practical starting points for thinking about how to better manage both the proximate and root causes of Global Overshoot.

Chapter 6
Ecohumanism and Other Stories

Stories Then and Now

Storytelling is an old social technology with the potential to serve a variety of practical functions, especially in oral cultures. For present purposes, the term *stories* is a catch-all for the myths, sagas, epics, fables, legends, plays, folktales, folk histories, etc., which members of religious, ethnic, political, tribal, etc., virtual species tell and retell amongst themselves. Apart from being entertainment, allowing the listener to enjoy vicarious adventures, etc., stories are a powerful socialisation and communicative technology which can mould and reinforce customs, belief systems, values and attitudes. For example, the Mahābhārata is a Hindu epic, the tale of a great dynasty, which supports a discussion of human goals (purpose, pleasure, duty and liberation) in terms of traditional understandings of the relationship of the individual to society and the world, including the nature of the 'Self' and the consequential nature of one's actions.[1] For individuals, stories can help satisfy their ever-present needs for a sense of meaning (e.g. understanding the past) and a sense of belonging to a group with a strong identity. In particular, religious stories, to the extent that they are believed, can console the grieving individual, allay her fear of death and help her endure great misfortune.

Cultural anthropologist Joseph Campbell is well-known for his thesis that many important myths from around the world, some having survived for thousands of years, share, in part or whole, a common structure. He summarises same in a well-known quote from the Introduction to *The Hero with a Thousand Faces*: 'A hero ventures forth from the world of common day into a region of supernatural wonder: fabulous forces are there encountered and a decisive victory is won: the hero comes back from this mysterious adventure with the power to bestow boons on his fellow man'.[2] Examples include Moses, Jesus, Mohammed, Buddha and Odysseus.

[1] http://en.wikipedia.org/wiki/Mah%C4%81bh%C4%81rata (Accessed 20 July 2009).

[2] Campbell, J., 1968, *The Hero with a Thousand Faces*, Princeton University Press, Princeton.

D. Cocks, *Global Overshoot: Contemplating the World's Converging Problems*,
DOI 10.1007/978-1-4614-6265-1_6,

Another helpful perspective on how stories are useful is that of Karl Kroeber in his book *Native American Storytelling*[3]: 'Storytelling was a recognised way of "debating" solutions to practical personal, social and political contemporary problems'. Some stories were told for amusement and relaxation but most were active applications of historical tribal experience to specific current issues, individual and communal. Amongst others, the anthropologist Claude Lévi-Strauss has recognised that myths invariably introduce conflicting ideas about how the world works or should work and then show how 'thesis' and 'anti-thesis' can be synthesised or reconciled.[4] Thus, taking this book as an example could my three different ways of reacting to an overshoot scenario be reconciled or synthesised?

Stories abound in contemporary society too. Some, survivors from the distant past, are still important for specific communities, particularly those stories which have survived as sacred religious texts. Because the stories in these texts cannot evolve, they can only remain relevant to contemporary communities by being continually reinterpreted. Alternatively, communities that believe in such a text attempt to hold on to the culture and social organisation which existed when their stories were young.

The bulk of 'new' stories are fictitious; they involve imaginary characters working through a plot-line of relationships and events, and are widely available through the media of film, television, radio, theatre and print. Most fiction is created for entertainment but, when vividly presented, it exposes people to experiences they can learn from and ideas they can use to expand their own behavioural options, e.g. by challenging or confirming conventional wisdoms, or by providing memes and role models.

Newspapers and electronic news media present the public with large numbers of 'non-fiction' stories every day. These provide people with a selective sense of what is happening and mould public opinion, sociality and social character as people exchange their responses to these widely shared experiences. While a majority of news stories are transient, many present as chapters in ongoing narratives; the state of the economy and progress in sporting competitions are examples here.

As discussed earlier, we live in a world where propagandists from one virtual species routinely distort non-fiction stories in order to persuade (cf. convince) other virtual species to come to beliefs and values which covertly advantage the propagandists. Governments which deliberately 'revise' history provide many examples—Stalin's and now Putin's Russia; Hitler's Germany; Japan's sanitised version of its atrocities in the Second World War; such rewritten histories find scapegoats and excuses for past failures or inspire populations to believe their forebears were great, creators of glories and triumphs, and never ignoble.

There may be circumstances in which the deliberate corruption of history can be justified—to motivate a shattered people perhaps—but people will react angrily and become indelibly suspicious when they eventually conclude they have been

[3]Kroeber, K., 2004, Native American Storytelling: A Reader of Myths and Legends, Blackwell, Oxford, p. 2.

[4]Lévi-Strauss, C., 1966, *The Savage Mind*, Weidenfeld and Nicolson, London.

deceived. Or, if they continue to be deluded, they may well adopt dangerously unrealistic goals. A complication here is that corruption is not always a black and white matter. Even honest history has to be periodically rewritten to match contemporary understandings and to incorporate new data. With the best of intentions, historians may not be fully aware of their own world views, their unrecognised prejudices and assumptions; unconscious racism provides a good example. Or, quite genuinely, they may not regard their prejudices as prejudices.

And then there are 'true' stories, told by people who want to create meaning and understanding by linking available pieces of information together in a plausible, coherent way. Amongst others, scientists or, more generally, scholars, aspire to tell (provisionally) true stories; plate tectonics and evolution through natural selection are powerful examples.

This Book Is a Story

This book is a story of course, albeit not one with a hero in Campbell's sense. It is a 'rock-hopping' story of how evolutionary and ecological processes have led, step by plausible step, from the early universe to a Global Overshoot Crisis which now threatens to massively reduce humans' average quality of life. At this point the *Story of Global Overshoot*, to give it a name, moved to discussing just how threatening the Crisis is perceived to be by people of different temperaments, how world society might respond and what might actually happen to quality of life. It recognises that some see no Crisis, that some see a Crisis that can and will be averted, and some a Crisis that will unstoppably turn into a disastrous bottleneck for humanity. My tentative conclusion is that reductions in quality of life over coming decades, whether they are to be large or small, are already determined and unlikely to be greatly altered by human intervention.

Why am I telling such an uninspiring story? It offers no solution to the Overshoot Crisis and no vision of steady improvement in average quality of life for the world's people. Notwithstanding, the story is offered as a useful response to perceptions of an Overshoot Crisis. This chapter recapitulates and reviews that claim.

Descriptive and Prescriptive Philosophies

Is it too grand to call my story a philosophy? Is it anything more than a 'philosophy' in the everyday sense of that word?[5] Its starting point is certainly an acceptance of the central idea of process philosophy, the assertion that reality is best understood by seeing it as a process of continuous change driven by the spontaneous dissipation

[5] Wilson, J., 1966, *Thinking with Concepts*, Cambridge University Press, Cambridge, Ch. 3.

of energy gradients set up when the universe began. It is a story which might equally have been called *Nothing is at rest*, a linked chain of questions and answers about how and why things have been changing; and what might have caused them to change otherwise. Each step in the evolutionary chain sees the creation of a more or less stable ‘platform’, composed of material and energy flows diverted out of those already in existence. Each new platform then functions as an environment in which, for the first time, certain conditions necessary for the emergence and persistence of the next link (platform) in the evolutionary chain (hierarchy) are satisfied. It’s platforms all the way up! This perspective is a *descriptive philosophy* in the sense that it is a quite general approach to understanding the Crisis—its origins, its present character and its possible future.

It is also quite abstract. For the story to have everyday meaning, it has to be told in terms of a mutually compatible (coherent) set of concepts, a *world view* or *belief system* which allows successive platforms to be described in terms of their own peculiarities. Thus, separate vocabularies are needed to describe and understand evolutionary change in, for example, the radiation era, the chemical era, the biological era and the cultural era. This book is based on, and intended to demonstrate, the naturalistic belief that, in general, the set of concepts provided by contemporary science and the humanities is a sufficient world view to allow the story of the Overshoot Crisis to be developed in a way that is both plausible and consistent with a core philosophy of understanding reality as a process of continuous change.

As told here, the story of the Overshoot Crisis is also an exercise in *moral philosophy*.[6] Thus, it prescriptively (normatively) proposes that *quality survival*, the achievement of high quality of life for most people into the indefinite future, be treated as global society’s overarching goal. From this moral standpoint, the Overshoot Crisis is only a crisis because it carries a threat to average quality of life. It is only by embracing some such goal that alternative what-to-do proposals can be compared for expected effectiveness; or, likewise, that one can compare the expected impact of alternative Crisis trajectories. How do you know which bus to catch if you don’t know where you are going!

Despite its fuzziness, I find the humanist goal of quality survival, perhaps more easily recognisable as *humanitarianism* or *cosmopolitanism*,[7] a more fundamental anchor point for thinking about the impact and management of the Overshoot Crisis than more conventional but instrumental alternatives such as economic growth, sustainable development and security or religious conformity; it is all too easy to confuse ends and means. Notwithstanding my own conviction, there is a broader injunction here—global society must recognise that goals are chosen, not revealed, and that they must never be closed to debate and revision. They are certainly not naturalistic in the sense of somehow being consequences of what is materially true. Apart from the adaptive value of this directive, humanity’s image of itself needs to

[6] Williams, B., 2006, *Philosophy as a Humanistic Discipline*, (A.W. Moore Ed.) Princeton UP, Princeton, Ch. 8.

[7] http://plato.stanford.edu/entries/cosmopolitanism, Stanford Encyclopedia of Philosophy (Accessed 26 Dec 2010).

include the perception of being a species which, in an ever-changing world, is willing and able to keep questioning fundamental beliefs. For example, as noted earlier, it might suffice to judge a person's quality of life in terms of their success in satisfying Maslow's hierarchy of physiological and psychological needs[8] or it might be time to (say) rethink his concept of self-actualisation.

Ecohumanism: My Suggested Response to Global Overshoot

I have been advancing the idea that even if global overshoot were about to become widely recognised as a massive threat to average quality of life, world society would not have the social and cognitive technologies or the process knowledge to address this threat in a rational comprehensive manner. For a humanist, the best that could be hoped for would be a piecemeal response in which each virtual species, while acting primarily to protect its own quality of life, shows a degree of concern for the wellbeing of other virtual species.

But, beyond such a 'hope', how might an individual, group, nation state or other virtual species wanting to proactively improve global society's capacity to respond to the global problematique think and act? The suggestion I want to consider here is that such protagonists might choose to develop, promote and, as far as possible, within their sphere of influence, be guided by an Ecohumanist philosophy or, if you prefer, belief system. Humanism is a philosophy which puts human progress at its centre, and *Ecohumanism* is a humanism which is *informed by an extended awareness of ecosphere processes*—call it *Eco-awareness*—including both ecological and evolutionary processes.

For example, in the spirit of Ecohumanism, I have found it illuminating and a useful organising framework to view human history and prehistory as a pageant organised around the core ecological idea of a succession of interdependent (pseudo) species-populations and the core (cultural) evolutionary idea of selective retention (by virtual species) of (technological) variation. More generally, Eco-awareness is a large idea, a world view, within which the universe's biological and pre-biological eras can be understood equally as well as its cultural era, e.g. trophic webs in biology are 'analogues' of economic systems in the cultural era.

Benefits of Being Eco-Aware

Whether an Ecohumanist's focus and sphere of influence within the human ecosystem is local or global, he or she will try to understand what is happening in his or her system of interest by, typically:

[8] Maslow, A., 1968, *Toward a Psychology of Being*, Van Nostrand, New York.

Identifying the main virtual species involved and how each is changing in terms of numbers, roles, material and energy use and acquisition, food supplies, technology mix, belief systems and quality of life. The task here may include the documentation of emerging and declining virtual species.

Identifying the main ecological interactions between virtual species (their niches), including conflictual relations and cooperative relations, such as trade flows, joint institutions and knowledge transfers.

Identifying processes in the focal system's parent platforms, both the social and bio-physical environments, which are affecting and being affected by virtual species activities, e.g. the anthropogenic hole in the ozone layer. This will include identifying interactions between these processes, and threatening-promising trends within them.

Identifying emerging and evolving technologies—material, social, cognitive and communicative—and their role in niche construction.

The example to hand is that this book's much-abridged story of the long slow rise of global overshoot has been written with the help of similar background guidelines. It is not being suggested that being eco-aware in this way automatically identifies the what-to-do behaviours that will best promote quality survival. Nor does it produce a canonical understanding of what is happening. What it does offer is an initial frame of reference and a common language (virtual species, platforms, social technologies, etc.) which members of a virtual species can use for debating what-to-do/how-to-intervene proposals and for moving towards a shared understanding of what is happening. More generally, having a heightened (eco) awareness of any complex system's components stands to improve one's *intuitive* capacity—all that one normally has—to make what-to-do choices in relation to that system.[9]

Identifying Meta-Problems

Especially when it extends back into the distant past, systematic Eco-awareness can trigger and crystallise alternative perceptions of today's problems and opportunities. Thus, when writing the present history, it became apparent that the meta-problems of managing complexity and achieving cooperation and coordination have frequently blocked opportunities to improve quality of life or, worse, have reduced quality of life for sizeable numbers of people.

It can be suggested that, in the face of Global Overshoot, it is at least as important to find technologies for addressing these and other meta-problems—such as technological biteback, short-termism, parasitism, temporal myopia, pervasive deception, sequacity, etc.—as it is to manage the *proximate causes* of the Crisis (over-connection, over-depletion, overheating, overpopulation) and prepare for its consequences (depopulation, deurbanisation, deindustrialisation, decoupling). Indeed,

[9] McKenzie, C., and James, K., 2004, Aesthetics as an Aid to Understanding Complex Systems and Decision Judgement in Operating Complex Systems, *E:CO*, 6 (1–2), pp. 32–39.

it qualifies as a conceptual advance to perceive that a handful of meta-problems are the *root causes* of the Global Overshoot Crisis. Presently we will consider what might be done to overcome several of these.

Identifying Issues Which Need to be Widely Debated

If Ecohumanists want their cosmopolitan philosophy and naturalistic world view to become more widely accepted as a valuable resource for managing global society, and they do, they have to be willing to constantly articulate, refine, question, debate and defend their views. Capitalist economics (more generally, economismic thinking) and, to a lesser extent, organised religion and nationalism are the dominant or privileged discourses in contemporary global society and it is with these that Ecohumanism must compete for influence over public policy. Perhaps *environmentalism*[10] too has become significant enough to be included here.

Most obviously, it is Ecohumanism's idea that *quality survival* should be an overarching goal for global society (see page 193) that needs to be closely examined and regularly re-examined. While there is no space to do so here, the quality-survival goal should be compared–contrasted with the broad social goals of the more privileged discourses. How should goals change with circumstances? At the next level down, debateable questions abound. Are simple, robust indicators of quality of life available? Should quality of life continue to be understood in terms of satisfying a hierarchy of needs? How does one balance quality of life today against quality of life tomorrow? How should one's understanding of quality of life change as society's issues of concern change? Earlier, a modest case was made for the claim that overshoot and declining quality of life are already realities and that, under the intertwined impact of several 'juggernaut' trends, a scenario in which global quality of life falls dramatically in coming decades becomes highly plausible. This was the reference scenario I used for exploring alternative perceptions of global overshoot and what should be done about it (see page 289). However, while developed sufficiently for the purposes of this book, the implications of that reference scenario are so enormous that it needs to be questioned, challenged, reworked and extended as competently and as fully as global society can manage. It is not that these efforts will reveal the future, rather that they will help us decide what to assume about it.

Shaping Attitudes Towards Threatening Trends

While it is doubtful if there are any 'laws of history', viewing history and prehistory through the lens of Eco-awareness does generate insights which, if more widely appreciated, might reconfigure conventional attitudes towards what is happening in

[10]Environmentalism is the belief that an especially high priority should be placed on protecting ecosystems from direct and indirect disturbance by humans.

global society today (attitudes are 'habitual ways of regarding issues'). Bernard Williams points out that the authority of such insights is vindicated or strengthened by the very fact that they have plausible step-by-step histories.[11]

Consider, as brief examples, the four juggernaut processes nominated as 'driving' global society towards a major self-reorganisation (see pages 298, 296):

Population Growth

History is crammed with examples of societies where, after a long period of growth, the population has crashed for one reason or another, bringing with it war, famine, disease and/or collapse of the social order. Surely it is up to those who read no threat to global society in present population growth to argue why 'things are different this time'.

Resource Depletion

Another of eco-history's lessons is that humans commonly destroy the resource base on which they depend. Jared Diamond notes three situations in which human populations tend to wreak great damage on their environments[12]:

1. When people suddenly colonise an unfamiliar environment, e.g. Maori destruction of megafauna in New Zealand, European settlers in Australia.
2. When people advance along a new frontier (like the first peoples to reach America) and can move on when they have damaged the region behind.
3. When people acquire a new technology whose destructive power they have not had time to appreciate, e.g. New Guinea pigeon hunters with shotguns.

Societies come to rely on various renewable and non-renewable resources and when these run out, prove inadequate (e.g. for a growing population) or degrade faster than countervailing technologies can be developed, social reorganisation or disorganisation becomes inevitable. Particularly in arid and variable climates, deforestation, time and again, has led to soil erosion and the destruction of dams and terraces, e.g. in the classical Aegean civilization. As a rule of thumb, irrigation-based civilizations such as first arose in Egypt, Mesopotamia and the Indus Valley several thousand years BCE seldom last more than a few centuries before degrading the soil resource through salting and waterlogging. In general, it is intensification in resource use which leads to environmental depletion and, from there, to either

[11] Williams, B., 2006, *Philosophy as a Humanistic Discipline*, (A.W. Moore Ed.) Princeton UP, Princeton, Ch. 16.

[12] Diamond, J.M., 1992, *The Third Chimpanzee*: *The Evolution and Future of the Human Animal*, Harper Collins, New York.

sudden collapse of the cultural system or a shift to a new mode of production. Even when resource degradation has not been fatal, adjustment to it has usually been painful in quality-of-life terms for ordinary people.

Now we have the situation where global society has become highly dependent on a number of resources which are rapidly depleting or degrading or in shortening supply. Oil and arable land are the standout examples with rock phosphate, fresh water and marine fish stocks somewhat less so. Where Interventionists and Reconstructionists differ is on whether the human ecosystem is headed for reorganisation or disorganisation.

Global Warming and After

In recent decades, historians have become increasingly aware of the recurring role played by environmental events (e.g. earthquakes, floods, droughts, tsunamis, cyclones and storms, volcanic eruptions) and transitions (e.g. climate change, sea level change) in guiding and channelling human history.[13] Chapters 2 and 3 provide many examples, most involving disruption of existing social organisation—migrations, invasions and dispersals—and some, like the Mt Toba eruption and the Holocene thawing having had world-wide (cf. regional) impacts on quality survival.

Now, the whole world is experiencing a period of rapid warming of unpredictable duration and magnitude. Environmental history allows us to see this in perspective. At one level, such an environmental transition is not unusual and humans will adapt to it as best they can—just as they will when, within the next few thousand years, another glacial age that will last 100,000 to perhaps 120,000 years will probably begin on Earth, reducing mean temperatures from current levels by as much as 10°C at times.

At another level, current global warming has the potential to be incredibly disruptive by historical standards. Most regions stand to be directly affected in terms of temperatures, rainfall and storminess. Recent population growth means a billion people in coastal cities stand to be displaced as sea levels rise. The oceans stand to become stagnant biological deserts as they acidify and as circulatory flows slow. Note also that faster than anticipated warming will produce greater disruption than slower warming. Because most regions will be themselves disrupted, they are more likely to transmit disruption (e.g. uncontrolled emigration) rather than assistance to their distressed neighbours. This is what happened as a chain of societies collapsed across Eurasia in the late Bronze Age.

Unless something is to be done about them, the fact that global warming is being caused, to a greater or lesser extent, by humanity's greenhouse gas emissions is

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[13] Fagan, B.M., 2008, *The Great Warming*: *Climate Change and the Rise and Fall of Civilizations*, Bloomsbury, New York.

irrelevant. Nevertheless, if society's implicit strategy is adaptation, not mitigation, it will still be important to understand the trajectory of the warming process, and tracking emissions will be part of that.

Complexification

As noted earlier, Eric Chaisson has championed the useful idea that the complexity of a dissipative system is measured by its *free energy rate density*.[14] This is the extent to which, per gram of material in a system, the system is taking in and processing high quality (free) energy and excreting low quality energy (entropy). Consistent with the principle of maximum entropy production, he has further argued that the upper threshold of observable complexity has been rising since the beginning of the universe. For example, while stars have a free energy rate density of approximately 2 ergs per 0.1 g per 0.1 s, the figure for the human body is approximately 20,000 ergs per 0.1 g per 0.1 s.[15] Drawing the bulk of its energy supplies from the Earth's stock of non-renewable fossil fuels, the figure for a modern industrial ecosystem might be 20–30 times higher again.

The world-wide human ecosystem is continuing to become more complex as primary energy use rises. However, as fossil fuel supplies are drawn down, the system stands to spontaneously self-reorganise, in one way or another, to a multiplicity of simpler structures, e.g. with fewer links between nation states. Alternatively, if renewable energy sources come to be tapped in sufficient quantities, the system could retain its present complexity, or even self-reorganise to a higher level of complexity. Complex technologies (may) allow society to tap the large energy flows needed to maintain complexity!

Practical Ecohumanism

We now turn to a discussion of Ecohumanism as a source of *praxis*, a useful word meaning 'informed action'. It was suggested above that the Global Overshoot Crisis has proximate causes in the form of various juggernaut processes and root causes in the form of various meta-problems which are pervasive and which make the effective management of the juggernauts, singly or collectively, difficult in the extreme. Here, I present perspectives on two perennially intractable meta-problems, complexity and cooperation, and offer several exemplary guidelines, not for overcoming these, but for helping to better *cope* with them.

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[14] Chaisson, E., 2001, *Cosmic Evolution*: *The Rise of Complexity in Nature*, Harvard UP Cambridge, MA; Rees, M.J., 2003, *Our Final Century*, Heinemann, London.

[15] Chaisson, E., 2001, *ibid*., p. 139.

Some Guidelines for Coping with Complexity

1. Acknowledging complexity
   The first principle for guiding what-to-do decision-making in a complex world is to acknowledge that complexity and the need for complexity-sensitive thinking. Consider policy-making in the nation-state as an example. It has already been argued that all behaviour is more or less experimental (see page 284). So, when trying to solve a what-to-do problem rationally, a government must be routinely prepared to respond further as its actions prove inadequate for the problem as initially conceived. Things are nearly always more richly connected than is obvious.[16]

   However, politicians in the developed world are locked into a convention that they should pretend to know with certainty how to respond to issues of concern (e.g. the juggernaut processes) and what the consequences of their confident policies will be. In adversarial societies, and that includes Western democracies, political conflict can enrich perceptions of issues, but the cost of coping with pretence and deceit is enormous. Seeking a balance here will be considered presently as an aspect of the virtual-species problem.
2. Deliberate experimentation
   Once complexity and its uncertainties are acknowledged, a variety of other principles for improving decision-making under complexity emerge for consideration. One such is to explicitly treat each policy initiative as a deliberate (i.e. not unplanned) experiment, note its effects and, based on these, design a further policy experiment.[17] A refinement which might be possible sometimes would be to trial multiple policy 'treatments' simultaneously. There is a parallel here with the operation of natural selection on a genetically diverse population.
3. Monitoring societal change
   Homeostasis (see page 275) is the ability of biological organisms (and ecosystems) to return to 'normal' functioning after being subjected to outside disturbance, e.g. regulation of body temperature. The effectiveness of homeostatic mechanisms depends on signals of environmental change (e.g. warming) being fed back rapidly from environment to organism, i.e. via short unimpeded pathways.

   In the same way, knowing what is happening in and to a human ecosystem as it is happening allows decision-makers to begin correcting problems before they get out of hand. If unemployment (e.g.) is measured (monitored), and judged to be too high, some countervailing action such as reducing interest rates can be taken even though the effects of such action cannot be accurately predicted. It is *monitoring* which then tells us if the countervailing action has worked or needs further adjustment.[18] To some degree, monitoring in real time can be thought of as

[16] Levins, R., 2006, Strategies of Abstraction, *Biol. Philos.*, 21**,** pp. 741–755.

[17] Walters, C., 1986, *Adaptive Management of Renewable Resources*, Macmillan, New York.

[18] de Groot, R.S., 1988, *Environmental Functions: An Analytical Framework for Integrating Environmental and Economic Assessment*, Workshop on Integrating Environmental and Economic Assessment, Canadian Environmental Assessment Research Council, Vancouver.

compensating for humanity's limited ability to predict system behaviour. In practice, balancing the costs and benefits of developing monitoring programmes will always be difficult.

Besides changing in response to outside disturbances (e.g. invasion), activity levels in human ecosystems tend to go through *cycles* or *oscillations*, such being part of the 'normal' internal dynamics of any chaotic dissipative system. Many such cycles are the result of a time-lag between a causal trigger and its subsequent effect. For example, there is evidence that unemployment rates are driven by birth rates 15–20 years earlier.[19] Or, recall the earlier discussion of longer and shorter cycles of economic activity in mature economies (see page 222). Without monitoring, the cyclical behaviour of socio-economic activity is unlikely to be understood and taken into account when deciding how to respond to change. The longer the period for which a socio-economic activity is monitored, the more valuable the accumulated data becomes in terms of being able to recognise if a recent downturn (say) in some indicator of interest is due to:

A downturn in a long-term trend.
A downturn in a wavelike oscillation about that trend.
A downturn in a (short-term) high-frequency fluctuation about an oscillation.[20]

4. Technology design and assessment
New technologies are the raw materials of eco-cultural evolution. Within a decision-maker's sphere of influence, problems and opportunities are putatively addressed by devising or collating a range of candidate technologies and selecting one for implementation. It is because so many technologies (material, social, etc.) solve problems as intended, only to then 'bite back' and create new problems, that technology assessment and design should be an important part of coping with the uncertainties of managing contemporary socio-economic systems.[21] The guideline here is that technologies should be designed and 'pre-assessed' in a broader context than their immediate functionality.

When a society adopts a new technology, resources have to be diverted from other uses and, as well as the obvious beneficiaries, there will be those who, suffering from the disruption of the *status quo*, seek redress. But the bigger challenge in assessing a proposed technology is to foresee the ways in which the benefits of the technology might be eroded by the slow march of ancillary processes set in train by the new technology. For example, China's 'one child' policy, a social technology designed to slow population growth, has now led, after a generation, to problems of gender and demographic imbalance. Given

[19] Watt, K.F., 1992, Taming the Future: A Revolutionary Breakthrough in Scientific Forecasting, Contextured Web Press, Davis, CA.

[20] Watt, K.F., 1992, *ibid*.

[21] Tenner, E., 1996, *Why Things Bite Back*: *New Technology and the Revenge Effect*, Fourth Estate, London.

our inability to develop formal predictive models of eco-cultural evolution, decision-makers can only rely on having an intuitive understanding of their focal systems to foresee strongly lagged feedback effects and imagine how such might be circumvented. The more general advice here is to be aware that 'biteback' is widespread and to be looking for it.

5. Encouraging recycling and renewable energy technologies
   In both human-free and simple human ecosystems (societies), materials tend to be used cyclically, passing from one use to another before returning to their original uses. Long-lasting ecosystems retain (hold within their boundaries) the materials (e.g. nutrients, substrate) on which their participants depend; or, at least, materials 'leak' from the ecosystem no faster than they are acquired from the parent system. Ecosystem participants (e.g. species, virtual species) are linked mutualistically (interdependently) through an intricate set of feedback relationships in which the well-being of any participant depends on the well-being of many other participants. These feedback loops, the so-called web of life, are the paths over which materials are (re)cycled.

   Under what conditions does recycling help a society cope with complexity? City ecosystems in particular recycle and reuse only a small fraction of their material inputs. Most becomes waste or dispersed pollutants. For example, many coastal cities lose most of their food-nutrient inputs offshore as sewage; petroleum is not recycled at all. If an input is abundant and readily acquired, the costs of establishing a recycling capability may well exceed the benefits, even including the external benefits of waste and pollution reduction. However, as pollutants accumulate or supplies dwindle, recycling, reusing and rationing of material inputs stand to become more attractive options. In terms of coping with complexity, these technologies extend the overshoot 'lead' time before disorganisation or reorganisation is rudely imposed on the society. This delay period can be used to develop and implement less problematic substitute technologies, paving the way for a minimally disruptive reorganisation.

   The 'unsustainable' use of fossil fuels associated with oil depletion and carbon dioxide pollution is the supreme example of our time. For more than a century, economic growth and the complexification of global society has been made possible, indeed 'subsidised', by the ready availability of fossil fuels, notably oil, which have high *energy-profit ratios*; that is to say, a large quantity of usable energy in the form of oil can be captured by expending a small quantity of usable energy, e.g. drilling a hole. Renewable-energy technologies (solar, wind, hydro, etc.) have much lower energy-profit ratios than fossil-energy technologies. While this greatly magnifies the rate of capital investment required to largely replace fossil-energy technologies with renewable-energy technologies over a period of a few decades, many Interventionists believe such to be possible and something to be encouraged.

6. Investing in resilience
   Looking backwards, societies we think of as having been *resilient* or robust are those which pre-empted or recovered quickly from large and rapid falls in average quality of life (e.g. deaths, disabilities, diseases, hunger, fear) precipitated by

large exogenous disturbances (such as floods, fires, droughts, invasions, epidemics); or, less often, internally generated disturbances such as coups. In the Mediaeval Warm Period for example, comprehensively documented by Brian Fagan,[22] civilizations around the world survived repeated extended droughts before, resilience exhausted, most finally crumbled, e.g. the Mayans.

Can we judge the as-yet-untested resilience of contemporary global society, threatened as it is by the juggernauts of global overshoot—overpopulation, over-depletion, overheating and over-connectedness between social structures? My reference scenario postulates gross disorganisation of world society over coming decades, implying, not a resilient society, but a *brittle* or *fragile* one. In rejecting that scenario, Interventionists imagine that quality of life can and will be protected through the use of conventional collective instruments for coping with change in the stocks and flows associated with population, material resources, pollutants and trade, e.g. taxes-subsidies, cap-and-trade schemes and regulations.[23]

This may or may not be so. Our immediate interest is in whether complex dissipative systems have properties which suggest general strategies for making societies more resilient.[24] For example, as noted above, monitoring the advance of threatening change and designing forward-looking technologies are both approaches to countering the inherent unpredictability of such systems. Creating an educated, sociable society may be another (see page 346).

Unusually large oscillations in a society's activity levels may indicate that the society is near its homeostatic limits and at risk of disorganisation or reorganisation. Reducing current consumption to allow deliberate investment in (a) buffer stocks and (b) redundant pathways is a basic strategy for reducing that risk by, in effect, expanding the society's homeostatic limits. *Buffer stocks* of uncommitted capital (e.g. wheat stockpiles, American oil farms, stored vaccines) can be drawn down when supply chains are interrupted. Increasing resilience by investing in *redundancy* means building infrastructure which has spare capacity under normal operating conditions, e.g. power grids with alternative links and back-up generators; the Internet. Normal operating levels can then be maintained by calling on this spare capacity when other parts of the infrastructure complement fail or become unavailable in some way.

A brittle society is one where initial disturbances, rather than being buffered or diverted, spread rapidly, bringing widespread disorganisation. Such runaway change is more likely in societies where activities are connected in certain particular ways. For example, in strongly hierarchical societies where decisions flow down from a central authority, the inactivation or malfunction of the

[22] Fagan, B.M., 2008, *ibid*.

[23] Cocks, D., 2003, *Deep Futures*: *Our Prospects for Survival*, University of New South Wales Press and McGill University Press, Sydney.

[24] Walker, B.H., 2008, *Building Resilience*: *Embracing an Uncertain Future*, The Alfred Deakin Lectures, Deakin University.

society's control centre, or its few communication links, can disrupt activities at all lower levels in the hierarchy. Or, more generally, societies where activities are grouped into a relatively small number of tightly integrated sub-systems (hubs), each loosely linked to its neighbours, can be badly disrupted by disconnecting a single hub. In 2008, the global finance system proved to be such a hub in global society. Another source of brittleness is *long-chain dependency*, the situation where important activities can only be completed after a long chain of prior activities is first completed (see page 290), e.g. supplying component parts to the automobile industry. Breaking any link disrupts all links. Conversely, modular societies, those organised into a large number of small but relatively self-sufficient sub-systems, only loosely connected, are more likely to prove resilient, e.g. tribal societies.

Note, finally, that investing in resilience always has an *opportunity cost*, one involving a trade-off between (a) saving the system from possible future failure and (b) foregoing beneficial output (e.g. immediate gains in quality of life) from the system in the short term.

7. Marginal incrementalism
The political scientist C.E. Lindblom has argued that very few situations can be changed other than marginally in democratic societies and that a philosophy of 'muddling through' by making frequent small changes in the 'right' direction without particular reference to ultimate destinations is in fact an optimal strategy for managing society—not terribly effective but optimal.[25] Certainly better than deconstructing the system and having faith in 'market forces'. Recall that evolution works the same way. It must be accepted though that 'marginal incrementalism' is a slow business, not suited to tackling urgent problems such as global overshoot.

As part of 'muddling through', intermediate goals themselves need to be regularly revised, even as progress towards those goals is being monitored. As noted earlier (see page 284), many social problems are 'wicked' in not having any definitive formulation and it has to be accepted that ideas as to what is wanted from an intervention may well change as intervention proceeds. In the same vein, initial working goals should always be chosen from a sufficiently large pool of candidates (see page 135).

8. Avoiding gridlock
It was suggested earlier (see page 276) that human ecosystems which keep increasing in complexity as a consequence of processing more and more energy from the larger environment (e.g. an industrialising society) will, at some stage, begin to senesce or, metaphorically, to age. A senescent society is not necessarily brittle (subject to runaway change), but it will not be (as) resilient in face of large disturbances. Nor will it be (as) able to find ways of reorganising to improve quality of life significantly, e.g. Australia has great difficulty in changing its Constitution. These are the characteristics of a society entering *gridlock*, i.e. one

[25] Lindblom, C.E., 1965, *The Intelligence of Democracy*: *Decision Making through Mutual Adjustment*, Free Press, New York, Ch. 9.

where resources are increasingly unavailable for investing in either 'future-proofing' or progress. Causes can include the inertia of habitual behaviour, inertia from information overload and the self-interested locking-up of resources by elite virtual species, e.g. feudal estates.[26] As stock resources (e.g. accessible land) become scarcer in a growing society, existing activities have to be reduced to release resources for new activities. This may be difficult. *Pluralistic stagnation* (see page 239) is a form of gridlock found in mature societies where adversarial stakeholders with little concern for the public interest continually nullify each other's attempts to improve their lot—even when the collective benefits exceed the collective costs. Pluralistic stagnation, so common in the politically stable societies of the developed world, is an excellent example of the virtual-species problem to be discussed below (see page 344)

An increasingly senescent society can persist for generations in an unchallenging environment, but can the onset of senescence be delayed? Graeme Snooks argues that the rise and fall of societies is an outcome of their opportunistic development and exhaustion of the four dynamic strategies of family multiplication, conquest, commerce and technological change.[27] In the present context, these are strategies for delaying senescence; they expand the availability of resources perceived to be limiting or, in the case of technological change, using a resource more efficiently makes it less limiting. In our globalised overpopulated world it is technological change (the basis of economic growth) and trade which continue to be recognised—not explicitly as bulwarks against senescence, but as engines of 'progress'.

For societies which recognise and acknowledge that senescence and gridlock can happen, and which have the necessary cohesiveness and purpose, there exists a wealth of ideas that might be explored with the hope of delaying senescence. For example, societies can be kept simple by capping their energy use. This may confer the additional benefit of protecting long-term energy supplies. If an energy cap can be reduced slowly over time, it will allow the society to reorganise smoothly. And there are various ways in which the power of conservative elites to block adaptive change can be reduced, e.g. by strengthening democracy (see page 227).

While it is more difficult to coordinate strategic activities in a more modular society (e.g. one with strong local government), such organisation does allow resources to be reassigned, module by module, without challenging the society's overall resilience. For example, sunset legislation (e.g. regular elections) allows a module to 'die', in evolutionary terms, and to be 'reborn' without some of the shackles of previous arrangements. Given the implications for senescence, resilience, brittleness and adaptability, balancing devolution and centralisation will always be a challenge.

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[26] Olson, M., 1982, The Rise and Decline of Nations: Economic Growth, Stagflation and Social Rigidities, Yale University Press, New Haven.

[27] Snooks, G.D., 1996, *The Dynamic Society*: *Exploring the Sources of. Global Change*, Routledge, New York.

9. Encouraging cultural diversity
   A culturally diverse society is one which has a wide range of institutions and economic activities and a mixture of virtual species with a wide range of world views, occupations and lifestyles. For example, the coexistence of a broad range of political and religious opinions (John Rawls' 'reasonable pluralism'[28]) reflects diversity in a society's superstructure.

   A diverse society stands to be more brittle than a theocratic or simple tribal society (see page 340) but it is also more likely to generate policy ideas, not only for improving resilience, but, more proactively, for advancing mean quality of life. Just as genetic and trophic diversity allows biological systems (species, ecosystems) to survive and (pre)-adapt to change, ideas and recipes for implementing ideas are the raw materials of cultural evolution. It was suggested above that policy initiatives in complex societies be treated as experiments and that such need to be carefully designed to avoid unwelcome side-effects. It is around emergent ideas that such initiatives are constructed. If ideas are to emerge freely, it is particularly important that all individuals be supported (e.g. through the school system) in their efforts to develop their own individuality and, especially in a gridlocked society, helped to avoid being conformists. Radical ideas (e.g. questioning the value of prisons or of drug prohibitions) need to be properly debated, not dismissed.

   Let us pause here on the grounds that space does not permit a fuller presentation of the many principles and on-ground options that societies might benefit from keeping in mind as they tackle what-to-do problems in a complex unpredictable world. We turn now to our second suggested root cause of the Overshoot Crisis, namely, the difficulty that groups of all sizes have in working cooperatively towards mutually beneficial ends.

Some Guidelines for Coping with the Virtual-Species Problem

Recall that a (human) virtual species is a group of people who, mostly, interact cooperatively and who may sometimes have conflictual or competitive interactions with other virtual species (see page 204). The concept is basic to understanding inter-and intra-group relationships—from war and class struggle to street gangs and 'partisan mutual adjustment'[29] in liberal democracies. Here, we will focus more on the virtual-species problem as it appears at the scale of the international community, namely, the problem of improving cooperation and reducing conflict within the existing system of nation states. We have in mind, of course, the Interventionists' goal of securing international cooperation in response to the perception of a Global Overshoot Crisis.

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[28] Rawls, J.R., 1993, *Political Liberalism*, Columbia University Press, New York, p. 134.

[29] Lindblom, C.E., 1965, *ibid.*

1. Towards a world federation
   From an Ecohumanist perspective, there can be no permanent answer to the question of how world society should be organised politically. Inevitably, as times change, so do political solutions. Nevertheless, the guideline suggesting itself here is that now is an appropriate time for moving towards a *World Federation* in which nations can both cooperate and develop individually.[30] Federation is a well-tried form of political union. The version being suggested here, like the Australian federation, leaves all responsibilities not specifically covered in the articles of association, to the individual state.

   As noted earlier (see page 238), it is difficult to envisage any scenario where a World Federation arises outside the platform of the United Nations. Despite being undemocratically controlled by Security Council members and their vassals in their own short-term interests, such a transformation is not inconceivable. It would probably have to start with another charter-making conference—San Francisco Two. Progress may also have to wait on prior federations in Europe, Africa and Latin America. The magnitude of this task relative to the time that might be available before a contractionary bottleneck appears will seem unrealistic to many.

   Membership of the World Federation would be open to any state accepting the UN's Universal Declaration of Human Rights, a remarkable document. Secession from the Federation would require a people's referendum to protect against self-serving leaders. Indeed, the people might need to be represented directly, as well as through their states, if the World Federation is to be seen as legitimate. Procedures for suspending states breaking the Federation's laws would have to be established, as would procedures for disadvantaging free riders. The massive funding required to run a World Federation would probably come in part from taxes on all international transactions including trade, capital and communications and in part from taxes on resource use (e.g. fossil energy, land clearing) and pollution (e.g. carbon emissions). International companies might be taxed on some mix of their profits, assets and dividends.

   No state is going to act against its perceived national interest, so what would be the benefits of Federation membership? Given that the Federation's goal would be to seek quality survival there would be obvious immediate material benefits for disadvantaged third world countries pursuing modernisation. More broadly, the world's capacity to solve its trans-national problems (war, crime, pollution, trade, aid, migration, capital flows, espionage, terrorism, water flows, etc) would benefit from an enhanced sociality, stability and predictability in international relations.
2. War and conflict
   To take a specific example, how might the World Federation move to reduce the scourges of war and armed conflict, destined as these are to worsen if the reference

[30] Polanyi, K., 1944|2001, The Great Transformation: The Political and Economic Origins of our Time, Beacon Press, Boston.

scenario eventuates? There may be 'just' wars but, given a goal of quality survival, the costs of war mostly outweigh any possible gains.

Let me start with a bright idea. Hazel Henderson includes a United Nations Security Insurance Agency in a list of desirable new global institutions.[31] Nations could buy insurance against potential aggression with premiums being used to fund peacekeeping and conflict-resolution contingents. Perhaps, to further boost the fund, those major powers that are heavily involved in arms sales and nuclear proliferation should be taxed on these activities. Other ideas with further potential to ameliorate the horrors of war include the International Criminal Court, disarmament negotiations and weapons conventions (e.g. banning anti-personnel mines). Community and international peace organisations should be given every encouragement. The prevention of war is a responsibility the world has to keep nibbling at on diverse fronts. The overarching guideline for preventing war and conflict is that the world, whether federated or not, should be run as a participatory and pluralist democracy.

But what happens when conflict does appear? Traditional international relations models (e.g. Morgenthau and Thompson, 1985[32]) assume conflict (having incompatible goals) inevitably turns to war unless constrained by deterrence, i.e. the threat of deadly retaliation. Given the prevalence of war, it has to be assumed that deterrence is not applied sufficiently or that the theory is wrong and deterrence does not deter, e.g. Korea, Vietnam. The non-traditional view, my preference, is that inter-group conflicts can frequently be resolved without (further) deadly violence if the underlying frustrated needs of the conflicting virtual species can be teased out, through dialogue and if the parties then jointly search for political solutions satisfying both sets of needs.

Having said that, resource-based conflicts which are being driven by population growth do seem depressingly intractable. The conflict-resolution approach has some successes to its credit but, once spear–rattling, demonization, historical revisionism and counter-accusations have commenced, conflicting parties find it difficult to come together in this way. A period of violence seems, almost, to be first necessary. It may be that conflict-resolution methods will have to prove themselves at the domestic and community level (as is happening) before being accepted for use in international and 'tribal' conflicts. Nonetheless, conflict-resolution conferencing and dialoguing, conducted in secret, should be offered to all parties in actual or potential war situations.[33] The importance to a people of just having their group identity recognised by others cannot be over-emphasised.

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[31] Henderson, H., 1998, Economics and Evolution: An Ethos for an Action Researcher, in Loye D (Ed) *The Evolutionary Outrider: The Impact of the Human Agent on Evolution*, Praeger, New York, pp. 215–232.

[32] Morgenthau, H., and Thompson, K.W., 1985, *Politics Among Nations: The Struggle for Power and Peace*, 6th edn, McGraw Hill, New York.

[33] Burton, J.W.,1996, *Conflict Resolution: Its Language and Processes*, Scarecrow, London.

3. Educating for sociality
   Besides improving the political institutions and processes through which extant virtual species interact, there is a second broad approach to ameliorating the virtual-species problem. It is socio-psychological and centres on attempting to bring about widespread changes in people's attitudes towards others. Specifically, this is a strategy to develop societies in which *sociality* is high, i.e. where amicable relations between people predominate. In such societies, attitudes are *fraternal* or *sisterly*, meaning that people tend to regard others, even strangers, as their metaphorical brothers and sisters. Sociality is more than sociability. It implies social relationships marked by the expression of such behaviours as nurturing, fellowship, goodwill, empathy, altruism, love, affection, concern, trust, agape, civility, collaboration, helpfulness, togetherness, belongingness, inclusiveness, mutualism, cohesion, loyalty and solidarity. Sociality can be contrasted with *sociopathy*, a set of attitudes under which most people tend to regard others as enemies to be mistrusted and exploited. Tribalism, territoriality and hostility-indifference to others characterise sociopathy.

   Sociality is important for two reasons. In a society where sociality is the norm, many of the individual's higher needs which have to be met if a quality life is to be achieved will, to some extent, be automatically satisfied, including the needs for safety, security, belongingness and affection, esteem, respect and self-respect. The second importance of sociality is that it is indicative of a cooperative society, meaning one in which people easily and readily come together to exploit the synergies of collective action (see pages 204, 285). More than that, a civilised society which has learned the benefits of amicable relations amongst its own interest groups will be open to extending these local attitudes to relations with other societies.

   At this point, the practical question is whether sociality can be taught and learned. Both sociality and sociopathy have their roots in the behaviour of our hunter-gatherer forebears who evolved instinctive and useful appetencies for cooperation within the group and for hostility towards outsiders (see page 204). It needs to be recognised that both appetencies still exist even though, apart from a limited role in stimulating social criticism and as an indicator of unmet needs, sociopathy has no apparent function in a complex society. Human behaviour is very malleable and children can be brought up to hate or to be fraternal-sisterly and cooperative. For example, children in lightly supervised playgroups teach each other cooperation. Such socialisation is easy in a society which is already fraternal-sisterly simply because most behaviour is imitative. People treat each other much as they themselves have been treated. However, under conditions of stress, insecurity, crisis and declining expectations, sociality tends to be replaced by sociopathy. Along with meliorating those imposts, as part of restoring people's quality-of-life prospects, sociality has to be actively nurtured by teaching and example.

   Experiential learning is one social technology with an important role to play in blurring the boundaries between virtual species. Children and young adults who are helped to spend time living outside their own societies (e.g. studying abroad) are more likely to recognise the essential similarity of peoples from different cultures. Familiarity breeds acceptance and, in conflict situations, perhaps empathy and respect for the other's position. By the same token, given the importance to sociality of being able to trust that one is not being deceived, educating people to understand and detect deceit would also seem to be a guideline for building or rebuilding sociality (see page 271).

4. Constraining elites
   History shows, in almost every society, that once elite groups have obtained control of energy surpluses and the social and economic privileges these support, they are loath to return to a society offering a more equitable distribution of life opportunities (see pages 285, 204). And to the extent that the majority accept this order of things there is no 'virtual-species problem'. In modern democratic societies, persuasion, not coercion, is the instrument that elites use to maintain their position. This is done by controlling the institutions which reproduce the thought patterns of the state, namely, the education system, the media, the churches and government itself.

   To the extent that the majority are unhappily conscious of this imbalance, political democracy remains their most promising social technology for achieving change. What they need to first realise is that democracy itself is a generic instrument which can be used to support the search for and adoption of diverse social technologies which further improve democracy as a change instrument, e.g. through the elimination of privilege, the management of populism.

   The body of social technologies which may have a part to play in reducing the uncertainties caused by complexity and pervasive disagreement has only been touched on here. Also, it would be quite wrong to suggest that those mentioned are uniquely the products of an Ecohumanist perspective. The point remains though that this perspective is a promising source of ideas for overcoming the root problems that impede attempts to address the more proximate causes of global overshoot. We move on to asking if Ecohumanism's story of the origins of global overshoot offers appropriate emotional inspiration to a global society facing the possibility of massive disorganisation.

But Is It Emotionally Satisfying?

In this chapter, I have so far argued that Ecohumanism—a mixture of a story, a philosophy and a belief system—is a doctrine which people may find useful for rationally understanding how and why the human ecosystem has changed historically, is changing now and might presently change. Also, the chapter is intended to illustrate that Ecohumanism contains sufficient ideas to spawn guidelines for better managing the processes that are driving changes in global quality of life.

But, beyond these virtues—praxis and factual understanding—we now ask if people will be *emotionally* inclined to accept Ecohumanism as a platform from which to contemplate the possibility of global overshoot. More specifically, does the Ecohumanist's *Story of Global Overshoot* have qualities which are more rather than less likely to evoke positive emotional reactions in those exposed to it? This is important. Recall (see page 85) that it is (only) ideas carrying a positive emotional tag which gets accepted as input into decision-making processes. For example, is Ecohumanism likely to appeal to post-modern people, attuned to making their way in an individualistic marketised society? Can one be an Ecohumanist while remaining loyal to one's ethnic, political, national, ideological, religious, etc., virtual species? Will a fear that global society is about to be overwhelmed by multiple problems prompt people to look beyond their existing belief systems?

While people cannot be reasoned into switching from one belief system to another, and encouraging that is not my intention, I will recapitulate some elements of Ecohumanism which I believe are more likely, on balance, to evoke positive rather than negative emotions:

To start, Ecohumanism is a narrative for all humanity. No one is excluded. It emphasises that we are all members of one species, the product of one continuous evolutionary process extending back to the beginning of the universe.[34] Science has demonstrated that physiognomic and physiological differences between peoples rest on minor genetic differences. From there, it is a small step to accepting that strangers have minds like one's own and, notwithstanding cultural differences, needs like one's own. Strangers lose their strangeness. For many people, once this common biological inheritance is accepted, the inherent concern they have for the wellbeing of their immediate relatives expands to embrace the species as a whole; and that is the humanist perspective.

Ecohumanism recognises that any group of people living in a particular place for generations will evolve a place-specific culture which helps the group to persist; and that if the group is transplanted it will, to a greater or lesser extent, take its culture with it. Notwithstanding, when its environment changes, a culture can only evolve at a rate which does not destroy its overall coherence. Recognising the origins of cultural differences does not automatically preclude conflict and tension when cultures intermingle. But it may help. That is, knowledge offers an alternative to knee-jerk hostility.

Ecohumanism finds no need for a belief in the supernatural. Much that puzzled our pre-Enlightenment forebears can now be explained scientifically, while remaining puzzles such as biogenesis and the pre-universe are being slowly clarified. Religious beliefs in interventionist gods are best viewed as elaborations of the primitive animistic belief that everything is alive (see page 117). Such religions are social technologies which, *inter alia*, help people satisfy their need for meaning, for a model of the world. While Ecohumanism is not a religion, it is a 'spiritual' doctrine in the sense that understanding how the world and its people evolved is a precursor to feeling 'at home in the universe' and 'at home with humanity'.

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[34] Christian, D., 2003, World History in Context, *Journal of World History*, 14(4), pp. 437–458.

Ecohumanism offers the individual the existential challenge of being responsible for their own morality. Viewed as a moral philosophy, Ecohumanism suggests *quality survival* as an overarching goal for global society and hence as a broad criterion for guiding social and individual choices. Beyond that broad criterion, Ecohumanism is situational and pragmatic rather than prescriptive. For example, faced with multiple candidate interventions for addressing Global Overshoot, the Ecohumanist does his or her intuitive, aesthetic best to choose the one offering most in quality survival terms. In interpersonal relations, the ethic which flows naturally from the Ecohumanist perspective is present already, in one way or another, in all the world's major religions, both theistic (e.g. Islam, Judaism, Christianity) and non-theistic(e.g. Buddhism, Confucianism, Taoism). Because every person's quality of life is equally important, and every person has an equal right to happiness, humans must take loving responsibility for the wellbeing of others.[35] The 'golden rule' or 'ethic of reciprocity' against which one's actions can be checked has been expressed in startlingly similar terms in a score of religions.[36] While Ecohumanism has no place for mythical and supernatural figures, it recognises educational and inspirational value in the stories of great human beings such as Mohandas Gandhi, Nelson Mandela, William Wilberforce and Paul Robeson. While Ecohumanism is not an optimistic doctrine *per se*, it recognises that optimistic individuals are often more successful than pessimists in finding solutions to problems.

Ecohumanism is an expanding and adaptive doctrine, not rigid. It is built around a revelatory and ever-richer story of an evolving cosmos. In the spirit of science, all its 'truths' are provisional and open to question. Notwithstanding, the authority of those 'truths' is strengthened by both their long intellectual history and a knowledge of their bio-physical evolutionary history.[37] Inescapably though, it takes curiosity, time, effort and opportunity to become eco-aware.

Ecohumanism is an honest doctrine, unbeholden to the interests of any particular virtual species. It tries to listen to and understand all points of view. It does not pretend to knowledge or authority it does not have. But it gives no credence to implausible hopes such as life after death or, indeed, implausible threats such as judgement day and eternal Hell.

Nevertheless, Ecohumanism recognises that fear of the future, particularly death, is a powerful, universal emotion and identifies insights which might help people accept their fear and not be paralysed by it. As Rilke's Duino Elegy muses (see Preface), it is knowledge of death that makes life so precious. As individuals and as a species, we have emerged from a cosmic process and will be reabsorbed by it. Without the metaphorical 'deaths' of anti-matter and exploding 'furnace' stars, there would be no Planet Earth today. Without the deaths of innumerable plants in the Carboniferous era, there would be no oil to energise global society. In the economy,

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[35] Clark, M.E., 2002, *In Search of Human Nature*, Routledge, London, p. 298.

[36] http://www.religioustolerance.org/reciproc.htm (Accessed 31 Oct 2009).

[37] Williams, B., 2006, *Philosophy as a Humanistic Discipline*, (A.W. Moore Ed.) Princeton UP, Princeton.

it is the deaths of old enterprises which unlock resources for the creation of new enterprises. In a finite world, it is human death which allows cultures and genomes to evolve. In general, death can be seen as a creative 'technology' which makes evolution—the selective retention of variation—possible.

Ecohumanism is non-judgemental. A simple but rich way of looking at people is to see them, whether by virtual species or individually, as rational agents, busily devising new technologies and applying received technologies (material, social, cognitive, communicative) to the end of meeting a spectrum of needs. People make their rational choices from sets of possibilities which are constrained in numerous ways, including being constrained by their values, their present technologies, their beliefs and their cognitive skills (see pages 162, 119). It is commonplace, but usually unproductive, to judge past behaviours from contemporary perspectives, e.g. as noble, altruistic, immoral, stupid, short-sighted, etc.[38] Indeed, I am inclined to accept the argument of Jaynes and others that humans, prior to the first millennium BCE, did not experience consciousness as we understand it (see page 154).

Ecohumanism has few illusions about the status of *Homo sapiens*. It should not need saying, but, given our appetency for self-deception, we may need to remind ourselves that we are not lords of the universe, destined for endless progress. Nor are we participants in some Manichean drama, fighting to secure the ultimate victory of good over evil. At this stage in our history we are more like impulsive adolescents, with limited foresight and self-discipline; notwithstanding, we are unlikely to wipe ourselves out yet awhile. We have been lucky in two important ways. One is with pre-adaptations, particularly the adaptations we brought with us when moving from a forest habitat to a savanna habitat (see page 134). The other is that while the environment is always changing and threatening extinction, it has never changed fast enough to overwhelm our capacity to adapt. I have found the metaphor of the species as an individual slowly learning to make the best of the finite life he or she has been granted, to be one which many people regard as illuminating and satisfying.

Tamam Shud: It Is Finished

This book started with a perception that, in terms of people's quality-of-life prospects, the future of global society has become much more uncertain in recent years. While the data which might show average quality of life to be falling is inconclusive, the world is certainly being impacted by a number of accumulative processes which, considered jointly, give a degree of plausibility to a *Global Overshoot* scenario, meaning a scenario in which global quality of life falls dramatically in

[38] Yardley, J., 2008, Review in *Washington Post* (16 Mar) of Wood, G.S., 2008, *The Purpose of the Past: Reflections on the Uses of History*, Penguin, New York.

coming decades. This 'dark age' scenario, dégringolade, became the proposition around which I postulated three alternative perceptions of global overshoot processes and what should be done about them, viz.:

Not plausible at this time, not to the point of requiring pre-emptive action (Empiricists).
Plausible if ignored, but likely to be managed to the point of having a low impact on global quality of life (Immediate Interventionists).
Plausible, but unmanageable in any comprehensive way; better to focus on post-bottleneck recovery measures (Reconstructionists).

So, based on this span of reactions to the reference scenario, we have an emerging Global Overshoot Crisis which could have severe or mild or even insignificant consequences. My own working hypothesis, a provisional diagnosis perhaps, but increasingly supported as I have conceptualised and filled out my understanding of the deep origins of this Crisis, is that, for good reasons, something like the reference scenario will play out in coming decades.

Let me recapitulate those reasons. Humans, endowed as they are with a talent for technological innovation, have created a highly connected global society, a dissipative system which requires massive and increasing quantities of exogenous energy, and other inputs, to maintain it and to support its ongoing complexification. Should the normal operations of this system change rapidly (over several decades, say) and extensively, many people's lives will be disrupted and global quality of life may, likewise, fall rapidly.

In particular, if the four juggernaut processes I have nominated do not slow of their own accord, or are not mitigated in some way, they stand, singly and interactively, to trigger waves of rapid reorganisation in global society. Simple ecosystemic reasoning is enough to produce plausible scenarios of how population growth, resource depletion, global warming and linkage proliferation might overwhelm global society's capacity to absorb change without disintegrating (see page 289). Conversely, I cannot find plausible scenarios which suggest that these proximate causes of the Global Overshoot Crisis might slow of their own accord (e.g. through value shifts) in coming decades or how they might be defused by purposive human action on a sufficiently large scale.

Why not? Didn't the Interventionist response to the reference scenario (see page 304) envisage a range of measures that global society could take to ameliorate/adapt to the proximate causes of the Crisis? Some such have already been implemented, albeit in a limited and piecemeal way, by governments and other virtual species. But, like the Reconstructionists, I see little evidence that global society has the cognitive ability or the knowledge base to devise promising solutions to such large what-to-do problems or to forge the required cooperation between the world's virtual species, particularly its nation states. I suggest that these two problems, managing cooperation and complexity, be viewed as root causes of the Crisis in that they are stopping its proximate causes from being successfully addressed—just as both are partly responsible for the development of those problematic trends in the first place.

This is an important conclusion. The implication for Interventionists is that developing social and other technologies for managing cooperation and complexity is at least as important as developing material and social technologies for slowing or reversing the momentous trends threatening global quality of life and, in the long term, quality survival. And Reconstructionists too need to be aware that unless humans can make considerable progress here, the post-bottleneck world they think we should be preparing for will once again begin creeping towards the next Overshoot Crisis.

Here then is my framework for thinking about the world's converging problems—a jostling set of hard-to-manage processes and lurking meta-problems which are threatening global society with massive disorganisation in coming decades. I recognise 'Wait-and-see' Empiricism, 'Noah's Ark' Reconstructionism and 'Stop fiddling' Interventionism as three 'not unreasonable' what-to-do responses to the suggestion of a dystopic future. While my own inclination is towards Reconstructionism, I do not think it can be argued that one of these is 'right' and the others 'wrong'.

However, while I find myself unable to recommend any step-by-step programme for confronting the Overshoot threat, I am keen to see the global community continuing to search for and experiment with ways of avoiding a sharp drop in average quality of life[39]; or preparing for recovery from any such drop. Also, if Empiricists are not concerned as yet about falling quality of life, they always have the constructive (cf. defensive) option of working to raise global quality of life above current levels.

While this book has nothing to offer those who hate or those who have found the truth, the tool it is offering people of goodwill who want to think constructively about the world's converging problems is Ecohumanism, packaging it, metaphorically, as 'lodestar with travel-guide'.

Ecohumanism is a lodestar, a 'light on the hill', in that it offers a reference point against which ongoing what-to-do decisions and choices can be checked, i.e. for which present and future groups, what are the quality of life implications of this choice?

When you arrive in a strange country, having a travel-guide allows you to understand what is happening around you, at various time-space scales, and how what you are seeing got to be the way it is. It describes how the locals customarily behave and think. It suggests what-to-do activities, along with places to perhaps avoid. In more general terms, a good travel-guide primes your imagination with enough ideas to flesh out your mental model for an itinerary and, as required, provide a string of intuitively generated what-to-do suggestions.

The Ecohumanist's 'travel-guide' to the 'strange country' which is the Global Overshoot Crisis is, similarly, suggestive-but-not-prescriptive. The story of this Crisis is the story of the human ecosystem, interpreted here as the working out of complex evolutionary and ecological processes going back to the beginning of the

[39] For example, Buzaglo, J., Global Commons and Common Sense, *Real-world Economics Review,* No. 51 (http://www.paecon.net/PAEReview/issue51/Buzaglo51.pdf (Accessed 2 Dec 2009)).

universe. Ecohumanism suggests that this story can contribute to humanity's short-term quality of life prospects and long-term-quality survival prospects in a variety of ways. At the risk of underplaying others, let me finish by recapitulating several of these contributions that I consider to be particularly important:

Ecohumanism provides a way of talking and thinking about the origins and tractability of the world's converging problems. It offers some hope that while we are confronted with problems we don't as yet know how to solve, we will, barring overwhelming setbacks, continue to mature in our ability to provide ever-more people, now and into the indefinite future with the opportunity to lead satisfying lives. But progress could be intermittent and glacially slow. For the Ecohumanist, it is Eco-awareness, the coherent exposition of evolutionary and ecological relationships, which gives meaning to the world, i.e. confers a feeling of knowing what is happening, what has been happening and why things are the way they are.

Ecohumanism recognises that there is an inescapable need for intuitive judgement in the management of complex systems. To this end, it yields insights and guidelines for improving such judgements, e.g. guidelines for better managing the proximate and root causes of the Global Overshoot Crisis. At very least, these become opening theses for dialectic discussion.

Ecohumanism stands to strengthen and expand people's feelings of belonging to one human family; and their sense of identity—what it means to be human and a human. As individuals and as a species, humans are going through life cycles. We have evolved to a level of consciousness and understanding which can recognise that while life may be short or long, fulfilling or cruel, there is much that we can do to make it better than it would otherwise be, for ourselves and for others.

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