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The Welfare of Pigs

Edited by

Jeremy N. Marchant-Forde

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The Welfare of Pigs

Animal Welfare

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The Welfare of Pigs

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Animal Welfare Series Preface

Animal welfare is attracting increasing interest worldwide, especially in developed countries where the knowledge and resources are available to provide better management systems for farm animals, as well as companion, zoo and laboratory animals. The key requirements for adequate food, water, a suitable environment, companionship and health are important for animals kept for all of these purposes.

There has been increased attention given to farm animal welfare in the West in recent years. This derives largely from the fact that the relentless pursuit of financial reward and efficiency, to satisfy market demands, has led to the development of intensive animal production systems that challenge the conscience of many consumers in those countries.

In developing countries, human survival is still a daily uncertainty, so that provision for animal welfare has to be balanced against human welfare. Animal welfare is usually a priority only if it supports the output of the animal, be it food, work, clothing, sport or companionship. In principle the welfare needs of both humans and animals can be provided for, in both developing and developed countries, if resources are properly husbanded. In reality, however, the inequitable division of the world's riches creates physical and psychological poverty for humans and animals alike in many parts of the world. Livestock are the world's biggest land users (FAO, 2002) and the farmed animal population is increasing rapidly to meet the needs of an expanding human population. This results in a tendency to allocate fewer resources to each animal and to value individual animals less, particularly in the case of farmed pigs where herds of several thousand are not uncommon. In these circumstances, the importance of each individual's welfare is diminished.

Increased attention to welfare issues is just as evident for companion, laboratory, wild and zoo animals. Of increasing importance is the ethical management of breeding programmes, since genetic manipulation is more feasible, but there is less public tolerance of the deliberate breeding of animals with genetic abnormalities. However, the quest for producing novel genotypes has fascinated breeders for centuries. Dog and cat breeders have produced a variety of extreme forms with adverse effects on their welfare, but nowadays the quest is pursued in the laboratory, where the mouse is genetically manipulated with equally profound effects.

The intimate connection between animals and humans that was once so essential in some spheres is rare nowadays, having been superseded by technologically efficient production systems where animals on farms and in laboratories are tended by increasingly few humans in the drive to enhance labour efficiency. With today's busy lifestyle, companion animals too may suffer from reduced contact with humans, although their value in providing companionship, particularly for certain groups such as the elderly, is increasingly recognised. Consumers also rarely have any contact with the animals that produce their food.

In this estranged, efficient world, people struggle to find the moral imperatives to determine the level of welfare that they should afford to animals within their charge. Some, in particular many companion animal owners, aim for what they believe to be the highest levels of welfare provision, while others, deliberately or through ignorance, keep animals in impoverished conditions where their health and wellbeing can be extremely poor. Today's multiplicity of moral codes for animal care and use are derived from a broad range of cultural influences, including media reports of animal abuse, guidelines on ethical consumption and campaigning and lobbying groups.

This series has been designed to help contribute towards a culture of respect for animals and their welfare by producing academic texts discussing the provision for the welfare of the major animal species that are managed and cared for by humans. They are not detailed blue-prints for the management of each species, rather they describe and consider the major welfare concerns, often in relation to the wild progenitors of the managed animals. Welfare is considered in relation to the animal's needs, concentrating on nutrition, behaviour, reproduction and the physical and social environment. Economic effects of animal welfare provision are also considered where relevant, as are key areas where further research is required.

In this volume one of the world's leading scientists in the field of pig welfare science, Dr. Jeremy Marchant-Forde, has brought together many experts in the field of pig science. Dr. Marchant-Forde has been one of the most active researchers in pig welfare worldwide in recent years, at Cambridge and De Montfort Universities in the United Kingdom and most recently with the U.S. Department of Agriculture – Agricultural Research Service in the United States.

With the growing pace of knowledge in this new area of research, it is hoped that this series will provide a timely and much-needed set of texts for researchers, lecturers, practitioners, and students. My thanks are particularly due to the publishers for their support, and to the authors and editors for their hard work in producing the texts on time and in good order.

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Acknowledgements

Editing or writing a book is not a task that should be taken lightly – I understand that now! The biggest problem is that the writing of a book chapter, though nice to be asked to do, falls below writing grant proposals, writing refereed journal articles, and carrying out research and teaching in the priority list. Firstly, therefore I am very grateful to those chapter authors who did contribute to this volume – I sincerely hope that the wait was worthwhile. I would also like to thank the publishers and Prof. Clive Phillips, the series editor-in-chief, for their patience and help as the book evolved into its final form. My current supervisor, Dr. Don Lay, Jr., USDA-ARS, has played an important part in the finalization of this book. I have been very appreciative of the support and time that he has given me to complete this project. Throughout my career, I have been very fortunate in working with, and interacting with, many excellent scientists from all over the world. The field of applied ethology is truly welcoming, nurturing and challenging and I will forever be grateful to Prof. Don Broom for giving me the first opportunity to dip my toes into research in such an influential group as the one that he has led for so long at the University of Cambridge.

Finally, I have to thank Ruth, Millie and Harry Marchant-Forde. The love and support that you show me is the best thing in my life and I dedicate this book to you.

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Chapter 1
Introduction to the Welfare of Pigs

Jeremy N. Marchant-Forde

The domestic pig is an enigma. It is an animal of contradictions which gives rise to equally strong positive and negative feelings. Many perceive the pig as an intelligent creature, yet it is reviled by a third of the world's population on religious grounds, who consider the pig unclean and not fit for human consumption. There is, however, no doubt that where the pig is reared and farmed, it has a special place in the animal hierarchy and is perhaps seen differently to other domestic farm animal species such as the cow and sheep. For whatever reason, the pig is viewed with respect and even affection and its place in popular culture is assured. The pig has been portrayed as a hero in Babe (King Smith, 1984) and a tyrant in Animal Farm (Orwell, 1945). In short, the pig is often assigned human personality and intelligence without hesitation. Sir Winston Churchill is credited with the quote "I like pigs. Dogs look up to us. Cats look down on us. Pigs treat us as equals". And yet, over forty years after Churchill's death, pigs in many of the farming industries of the world are housed in systems that give rise to welfare concerns.

Pig farming in the developed world is one of the most intensive of all livestock production systems. Animals are kept in large buildings, with a high degree of automation to supply feed, water, heat and ventilation and to remove waste. Intensification has been a commercial success because it has reduced costs of production, by reducing feed costs, reducing labour costs and improving disease control. However, intensification has been in response to, and reinforced by, consumer pressure for a cheaper product. It is ironic, therefore, to now find that it is the consumer that is questioning intensification and its effect on the welfare of pigs. All aspects of pig production are attracting welfare concerns – breeding herd housing, slaughter herd housing, transport and slaughter – and in terms of housing, the major concerns are associated with close confinement and housing in barren environments. Concern is perhaps heightened because of the public's perception that pigs are intelligent and should be kept in an environment that provides at least some stimulation.

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Historically, pigs have been kept on a small-scale (Malcolmson and Mastoris, 1998). In rural areas the world over, and even within urban settings, individual families would rear a few pigs to supplement their diet, in effect "recycling" waste food by feeding it to the pig. During the course of the last century, change has swept throughout the agricultural industry and the ever-increasing scales of commercial livestock operations influenced by advances in mechanization and economic pressure have changed the way our animals are kept. At the individual family level, at least within the developed world, meat is now readily available in supermarkets and relatively cheap. There is tightening legislation regarding feeding, transport, slaughter and meat hygiene, which can essentially make small-scale production unfeasible. Rural dwelling is no longer tied to rural working and the population has become several steps detached from food production. Thus, pig keeping is no longer familiar and the vast majority of the population has little idea how pigs are now reared, slaughtered and processed.

Over the last few years, the world-wide production and consumption of pigmeat has risen (USDA-FAS, 2008), as the global population has increased and income has grown in places like Asia and Latin America. However, as demand for pigmeat grows, there will be significant changes in where the extra production is carried out, and the traditional "powerhouses" of the developed western world could well see their overall production fall, as technology spreads into Asia, Latin America and the former Eastern Block, where reduced production costs will give advantages in the world economic market. The trend for fewer, larger units is continuing worldwide and the large-scale commercial production practices common within the western world are having profound societal effects linked to the need to maintain minimal disease herds. In many instances, local family pig rearing has been stopped near new large commercial farms, which, in poorer countries, disenfranchises the local population. Where pigs are kept in large quantities, manure or slurry storage and disposal also becomes as issue, with both groundwater and aerial pollution concerns well documented.

Thus, the global intensification of pig farming raises not only animal well-being issues, but also human welfare and environmental issues, which themselves may directly or indirectly impact animal welfare – both of pigs, but also other domesticated species and wildlife. Although the human welfare, non-pig welfare and environmental issues are outside the scope of this book, readers should be aware of them. It is all too easy to judge intensive farming practices, when we consider only the welfare of animals within a given system. We have to consider the bigger picture and balance the positive and negative aspects that intensive agriculture has on our society as a whole, before reaching a decision about overall acceptability of a given husbandry practice. The various impacts of a husbandry practice on animal welfare, human welfare and the environment may be fairly indisputable as points on a scale of measurement, but a person's interpretation of whether these points are acceptable or unacceptable will vary according to their personal moral considerations or indeed, and perhaps unfortunately, their financial position. Safeguarding animal welfare in poorer countries may well be an unaffordable luxury.

1.1 Welfare as a Concept

What do we mean when we talk about an animal's "welfare"? The definition of welfare has been, and still is being, widely argued. One concept is that welfare is to do with the extent to which an animal can behave naturally – i.e. "in order to avoid suffering, it is necessary over a period of time for the animal to perform all the behaviours in its repertoire because it is all functional" (Kiley-Worthington, 1989). Certainly, in order to assess welfare within farming systems, we need knowledge of how animals behave within natural environments. This allows us to determine what behaviours performed within housing systems are thwarted and what behaviours are "abnormal". However, it is perhaps simplistic to assume that just because behaviours are performed in a natural environment, the inability to perform them within a housing system then compromises welfare. It is entirely possible that certain behaviours are only performed in natural environments at moments when the animal is severely challenged – e.g. anti-predator behaviours – and thus, systems that remove the need for these types of behaviours to be performed are by Kiley-Worthington's definition, compromising the animal's welfare, whereas most observers would contend the opposite. The natural behavioural repertoire of the pig will be covered in detail in Chapter 2.

Another school of thought is that the concept of welfare exists as a state that has to be quantifiable, by an amalgam of measures – i.e "the welfare of an individual is its state as regards its attempts to cope with its environment" (Broom, 1986). This school of thought relies heavily on the theory that welfare is primarily concerned with an animal's adaptive response to stress and the potential impact that this has on biological functioning. In response to acute or chronic stress, an animal may alter its behaviour and may adjust its physiological functioning in order to cope with that stress. These changes are directly measurable and can be interpreted to yield information about the animal's welfare. Thirdly, there is the concept that welfare is all about the animal's emotional state and whether it is suffering, i.e. "welfare is dependent on what animals feel" (Duncan, 1993). Animal suffering is extremely difficult to address but remains central to the concept of animal welfare for many scientists and is possibly the most important factor when the general public form opinions about farming systems. Historically, these two approaches have been relatively distinct, but over recent years, there has perhaps been movement towards a "merging" of concepts, particularly as scientific advances in the areas of neuroscience (e.g. Phan et al., 2002), psychophysiology (e.g. Lang et al., 2000) and testing of behavioural needs begin to demonstrate that perhaps the measurement or quantification of emotional states can be attainable. Some of these areas of research will be addressed further in Chapter 3. Webster (1995) has essentially attempted to merge these last two schools of thought with his definition that "the welfare of an animal is determined by its capacity to avoid suffering and sustain fitness".

There is no doubt that the arguments over the definition of welfare will continue, as researchers will all have a personal point of view as to what should be included in a definition. However, what can perhaps be agreed upon is the fact that at any given time, an animal's welfare ranges on a scale from very good to very poor (see Fig. 1.1). It contains both physical and mental elements. The physical elements, such as behaviour, physiology, health, productivity and pathology, can be measured relatively easily but the mental elements, i.e. emotional state, remain much harder to quantify. We may be able to attempt to quantify an individual's welfare as long as physical elements are present, but it may be argued that mental welfare in humans can be poor without any obvious physical signs, e.g. in certain types of depression. If this can be paralleled in animals, it would be extremely difficult using present techniques to quantify the welfare of those affected.

At the present time, welfare scientists are perhaps being diverted by the arguments over precise definitions, rather than addressing specific welfare issues. Certainly there is an element of trying to identify "welfare catch-alls", i.e. measures that can be universally applied to quantify and improve animal welfare in many different species and situations. This is probably unrealistic and welfare scientists have been guilty in the past of applying assessment methods, which have been developed for a single species in a given situation, somewhat haphazardly and without validation, thus leaving results open to misinterpretation. There is also no doubt that the measurement of welfare requires greater understanding of animals' cognitive processes and how they perceive their world and a greater understanding of the biological significance of many of the measures currently used. Further refinement of techniques, both in terms of improving current methods of behavioural, physiological, immunological and pathological measurement and the development and validation of new measures, may ultimately enable us to determine an animal's mental state and so be able to really quantify an animal's welfare to the satisfaction of most people – scientists and general public.

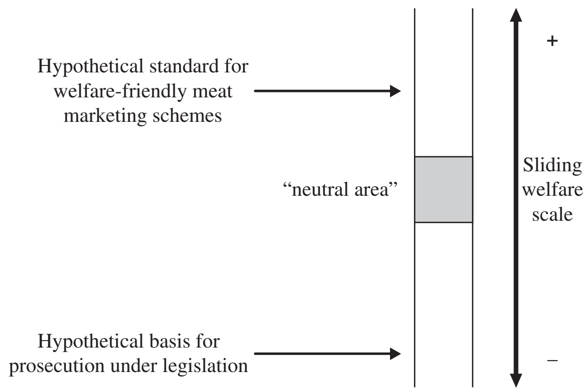

Fig. 1.1 Diagrammatic representation of a sliding scale of welfare quantification
After: Ewbank (1988)

Notwithstanding this current debate, the tools currently possessed have to be used in order to draw some conclusions about the welfare of pigs in a given situation. The conclusions that are drawn have been used formally in the drafting and implementation of legislation, such as that seen within the European Union regarding gestation crates for sows and other pig welfare issues (Council Directive 2001/88/EC and Commission Directive 2001/93/EC). Or, they have also been used to formulate guidelines for industry to adhere to – either drawn up by industry bodies themselves (e.g. Assured British Pigs (ABP, 2008)), niche marketing schemes (e.g. the RSPCA's Freedom Food Scheme (RSPCA, 2008)) or retailers, be they supermarkets (e.g. Tesco Codes of Practice (Tesco, 2008)) or global restaurant chains (e.g. McDonald's Animal Welfare Guiding Principles (McDonald's, 2001)). The demand for on-farm welfare auditing has increased greatly over the last few years and is set to continue expanding globally, which will be discussed further in Chapters 9 and 10.

The method of welfare assessment that has been widely used so far is that of systems evaluation, using a multidisciplinary approach. Legislative bodies generally look for quantification of welfare of populations of pigs kept in a given type of system, in comparison with populations of pigs kept in other systems. This may sound fairly straightforward, but in reality, this approach carries inherent difficulties. Firstly, it tends to make the assumption that all animals in a given system are doing equally well or equally badly, in welfare terms – i.e. it does not easily allow for variation that occurs between individuals within a given system. Secondly, it means that a value judgment has to be taken on the relative merits of specific welfare parameters – i.e. certain measures, for example freedom to express normal behaviour, may be "ranked" as more important than other measures, for example parasite burden – the decision being made on what we perceive as more important rather than what the animal may perceive as more important.

These problems do not necessarily mean that the approach is flawed, but they do mean that caution has to be taken and judgments made have to be based on sound science, wherever possible, rather than anthropomorphic reasoning. Figure 1.2 can perhaps illustrate the problems of the systems-assessment approach. As the overall welfare status exists as a sliding scale, we can conceptualize that individual welfare measures likewise exist on sliding scales, ranging from very good to very poor. A multidisciplinary approach to assess sow welfare within two different hypothetical gestation systems might include measures of behaviour (e.g. amount of aggression and time spent performing stereotypic behaviour), physiology (e.g. plasma cortisol concentrations), health status (e.g. lameness incidence), pathology (e.g. bone strength) and productivity (e.g. litter size).

After quantification of each of the individual measures in both systems, their positions can be marked on each of the sliding scales, relative to the known normal and pathological ranges of each of the measures. This hypothetical example shows that System 1 has positive attributes for four measures, neutral attributes for one measure and negative attributes for one measure. System 2

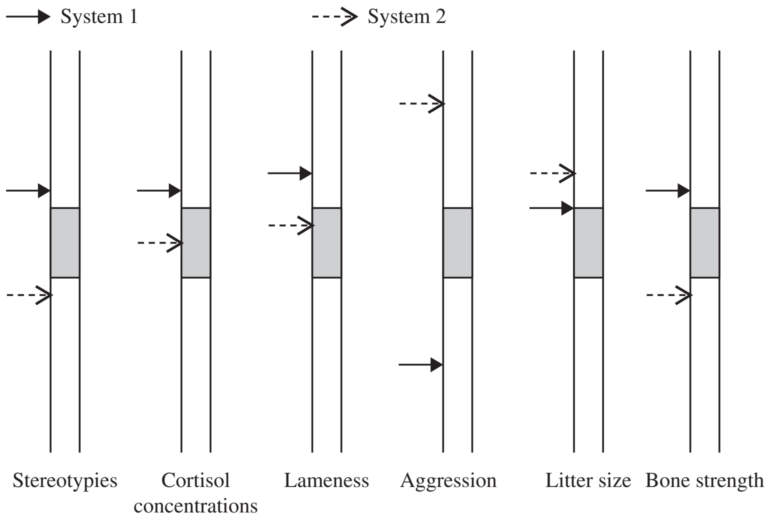

Fig. 1.2 Diagrammatic representations of sliding scales of welfare parameters within two different hypothetical gestating sow systems

has positive attributes for two measures, neutral attributes for two measures and negative attributes for two measures. So, on the surface it might appear a fairly straightforward judgment that System 1 is more "welfare friendly" than System 2. However, this judgment would be on the basis that all measures carry equal weighting and that no account is taken as to the relative difference between each of the System's values within each measure. As Fig. 1.2 shows, differences between systems in plasma cortisol concentration, lameness incidence and litter size are relatively small. Differences in stereotypic behaviour incidence and bone strength are slightly greater, but the difference between systems in aggression incidence is very large, and in this measure, System 2 performs much better than System 1.

We might question the biological significance of some of the measures. For example, is a reduction in bone strength a welfare issue if it is not mirrored by an increase in bone fractures? Probably not at a practical level, but it could be argued theoretically that it is an indication that sows in System 2 are experiencing some deficiencies with their environment that impacts normal bone modeling. Does the fact that litter size in System 2 is 0.2 piglets per litter greater than in System 1 highlight a welfare issue? It could well be a sign of a welfare problem in System 1 associated with the timing of embryo attachment, but this 0.2 piglets per litter reduction probably means nothing to the sow. Does the high incidence of aggression in System 1 impact the welfare of the sows? This is likely to be an extremely important factor. We know that within the framework of sow behaviour in a natural environment, aggression is rarely seen, and we also know that aggressive interactions do elicit acute (Marchant et al., 1995) and chronic physiological responses (Mendl et al., 1992) and can severely reduce certain individual's access to resources. Thus, we might re-evaluate our original decision that System 1 is more "welfare friendly", by giving the aggression measure greater weighting in our deliberation.

The other major factor, some would argue the main factor, that influences the welfare of animals within a given system is that of the quality of stockmanship (Hemsworth, 2003). Whatever the housing system, even in those with high degrees of automation, there is a need for human input for the system to function. All phases of pig production involve interactions between humans and pigs during routine husbandry. The skill of the human is of paramount importance and with poor quality of stockmanship, the welfare of pigs within the best, "welfare-friendly" system can be extremely poor. Some degree of quantification of the human impact on welfare within a system is invariably being included within welfare auditing schemes. This aspect of pig welfare will be covered in detail in Chapters 7 and 9.

Thus, the overall judgment as to which system better safeguards a pig's welfare is much more difficult than it would appear at first and different people will draw different conclusions. Welfare scientists, veterinarians, farmers and lay people will generally put different emphases on different measures. For example, veterinarians often equate welfare with disease and thus will weight their decisions heavily towards measures of health. The link between disease and welfare is important and is covered in detail in Chapter 8, but it is only part of the complete picture. Furthermore, within these groups of people, opinions will vary as to what measures are most important and what value of each measure is morally or ethically acceptable, both at an individual level and a societal or cultural level. These differences in opinion do perhaps in part explain why close confinement systems for pregnant sows are banned in Europe but not in North America (except Florida, Arizona, Oregon & Colorado), South America, Asia or Oceania.

1.2 The Commercial Pig Unit

There are essentially three different types of commercial pig unit; a breeding only unit – which houses only the breeding herd and piglets commonly up to about 25 kg; a rearing/finishing only unit – which houses the pigs from 25 kg up to age of slaughter; and the combined unit – which houses both the breeding herd and the rearing/finishing herd up to slaughter. Early weaning practices in some countries have resulted in greater separation of the various phases of slaughter pig rearing, but in terms of housing and welfare considerations, pig production is essentially split into three distinct phases: (1) the dry sow – meaning all gestating sows, sows awaiting service and barren sows within the herd; (2) the farrowing/lactating sow and her litter; (3) the weaned pig being reared for slaughter.

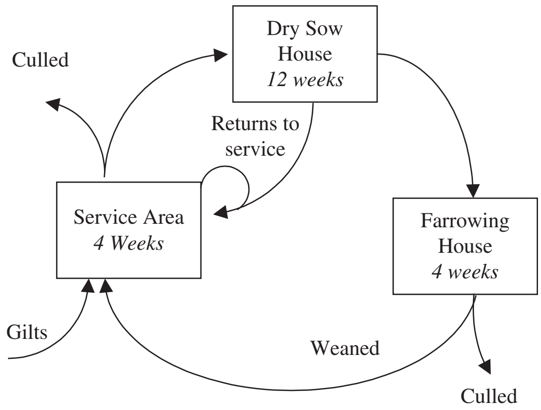

Fig. 1.3 Diagrammatic representation of the sow management cycle

The breeding cycle of the sow already in the herd begins at weaning from the farrowing house (see Fig. 1.3). After weaning, the sow is usually moved to a special service area with boar contact, which encourages oestrus, optimally, from a production viewpoint, at around 4–5 days after weaning. Service itself can either be natural, using a boar, or by artificial insemination (A.I.) or commonly a mixture of both. After serving, the sow will typically remain in the service area for 3–4 weeks, where the stockperson will watch for any signs that she is not pregnant – i.e. signs of oestrous behaviour at 21 days after service. Typically, between 10–20% of sows do not hold their pregnancy and those that consistently fail will be culled from the herd and replaced by new breeding females, which are called gilts until after the birth of their first litter. Most units will also cull sows at weaning on the basis of age or number of litters, irrespective of whether or not the sow is still producing and rearing good piglet numbers. The mean culling rate for sows is often as high as between 40 and 50% (Boyle et al., 1998; Rodriguez-Zas et al., 2003; Anil et al., 2005), the majority due to fertility and age reasons, but also including culling due to other causes such as lameness and various ailments. Another 5–10% of sows may die annually, thus resulting in an annual replacement rate of 50–60%.

1.3 Gestating Sow Housing

Once the sow does not obviously come back into oestrus or after pregnancy is confirmed by ultrasound scanning, she will then be returned to the gestating sow system, where she will spend approximately 12 weeks prior to moving back to the farrowing house about a week before the predicted date of birth. There is a great diversity of dry sow housing systems currently in use worldwide ranging from pasture-based systems to close confinement stall systems. Although the last few decades have seen sow housing moving increasingly away from extensive to intensive, recent legislation in some countries, notably those within the

European Union, will reverse this trend as close confinement systems have already become (e.g. the UK and Sweden) or will become illegal. There are signs that the movement away from close confinement during gestation may spread further than Europe, with major producers in North America (e.g. Smithfields & Maple Leaf Foods) bringing in their own voluntary change.

Until recently, the major factor behind sow housing systems was that of economics of production. Since World War II, there has been a steady reduction in the number of individual pig producers but increases in the number of pigs being kept. The trend away from extensive systems with small herd numbers towards larger intensive units was initially fuelled in some countries by government-backed price incentives in the 1940s and accelerated during the 1950s as new, intensive, system-based technology was applied. Troughs and peaks in production and total sow numbers in response to pig prices notoriously categorize pig production in many countries and this has also accelerated the decline of the small producer. It made economic sense to increase herd sizes, increase stocking densities, increase turnover and decrease labour costs by mechanisation wherever possible.

The ultimate developments in terms of dry sow housing, were those of stalls and tethers. Keeping sows in permanent confinement gave the farmer a number of advantages over less intensive systems. For example:

1. Stocking density. A larger number of sows could be housed in a given area compared with loose-housed systems.
2. Cost effectiveness. Housing sows on concrete slats with incorporation of a mechanised slurry handling system reduced both straw and labour costs.
3. Ease of management. The stockperson is able to monitor individual sows easily and adjust husbandry regime where necessary. Arguably, the degree of skill required to manage confinement systems is also less than loose-based systems.

However, it has since become apparent that such intensive systems, although perhaps conferring some welfare advantages over loose-housed systems, also have a number of welfare disadvantages and, importantly, also project a negative image of the industry to the consumer. Loose-housed systems, incorporating a wide variety in terms of flooring, group size, method of feed delivery etc., do present their own specific set of challenges to the sow and the stockperson and aspects of dry sow housing welfare will be discussed in detail in Chapter 4.

1.4 Farrowing Sow Housing

Sows generally move to the farrowing house around 7–5 days prior to expected farrowing date, which itself is usually based on 115 days after service. Just as with gestating sow housing, there is a great diversity of housing types for the farrowing, but worldwide (including those countries with little or no confinement housing of gestating sows) the majority of sows give birth in a confinement system of a farrowing crate, although this may be only temporarily in place immediately around farrowing itself. Prior to intensification, sows most often farrowed in open pens with large amounts of straw. Again, economics forced development. As straw use and pen size decreased and litter size increased, piglet mortality primarily due to crushing, was found to rise. Introduction of crates into this situation was found to reduce mortality back towards pre-intensification levels. Coupled with this effect on piglet mortality, which is the main reason given by farmers for continued usage, crates were also found to confer management benefits, such as reduced labour costs and ease of piglet handling.

The great amount of research on modification of farrowing crate design has yet to improve live born piglet mortality much below 10%, and this fact, together with increasing concerns for the welfare of the sow and a desire for alternative systems that require minimal financial input, has led to a re-examination of the factors necessary for defining the optimum farrowing conditions. As with gestating sow housing, there has been recent development of both old and new farrowing systems. A return to basic individual straw pens with farrowing rails has often given increased mortality from crushing (Marchant et al., 2000), as the sow is given greater freedom of movement without necessarily having either the maternal behavioural skills or the physical ability to carry out careful posture changing (Marchant et al., 2001). Other designs include circular or oval crates or the incorporation of farrowing areas into communal systems and, as with alternative gestating sow housing, these alternative farrowing sow systems present their own set of potential welfare challenges, not just for the sow, but also for the litter and these will be addressed in detail in Chapter 5.

1.5 Slaughter Pig Housing

Once weaned, piglets usually pass through a number of different housing systems during their growth, up to the age they reach slaughter weight. The number of changes in accommodation varies but intensive units typically move piglets at weaning to specialist nursery accommodation and thereafter move pigs only once more into finishing accommodation. It is not uncommon, however, for pigs to move through four different systems from weaning, each specific for particular stages of the growing phase. The age at which pigs are slaughtered also varies from country to country and is also dependent on the type of product required, e.g. pork, bacon, ham or processed products. Slaughter weights can therefore be anywhere from 60 kg up to 125 kg, with a slaughter age of between 18 and 26 weeks.

As with sow housing, there is a very large variety of housing types for slaughter pigs (Millet et al., 2005), but the majority of pigs, including those bred from outdoor-housed sows, are reared indoors. This is because it is with the slaughter pig herd that the money is really made. The goal of the producer is to grow the pig from weaning to slaughter in as short a time possible and using as little feed as possible. This is best achieved indoors, where the thermal environment can be controlled and feed wastage minimized. There is, however, much variety ranging from fully-enclosed, fully-slatted systems to open-fronted, kennel-type, deep-straw systems with access to outdoor pens. In general, the slaughter pig has been subject to less welfare research than sows, but this has been a result of political expediency rather than any particular lack of welfare problems. The welfare of slaughter pigs will be discussed in Chapter 6.

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Chapter 2
The Natural Behaviour of the Pig

Richard B. D'Eath and Simon P. Turner

2.1 Introduction

2.1.1 What Does Natural Behaviour Have To Do With Welfare?

In a book about the welfare of the pig, the need to understand the natural behaviour of the pig will be immediately obvious to those who define good welfare in terms of an animal's capacity to behave in a natural way (Kiley-Worthington, 1989; Rollin, 1993). Other authors prefer to define welfare mainly in terms of health and biological functioning (Broom and Johnson, 1993), or in terms of subjective mental states or feelings (Dawkins, 1990; Duncan, 1993; reviewed by Fraser et al., 1997). However welfare is defined, knowledge of natural behaviour can be useful in identifying welfare problems.

Recent changes in husbandry and housing environments have occurred relatively rapidly in the context of both evolutionary time, and the domestication history of the pig. As a result, welfare problems can arise due to a mismatch between the pig's behavioural needs and its environment. Problems can occur where natural behaviour is thwarted (e.g. a sow attempting to nest-build without substrates and in a restricted space) or is inappropriately re-directed (e.g. tail-biting). Studying the unrestricted behaviour of pigs in a natural setting can provide useful information about the range and role of behaviours that pigs perform, and their choices and use of habitat could provide clues to their housing needs. When behaviour in natural and more intensive environments is contrasted, differences in behaviour may reveal aspects which are prevented or not stimulated (Graves, 1984; Stolba and Wood-Gush, 1989; Mendl, 1995; SVC, 1997). Stolba and Wood-Gush (1984) directly applied this thinking by studying free-ranging pigs, and identifying key environmental features to apply directly to a new housing system design (see also Arey and Brooke, 2006). At the end of this chapter, we return

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to this issue and discuss some examples of how lessons learned from studying natural behaviour illuminate our understanding of pig welfare.

2.1.2 How Can We Find Out What the Pig's 'Natural' Behaviour Is?

Pigs are the domesticated descendants of the wild boar (*Sus scrofa*), and wild boar behaviour has been described from studies in the wild (Frädrich, 1974; Mauget, 1981; Howells and Edwards-Jones, 1997; Leaper et al., 1999) and in captivity (Gundlach, 1968; Blasetti et al., 1988). However, the process of domestication may have produced changes in behaviour (Gustafsson et al., 1999a,b; Spinka et al., 2000), so it is also useful to observe domestic pigs released into free-ranging conditions, and a number of experiments have done this (e.g. Stolba and Wood-Gush, 1989; Petersen et al., 1990; Dellmeier and Friend, 1991; Jensen, 1995). One limitation of this approach is that when intensively-reared adults are released, they may lack the developmental experience to equip them with suitable behaviour. Information is also available from a series of 'natural' experiments in which domesticated pigs have been deliberately or accidentally released into the wild and have been observed as feral populations surviving many generations after leaving captivity (Graves, 1984; Gabor et al., 1999).

2.2 Origins of the Wild Boar and the Domestic Pig

2.2.1 Evolution

The first artiodactyls evolved in the early Eocene Epoch (54–37 Million Years Ago), lived mainly in forests and ate a variety of plants. During the Miocene (23-5 MYA) climate change led to a spread of grassy plains, and the evolutionary radiation diversified to include swifter moving, more specialised plant-eaters such as the giraffes, camels and deer. The first fossil remains of the genus *Sus* are found during the Miocene, but the pig has essentially retained the mode of life of the Eocene artiodactyls; an unspecialised diet, absence of horns and antlers, and the carnivore-like habits of using dens, making nests and bearing litters (Young, 1981; Fraser, 1984). Fraser (1984) stated that 'I find it useful to think of the pig as an early, simple and unspecialised member of the cloven-hoof family, with one trotter still in the camp of the carnivores'.

Originating in Southeast Asia (Larson et al., 2005), the wild boar (Fig. 2.1) is the most widely distributed member of the nine species of the *Suidae* family (Spitz, 1986; Macdonald, 1984). It is found in temperate and tropical regions of the Old World including most areas of Europe, where its population has risen in

Fig. 2.1 Wild boar sow with her piglets
(Photo source: Fritha Langford)

recent years (Sáez-Royuela and Tellería, 1986), the Mediterranean basin including North Africa, in the Russian taiga, India, South-East Asia, Sri Lanka and Japan (Spitz, 1986; Lever, 1994; Leaper et al., 1999). The wild boar has been classified into as many as 26 subspecies, although a recent morphological analysis proposed only four (Genov, 1999).

2.2.2 Domestication

Archaeological records suggest that the domestic pig was independently domesticated on at least two occasions. The first domestication episodes occurred in the Near East at around 9000 years before present (BP; Spitz, 1986; Porter, 1993; Giuffra et al., 2000), and in the Far East (China) around 4900 (Nowak, 1997) to 7000 years BP (Porter, 1993). However, recent mitochondrial DNA evidence suggests that up to six separate domestication events occurred, and that modern European breeds are derived from local wild boar populations in central Europe (Larson et al., 2005). Asian pigs were introduced to Europe in the 18th and early 19th centuries and crossed with local breeds. The genome of the modern European Large White and Landrace breeds reflect this hybridisation (Giuffra et al., 2000; Larson et al., 2005).

In early domestication, pigs were allowed to roam relatively freely in woodlands surrounding human settlements. These pigs differed little from wild boar except that they were smaller in size, and were more amenable to human contact. Clutton-Brock (1987) reports the Roman writer Varro who described how these pigs were trained with food to return to the sound of a swineherd's horn. The Romans also kept pigs confined in sties, and these were larger and fatter animals, possibly due to artificial selection.

In Britain, as woodland gave way to agricultural land during the Middle Ages, pigs' capacity to damage crops meant that they were increasingly confined (Wiseman, 1986) and access to woodland was restricted to the autumn (when acorns and beech nuts were available). It became common for each poor family to keep a sty pig, which was fattened mainly on kitchen waste (Wiseman, 1986; Clutton-Brock, 1987). More recently, practices of pig keeping have continued to vary widely. Access to woodlands continued into the 18th century, some pigs were fattened outdoors on clover or kale, whilst other pigs were housed indoors, and fed waste products from brewing and distilling. In the 18th and 19th centuries, deliberate artificial selection accelerated change, as pigs grew more rapidly, became fatter, and had a larger mature size (Wiseman, 1986). Hybridisation with Asian breeds further accelerated the improvement of stock. In the modern era, genetic selection has focussed on reproductive performance such as litter size, as well as rapid growth and leanness. There remain some behavioural and phenotypic variations between breeds, reflecting the differences in selection pressure placed on individual traits. Modern domestic pigs are now much larger than wild boar; mature individuals weighing in excess of 300 kg (Whittemore, 1994) compared to 35–230 kg for wild boar (Sjarmidi and Gerard, 1988; Nowak, 1997; Macdonald, 1984).

How has behaviour been influenced by domestication? The relaxation of natural selection has probably led to reduced vigilance and fear of predators, and unconscious and then deliberate artificial selection will have favoured pigs that were easy and safe to handle (Price, 1984). Placing selection pressure on rapid growth and a high reproductive rate has probably concurrently favoured the selection of animals which divert a high proportion of dietary energy towards tissue deposition and reproductive effort at the expensive of activity (Gustafson et al., 1999a,b). In general, the behavioural repertoire of the domestic pig is complete when compared to its wild forebears (Stolba and Wood-Gush, 1989; Mendl, 1995). However, there may be quantitative changes in the level of behavioural expression, probably because of changes in sensitivity to the stimuli that trigger the behaviour. For example, wild boar and feral pigs are more reactive in the presence of predators, including humans (Kurz and Marchinton, 1972).

2.2.3 Feralisation

The 'natural experiment' of release into the wild has happened on numerous occasions. Successful populations exist in the USA, Central and South America, several European countries, South Africa, Sudan, Australia, New Zealand

and numerous oceanic archipelagos (Hanson and Karstad, 1959; Graves, 1984; Lever, 1994). In the USA, feral populations have been established several times, beginning with their introduction to the continent in 1539 (Hanson and Karstad, 1959). Pigs also became feral following their introduction to Australia and New Zealand by the first European settlers at the end of the 18th century (Tisdell, 1982). More recently, feral pigs quickly became established in the Namadgi National Park in South Eastern Australia following a vehicle accident in 1959 (Hone, 2002). This suggests that even relatively modern genotypes of pig are equipped with competent behaviour to quickly adapt and survive in the wild (admittedly in the absence of natural predators).

When a domestic animal becomes feral, natural selection immediately begins to act. Feral pigs vary greatly in colour and conformation, but after several generations, they typically become slimmer and have longer legs than their captive domestic counterparts (Hanson and Karstad, 1959). Under the influence of natural selection, traits relating to mature size, growth and reproduction quickly return to being similar to those of the wild boar (Dzieciolowski et al., 1990, 1992).

2.3 Wild Boar Behavioural Ecology

In general, when the behaviour of wild boar and feral pigs are compared, very few differences are apparent. When these in turn are compared with domestic pigs in extensive conditions, the behavioural differences seen are more often quantitative rather than qualitative in nature. Throughout the rest of this chapter, information from wild boar, feral pigs and extensively kept domestic pigs are combined. Where the text does not make it clear which type is being discussed, this will be indicated in parentheses as follows: studies on wild boar (boars), feral domestic pigs (feral pigs) and extensively kept domestic pigs (pigs).

2.3.1 Habitat Use

Wild boar exploit a variety of habitats from coastal scrubland to vegetated mountainous areas, including forests, swamps and farmland (Frädrich, 1974). Ideal habitats are those that provide high-energy food, cover from predators and hunters, and protection from extremes of weather.

Although not strongly territorial, wild boar may return to preferred sites within their home range, which are used for specific activities including foraging and drinking (Frädrich, 1974). Boars rest and sleep in nesting areas, which are usually located in heavy thickets or dense copsewood (Gundlach, 1968; Mauget, 1981; pigs, Stolba and Wood-Gush, 1984, 1989;

Newberry and Wood-Gush, 1986). They often dig slight hollows in the ground before lying down (boars, Gundlach, 1968). Eliminative behaviour is performed away from these nesting sites (pigs, Hafez et al.,1962; Stolba and Wood-Gush, 1984). Boars also find a place for comfort behaviours such as scratching themselves (pigs, Dellmeier and Friend, 1991), particularly for rubbing off dried mud after wallowing (boars, Gundlach, 1968; Frädrich, 1974). Wild boar may move slowly when foraging and exploring for new food sources, but also move quickly and purposefully between distant sites for specific purposes, suggesting that they have a good memory of their home range which may be augmented by the use of scent-marked trails (Spitz, 1986).

Boars and pigs alike use mainly behavioural means of temperature regulation. In hot seasons or locations, they seek shade, and may shift periods of activity to cooler times of the day, or to the night (feral pigs, Hafez et al.,1962; Kurz and Marchinton, 1972; pigs, Signoret et al.,1975). Wallows are also used to cool down in hot weather, and to protect against insects (pigs, Dellmeier and Friend, 1991; Fig. 2.2). Adult males wallow more during the rut, suggesting that wallowing could also have some sexual function (Fernández-Llario, 2005). In cold weather conditions, they huddle together for warmth (pigs, Signoret et al., 1975), and bite off vegetation to construct nesting areas for insulation (boars, Frädrich, 1974; Ruhe, 1997). In winter, activity increases during the day and reduces at night (boars, Singer et al., 1981; feral pigs, Hanson and Karstad, 1959). Young piglets are particularly poor at regulating

Fig. 2.2 Outdoor sows and piglets using a wet muddy area for wallowing. Lacking the capacity to sweat or pant efficiently, pigs use behavioural methods of thermoregulation (Photo source: Marianne Farish)

their body temperature, and often rest against the sow's udder for warmth (Jensen et al.,1991; Fig. 2.5c).

2.3.2 Activity Patterns

Unlike ruminants, which generally do not sleep for long periods, wild boar divide their day into long periods of deep sleep and long periods of activity (Gundlach, 1968; Frädrich, 1974). In areas where they are relatively undisturbed, wild boar are primarily active during the day (feral pigs, Kurz and Marchinton, 1972; boars, Graves, 1984, Zhang et al., 2007). There are typically two peaks of activity, one in the morning, and another in the afternoon and evening, with a rest period at around midday (boars, Gundlach, 1968). A similar bimodal pattern has been observed in feral pigs in semi-tropical (Hanson and Karstad, 1959; Kurz and Marchinton, 1972) and tropical environments (Caley, 1997). In many areas, wild boar and feral pigs have adopted twilight and nocturnal habits in response to hunting pressure (Hanson and Karstad, 1959; Kurz and Marchinton, 1972; Blasetti et al.,1988; Lemel et al., 2003). Both wild boar and feral pigs are hunted because of the damage they can cause to crops or native ecosystems and also for their meat or for sport (Frädrich, 1974; Caley, 1997). As mentioned above, pigs also shift their activity periods in response to seasonal temperature.

2.3.3 Diet and Feeding Behaviour

During their active periods, wild boar spend the bulk of their time foraging (Frädrich, 1974). Domestic pigs kept in semi-natural conditions, are active during the day, and spend 75% of their active time in foraging-related activities including rooting, grazing and exploring substrates with their snout (Stolba and Wood-Gush, 1989). Being monogastric, the wild boar is much less capable than ruminants of handling fibrous plant material and is less able to extract energy from cellulose, although adults can extract considerable energy from non-starch fibre sources by fermentation (pigs, Rijnen et al., 2001), and outdoor pigs will eat grass and other available plants (Edwards 2003; Fig. 2.3). Boars are more omnivorous than most other ungulates. The proportion of plant material in the diet varies geographically (feral pigs, Hanson and Karstad, 1959; boars Skewes et al., 2007), but generally forms around 90% of their diet (boars, Pinna et al., 2007). The remainder of the diet consists of animal food such as earthworms, crustaceans, insects, small amphibians, reptiles and rodents. (boars, Genov, 1981; Dardaillon, 1987; Massei et al., 1996; Baubet et al., 2003; feral pigs, Hanson and Karstad, 1959). Carrion may be eaten, and adult boars may even consume fawns (Gundlach, 1968).

Fig. 2.3 Outdoor sow and piglets in a grassy paddock. Adult pigs can obtain up to 50% of their energy intake from foraging on green plants
(Photo source: Marianne Farish)

Wild boar adapt their diet to a variety of different habitats (reviewed by Schley and Roper, 2003). In agricultural areas, boars will eat potatoes, cereals such as oats and maize, and grapes (Genov, 1981; Dardaillon, 1987; Herrero et al., 2006). In deciduous woodland habitats, acorns and beech mast are preferred (Groot Bruinderink and Hazebroek, 1994; Massei et al.,1996; Herrero et al., 2005; feral pigs, Hanson and Karstad, 1959). In areas of coniferous forest, alder marshes and reeds, boar will eat tree bark, carrion, invertebrates and roots (Leaper et al.,1999). The keen olfactory sense of the boar, combined with its shovel-like snout and strong neck muscles (Gundlach, 1968) are an adaptation to digging and rooting. Underground food items such roots, tubers, bulbs and underground invertebrates usually form an important part of the diet (Leaper et al.,1999; Cocca et al., 2007), particularly during the winter and spring (Dardaillon, 1987).

There is also a great deal of adaptability in the diet across the seasons, and it may differ from year to year. For example, in a deciduous forest habitat, acorns were observed to make up 60% of the diet in January, but as these became exhausted, boars switched to feeding on grasses and roots, and also rooted up hoards of acorns buried by small mammals such as wood mice (Focardi et al., 2000). In a year of 'mast failure', when acorns were low in abundance, wild boar switched to roots, tubers, invertebrates and herbaceous plants (Singer et al.,1981). The generalist and adaptable nature of the diet of wild boar in comparison with other ungulates, may partly explain their wide geographical distribution (Frädrich, 1974).

2.3.4 Social Behaviour

2.3.4.1 Social Structure and Home Ranges

The group structure of wild boar and feral domestic pigs is very similar (Mendl, 1995) and shows a degree of flexibility in group size and organisation to adapt to habitat type and resource availability (Mauget, 1981; Graves, 1984). Typically, mature sows form small social groups of 2–4 (Mauget, 1981) known as 'sounders' (Macdonald, 1984) which are accompanied by their piglets from the most recent breeding season (boars, Graves, 1984; Dardaillon, 1988). Sows in these groups are likely to be genetically related, probably as mother and daughter or as sisters (feral pigs, Gabor et al.,1999; Gonyou, 2001). Members of a sounder share a home range, and often move around their home range in a group (feral pigs, Gabor et al.,1999). Group cohesion is probably enhanced by social facilitation of behaviour: the sows in a group synchronise their activities, and appear to take their lead from older sows (pigs, Stolba and Wood-Gush, 1989; feral pigs, Graves, 1984). Social interactions between group members may involve vocal communication, and olfactory cues are also important for recognition (boars, Frädrich, 1974; Graves, 1984). Sows within a sounder also engage in co-operative defence of their piglets against predators (boars, Frädrich, 1974; Mauget, 1981). One female has been observed to remain with the young, which allows other adults to forage more efficiently (feral pigs, Graves, 1984).

The home range of a sounder can vary dramatically (boars, 100–2500 ha, Mauget, 1981; up to 6000 ha Janeau and Spitz, 1984) depending on resource availability and population density (feral pigs, Caley, 1997; Saunders and McLeod, 1999). In a given day, a sounder may be active within a relatively small area (boars, 60–75 ha, Janeau and Spitz, 1984). This area of activity changes at intervals within a more extended annual home range (feral pigs, Wood and Brenneman, 1980). The daily activity range may be extended when food is scarce (boars, Singer et al.,1981; Mendl, 1995; feral pigs, Kurz and Marchinton, 1972; Wood and Brenneman, 1980).

Different sounders can have overlapping home ranges, suggesting that territorial boundaries are not strictly observed. Territorial aggression is rarely seen; instead sounder groups show mutual avoidance (feral pigs, Gabor et al.,1999). Sows have been seen rubbing their heads on trees close to their communal nest area, in a manner suggestive of scent-marking (pigs, Stolba and Wood-Gush, 1984, 1989).

The requirements of maternal care lead to seasonal differences in sow movements: sows stay very close to their nest when piglets are new-born (Mauget, 1981), and sounder groups with suckling piglets have a relatively restricted range (Spitz, 1992; Gonyou, 2001) which they gradually increase as the piglets age. As the piglets mature following weaning, they show increasing independence from their dam (Cousse et al.,1994), and begin to form separate groups. These juveniles and sub-adults typically share a home range with the main group, but remain separated from them both during activity and at rest (boars, Spitz and Janeau, 1995; pigs, Stolba and Wood-Gush, 1989; feral pigs, Gabor et al.,1999). When sub-adult females reach their first oestrus at around 8–10 months (boars, Frädrich, 1974), they may re-join their dam's group, or occasionally disperse to an adjacent group (feral pigs, Gabor et al.,1999). Evidence of close genetic relationships between all of the pigs in two different sounders suggests that sub-groups may split off to form a new sounder (feral pigs, Gabor et al.,1999).

Males typically disperse further than females (Truve and Lemel, 2003), occasionally over great distances (feral pigs Caley, 1997). Dispersal begins once they reach 40–50 kg at around 6–10 months of age (Frädrich, 1974; Truve and Lemel, 2003; feral pigs, Gabor et al.,1999). Dispersal by males over greater distances, which is complete before females of a similar age reach sexual maturity, limits inbreeding by the polygynous boars (feral pigs, Gabor et al.,1999). These sexually mature males then form groups of up to 3 (feral pigs, Graves, 1984; Gabor et al.,1999), and become increasingly solitary with age (Frädrich, 1974; Mauget, 1981). Adult males typically have similar-sized (feral pigs, Wood and Brenneman, 1980; boars, Massei et al.,1997) or larger home ranges than females (boars, Janeau and Spitz, 1984; feral pigs, Saunders and Kay, 1996; Caley, 1997; Gabor et al.,1999; Hampton et al., 2004), and also tend to cover more of this area in any given day than do sows (boars, Spitz, 1992; feral pigs, Caley, 1997). Adult males do not maintain exclusive territories (Mayer and Brisbin, 1986).

Adult male home ranges typically overlap with those of a number of sounders, but males do not interact with adult females, other than during the mating season at which time males usually compete with each other for access to oestrous females (feral pigs, Kurz and Marchinton, 1972; Gonyou, 2001). At this time, the young sub-adult males associated with a group of females distance themselves from the maternal group or may disperse completely (Gundlach, 1968; Frädrich, 1974). After mating, the adult male leaves the female group, and younger individuals who have not dispersed may re-join the maternal group.

2.3.4.2 Aggressive Behaviour and Dominance

Sows within a group are recognised individually by other group members and a stable, linear dominance hierarchy persists which is regulated mainly by the subordinate avoiding conflict (boars and feral pigs, Mauget, 1981; Gonyou, 2001; pigs, Jensen and Wood-Gush, 1984). High social status is conferred by maturity, a large body mass and physical strength (Mauget, 1981). Adult sows are dominant to sub-adults and juveniles in the group, although dominance hierarchies also exist within these demographic classes (Gonyou, 2001). Adult boars are dominant to all other individuals when they join the group during the mating season.

Aggressive interactions can occur between individuals in the context of food competition (boars, Frädrich, 1974; feral pigs, Gabor et al.,1999; pigs, Stolba and Wood-Gush, 1989). As milk yield differs according to teat position on the udder, piglets shove and bite their littermates in the course of competition for the most productive teats. This aggression is apparent within a short time after birth, and piglets are allocated a teat position on the outcome of these contests to which they show fidelity throughout lactation (Newberry and Wood-Gush, 1985). The first social contact with non-littermates in a piglet's life is at around 7–14 days of age when following the sow away from the nest site and when the nest is visited by other group members. No aggression is observed during these interactions (pigs, Petersen et al.,1989; Newberry and Wood-Gush, 1988). Away from the teats, some aggressive behaviour between littermates and between non-littermates is seen, although this generally occurs as part of playful sequences (pigs, Petersen et al.,1989). The process of behavioural development and integration of young into the matrilineal group is discussed further in Section 2.4.7 – 'Social Integration'. Competition for solid food begins at around 10 weeks of age (pigs, Newberry and Wood-Gush, 1988). As adults, aggressive behaviour within the matrilineal group is rare (Mendl, 1995) and the most vigorous aggression occurs between adult males during the rutting season (Mendl, 1995) (this is described later in Section 2.4.2 – 'Mating').

2.4 The Life Cycle of *Sus Scrofa*

2.4.1 Breeding Season

Wild boar sows show seasonal anoestrus during the summer and early autumn, which is probably controlled by daylength (Delcroix et al.,1990; Tast et al., 2001). Despite breeding all year round, domestic sows still show a slight reduction in fertility at this time (Love et al.,1993). Males also show seasonal changes in reproductive functions. Outside the breeding season, semen volume and spermatozoa number decline (Kozdrowski and Dubiel, 2004), as do testicular weight and plasma testosterone, although the seasonal depression in steroids is less pronounced in domestic males than in wild boar (Mauget and Boissin, 1987).

In European wild boar, the proportion of females which breed can vary between 11 and 90% (Leaper et al.,1999) depending on food availability, which also affects the timing of the breeding season (Spitz, 1986; Pépin et al.,1987). Breeding can begin in October in good years, or as late as December in a poor season (Frädrich, 1974; Mauget, 1981). Since gestation lasts around 115–118 days (boars, Macdonald, 1984; Harris et al., 2001), if breeding begins late, sows will have only one litter in the year, with the peak of farrowings occurring in April–May. In a year of ample food, two litters may be produced. The first will typically be born in February, and the second in August– September (Gundlach, 1968; Mauget, 1981; Pépin et al.,1987). This is dependent on the first litter being weaned before late June or early July, in which case a second oestrus can occur (Mauget, 1981). In wild boar, seasonal breeding occurs even in tropical areas (Spitz, 1986).

Feral domestic sows also show some evidence of a return to a seasonal pattern (Dzieciolowski et al.,1992), but are capable of breeding all year-round like their domestic counterparts (Hanson and Karstad, 1959; Dzieciolowski et al.,1992; Gabor et al.,1999).

2.4.2 Mating

Females within a herd will usually show synchronisation of oestrus, probably by means of pheromonal communication (boars, Spitz, 1986; Delcroix et al.,1990). Pheromones released by the boar also play a role in the stimulation and synchronisation of oestrus (boars, Mayer and Brisbin, 1986; pigs, Signoret et al.,1975) A sow's oestrous period usually lasts for 2–3 days (pigs, Signoret et al.,1975).

During the breeding season, adult males begin to associate with oestrous females, possibly in response to olfactory cues (boars, Frädrich, 1974). More than one male usually approaches one group, at which point they engage in aggressive contests to compete for access to oestrous females. It is believed that boars that are successful in these contests are able to sire more young (Kurz and Marchinton, 1972) as larger boars have greater reproductive success (Hampton et al., 2004). A contest usually begins with a parallel walk, where the two boars walk some distance apart, raising their bristles along the spine (boars, Barrette, 1986). This probably allows some initial assessment of competitive ability, based on size. Following this, the competitors may circle and then engage in shoulder-to-shoulder pushing, in which each tries to lever the other over using their snout. This non-injurious 'limited fighting' (Frädrich, 1974) can last for several minutes and may not always escalate to serious fighting (Gundlach, 1968; Frädrich, 1974).

Unlike other Suidae, *Sus scrofa* do not have well developed anatomical features used for displays and fighting (such as wart-like skin outgrowths and long upper tusks). However, males are larger than females and have longer canine teeth (Frädrich, 1974). These are used to slash and bite at the neck and shoulder region of the opponent whilst in a parallel posture (feral pigs, Kurz and Marchinton, 1972; boars, Frädrich, 1974). Greater damage is typically caused by the lower canines which, although shorter, are typically sharper. They also bite at other areas such as legs or ears if given the opportunity (Frädrich, 1974). During the rut, adult male boars develop particularly thick skin, with a heavy shield of connective tissue in the typical fighting target areas: the front part of the flanks and the neck. Boars may also rub against trees to impregnate this area with tree gum as a further protective layer (Frädrich, 1974). It has been proposed that successful males wallow more during the rut, but the function of this is unclear (Fernández-Llario, 2005). Once dominance is determined after contests, the victor scent-marks using the metacarpal glands on his front legs, perhaps to assert dominance over subordinate males, or to stimulate females for breeding (Mayer and Brisbin, 1986).

Despite competing for access to females, often more than one male manages to mate with an individual female (feral pigs, Barrett, 1978). This can result in litters of mixed paternity (Fraser et al.,1995). The long, synchronised oestrus appears to make effective mate-guarding difficult, and in fact the usual ungulate mechanisms for ensuring paternity (harem formation, mate-guarding and non-receptivity by the female) are not apparent. The large sperm volume of male boars is probably an adaptation to the sperm competition that results from multiple males mating with a single female (Fraser et al.,1995).

Behaviour before copulation has been described in detail by Frädrich (1974) and Signoret et al. (1975). When females are in oestrus, males are seen to sniff at their urine, which probably enables males to detect when females become fertile. Mating is preceded by courtship behaviour. The male begins by showing a broadside display, and then may pursue the female in a quick walk or trot. He produces a characteristic vocalisation of short, rhythmic grunting, and clacks his teeth together, and also produces a froth of saliva. The female stops walking away and the male nuzzles her vulva and sides before mounting. Oestrous sows show an immobilisation reflex ('standing') in the presence of a boar, and when pressure is applied to the rear of her back. During mating, the male produces a 'mating song' characterised by soft rhythmical grunts. He also urinates and chews, continuing to produce large quantities of saliva.

2.4.3 Nest-Site Selection and Nest Building

In the latter stages of pregnancy, a sow's home range can become restricted to around 1 ha, as she separates from her group (boars, Mauget, 1981). The pregnant sow becomes intolerant of group mates, and may direct aggression towards them as she seeks isolation (pigs, Stolba and Wood-Gush, 1984, 1989). She typically leaves the group 1–3 days before farrowing and seeks out a suitable nest site away from the home range of her group (boars, Gundlach, 1968; Spitz, 1986; pigs, Jensen, 1986; Jensen et al.,1987; Petersen et al.,1990; Stolba and Wood-Gush, 1984, 1989). She may spend a few days investigating an area before selecting an undisturbed, well-protected location such as a ravine or in thick undergrowth at the edge of a forest, or occasionally in meadowland surrounded by long grass (boars, Gundlach, 1968; Spitz, 1986; Fernández-Llario, 2004; pigs, Jensen, 1986; Stolba and Wood-Gush, 1984, 1989). Warmth and the presence of a water source are also considerations in nest site choice (Fernández-Llario, 2004). Forest edges may be selected because sows prefer an open view from their nest (Stolba and Wood-Gush, 1984).

Nest-building occurs in several phases, described by Gundlach (1968) and Frädrich (1974) in wild boar. The sow begins by digging a small hollow in the soil with her snout for her to lie in. She then makes a series of trips to collect grass, leaves, small twigs and other leafy vegetation from nearby, and deposits these in the nest area (Fig. 2.4). This material is arranged in and around the edge of the nest hollow by rooting and pawing with the forelegs while turning around. The central lying area of the nest is then provided with insulation and

(a)

(b)

Fig. 2.4 Nest-building: **a**) A free-ranging domestic sow carries grass to her nest site. **b**) A domestic sow on an outdoor farm arranges straw into a nest inside her farrowing hut (Photo sources: a. Per Jensen, b. Marianne Farish)

camouflage as the sow covers it with longer branches up to 2 m in length (Frädrich, 1974), and a further covering of hay, grass or leaves. The completed nest is about a metre in height. Close to parturition, the sow enters the nest, and may continue rooting, then becomes inactive and lies on her side before delivering the piglets. After the piglets are born (described in the next section), the sow may continue to rearrange the nesting material.

Descriptions of nest building by free-ranging domestic sows (Jensen, 1986; Jensen et al.,1993; Stolba and Wood-Gush, 1984, 1989) are broadly similar to this, although the final stages of camouflaging the nest appear to be less elaborate. Instead, sows appear to nest in sites with natural or artificial cover.

2.4.4 Farrowing

Pigs are atypical among the ungulates in the form of their reproduction showing a relatively 'primitive' pattern which has more in common with insectivores, rodents and many carnivores (Frädrich, 1974; Fraser, 1984). They have a large litter, and the young weigh $<1\%$ of their final adult bodyweight (Stangel and Jensen, 1991). The young spend the first few days of their lives in the nest and are poor at thermoregulation, relying on each other and the udder for warmth (Fig. 2.5c). Compared to rodent pups, piglets are precocious behaviourally, opening their eyes and showing co-ordinated locomotion from birth, and many elements of adult behaviour appear when they are only a few days old (Gundlach, 1968; Jensen, 1988).

The farrowing process has been described by several authors (boars, Gundlach, 1968; Frädrich, 1974; pigs, Jensen, 1986; Petersen et al.,1990; Stolba and Wood-Gush, 1989). After completing nest-building, the sow lies in her nest for a few hours before farrowing begins. Piglets (or boarlets, Horrell, 1997) are normally delivered with the sow lying on her side (Fig. 2.5a,b). The sow is largely passive throughout the farrowing process. After the first piglet is born, the sow may stand up, turn round and sniff at it. She may do this again at intervals, although the sow increasingly lies still on her side as farrowing progresses.

Piglets are born covered in transparent foetal membranes which quickly dry and rub off. The sow does not lick her offspring. The umbilical cord may remain attached at first, but movements of the piglet or sow detach it after a few minutes. As soon as they are born, the piglets struggle to their feet and begin searching for the teats to get colostrum (Fig. 2.5b). The interval between the first and last piglet is typically 1–3 hours (pigs, Jensen, 1986; indoor boars, Harris et al. 2001). Few behavioural differences were found between domestic sows and wild boar $\times$ domestic sow crosses allowed to farrow in large outdoor enclosures, when nest-building and farrowing behaviours were compared (Gustafsson et al.,1999a).

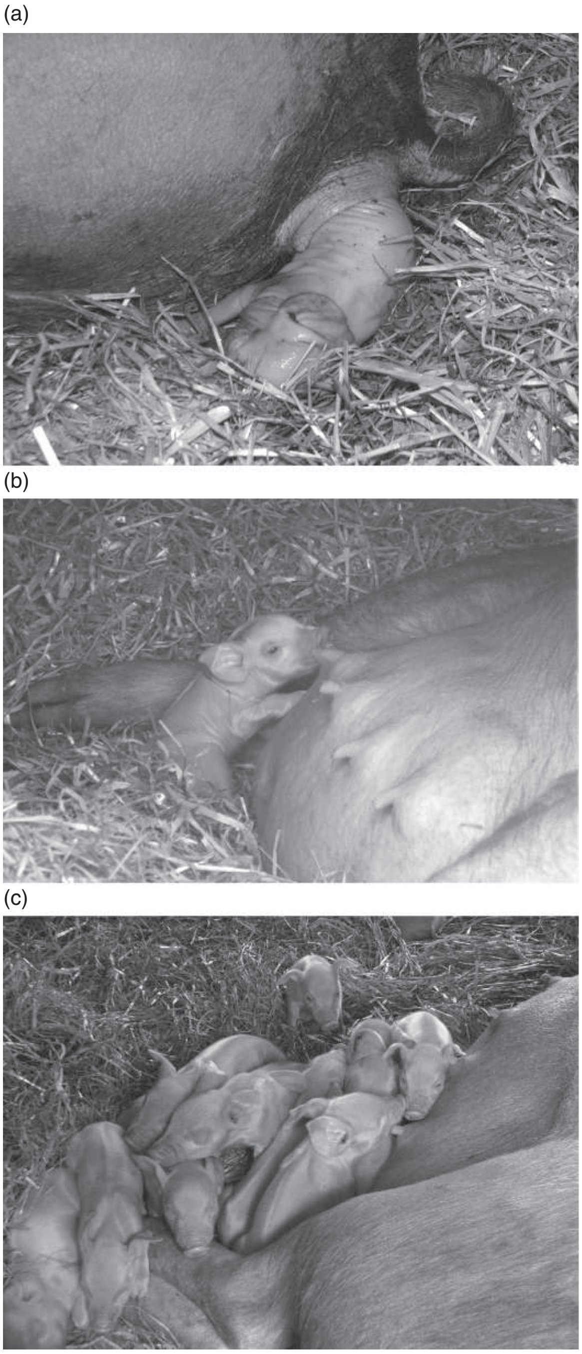

Fig. 2.5 Sequence of events at farrowing (**a**) Piglet being born. The sow typically lies passively on her side leaving piglets to struggle to their feet and attempt to find the udder (**b**) which is an important source of warmth as well as nutrition (**c**) (Photo source: Marianne Farish)

Wild boar litter size varies with the size and age of the sow, and with food availability (Mauget, 1981; Fernández-Llario et al.,1999; Leaper et al.,1999; Nahlik and Sandor, 2003). It ranges between 1 and 7, with a mean of around 3, although in good habitats, the mean can be higher (e.g. 6.7; Nahlik and Sandor, 2003). Well-fed captive wild boar can produce larger litters (5.4 ± 1.5, Harris et al., 2001). In contrast to their captive domestic counterparts whom regularly produce litters of 10 or more piglets (Setchell, 1992), the litter size of feral pigs is more similar to that of the wild boar (Kurz and Marchinton, 1972; Dzieciolowski et al.,1992).

2.4.5 Sow and Piglet Behaviour After Farrowing

In the first 1–2 weeks of life, sows restrict their movements to a limited area (about 20 ha, Mauget, 1981) around the farrowing nest. The piglets stay in the nest for the first few days, and stay close to one another and to the sow to conserve body heat (Gundlach, 1968; Frädrich, 1974; Fig. 2.5c). Piglet mortality may be high if late frosts occur (Jezierski, 1977). The sow may leave the piglets alone in the nest for short periods in order to defecate or forage. On returning to the nest, the sow carefully roots the ground before lying down, perhaps to arrange nesting material, or to check it is free from piglets (pigs, Petersen et al.,1990). She noses the piglets away from where she wants to lie, and if a piglet squeals as she lies down, she will shift position (Gundlach, 1968; Frädrich, 1974). Deaths due to crushing have not been reported in wild boars or feral domestic sows. Piglets did die from crushing in a study of extensively-kept pigs (Newberry and Wood-Gush, 1985, 1986) although this may have been due to the intrusion of other adult or sub-adult pigs into the nest area.

Separation of the sow and litter from other group members in the first days of life ensures that the piglets do not have to compete with foreign piglets for milk, giving them a chance to establish teat preferences (Fraser et al.,1995). This period may also facilitate the establishment of recognition between the sow and offspring, possibly through nose-to-nose contacts, mainly initiated by the piglets (pigs, Newberry and Wood-Gush, 1985; Petersen et al.,1989, 1990).

After the first few days, the piglets may leave the nest in the presence of the sow for short periods (boars, Gundlach, 1968; pigs, Jensen and Redbo, 1987; Petersen et al.,1989; Stangel and Jensen, 1991). She makes short rhythmical grunts for them to follow, and they remain in close contact with her and with each other, hiding under cover when resting (boars, Frädrich, 1974; pigs, Newberry and Wood-Gush, 1986). These early forays from the nest are likely to be shorter and begin at a later age in cold weather (Gundlach, 1968).

If the sow perceives danger, she gives warning grunts which cause the young to hide in the nest or undergrowth, or in the absence of cover to crouch motionless (Gundlach, 1968). If a piglet is seized by a predator, it will squeal loudly, inducing a defensive attack by its dam or by other sows in the group

(Gundlach, 1968; Frädrich, 1974). Despite this defence, piglet mortality in the first year of life can be high (e.g. Howells and Edwards-Jones, 1997, range 10–90%, mean 45–50%). Causes of death include predation by birds of prey (Seguin et al., 2001) and wolves (Jedrzejewski et al., 2002) and other regionally native species such as bobcats. High piglet mortality may occur due to late winter frosts (e.g. in Poland, Jezierski, 1977).

2.4.6 Suckling

In domestic pigs, colostrum is constantly available at the udder for the first 2–3 hours after farrowing ends, after which, a cyclical suckling pattern gradually develops, so that by around 10 hours post-partum, suckling bouts occur at intervals of about 40–80 minutes (Fraser, 1980; de Passillé and Rushen, 1989). When signalled by the sow issuing short rhythmical grunts, which are most rapid just before milk ejection, the whole litter assembles at the teats. Each piglet returns to its own teat position, established by vigorous competition with littermates during the first week of life (Fig. 2.6). The piglets massage the udder with rooting-like head movements. Milk ejection occurs for a brief period only (15–20 seconds), and the piglets suck rapidly. After milk ejection, further udder massage may occur, and the piglets may go to the sow's head to make nose-nose contact, possibly to reinforce mother-young recognition. The pattern is

Fig. 2.6 Domestic pigs assembled at the udder for suckling. Each piglet establishes and defends its own teat position
(Photo source: Marianne Farish)

essentially identical in wild boar (Gundlach, 1968; Horrell, 1997), and in free-ranging domestic pigs (Newberry and Wood-Gush, 1985; Jensen, 1988).

In the first days of life, suckling bouts are initiated by the sow and end when the piglets leave, or fall asleep at the udder (boars, Frädrich, 1974; pigs, Newberry and Wood-Gush, 1985; Castrén et al.,1989; Jensen et al.,1991). As piglets age, they may try to initiate a suckling bout by squealing and by massaging the udder of a standing sow, inducing her to lie down (Gundlach, 1968; Newberry and Wood-Gush, 1985). At these later stages, suckling bouts are increasingly likely to be terminated by the sow rolling onto her udder or getting up, cutting short the period of udder massage which can follow milk ejection. Termination of suckling bouts in this way occurs when the piglets are at a younger age and occurs more rapidly after milk ejection in wild boar (Horrell, 1997) than in extensively-kept domestic pigs (Newberry and Wood-Gush, 1985; Jensen, 1988; Jensen and Recen, 1989). Gustafsson et al. (1999a) recently compared wild boar × domestic pig crosses and pure domestic sows kept in similar outdoor pens and confirmed this finding. Later in lactation, suckling bouts can occur when the sow is standing up (pigs, Jensen and Recen, 1989).

Suckling bouts do not always lead to milk ejection, particularly if they are initiated by the piglets rather than the sow. These unsuccessful sucklings occur in a farm environment, but also in free-ranging domestic pigs (Newberry and Wood-Gush, 1985; Castrén et al.,1989) and in wild boar kept in outdoor pens (Gustafsson et al.,1999a).

Sows in the same herd show synchrony in suckling (boars, Gundlach, 1968; Horrell, 1997; pigs, Newberry and Wood-Gush, 1985). Synchronised suckling may help to minimise competition for milk from an opportunistic non- littermate. Piglets attempting to suckle from the wrong sow (cross-suckling) may be chased away by that sow and her piglets (boars, Gundlach, 1968; Frädrich, 1974). However, cross-suckling does occur and is frequently unimpeded by the sow (boars, Mauget, 1981; Delcroix et al.,1985; feral pigs, Eisenberg and Lockhart, 1972; Kurz and Marchinton, 1972; pigs, Newberry and Wood-Gush, 1985; Jensen, 1986). Fraser et al. (1995) proposed a number of reasons why cross-suckling may be tolerated including the fact that other sows in the group are often relatives, thereby gaining inclusive fitness benefits from providing care. Alternatively, a sow may rely on the period of isolation at farrowing when only her piglets can access the udder and form stable teat preferences. Unused teats begin to regress, and used teats will be fiercely defended.

2.4.7 Social Integration

The piglets begin to follow the sow on forays from the nest towards the end of the first week of life (boars, Gundlach, 1968; pigs, Jensen and Redbo, 1987; Petersen et al.,1989; Stangel and Jensen, 1991). These forays often result in a piglet's first social contact with other pigs. Due to the synchrony of oestrus

Fig. 2.7 Piglets running together. Locomotor play is the most common form of play in young pigs. On this outdoor farm, electric fencing keeps sows in individual paddocks, but allows piglets from different litters to interact as they would in the wild
(Photo source: Marianne Farish)

within a group of sows (boars, Spitz, 1986; Delcroix et al.,1990), farrowings are also quite synchronised, so piglets in a matrilineal group will often be of a similar age. After about 1–2 weeks, the nest is abandoned (pigs, Jensen and Redbo, 1987), and the sow and piglets sleep closer to the group's communal nest (pigs, Petersen et al.,1989). Soon after this (around 2 weeks of age), the piglets also accompany the sow when she is foraging, bringing them into regular contact with the rest of the social group. The piglets socialise with piglets from other litters during active periods, making regular nose-nose contact with them, and engage in play (see next section and Fig. 2.7). There is little overt aggression. The frequency of this social contact then declines gradually (pigs, Petersen et al.,1989). Piglets show a strong preference for resting and interacting with their littermates, which persists for several weeks of life (pigs, Jensen, 1986; Newberry and Wood-Gush, 1986).

2.4.8 Play

Play begins at 2 days of age (pigs, Stangel and Jensen, 1991; Jensen et al.,1991), but peaks between 2 and 6 weeks of age (pigs, Newberry et al.,1988). The decline in the frequency of playing after 6 weeks may coincide with an increased motivation to spend time foraging in response to the beginning of weaning (pigs, Newberry et al.,1988), whilst adult pigs seldom show playful behaviour (boars, Frädrich, 1974).

Behaviour patterns which have almost unanimously been described as 'playful' include tossing and waving the head, spinning around, and carrying and shaking objects (Newberry et al.,1988). Locomotor play is often accompanied by bark-like vocalisations, which occur both during bouts of play and when alarmed (Newberry et al.,1988). Solitary play, in which a piglet may perform jumping or head-swinging movements, is common (Frädrich, 1974), but social facilitation of play behaviour also occurs frequently. This results in a group of piglets engaging simultaneously in locomotor play, such as bouts of chasing, or object play (Frädrich, 1974; Newberry et al.,1988; Fig. 2.7). Play behaviour may incorporate aggressive elements, such as head-knocks and circling whilst in shoulder to shoulder contact (Newberry and Wood-Gush, 1988; Newberry et al.,1988; Petersen et al.,1989) which Dellmeier and Friend (1991) have suggested may have a role in determining dominance relationships between piglets.

2.4.9 Weaning

Investigation of substrates, rooting, and ingestion of solid food items can be observed in day old piglets (boars, Gundlach, 1968), and this increases with age (pigs, Newberry and Wood-Gush, 1988; Fig. 2.8). Ingestion of significant

Fig. 2.8 Outdoor sow and piglets rooting and foraging. In the wild, weaning is a gradual process. Piglets increasingly forage for solid food as suckling bouts become less frequent (Photo source: Marianne Farish)

quantities of solid food begins at around 4–5 weeks, and increases considerably between 6 and 8 weeks (pigs, Petersen et al.,1989; Jensen, 1995). At the same time, reliance on milk reduces gradually over a period of weeks, as the frequency of suckling bouts becomes less, and suckling bouts are not attended by the whole litter (pigs, Jensen and Recen, 1989). Occasionally, sows may sometimes discourage suckling by being aggressive to piglets (beginning at around 5–7 weeks). However, the timing of this appears to show no clear relationship with the age at which weaning is completed (pigs, Newberry and Wood-Gush, 1985), and is probably too rare to be the main mechanism by which sows control weaning (pigs, Jensen, 1988). In extensive domestic pigs, the completion of weaning has been variously estimated to occur by 14–17 weeks (Jensen, 1986), 15–19 weeks (Jensen and Recén, 1989) or 8–14 weeks (Newberry and Wood-Gush, 1985). Variation in weaning age occurs between piglets in the same litter (pigs, Jensen, 1995). Weaning is usually later in winter and in older sows (pigs, Jensen and Recen, 1989).

2.4.10 Independence, Growth and Sexual Maturity

After weaning, juveniles show increasing independence from their dam, and may explore away from her in groups containing littermates and other pigs of a similar age (pigs, Petersen et al.,1989; boars, Cousse et al.,1994). Juveniles show some degree of fidelity towards the sow's home range during lactation, which persists into sub-adulthood (8–24 months; Cousse et al.,1994). As such, groups of juveniles and sub-adults usually share a home range with their sounder group but move around within the area independently of the sows (boars, Spitz and Janeau, 1995; pigs Stolba and Wood-Gush, 1989; feral pigs, Gabor et al.,1999).

Growth rates of wild boar are many times lower than their intensively reared domestic counterparts (<1 yr age; 0.11 kg/d; Pépin et al.,1987, compared to e.g. 1.10 kg/d Kyriazakis et al.,1993). Feral pigs show growth rates comparable to those of wild boar (Dzieciolowski et al.,1990). Male and female wild boars grow at a similar rate during the first year (Gaillard et al.,1992; Pépin et al.,1987), after which males grow more quickly than females. In a study in South-west France, yearlings weighed 45 kg, after which males gained weight more rapidly, becoming 25–30% heavier than females of a similar age. Among the mature adults aged over 3 years, males were 100 kg, and females 75 kg (Pépin et al.,1987). Adult size in wild boars can vary greatly (35–230 kg – Sjarmidi and Gerard, 1988; Nowak, 1997; Macdonald, 1984). In Europe, this range in size occurs along a NE-SW cline, with the smallest adults found in Mediterranean areas (Sjarmidi and Gerard, 1988). Body weight may also show seasonal fluctuations in Mediterranean conditions that may be linked to summer droughts (Spitz et al.,1998).

Females typically reach their first oestrus at around 8–10 months of age (boars, Frädrich, 1974) although puberty may be delayed until 24 months of age depending on conditions (Spitz, 1986). These young adult females usually re-join their dam's group. Occasionally, dispersal of females to adjacent sounders can occur, and possibly sub-groups may split off to form new sounders (feral pigs, Gabor et al.,1999). Females typically achieve mature adult size in about 2 ½ years (Fernández-Llario et al.,1999).

Males disperse from the home range of their sounder before they reach sexual maturity at around 6–10 months of age (40–50 kg; boars, Frädrich, 1974; Truve and Lemel 2003; feral pigs, Gabor et al.,1999). They form small bachelor groups, and older males become increasingly solitary (feral pigs, Graves, 1984; Gabor et al., 1999; boars, Frädrich, 1974); Mauget, 1981). Males may not be large enough to compete successfully with other boars for mates until they reach 4–5 years of age.

2.5 The Implications of Natural Behaviour for Pig Welfare

Some authors take the view that the absence of 'natural' behaviour in itself indicates poor welfare (Kiley-Worthington, 1989; Rollin, 1993). For Dawkins (1988), who believes 'subjective feelings' to be fundamental to welfare, the absence of 'natural' behaviour may not necessarily imply suffering. This is because the animal may have adapted to the conditions, either during the development of the individual (e.g. 'tameness' of zoo animals), or through changes at the genetic level through domestication. In addition, behaviour that is dependent on external stimuli may not be elicited in captivity and 'out of sight is out of mind'.

The first of these objections can be addressed to some extent by comparing the behaviour of domestic, feral and wild boar genotypes reared in both captive and extensive environments, as has been done throughout this chapter. A more explicit example of this approach is a series of recent experiments, in which wild boar × domestic pig crosses have been compared to pure domestic pigs when both have been reared and kept in similar environments (Gustafsson et al.,1999a,b; Spinka et al., 2000). In general, it appears that there are relatively few differences between the genotypes. Also, the ability of domestic pigs to thrive in a 'pig park' environment, and to form viable feral populations when released into the wild, suggests that even highly selected domestic pig genotypes remain reasonably well equipped with the behavioural skills for extensive living.

The 'out of sight out of mind' objection is harder to address. Pigs may be less likely to suffer if a particular behaviour is controlled mainly by external stimuli, and these are absent (Warburton and Mason, 2003). Also, the full range of behaviour shown by the wild pig enables it to cope with adverse situations, for example defending young against predators, huddling to keep warm in cold weather. It may be unnecessary for good welfare to re-create all the challenges of the wild. On the other hand though, there are likely to be some behaviours which have a strong component of endogenous motivation, or where external stimuli in a farm environment are sufficient to trigger motivation for a behaviour (Jensen and Toates, 1993; Warburton and Mason, 2003). In these cases, the resources available may not be sufficient for the animal to achieve a satisfactory consummatory performance, which is likely to lead to thwarting or re-direction of behaviour, and perhaps welfare problems.

In the following section, we highlight differences between the natural situation and farm practice which may lead to welfare problems.

2.5.1 The Farm Habitat

In the wild, pigs apart from adult boars and peri-parturient sows are social animals, which spend most of their lives in contact with group mates. Individual housing is generally unnatural for pigs. Pigs lie together with group-mates in communal nests when at rest, and leave these nest area to defecate and urinate (Stolba and Wood-Gush, 1984). Sows and piglets also avoid soiling the farrowing nest (Gundlach, 1968). In indoor housing, pigs often make use of one area of the pen for dunging (Signoret et al.,1975). Some housing designs include specific 'dunging areas' or 'dunging passages' which can be easily cleaned (e.g. SVC, 1997).

Pigs depend on behavioural means for effective thermoregulation, seeking shade or wallows in the heat and nesting and huddling in the cold. If temperature is not adequately controlled, pigs adapt behaviourally. As temperatures increase further, the motivation to wallow in wet substrates to encourage evaporative cooling can even over-ride their natural motivation to avoid their own urine and faeces (Huynh et al. 2005). Eventually, if pigs are not given adequate opportunities to adapt behaviourally, they are likely to suffer a series of problems which affect both welfare and production including lactation failure in sows (Fraser, 1970), and reduced appetite and growth (Fraser, 1984).

2.5.2 Foraging

Pigs spend 75% of their active time engaged in foraging-related behaviour, and appear to be motivated to explore their environment with their snout. Feeding concentrated food in the absence of manipulable substrates has been at the root of a variety of 'problem' behaviours in pigs. Restricted-fed pregnant sows housed in tethered stalls develop oral stereotypies including chewing and biting their chain, and at the bars of the stall, 'sham chewing', and manipulation of their drinker (Lawrence and Terlouw, 1993). Even when pigs are not restricted-fed, the absence of foraging substrates can lead to problems. Provision of concentrates in a single location means that food intake needs can be satisfied in a small fraction of the active time, and this does not appear to satisfy the motivation to explore and forage. The absence of suitable substrates as an outlet for these behavioural needs may lead to a re-direction to unsuitable targets such as pen-mates. Lack of substrates is the key factor leading to undesirable oral behaviours such as tail-biting and ear-chewing (Van Putten, 1969; Fraser, 1987; Schrøder-Petersen and Simonsen, 2001). When substrates such as straw are provided, pigs spend time manipulating them, and reduce pen-mate directed behaviour (Fraser et al.,1991). Newberry and Wood-Gush (1988) found that in extensively-reared domestic pigs, young piglets engaged in some chewing at other pigs during a period when all types of object were being investigated, although this was much less common than in intensively-reared pigs.

Pigs' active foraging behaviour can lead to the destruction of pasture when they are housed outdoors, and the age-old practice of nose-ringing (Wiseman, 1986) is still used today. Nose-ringing deters pigs from rooting because it is painful for them. They stand inactive more, and appear to re-direct some of their motivation for foraging behaviour by sham (or vacuum) chewing, and digging with the forefoot (Horrell et al., 2001).

2.5.3 Social Behaviour

Pig social groups are relatively stable in composition, and new individuals generally join by being born to a sow in the group. In a typical natural sounder group, adult females of various ages, including mother-daughter pairs as well as sub-adult and juvenile pigs, co-exist. In contrast, on farm, mixing of unfamiliar individuals into new groups often occurs and, usually, pigs of a similar age are kept together. In a sounder group, piglets probably learn social behaviour and their dominance status from other similar-aged or older individuals, and overt aggression to establish dominance is rare. Between-group aggression is rare because sounder groups avoid one another. Instead, aggression is confined to feed competition and sexual competition between adult boars in the breeding season.

Under farm conditions, piglets within a litter engage in mainly playful social behaviour, and learn dominance relationship with one another. Serious fighting can break out when unfamiliar pigs meet in a confined space, where tolerance through mutual avoidance is not possible. This fighting can be exhausting and stressful for the participants, and result in physical injury (Moore et al.,1994). Prolonged chasing and bullying may follow a fight, because the loser is unable to escape the aggressor. Aggressive behaviour at mixing leads to the establishment of dominance relationships within the group. Aggression may also break out sporadically within stable groups for no apparent reason, or in the context of food competition. Aggression at feeding is particularly prevalent in group-housed pregnant sows which are fed by dropping food in a pile onto the floor of the pen.

2.5.4 Farrowing

In most farm systems, sows which are due to farrow are individually-housed, which mimics their natural behaviour of isolating themselves from the group. Usually they are not given the opportunity to seek out and identify a nest-site for themselves. Some opportunity for nest-building can occur in outdoor systems, but indoors farrowing crates are the predominant system used, and these severely restrict the performance of nest-building. Sows become restless and perform behaviours directed towards the floor and pen fixtures, such as the bars of the crate. This thwarting of nest-building behaviour due to the lack of suitable substrates and especially space (Jarvis et al., 2002) also leads to physiological stress, which interferes with the normal endocrine control of parturition.

Savaging, where a sow kills her own new-born piglets by biting them has not been reported in pigs or boar living in extensive conditions (Petersen et al.,1990; Stolba and Wood-Gush, 1984, 1989) although it may be difficult to observe. Loose-housed domestic sows in indoor or outdoor systems also show savaging only rarely, but wild boar kept indoors in small pens (3 m $\times$ 1.5 m) exhibited savaging (Harris et al., 2001). This suggests that it may be a problem largely induced by confinement (Ahlström et al., 2002). Individuals that savage show more evidence of thwarted nest-building (Appleyard et al., 2000), and may take longer to farrow, being more restless during farrowing (Harris et al., 2001) and more responsive to piglets (Ahlström et al., 2002). This is consistent with studies in other animals suggesting that unsuitable environments may trigger infanticide (e.g. Silver Foxes, Braastad, 1991).

2.5.5 Weaning

Natural weaning is a gradual process, and it is difficult to identify exactly when it begins and ends. In a farm environment, weaning is very early (in comparison to studies with extensive domestic pigs), and a series of simultaneous sudden changes occur: piglets are usually placed in a new environment, without the sow, where only solid food is available. They may also be mixed with piglets from other litters. There are a number of signs that piglets do not respond well to weaning. Udder-massage behaviour may be re-directed to the bodies of other piglets in a behaviour known as belly-nosing (Dybkjaer, 1992). They undergo a 'growth check' as the gut adapts to the sudden change to solid food. There are other behavioural signs of distress including increased vocalisations (Weary and Fraser, 1997; Weary et al.,1999) and increased sitting inactive (Dybkjaer, 1992), and changes in physiological stress indicators including increased cortisol concentrations (Rantzer et al.,1995), increased neutrophil/lymphocyte ratio (Puppe et al.,1997) and increased growth hormone concentrations (Carroll et al.,1998). It is also possible that the absence of the dam and the rest of the social group, including other juveniles, might affect behavioural development, as there are no opportunities for social learning from these individuals.

2.6 Conclusions

In early domestication, several aspects of pigs' natural behaviour were seen as beneficial. They live in social groups, produce large numbers of offspring compared to other large mammals, they can eat a wide range of natural food sources such as acorns and roots which are of no direct use to man, and also make use of human food wastes. As such, pigs existed in extensive habitats on the periphery of human settlements. In later domestication, pigs have shown a great deal of adaptability to different diets and to a range of conditions from open forest (e.g. Brownlow, 1994) through to much more intensive indoor housing. On a behavioural level it is clear that even modern, highly-selected breeds possess almost all of the capacities of the wild boar, as is seen from their complete behavioural repertoire when released into extensive environments. The fact that many of these natural behaviours appear to be controlled to a large extent by internal factors can lead to welfare problems when there are no appropriate outlets for behaviour which pigs are strongly motivated to perform. In this chapter, we have seen how studying wild boar, feral pigs and domestic pigs in extensive environments can provide us with useful comparative evidence of behaviour that pigs might be motivated to perform, and suggest ways in which we could provide for their behavioural needs in a captive environment.

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Chapter 3
Advances in the Study of Cognition, Behavioural Priorities and Emotions

Suzanne Held, Jonathan J. Cooper and Michael T. Mendl

3.1 Introduction

Ask a human being how it is faring and chances are it will report on its state of mind. Ask a pig how it is faring and chances are that this direct verbal approach will not get you very far. Two important points are thus illustrated for our purposes here. Firstly, for most people the notion of 'faring well' or 'welfare' is inextricably linked to state of mind or 'mental state' (reviews in Broom, 2001; Dantzer, 2001; Dawkins, 2001; see also Duncan and Petherick, 1991). The second point is that where we aim to study the welfare of animals, we have to use non-verbal expressions or correlates of their mental state.

Our aim in this chapter is to provide an overview of how different aspects of the 'mind' of pigs have been studied and what these studies have shown. The studies have been loosely grouped into three sections with some inevitable overlap between them. The first section explores pigs' cognitive abilities. In our usage here, 'cognitive' is a collective term for all the mental processes which pigs may use to perceive, handle and store environmental information (cf Shettleworth, 2001). As such, it covers the pigs' sensory capacities, their learning and memory abilities, and other abilities which may go beyond associative learning of simple reward contingencies. We then turn to what pigs may 'want' to do or be motivated to get, and how this can be studied. Finally, we review ways in which emotions in general, and pig emotions in particular, might be studied.

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3.2 Pig Cognitive Abilities

3.2.1 Pig Senses

The pig's world is made up of a mass of sensory information that it must filter and interpret in order to function efficiently. How it interacts with its environment will depend on its sensory abilities and the impact of sensory information on emotional, motivational and cognitive processes. These processes and any conscious experience of their functioning will have evolved to meet the adaptive needs of ancestral pigs in natural environments over evolutionary timescales (Signoret et al., 1975; Hutson et al., 1991). They will include the sensation of, perception of, and attention to external sensory inputs mediated through the senses of hearing, vision, touch (including pain perception), olfaction and taste.

3.2.1.1 Hearing

One might expect pigs to have a well-developed sense of hearing to help communicate with conspecifics or detect potential predators in a forest environment, where visual cues are often impaired. Pigs, however, have relatively poor hearing thresholds, of for example 9 dB at their most sensitive frequency of 8000 Hz compared with –10 dB at 4000 Hz for man (Heffner, 1998) though their auditory range spans from 42 through to 40,500 Hz (Heffner and Heffner, 1992) compared with a range from 31 through to 17,600 Hz in man. There is, therefore, a danger of exposure to environmental noise, including ultrasound that would go undetected by humans and which could be highly aversive to pigs. This could include sound emitted by farm machinery, or during transport and slaughter (Talling et al., 1998a). Playback of white noise or of tapes recorded at abattoirs and during transport elicits changes in behaviour and physiology that are consistent with arousal (Talling et al., 1996). Moreover, Talling et al. (1998b) and Hutson et al. (2000) have both demonstrated that pigs find novel noises aversive, though how aversive and how quickly or whether pigs habituate to such noises is not clear.

As well as allowing pigs to detect environmental sound, hearing is also important in communication between pigs. Certain vocalisations have clearly established functions such as the sow's grunting that accompanies milk letdown (Whittemore, 1993), and other forms of communication between piglets and their dams (Hutson et al., 1992; Weary et al., 1996). Auditory signals are an important mode of communication between sows and piglets, as sows will crush models of piglets that provide visual and tactile cues but do not squeal like a real piglet (Hutson et al., 1991). These vocalisations can convey quite complex forms of information including the sender's identity and their arousal state. Piglets, for example, are able to recognise the grunts of their own mother (Walser, 1986), and sows are more responsive to vocalisations of their own piglets when these are in greatest need (Weary and Fraser, 1995b; Weary et al., 1996).

As well as their role in communication between pigs (Kiley, 1972), vocalisations can aid our understanding of their arousal state and cognitive abilities (Manteuffel et al., 2004). A wide range of call types have been identified (e.g. Grauvogl, 1958; Kiley, 1972), though these can be broadly divided into social contact calls, typically low-pitched 'grunts' with low tonality; and calls that are related to the level of arousal of the sender, typically longer, louder, high pitched 'squeals' or 'screams' with high tonality (Kiley, 1972; Schrader and Todt, 1998; Manteuffel et al., 2004). These high pitched calls have been investigated extensively as potential measures of pig welfare and have been associated with a number of stressors including social isolation (Weary et al., 1997), weaning (Weary et al., 1997), food deprivation (Appleby et al., 1999), immobilisation (Schrader and Todt, 1998) and castration (White et al., 1995; Taylor et al., 2001). Furthermore, a small number of studies have linked specific calls to physiological measures of arousal such as heart rate (Marchant et al., 2001) and adrenalin (Schrader and Todt, 1998). With increasingly sophisticated analysis tools in bio-acoustics, there is likely to be further elucidation of a pig's welfare state through calls and the potential to automatically monitor certain aspects of pig welfare using vocalisation (Schön et al., 2004).

Pig vocalisations also play an important part in social cognition including social recognition and assessment. These are dealt with in more detail later in this chapter, so we will note here only that it has been demonstrated that pigs are both capable of social recognition and assessment of need through vocal communication alone (e.g. Weary and Fraser, 1995b; Illmann et al., 2002).

3.2.1.2 Vision

Pigs are not thought to have particularly well-developed powers of vision (Hutson et al., 1993, 2000; Lomas et al., 1998). For example, pigs have been found to possess cones in the retina, but they perform poorly in abstract visual discrimination tasks based on colour alone (Tanida et al., 1991). Similarly Tanaka et al. (1998) and Zonderland et al. (2008) report poor visual acuity in pigs. These studies suggest that pigs have poor powers of visual discrimination and that generally, they do not rely on visual cues when evaluating environmental factors (Lomas et al., 1998). This may be because pigs use vision to collect information on what is immediately in front of them (Koba and Tanida, 2001), which could complement their tactile and olfactory senses during food seeking and ingestion (Meunier-Salaun and Picard, 1996; Arave, 1996). This likely reliance on environmental cues other than visual poses a challenge to investigators of visual abilities in pigs (Hutson et al., 1993). In heavily controlled studies, Tanida and Nagano (1998) found that mini-pigs readily discriminated between familiar and unfamiliar handlers, but performance declined when visual cues were obscured. Follow-up studies revealed that pigs can use quite subtle visual cues if olfactory or auditory cues are absent (Koba and Tanida, 1999, 2001; see also Section 3.2.2.3). Under laboratory conditions, mini pigs have been also found to locate food resources on the basis of colour cues alone (Croney et al., 2003) though to date, no studies have demonstrated this in agricultural breeds of pig.

3.2.1.3 Touch and Pain

The sense of touch is usually facilitated by mechano-receptors where distortion of tissues leads to the release of neurotransmitters (Simmons and Young, 1999). These mechano-receptors are involved in co-ordination of muscle groups during movement, maintenance of posture and co-ordination of physical interaction with the environment such as rooting and chewing. When focused on particular tasks, the activity of relevant mechano-receptors can, and will be, closely and consciously monitored during periods of selective attention. One area that has a disproportionate density of these receptors is the pig's snout (Kruska, 1988). This is involved in a number of manipulatory acts such as pushing, rooting, biting and carrying (Stolba and Wood-Gush, 1989).

Nociceptors or pain-detecting neurons take a number of forms including mechano-receptors that fire on more exaggerated distortion or actual severing of tissues or chemical-receptors which are triggered by thermal loads (Livingston et al., 1992). The function of pain is to bring attention to specific areas of tissue damage so as to protect an area of damage or reinforce the adverse consequences of a particular damaging action. It has, however, been argued that the perception of pain is unnecessary to avoid painful stimuli (Kennedy, 1992). For example, the behavioural response to a painful stimulus, such as withdrawal of the limb, is such an immediate, reflex action that it seems to precede the actual subjective experience of the painful stimuli (Livingston et al., 1992). Similarly, experience of pain can be modulated at a number of levels, by attenuation of the nerves themselves with repeated firing, by unconscious suppression by emotional responses such as fear or aggression, or an alternative more immediate source of pain, or by deliberate suppression of feelings of pain and/or their behavioural consequences in situations where it would be advantageous to conceal emotions (Kehoe and Blass, 1986; Livingston et al., 1992).

In farmed pigs, a number of husbandry processes are likely to lead to acute or chronic pain, including teeth clipping, tail docking and castration. These are usually conducted in neonatal animals (Noonan et al., 1994) and, as such, may precede the full development of a functioning pain detecting neuro-anatomy in the infant animal (Owens, 1984). Piglets often struggle and vocalise during these procedures, but these actions may represent the reflex responses to handling and restraint rather than conscious experience of pain. Piglets undergoing these procedures, however, do exhibit more teeth-champing, head-shaking, tail wagging and grunting than littermates that are only handled (Noonan et al., 1994; Rand et al., 2002). This suggests some degree of discomfort following the procedures, though the behavioural differences were not evident a few minutes after the procedures, suggesting any discomfort was transient. If, therefore, these procedures are to be carried out for the sake of the sow in the case of teeth clipping or the piglets themselves in the case of tail-docking, then it would appear to be preferable to do so on day-old piglets, rather than older animals (Whittemore, 1993) though it would be worthwhile considering the use of post-operative analgesics to reduce pain. Nevertheless, persistent neuromas still form in the damaged tissues even in piglets docked at one day of age, which appears to be one reason why tail-docking may help prevent tail-biting (Simonsen et al., 1991). Castration of male piglets also appears to be associated with pain with increased vocalisation compared to sham castrated or locally anaesthetised piglets (White et al., 1995; Weary et al., 1998; Taylor et al., 2001), activation of hypothalamic-pituitary-adrenal axis (White et al., 1995), and prolonged changes in behaviour and/or posture that are indicative of pain (Taylor et al., 2001; Hay et al., 2003).

3.2.1.4 Olfaction and Gustation

The pigs' snout hosts those senses that can be said to represent the major adaptation to their lifestyle: olfaction and gustation (Signoret et al., 1975). Both are important in the seeking and selection of appropriate food-stuffs and in social interactions. Pigs are opportunistic omnivores that are capable of eating a wide range of food-stuffs (e.g. Croney et al., 2003 and Section 2.3.3). As such, they are likely to be exposed to a wide range of associated flavors and odours that may guide them in the selection of what is good and what is not good to eat. These flavor preferences may develop from a range of sources. There may be certain inherent tendencies, such as for flavors or odours that tend to indicate high levels of protein, fat or carbohydrates (Kyriazakis et al., 1990), or pigs may have to learn to associate flavors with preferred food types (Cairns et al., 2002) or food selection may be socially facilitated by peers or parents (Newberry and Wood-Gush, 1985; Cox and Cooper, 2001).

Pigs have taste receptors sensitive to a wide range of flavors, including those described as 'bitter', 'sour', 'sweet' and 'salty' in human taste perception (Perry, 1992; Jones et al., 2000). Sensitivity to specific flavors can be demonstrated by changes in food consumption (Baldwin, 1976), in preference tests (McLaughlin et al., 1983) or using operant procedures (Arave, 1996; Meunier-Salaun and Picard, 1996). However, unless flavors are reliably paired with a limited amount of food, such measures of sensitivity may not be stable (Cairns et al., 2002). For example, addition of 'bitrex', a substance considered extremely bitter in man, causes an abrupt reduction in food intake (Blair and Fitzsimmons, 1970). This aversion, which may be due solely to novelty (Hutson et al., 1993), was overcome once the pigs had become sufficiently hungry to consume small quantities of bitter food and on discovering no unfavorable nutritional consequences their food consumption returned to normal despite the presence of 'bitrex'. This may represent one functional value of possessing taste receptors, namely the ability to determine new food types on the basis of flavor and avoid or exploit them on the basis of their post-ingestive consequences (Cairns et al., 2002). In addition, taste receptors may also help pigs to discriminate between feed-types on the basis of quality (Kyriazakis et al., 1990; Meunier-Salaun and Picard, 1996), for example, pigs prefer sweet-flavored feeds (Kennedy and Baldwin, 1972), when given a choice but show no long-term increases in intake when feeds are flavored with a preferred flavor (Forbes, 1998).

Olfaction is also an important mode of transmission of social information between pigs (Sommerville and Broom, 1998), including sexual state (Signoret et al., 1975), social identity (Meese et al., 1975; Mendl et al., 2002) and aggressive disposition (McGlone, 1990). Pigs frequently engage in nose-nose and nose-genital contact during social encounters, which may involve exchange of information through pheromones released from these areas, in saliva or in urine (Signoret et al., 1975). Pheromones such as androsterone and androstenol (Booth, 1975) in boar saliva, influence both the age at which gilts reach sexual maturity (Pearce et al., 1988) and early lactational oestrous in sows (Petchey and English, 1980). Adult sows are five times more sensitive to these compounds than boars (Dorries et al., 1995). The sow's sexual receptiveness is also influenced by these pheromones as, during courtship, boars produce copious amounts of saliva, which induces lordosis in sows (Booth, 1975).

In pigs, social recognition is important in aggressive interactions, which can lead to serious injury (Sommerville and Broom, 1998). When strange pigs meet, they intensively sniff each other and if evenly matched this will often escalate into fighting. Impairment of vision has little impact on fighting (Ewbank et al., 1974), but aggressive interactions between strangers can be reduced by sectioning the olfactory bulbs of pigs (Meese and Baldwin, 1975). Pheromones are also strongly implicated in individual recognition and the maintenance of stable social interactions. Meese et al. (1975) and Mendl et al. (2002) have shown that pigs are capable of discriminating between the urine of several con-specifics. Once stable groups are formed, pheromones may also be implicated in dominance hierarchies (Mendl et al., 2002). These appear to be breakdown products of glucocorticoid hormones that are secreted in saliva and urine, which are particularly high in dominant or aggressive pigs. In addition, an appeasement pheromone appears to be secreted by 'loser' pigs, which signals submission (McGlone, 1990). However, more evidence is needed to confirm these effects.

Finally, it has also been found that pigs emit an alarm pheromone that will affect behaviour of other pigs, for example during transport and slaughter (Amory and Pearce, 2000). Such a compound may partially explain the reluctance of pigs to move during transport and slaughter and the apparent high levels of fear expressed in these situations. During slaughter itself, gaseous agents such as high concentrations of carbon dioxide have been used to stun and kill pigs. Exposure to high concentrations of carbon dioxide causes relatively rapid knock down or apparent loss of consciousness (within 10–15 seconds) but behavioural and physiological tests suggest that such exposure is highly aversive due to irritation or nociperception on sensitive membranes and possibly sense of breathlessness associated with hyperventilation (Raj et al., 1997; Raj, 1999; Macold et al., 2003a,b; Velarde et al., 2007). Pigs show rapid changes in behaviour when exposed to environments with high (>70 %) concentrations of carbon dioxide (Raj, 1999; Macold et al., 2003a) and avoid entering or returning to such environments (Macold et al., 2003b; Velarde et al., 2007). The use of anoxia, for example stunning in an argon or nitrogen/argon environment, has been suggested as a pig-friendly alternative to carbon dioxide stunning (Raj et al., 1997; Raj, 1999; Macold et al., 2003a,b). Although a longer exposure time is required, for example over 180 seconds to achieve stunning, pigs show no overt behavioural signs of distess (Raj, 1999, Macold et al., 2003a), little elevation of blood noradrenalin post-anaesthesia (Macold et al., 2003b) and do not learn to avoid the anoxic environment (Macold et al., 2003b).

3.2.1.5 Summary

Domestication does not appear to have significantly altered the type of environmental information a pig is capable of detecting. Pigs are clearly capable of responding to a wide range of stimuli, many of which will go undetected by the stockperson. The modern husbandry environment may expose pigs to a number of potentially aversive stimuli, which if unavoidable will lead to a poor quality of life, unless pigs are able to habituate. In addition, a number of desirable behaviour patterns, such as food detection, sexual receptiveness and appeasement will depend on intact and functioning sensory facilities, which if disabled, may lead to failures in biological functioning (Hutson et al., 1991; Jones et al., 2000).

3.2.2 Learning and Memory

An unimpaired function of its senses, then, is the essential first step in the pig's cognitive processing allowing it to interact appropriately with its environment. The next step is processing and storing the information it has perceived through its senses. This is where the pig's learning and memory abilities come in.

For our purposes, learning is probably most usefully defined by Thorpe (1963) as '. . . that process which manifests itself by adaptive changes in individual behaviour as a result of experience'. Like other animals, pigs can learn about their environment in different ways (cf. Hemsworth, 2000): (i) they learn by associating certain aspects of their environment with rewarding or punishing consequences for themselves (Pavlovian or classical conditioning); outdoor sows, for example, will learn to associate approaching tractor-noise with the arrival of feed, (ii) they learn by habituating to stimuli that are without personal consequence such as frequent and irrelevant overhead airplane noise, (iii) they learn by associating their own actions with rewarding or punishing consequences (operant conditioning) such as learning to press a drinker nipple for water, and (iv) they can also learn from others (social learning). Because pigs are naturally inquisitive, highly food-motivated and easily trained, they have been the most widely used farm animal species in operant conditioning studies (Kilgour et al., 1991). One main application of operant conditioning techniques in domestic pigs has been in studies of their environmental and sensory preferences. A review of these is beyond the scope of this chapter, but a classic example is provided by Baldwin and Meese (1977). They trained young Large Whites to adjust ambient light and heat levels by pushing their snouts through a slit in the pen wall. This broke a light beam, which in turn activated extra lighting or infra-red heaters above the pen (Baldwin and Meese, 1977). Other applications of operant conditioning techniques have been in determining the sensory discrimination abilities of pigs (e.g. Koba and Tanida, 2001; see also Arave, 1996) and their behavioural priorities as reviewed in Section 3.3 of this chapter.

It seems that operant techniques have been used less frequently to test pigs' learning processes. One example is an early series of experiments on 'conditioned emotional responses' (Estes and Skinner, 1941) by Dantzer, Baldwin and colleagues (Baldwin and Stephens, 1970; Baldwin and Stephens, 1973; Dantzer and Baldwin, 1974; Dantzer and Mormede, 1976). They showed that pigs quickly learn how to get food in an operant task and to temporarily suppress this newly acquired behaviour. Pigs were first trained to respond for food by pressing with their snouts on a switch panel. Once pigs had learnt this, a tone was sounded as the pigs were still working for the food. The tone signaled the arrival of an electric shock. Pigs learnt after only 3–6 such sessions to stop pressing the panel during the tone even though they were highly motivated to press for more food (Baldwin and Stephens, 1973). This conditioned suppression did not generalise to a differently-pitched tone, not followed by an electric shock, indicating that pigs could discriminate between the two tones and their reward properties (Dantzer and Baldwin, 1974; see also Dantzer and Mormede, 1976). Pigs, then, can quickly learn new behaviours from operant contingencies and to change behaviours as contingencies change.

3.2.2.1 Learning About Food from Others

During weaning under natural conditions, piglets gradually learn about solid foods as they roam around with their dam and peers (e.g. Jensen, 1995; Newberry and Wood-Gush, 1985; Petersen et al., 1989; Petersen, 1994). Under commercial conditions, weaning is usually abrupt. This has several implications for the post-weaning behaviour of the piglets (Held and Mendl, 2001) including their voluntary solid feed intake (e.g. Pajor et al., 1991). Piglets may take some time to learn to accept solid food as a milk substitute even where it has been available as creep feed in the farrowing pen (e.g. Pajor et al., 1991; Appleby et al., 1992; Fraser et al., 1994; Pluske et al., 1995; Fraser et al., 1995). Studies by Keeling and Hurnik (1996) and Morgan et al. (2001) indicate that voluntary solid food intake after commercial weaning may be increased in the presence of others, especially where the companions are already experienced in eating solid food. This suggests that social factors are important as piglets learn about new sources of food. Exactly what type of food-related information piglets can acquire from each other was investigated by Nicol and Pope

(1994). They examined whether young pigs pick up information about what to eat, and where to find it, from watching their littermates. The pigs were 6–10 weeks old at the time of testing and already weaned. They were either allowed to watch a sibling eat a novel food or they were pre-exposed to the smell and sight of the new food before they themselves were given access to it. There was no difference between these two groups in how much novel food they consumed, indicating that social learning was no more effective than individual learning in this context. However, social effects emerged in learning about *where* to find food. Individual test pigs watched a trained demonstrator littermate feed from one of three troughs. After the demonstrator had left the feeding arena, the test pig was allowed in. A substantial proportion of test pigs that proceeded to feed from any trough chose the one previously demonstrated, indicating that they had learnt where to eat from watching their littermates (Nicol and Pope, 1994).

Observations under free-range conditions suggest that pigs continue throughout their lives to pick up information about the location of lucrative feeding sites from their group mates (Krosniunas, 1979). This was confirmed experimentally by Held et al. (2000). They trained pigs to search for food hidden in one of eight possible locations in a foraging arena. After training, pigs foraged in pairs consisting of a dominant and a subordinate individual, where only the subordinate knew where the food was. Over several such pair foraging trials, naïve dominant pigs learned to follow the pre-trained subordinates to the hidden food rather than searching randomly as they had done when foraging alone (Held et al., 2000).

3.2.2.2 Spatial Learning and Memory

Without exploitable group mates around, pigs have to find and remember good feeding sites for themselves under natural conditions. One might therefore expect pigs to have well-developed spatial learning and memory abilities. Several studies have found that this is indeed the case (e.g. Mendl et al., 1997; Laughlin et al., 1999; Laughlin and Mendl, 2000). These studies typically test the pigs' ability to remember one or more feeding sites out of several potential ones. Pigs are allowed to sample the food sites in an initial 'search visit', are then returned to their home pen ('retention interval'), before being re-introduced to the test arena to relocate the food sites ('relocation visit'). Mendl et al. (1997) showed that young male Large White × Landrace pigs used their memory rather than food-related cues to relocate food hidden in one of ten areas in a test arena. They remembered the food location over retention intervals of 10 min and 2 h. Young female Large White × Landrace × Durocs performed equally accurately in a spatial memory task in which the relocation of one of eight buckets was rewarded (Held et al., 2000). A recent study showed that they also have the ability to discriminate between food sites of different relative value and to remember their respective locations (Held et al., 2005). Pigs had to relocate *two* out of eight buckets distributed in a test arena (5.7 m × 12 m). The two buckets were baited with different amounts of feed. When allowed to retrieve both baits, the pigs showed no preference for retrieving a particular one first. However, when they were allowed to retrieve only one bait, a preference for retrieving the larger amount emerged, showing that the pigs (a) could differentiate between the two food amounts and (b) could remember which was hidden in which location (Held et al., 2005).

Domestic pigs, then, perform well in spatial learning and memory tasks, which require them to revisit sites where they previously found food. Laughlin and Mendl (2000) investigated whether this reflects a predisposition in pigs to return to previously lucrative feeding sites when foraging rather than to avoid them and search elsewhere. Domestic pigs might be predisposed to the former, or 'win-stay', foraging strategy because in most production systems their feed is predictably provided in the same place (Mendl et al., 1997). In contrast, wild and feral pigs forage for seasonal and patchily distributed foods such as roots and bulbs (e.g. Krosniunas, 1979; Janeau and Spitz, 1995). This might predispose them to avoid re-visiting sites where they have recently found food, thereby adopting a 'win-shift' strategy (Laughlin and Mendl, 2000). Laughlin and Mendl (2000) tested twenty pigs in a radial arm maze task, which is widely used in studies of animal spatial learning and foraging strategy (Olton et al., 1981; recent review in Lipp et al., 2001). In Laughlin and Mendl (2000) the radial maze comprised eight arms, four of which contained food. In search visits, pigs had access only to the four baited arms. During relocation visits, they could access all eight arms: half the pigs were trained in a win-stay task by re-baiting for them the four arms, which had contained food in the previous search visit; the other half were trained to use a win-shift strategy by baiting the four previously closed, empty arms. Win-shift trained pigs learnt their task much quicker and on average made fewer errors during relocation visits than win-stay pigs (Laughlin and Mendl, 2000). A closer examination of these errors revealed in both groups a tendency to shift to new arms rather than re-visit non-baited ones. Laughlin and Mendl (2000) therefore suggest that domestic pigs exhibit a general 'shift' predisposition, which would have produced the most adaptive foraging strategy in their ancestral kin.

The radial arm maze has also been used to examine the effects of the costs of acquiring and forgetting information on spatial memory in the pig. Using the same search and relocation paradigm as above, Laughlin and Mendl (2004) showed that pigs that incurred extra time costs (by having to step over a rope) when visiting arms during the first search of the maze each day showed fewer errors during the subsequent relocation visit to the maze. This was probably due to the time costs inducing enhanced attention to, and encoding of, information during sampling. Furthermore, pigs experiencing extra time costs during relocation trials were less susceptible to their memory recall performance in these trials being disrupted by disturbances during the memory retention interval, probably because of more considered and less 'impulsive' use of retrieved information. These findings indicate that information which is more costly to obtain or forget, even if that cost is only a small time delay, appears to be acquired, stored and retrieved more effectively. Domestic pigs thus show evidence of prioritization in memory of 'important' information, which can be viewed as an adaptive feature of memory processes (see Mendl et al., 2001).

3.2.2.3 Discriminating Between Different Humans

Most studies to date suggest that pigs on farms show generalised rather than discriminative behavioural responses to different humans (e.g. Hemsworth et al., 1981, 1994, 1996; Hemsworth 2000; Chapter 7). They learn to associate their stockperson with either rewarding or punishing consequences, for example gentle or rough handling, and behave accordingly in subsequent encounters with any human by approaching or avoiding him or her. However, in certain commercial situations, pigs do discriminate between different humans. Hemsworth et al. (1996), for example, compared the responses of young Large White × Landrace gilts to a handler and a stranger after different common husbandry procedures during which only the handler had been present. One such procedure was the introduction of the gilts to a boar for oestrus detection, which is thought to be an aversive experience for them (Turner et al., 1995). However, gilts were moved to and from the detection pens by their handlers, and handlers were instructed to use only one negative physical interaction such as a slap to any four positive ones (e.g. strokes, pats). In subsequent approach-avoidance tests, gilts tended to interact more frequently with the familiar handler than an unfamiliar one indicating a discriminative rather than a generalised response (Hemsworth et al., 1996). When fed in the presence of a familiar handler, the gilts showed an even clearer discrimination in subsequent approach-avoidance tests (Hemsworth et al., 1996).

The general ability of pigs to learn to discriminate between familiar and unfamiliar humans was demonstrated by Tanida and Nagano (1998). Five weeks of daily gentle and food-rewarded handling resulted in pigs recognizing their handler when tested against a stranger in a Y-maze. All five young male miniature pigs learnt within four sessions of 20 trials to approach only their handler. This shows that they could learn to discriminate between the two people, though two pigs had initially shown stimulus generalisation across them (Tanida and Nagano, 1998). Further investigations showed that the pigs used olfactory, auditory and visual cues in making the discrimination, but visual cues such as clothes colour and brightness were particularly salient (Tanida and Nagano, 1998; Koba and Tanida, 1999). However, miniature pigs can still learn to discriminate between people even if these wear identical clothing and cannot be identified by smell or sound. Koba and Tanida (2001) found that obscuring olfactory cues and excluding auditory ones did not decrease the pigs' ability to identify their handler, but increasing the pigs' distance to the two people and decreasing the light levels in the test room did (Koba and Tanida, 2001). Koba and Tanida (2001) suggest that, given enough exposure, pigs can discriminate between people merely using differences in body size and possibly in facial characteristics.

Overall, these studies show that pigs can learn to discriminate between different humans. Auditory, olfactory and visual cues are used, but pigs can also discriminate between two humans using only visual cues. However, whether pigs generalise or discriminate between different humans is likely to depend on how often and intensively they interact with them.

3.2.3 Recognizing, Remembering and Assessing Other Individuals

The social organisation of feral and free-ranging domestic pigs appears to be similar to that of the ancestral wild boar species. Typically, groups are made up of two to four adult females and their offspring. Males associate loosely with these groups, except during the mating season when competition for females can be intense. Groups tend to avoid each other, but integration of individuals into a group can occur gradually over time (Wood and Brenneman, 1980; Mauget, 1981; Stolba and Wood-Gush, 1989; Mendl, 1994). The social organisation of most farmed pigs is quite different. They may live in much larger groups, often comprised of individuals of just one sex, age or size, and sometimes numbering well over a hundred animals. This is especially true for weaned and growing pigs, but may also be the case for group-housed sows in systems such as those using electronic sow feeders. Mixing of animals is usually abrupt and involves many unfamiliar individuals being put together in a pen, without the time or space to get acquainted gradually. Individuals may be mixed several times during their life, for example after weaning, and when moving to new accommodation during the growing period. In contrast to this 'social overload', stall and tether-housed sows may spend most of their adult lives unable to interact directly with another individual.

Although the social environments on farms and in more natural conditions are quite different, both have the potential to enhance and threaten welfare. Long-term affiliative relationships can ameliorate the effects of novelty or challenging situations through processes such as social support and alliances. On the other hand, competition and aggression from group-mates may be a potent source of animal welfare problems (Mendl and Newberry, 1997). In all cases, it is likely that an animal will benefit from being able to recognise and remember others, to assess their relative competitive ability, to monitor their social status within the group, and to predict their future behaviour. An animal with these abilities will be more able to predict and control its social interactions and, in this way, minimise stress (see Mendl, 2001).

3.2.3.1 Discriminating and Recognizing Other Individuals

Indirect evidence indicates that pigs can discriminate familiar group-mates from unfamiliar non group-mates. Pigs tend to show aggression towards unfamiliar animals but not towards familiar ones (e.g. Zayan, 1990; Mendl et al., 2001). This may be because with increasing familiarity comes increasing information about relative competitive abilities, and this minimises the need for familiar pigs to fight in order to sort out relative status (Rushen, 1988, 1990). Other studies have shown that the development of a stable social hierarchy between unfamiliar pigs is delayed if pigs are unable to investigate each other's face area using their snouts, but not if sight alone is impeded (Ewbank et al., 1974). However, the speed of hierarchy formation and the occurrence or absence of fighting between individuals are indirect and sometimes inaccurate measures of conspecific discrimination, and tell us little about how such discrimination takes place. For example, fighting may occur between individuals who are prepared to compete vigorously for a resource even if they are familiar with each other. The propensity to fight unfamiliar rather than familiar individuals may be based on discrimination between 'in-group' and 'out-group' cues rather than on discrimination between specific individuals.

Studies using more direct measures offer better insights into pig social discriminative abilities. De Souza and Zanella (2001) used a habituation-dishabituation technique to demonstrate that 10–20 day old male piglets could discriminate between same-aged conspecifics. This technique involves repeated presentation of one individual to the subject animal, leading to a waning of interest in that individual (habituation). If the subject's interest is re-kindled (dishabituation) when a different individual is presented, this is taken to indicate the ability to discriminate between the two individuals (see Thor and Holloway, 1982). Young piglets showed this pattern of response in De Souza and Zanella's study. McLeman et al. (2002, 2005) used a food-reinforced Y-maze choice task to show that 6 week-old female pigs could learn to associate one out of two individuals with a food reward, hence demonstrating the ability to discriminate between individuals. Horrell and Hodgson (1992a,b) showed that sows could discriminate their piglets from others and vice versa using T-maze free choice tests. Sows orientated towards unfamiliar piglets rather than their own piglets, while piglets orientated towards their mother in preference to other sows. Horrell and Hodgson further showed that sows did not reliably discriminate their own 12 h-old piglets, when presented behind a wire barrier, but did so when they were 1 day old. Discrimination was delayed to 14 days of age if odour and sound cues from piglets were restricted. Piglets could discriminate between odours from the urine, feces and udder of their mother and those from other mothers by about 7 days, and could identify their mother's 'suckling call' grunts by 36 h of age.

Maletinska et al. (2002) showed that sows preferred to visit anaesthetised 1-day-old piglets that were their own and familiar to them in comparison to alien/unfamiliar animals. This contrasts with Horrell and Hodgson's finding of a preference for unfamiliar piglets, but confirms the general point that sows appear able to discriminate 1 day-old piglets on the basis of odour cues. Interestingly, and unlike Horrell and Hodgson, Maletinska et al. (2002) found that when piglets were awake, sows displayed no significant preferences for any piglet type. They suggested that the high rates of piglet vocalisations during these tests may have aroused the sow and induced a motivational state where discrimination on the basis of odour cues was not a high priority relative to general investigation of all stimuli. They speculated that sows were probably unable to discriminate piglets on the basis of their vocalisations at this early age. These findings indicate that spontaneous preference behaviour may be influenced by the precise nature of the experimental set-up and can provide contrasting data on discrimination abilities in different studies.

The use of urinary cues to discriminate different individuals has also been demonstrated in 6–9 month-old females using a food-reinforced operant procedure (Meese et al., 1975), and in 10-week-old females using a habituation-dishabituation test (Mendl et al., 2002). Mendl et al. (2002) also showed that pigs living in the same pen for 7 weeks were not more difficult to discriminate than those living in different pens. This suggests that any 'group-specific' urinary odour acquired through living together (e.g. from food (Brown et al., 1996)) does not appear to interfere with discrimination of individual urinary cues.

Exactly what components of urine were used by pigs to make these discriminations is unknown. Sex hormones and related pheromones could have been involved in the study of older females, but were less likely to be involved in the study of younger females where all urine donors were c.10 weeks old. Other components of urine that are important in other species include proteins of the major histocompatibility complex, and major urinary proteins (Hurst et al., 2001). Their role in pig odour discrimination is currently under investigation (Cheetham et al., 2002). Whether urinary cues are actually used by pigs to discriminate individuals and to provide functionally useful information about, for example, social status is not known. Odour cues do seem important, because Kristensen et al. (2001) showed, using a free-choice Y-maze test, that 6–7 week old male pigs could use such cues to discriminate between conspecifics from their own group and those from other groups. They also found that, when housed in ammoniated air (c. 36 ppm) as might occur on a commercial pig unit, the pigs preferred to move into the Y-maze arm closest to their group-mate, whereas when housed in fresh air, they tended to approach unfamiliar non-group-mates. Because ammonia is a component of urine, it is possible that it interfered with urine discrimination and led to this finding. Alternative explanations include the possibility that in aversive conditions (e.g. high ammonia) pigs prefer to spend time closer to familiar individuals, whereas in benign conditions, they are more likely to investigate novel individuals (Kristensen et al., 2001).

The role played by other olfactory cues, and visual and auditory cues is starting to be examined. McLeman et al. (2004; 2008) used a Y-maze task to demonstrate that pigs can discriminate other individuals on the basis of cues from any combination of two of the three sensory modalities (e.g. visual and olfactory), and also using cues from just one modality (i.e. only visual, only auditory, or only olfactory). Recent research has also shown that sows can distinguish their own offspring from alien offspring on the basis of piglet contact and isolation calls (Illmann et al., 2002). Sound analysis research indicates that the contact calls made by sows to their piglets during nursing show large individual differences in many call parameters (Schön et al., 1999), as do the scream calls given by young piglets (Schön et al., 2001). Hence there is sufficient information in the call structure of individuals to allow them to be used as individual identifiers.

The ability to discriminate between individuals does not tell us much about what animals exactly recognise about those individuals. For example, all the above discriminations could have been performed on the basis of particular cues which were salient in the context of the discrimination tests, but which are not actually used to identify individuals under more natural conditions. Discrimination and individual recognition are not the same thing. Recognition implies formation and memory of associations between an individual's identifying cues and aspects of their behaviour that have social relevance (e.g. that sow has a specific smell, lop ears, and a heavy build, and tends to attack me when I meet her), whereas discrimination simply requires the individual to tell one stimulus from another. The question of whether pigs develop a multi-modal representation of other individuals needs to be answered to start to address the issue of individual recognition. Johnston and Jernigan (1994) and Johnston and Bullock (2001) demonstrated that golden hamsters appear to have such a representation whereby different odours from the same individual are all classed as belonging to that individual, as long as the subject animal is familiar with it. Studies of this sort have just begun in pigs (McLeman, 2005; McLeman et al., 2006).

3.2.3.2 Remembering Other Individuals

Another important question is how long can individuals remember others? This is relevant because pigs are sometimes separated from each other and then reunited at a later date. For example, sows housed in groups during pregnancy will usually leave the group to farrow on their own and then return to that group several weeks later. Growing pigs may be separated from litter mates at weaning, and then become reunited later in life when mixed into new groups. Individuals may also be temporarily removed from groups for veterinary attention, recovery from illness, mating and so on. Fighting often occurs when animals are reunited and this may be because the memory of previously familiar group-mates has dissipated across time.

In an early study, Ewbank and Meese (1971) showed that high-ranking pigs could be removed from a group and returned up to 25 days later without receiving much aggression from their former group mates, whereas low-rankers were attacked after only 3 days away from the group. This could be interpreted as showing that pigs remember the identity of dominants for at least 25 days, but another interpretation is that these animals emit cues that indicate their social status, irrespective of their identity, and promote low aggression from others (cf. McGlone, 1990; Bradshaw, 1992). Similarly, whether low-rankers are attacked because they have been forgotten over a 3-day period, or because they emit cues indicating their status, or because animals remember that they have low social status, cannot be established from this study. Subsequent research has suggested that sows show low aggression when reintroduced to each other after spending up to 6 weeks apart (Arey, 1999) and thus may be able to remember each other for this period (see also Spoolder et al., 1996a). However, growing pigs appear not to discriminate between previously familiar and totally unfamiliar conspecifics when mixed after 4 weeks separation from the familiar animals, in that aggression to both types of individual is similar (Giersing and Andersson, 1998). Bearing in mind that measuring aggression is a very indirect method for assessing individual discrimination or recognition, one possible explanation for the difference between sows and growing pigs is that growing pigs may change physically more than sows over a 4–6 week period hence making the recognition task more difficult when they are reunited. Alternatively, sows living together for some length of time prior to separation might develop a stronger memory of group-members than growing pigs that have been living together for shorter time periods prior to separation. Other factors such as group size and composition, and the environment that the animal is in while separated from its group-mates, could all influence the strength of the memory trace for individuals and, therefore, may underlie apparent differences in the social memory abilities of sows and younger pigs.

Once again, measures of aggression can only provide an indirect indication of whether an animal is able to remember another one. Studies focusing specifically on measures of social recognition are required to determine how long other individuals are remembered for. Such work will provide a more solid foundation for predicting how long and under what circumstances pigs can safely be removed from their group and reintroduced with a low chance of aggression occurring.

3.2.3.3 Assessing Other Individuals

If pigs have the ability to assess their relative competitive potential through some sort of signal, and can use this ability to solve conflicts or facilitate hierarchy formation between unfamiliar individuals, then allowing them to express these abilities under commercial conditions could help to lower levels of aggression. For example, Kennedy and Broom (1994) showed that gilts pre-exposed through a barred gate to a group of sows before entering that group were involved in lower levels of aggression during the following weeks, than those introduced into the group without pre-exposure. The pre-exposure period may have allowed the animals to assess their relative competitive abilities such that lower levels of aggression were needed to establish relative status following mixing. Alternatively, increasing familiarity per se may have accounted for the effect observed. In a further study, Kennedy and Broom (1996) showed that if groups of fattening pigs were exposed to the sounds or odours (bedding covered in urine and feces) of pigs that were to be mixed into their group, the amount of aggression received by these pigs on mixing was lower than for pigs whose auditory and olfactory stimuli had not been presented to the group. This suggests that increasing familiarity per se (even with single modality cues) might minimise aggression following mixing, but the possibility remains that the vocal and olfactory cues may have also provided some information allowing pigs to assess relative competitive abilities and hence minimise aggression via this route. These explanations cannot be completely disentangled in Kennedy and Broom's studies, but Rushen (1988, 1990) attempted to do so. He showed that merely placing unfamiliar young pigs next to each other for up to 14 days before introducing them did not appear to decrease the amount of fighting they did when they were finally allowed to interact. However, he suggested that assessment of relative competitive ability did take place during fights and that these terminated once one pig accepted that it was the loser. Subsequent encounters between the same pair were then resolved on the basis of the dominance order established previously (Rushen, 1988).

Although Rushen concluded that young pigs are unable to assess their relative competitive status without fighting, Mendl and Erhard (1997) found that newly formed groups comprised of pigs classed as high-aggressive fast-attackers and low-aggressive slow-attackers (Erhard and Mendl, 1997) appeared to form social hierarchies with fewer fights between different dyads than did those groups comprised of either all high-aggressive or all low-aggressive individuals. One interpretation is that in the groups comprising a mix of high and low-aggressive individuals, pigs were able to assess clear differences in their relative competitive abilities (e.g. aggressiveness) in some way, and that this enhanced the speed and peacefulness of hierarchy formation. Further study is required to examine whether such assessment is taking place and, if so, what cues may be used. Olfactory cues are known to be involved in oestrous detection (Booth and Signoret, 1992), to detect that a fear-inducing event has occurred to another individual (Vieuille-Thomas and Signoret, 1992; Amory and Pearce, 2000), and to minimise levels of aggression (McGlone, 1990) in pigs, so it is possible that such cues (e.g. testosterone-related pheromones) might signal the relative competitive ability of individuals too. Alternatively, the process might involve more complex cognitive mechanisms such as the ability to evaluate one's own social status relative to a newcomer by observing how that newcomer fares in an aggressive encounter with a known dominant or subordinate. This ability could also underlie the findings of Mendl and Erhard (1997), and it has been demonstrated in studies of chickens and Siamese fighting fish (Hogue et al., 1996; Oliveira et al., 1998). Similar studies have not yet been carried out in pigs, but studies of related 'higher' social cognitive function have, and these are described in the next section.

3.2.3.4 Exploiting Others and Avoiding Exploitation

As already mentioned pigs can learn to follow an exploitable co-forager to a hidden food site when foraging in groups or pairs (Krosniunas, 1979; Held et al., 2000). In Held et al.'s (2000) study, this suggested the ability to compare some measure of own foraging efficiency with that of others. Domestic pigs generally retain the foraging behaviour of their wild ancestors (Graves, 1984; Wood-Gush et al., 1990). If afforded the chance, they are non-specialist feeders, foraging for patchily-distributed food in their family groups in large home ranges (Krosniunas, 1979; Janeau and Spitz, 1995; Section 2.3.3). Under such conditions, individuals would benefit from the ability to adjust their foraging behaviour flexibly to the presence and behaviour of other members of their group. The best tactics in terms of foraging returns for each individual depend on its social rank or relative competitive ability, and the resource distribution (Barta and Giraldeau, 1998). We might, therefore, expect domestic pigs to have the necessary social cognitive abilities that would allow them to express flexible social tactics in competitive foraging situations. An ability to use to its own advantage the pertinent information held by another group member as shown by the naïve dominants in Held et al.'s study (2000) contributes to this end. Furthermore, the ability to avoid such exploitation by concealing or supplying misleading information about the food location (deceptive tactics) would benefit particularly the low-ranking food-finders. We use 'deceptive tactics' here in a purely functional sense to describe behaviours whose consequence it is to exploit or deceive implying nothing about intentions or mental state attribution.

Detailed behavioural analyses revealed that the subordinate pigs in Held et al.'s (2000) study had indeed changed their foraging behaviour flexibly in response to the exploiting dominants. Overall, they were more likely to show food-directed behaviours in situations where their chances of arriving at the food site ahead of dominants were higher. Learning to avoid arriving at the food site at the same time as the dominants is the simplest cognitive interpretation of the subordinates' behaviour. However, it could be that some of the subordinates' behaviours worked to deceive dominant pigs by leading them away from the baited bucket, or even that they were used deliberately to do so (Held et al., 2002). Some of the behaviours that the subordinates showed in response to exploitation were exactly those that had conditioned tactical deception in monkeys (Coussi-Korbel, 1994; Byrne, 1997). Further work is needed to establish whether pigs, too, can learn to use unequivocally deceptive behaviours.

It is most likely that the flexible behavioural tactics of the subordinates were based on rapid learning about the associated reward contingencies. However, it is possible that the subordinate pigs actually understood what the dominants could and could not see at different points in the foraging trial, and adjusted their behaviour accordingly. Such ability would show the pigs' understanding of the behaviour and intentions of others to be a lot more complex than previously assumed. As such, it would drastically broaden the range of social situations pigs might perceive as stressful. In situations in which they cannot see what is going on, for example, they might use others who can as their source of information with resultant expectations of their environment. The ability of pigs to understand what others can and cannot see was tested by Held et al.

(2001). They tested whether pigs would base their foraging choices on the visual perspectives of others. Held et al. (2001) predicted that when pigs cannot see for themselves where food is being hidden they should follow an individual that had been able to see where the food was rather than one that had not (see also Povinelli et al., 1990). The feed site choices of the test pigs indicated strong positional biases overriding in many pigs any potential ability to use the companions' visual perspective. One pig, however, chose as predicted indicating in it at least the ability to take another's visual perspective in a foraging context (Held et al., 2001).

3.2.3.5 Summary

Research indicates that pigs, including sows and their piglets, can discriminate between different individuals, and may use olfactory cues to do so. However, there is conflicting evidence as to how long they are able to remember each other once separated, primarily due to studies relying on indirect measures of social recognition which do not rule out alternative explanations such as the use of general status-related cues. There is some evidence that pigs may be able to assess each other's relative competitive strength without fighting, but further investigation is required. Evidence from foraging studies suggests that pigs are also able to rapidly learn about the behaviour of other individuals and to use this to their own advantage. It is possible that they might understand what another individual can or cannot see, though this requires confirmation by further study. With increasing knowledge about these social cognitive abilities, it should be possible to specify environmental conditions and management procedures that enhance individual recognition, memory and assessment and help minimise aggression and uneven access to limited resources.

3.2.4 Negative Effects on Cognitive Development and Performance

3.2.4.1 Developmental Effects

Environmental experience is an important determinant of cognitive development in young animals. To develop to its full potential, the brain needs to be appropriately stimulated, particularly early on in its owner's life. Many studies have shown that stimulus-poor rearing conditions can lead to changes in neural form and function in several mammal and bird species (reviews e.g. in Rosenzweig and Bennett, 1996; Healy and Toveé, 1999). A few have investigated whether this extends to pigs. Results from these studies can sometimes be ambiguous and difficult to interpret, but overall they suggest differentiated effects of the stimulus properties of the rearing environment on brain morphology and cognitive ability in pigs.

Sneddon et al. (2000) tested whether pigs reared in enriched housing from birth to 15 wks old would perform better in operant and spatial learning tasks than pigs reared in standard housing. Enriched pigs did perform better in both tasks, leading the authors to suggest that the poor stimulus properties of standard rearing conditions negatively affect the learning abilities of piglets (Sneddon et al., 2000). In contrast, De Jong et al. (2000) concluded from a comparable study that only the development of long-term memory, but not learning, abilities was impaired by standard housing conditions, possibly mediated by differences in baseline cortisol levels.

More direct evidence comes from investigations of the neuronal morphology of pigs reared in different environmental conditions. Grandin (1989, cited in Jarvinen et al., 1998) compared the morphology of the somatosensory cortex (SSC) of 12–14 week old piglets kept in 'simple' and 'complex' environments. The SSC is the brain area where sensory input from the pig's snout is processed, and Grandin found it to be more highly differentiated in the 'simply' kept pigs. Behavioural observations revealed these pigs belly-nosed each other more than the pigs in the more complex environment, while the latter showed more ground-rooting behaviour. This led Grandin (1989) to conclude that while pigs get to exercise their snout in both environments, using it on another pig may be more stimulating to the SSC than using it on physical objects. Jarvinen et al. (1998) extended this to examine the effects of different rearing environments on the development of various cortical areas in young piglets. Three littermates were randomly assigned to one of three treatments: killed three days after birth, reared indoors or reared outdoors. One piglet of each litter was thus cross-fostered to a sow in the other lactation environment, the remaining piglet stayed with its mother until weaning at 4 weeks. After weaning, piglets were kept in indoor or outdoor nurseries, respectively. At 8 weeks, the indoor and outdoor-reared piglets were killed and their sensory cortices compared with each other and with the cortex of their littermate killed at three days old. Cross-fostering had no effect on the neural morphology measures. Rearing condition, however, did. Jarvinen et al. (1998) found morphological differences particularly in the auditory cortex, which at eight weeks was further developed in indoor reared piglets than in the outdoor ones. They suggest that this may reflect the greater demands on the auditory system of indoor pigs: the indoor environment challenged the pigs' auditory system with more inescapable and loud background noise in the frequency bands of pig vocalisations than the outdoor environment thereby making discriminative tasks more difficult (Jarvinen et al., 1998).

Preliminary results by Sumner et al. (2002) also suggest that early weaning (at 12 days old) may have lasting effects on the central nervous system of piglets, particularly on the serotonin system. They report that, at 76 days old, early-weaned pigs moved about less in an open field test than late-weaned piglets (weaned at 42 days). At 90 days, they had lower densities of serotonin (5-Hydroxytryptamine$_{1A}$) receptors in the hippocampal and amygdala regions of the brain (Sumner et al., 2002). The serotonin system has been shown in other species to be involved in affective control. In mice, for example, 5-Hydroxytryptamine$_{1A}$ receptors are involved in the antidepressant responses in mice: individuals without 5-Hydroxy-tryptamine$_{1A}$ receptors show behaviours that are consistent with heightened anxiety levels such as spending less time on the open arms of an elevated plus maze and less time exploring a novel object (Heisler et al., 1998). Sumner et al.'s findings (2002) may thus point to similarly impaired affective control in piglets which are weaned early.

3.2.4.2 Stress Effects

Even with appropriately developed brains, cognitive performance can still be disrupted. The general negative effects of stress on cognitive function are well documented and reviewed (e.g. Mendl, 1999). In pigs, we know that even mild stressors can affect spatial memory abilities (Mendl et al., 1997; Laughlin et al., 1999).

In their study, Mendl et al. (1997; see Section 3.2.2.2) found that how well pigs remembered the location of hidden food depended on what happened to them in the retention interval. They presented pigs with various treatments or 'disturbances' in the retention interval. These were chosen to act as mild stressors or at least to lead to changes in arousal, which are also known to affect cognitive function (e.g. Kavaliers and Colwell, 1995; in pigs e.g. van Rooijen and Metz, 1987). 'Disturbances' also mimicked common husbandry events: pigs were confined in a holding pen on the way back to their home pen for 3 min at the beginning of the retention interval, or for 3 min at the end when they were on their way back into the arena for the relocation trial; or they were placed into an unfamiliar isolation pen for the whole of the retention interval; or they received food in the isolation pen after the search trial and were then moved on to their home pen for the remainder of the retention interval; or they were allowed to explore an unfamiliar room for the duration of the retention interval. All disturbances negatively affected the performance of the pigs in the relocation trials. Pigs made more errors before relocating the food than in control trials, when they had not been disturbed during the retention interval. The treatments, however, did not totally block or destroy memory of the food location. In 'disturbance' trials, pigs still did better than they would have had, had they been searching totally randomly (Mendl et al., 1997). Laughlin et al. (1999) built on this to investigate whether a more complex spatial memory task might be more susceptible to interference from environmental stressors. Pigs were tested in a win-shift task in a radial eight-arm maze (see Section 3.2.2.2). There were four disturbance treatments, applied during the retention interval. Again, some were chosen to mimic common husbandry events, which are thought to be potential stressors. In the 'social encounter' treatment, the test pig spent the retention interval in a pen where it had contact with an unfamiliar pig through a barred gate; in the 'novel' treatment, the pig was led to an unfamiliar outdoor area where it spent the 10 min retention interval; in the 'maze' treatment, the pig was confined in the central bit of the radial maze with all arms closed off; and in the 'weigh' treatment, the pig was retained in weigh crate for 10 min, then released back into the maze for its relocation trial. All except the 'weigh' treatments significantly increased the number of arm visits in relocation trials when compared to control trials without disturbance (Laughlin et al., 1999). These disruptive effects were stronger than in Mendl et al.'s study (1997), as the performance of Laughlin et al.'s pigs dropped to that expected of a randomly searching animal. One possible explanation for this difference is that more complex memory tasks such as remembering multiple sites rather than just one may be more susceptible to interference from environmental stressors (Laughlin et al., 1999).

These two studies suggest that even common husbandry events may act as mild environmental stressors that can have deleterious effects on spatial memory performance in pigs, and may affect how efficiently they deal with their environment. If these effects extended to social memory, this would provide some explanation for the observation that even in previously familiar pigs aggression levels sometimes increase after temporary removal of individuals for routine management procedures (Luescher et al., 1990; Mount and Seabrook, 1993). Such procedures may be at least temporarily stressful enough to disrupt aspects of social memory and resultant social recognition necessitating the re-establishment of relative social status when the animal is put back into the group (cf. Mendl, 1999).

3.3 Studying Behavioural Priorities Of Domestic Pigs

3.3.1 Introduction

As we have seen in Chapter 2, the domestic pig is conventionally housed in conditions that differ markedly from those in which its ancestors evolved. Housing under modern intensive husbandry systems has removed the biological need for pigs to respond to environmental challenges by seeking out nutritious food, building weatherproof nest sites and avoiding potential predators. As a consequence, intensively farmed pigs show different patterns of behaviour from those of wild or free-ranging pigs (Stolba and Wood-Gush, 1989), generally expressing a smaller behavioural repertoire, but including apparently functionless activities such as stereotypic rooting and chewing (Lawrence and Terlouw, 1993) or physically harmful activities such as tail biting (Simonsen et al., 1991). It is often argued, on the one hand, that these differences in behaviour demonstrate general poor welfare in captive animals, and the inappropriate expression of frustrated patterns of natural behaviour in particular (see Dawkins, 1980; Hughes and Duncan, 1988). Animals may have well-defined expectations of the environmental resources they need to express species-specific behaviours (e.g. straw or similar nest-building materials for nest-building) either from past experience or from genetic pre-disposition, and thwarting of these expectations may lead to negative subjective experiences (Hughes and Duncan, 1988; Jensen and Toates, 1993). On the other hand, the expression of species-specific behaviours may be different in captivity, because it may depend on the presence and recognition of appropriate stimuli in the environment (e.g. sexually receptive mates, nesting or rooting material) (Dawkins, 1980; Hughes and Duncan, 1988). An important question in assessing and addressing welfare issues in domestic pigs as in any captive animals is therefore: what are their behavioural priorities? Or in other words: what behaviours are important to them; what do the animals 'want' to do, what are they strongly motivated to do?

3.3.2 How Can We Assess Behavioural Priorities?

An important first step in identifying the behavioural priorities of commercially-reared pigs have been observations of pigs and their relatives in more extensive systems, including studies of wild boar, feral or free ranging pigs (e.g. Stolba and Wood-Gush, 1989) and pigs in outdoor production systems (e.g. Jensen, 1986). These observations confirm that even following generations of selective breeding and intensive rearing, pigs readily adopt the patterns of behaviour shown by their wild ancestors including extensive rooting, even when fed a nutritionally-adequate ration, and building functional nest sites prior to farrowing without any practice (Stolba and Wood-Gush, 1989; Jensen et al., 1993). These studies are, therefore, useful in providing pointers to the sort of behaviours that may be priorities for pigs and that can be frustrated in intensive systems. Chapter 2 discusses this in more detail.

The next step is to investigate the value that intensively-reared pigs place on resources that allow expression of these behaviours (Ladewig and Matthews, 1996). This 'value' is assessed by measuring how much an animal is willing to pay for the chance to perform the behaviour under question. The idea of making a subject pay a price (incur a cost) to gain the opportunity to perform a behaviour as a means of measuring how strongly the subject is motivated to perform that behaviour has been used by psychologists for some time (e.g. Hodos, 1961; Teitelbaum, 1966). This technique has developed into a tool for assessing the value that a captive animal places on performing different behaviours since Duncan (1978) and Dawkins (1980, 1983, 1988) proposed it as a means of overcoming the short-comings of simple preference tests. Again, the idea is to use as a measure of an animal's motivational strength to perform a behaviour, its willingness to pay a price in order to do so or 'make a sacrifice of some kind' (Kirkden et al., 2003). For example, chickens may be willing to peck a key 100 times to gain access to a compartment littered with sand (for dustbathing), but only 10 times to gain access to a compartment littered with drawing pins.

Operant techniques such as this (where a cost is imposed by requiring the animal to perform a task to gain access to a resource that facilitates a behaviour) are commonly used to measure behavioural priorities or relative motivational strengths, and pigs have received considerable attention in terms of using operant techniques to investigate their behavioural priorities (Kilgour et al., 1991). They can easily be trained to perform a range of operant tasks (e.g. Dantzer, 1978; Young et al., 1994; Section 3.2.2) for a number of reinforcers (Arey, 1992; Hutson, 1992) and are thus, a suitable species for investigating behavioural priorities. For this, pigs are first trained to perform an operant response such as panel pressing (e.g. Lawrence and Illius, 1989; Matthews and Ladewig, 1994) or lever lifting (e.g. Hutson, 1991; Haskell et al., 1997) to obtain a reward, that is to gain access to a resource (e.g. straw) that allows them to perform a specific behaviour (e.g. nest building). Subsequently, the number of responses that have to be performed per access to the resource (the ratio) is increased, and different measures can then be used to assess the value of the resource to the animal. One measure is the number of responses at which the animal ceases to work for the resource, which has been called the ratio strain or maximum price paid (Mason et al., 2001). This measure has been used in pigs by Lawrence et al. (1988) and by Hutson (1991) where the number of responses required to access the resource was progressively increased, and the maximum number of responses the pigs would make to get to the resource (maximum price) was used as a measure of resource value. Another two measures of how valuable a resource is to an animal are price elasticity and income elasticity of demand. Price elasticity of demand is the rate at which an animal's consumption ('demand') of a resource changes as the price of a fixed amount of access to the resource changes (Varian, 1996, cited in Kirkden et al., 2003). For example, chickens may access that compartment littered with sand four times a day (for, say, 30 min ago) when they need to 'pay' with 100 pecks for each access. However, they may only access it twice a day (for the same amount of time at each go as before) when they need to 'pay' with 300 pecks. 'Income elasticity of demand' refers to how consumption of a resource changes as the consumer's income changes (Varian, 1996, cited in Kirkden et al., 2003). The chickens may, for example, be required to divide a fixed amount of time (income) between alternative resources such as a nest box and a dust bath.

Conventionally, price or income elasticity of demand are represented by log-log plotting consumption against price or income, and a rapid decline in consumption with increasing price or decreasing income would indicate a low value resource with 'elastic' demand. A shallow decline, on the other hand, would indicate 'inelastic' demand for a highly valued resource. Hitherto, this 'elasticity of demand' approach to measuring behavioural priorities has been the most commonly adopted in animal welfare research as it concentrates on the animals' willingness to preserve consumption (Dawkins, 1990), though it has been recently criticised, with a measure called 'consumer surplus' being advocated instead (Kirkden et al., 2003). While there is still some debate as to the best measure to use when assessing the value to animals of different resources (e.g. Dawkins, 1990; Houston, 1997; Mason et al., 1998; Kirkden et al., 2003), studies in mink indicate that assessments based on elasticity of demand and on maximum price paid can give the same ranking of behavioural priorities (Mason et al., 2001). In practice, several experimental factors such as the duration of tests (Ramonet et al., 2000), operant bias (Young et al., 1994), the quantity of resource received per response (Cooper and Mason, 2000) and the social situation (Pedersen et al., 2002) are likely to affect the results of such studies and their external validity (Mason et al., 1998). It is therefore important to take these into account when comparing the findings of different experimental studies and when extending their findings to pigs under commercial conditions.

3.3.3 What Do We Know About the Behavioural Priorities of Pigs?

Pigs like to eat, and feeding is certainly high on their list of behavioural priorities. Many studies have investigated exactly how important it is to pigs (e.g. Lawrence et al., 1988; Hutson, 1991), since adult pigs are conventionally food deprived in order to maintain body condition and reproductive fitness. These studies have been useful both for developing methods for assessing feeding motivation in pigs (e.g. Lawrence and Illius, 1989; Day et al., 1996a) and for investigating whether they respond in predictable ways to changing environmental factors such as level of feed restriction (Lawrence et al., 1988) or increasing dietary bulk (Day et al., 1996b; Ramonet et al., 2000). Lawrence et al. (1988) demonstrated that adult boars on a conventional ration of a concentrated feed (60% of ad libitum intake) show higher feeding motivation than boars fed the same feed but at 80% or more of ad libitum intake. Hutson (1991) showed that pregnant sows were so motivated to feed (hungry) that they were prepared to sustain short-term energy deficits, as a result of a high rate of lever lifting, in order to obtain more food. Several studies have shown that dilution of feeds by the addition of fibre reduces feeding motivation (e.g. Day et al., 1996b; Robert et al., 1997), but this appears to be limited to the hours immediately following meals as longer term studies (Ramonet et al., 2000) have found no effect of increasing dietary fibre on feeding motivation 4.5 and 23 h following mealtimes. This suggests that a larger iso-calorific meal can reduce feeding motivation in the short term, for example as a result of gut-fill, but that restrictively fed pigs are highly motivated for food over the major part of the day (Ramonet et al., 2000).

In addition to assessing feeding motivation per se, the demand for food is a useful yardstick for comparison with demand for other resources such as rooting materials, companionship (Matthews and Ladewig, 1994) or nest-building material (Hutson, 1992; Pedersen et al., 2002). Conventionally, these studies use the same operant task to investigate the value of alternative resources and may include the opportunity to work for an empty resource compartment (Hutson, 1992; Matthews and Ladewig, 1994) to control for the value of the additional space or simply the rewarding properties of performing the operant task per se. These studies consistently find that pigs place a higher value on food, than on other resources, such as companionship (Matthews and Ladewig, 1994) or nesting substrates (Hutson, 1992; Pedersen et al., 2002). For example, Matthews and Ladewig (1994) found that growing pigs showed a higher demand for food than companionship on a test protocol where lever pressing allowed access for a fixed length of time to a compartment that either contained food, or another pig, or was empty. They also found no difference in the demand for the companion and for the empty compartment alone, suggesting that companionship was a low environmental priority in growing pigs. However it has been argued that this approach may underestimate the value of non-food items, firstly because of operant bias, in that pigs may find it easier to associate certain operant tasks with certain rewards because of their operational similarity (e.g. Young et al., 1994; Mason et al., 1998). Furthermore, working for fixed quantities of resource may devalue activities that require longer bouts for satisfactory performance (Mason et al., 1998). For example, feeding may persevere as the pigs can consume a large number of small meals, but short spells of companionship may be under-valued, as the pigs require longer time periods in which to perform meaningful social behaviour.

Other studies of behavioural priorities in pigs have investigated demand for access to rooting and/or nesting material such as straw of pigs at various ages (Hutson, 1992; Ladewig and Matthews, 1996; Pedersen et al., 2002). When piglets have the opportunity to work for a foraging substrate such as straw (Pedersen et al., 2002) or earth (Hutson, 1989) they appear to value these resources less than they value food. Hutson (1989) found that access to earth was a mild reinforcer for weaner pigs learning an operant task, whilst Pedersen et al. (2002) found pigs worked harder for delivery of discrete quantities of food than they did for delivery of straw. Ladewig and Matthews (1996) found that the demand for straw depended on context as pigs worked hard for access to a compartment containing enough straw to allow rooting and nesting, even when access was only granted for 30 min at a time, but did not work as hard for straw presented in a rack.

The value of nesting behaviour appears to be highest for pregnant sows prior to parturition. Free-ranging pigs build a nest prior to parturition which involves both gathering and molding of material (Jensen et al., 1993), whilst confined sows in farrowing crates commonly show high levels of activity and vacuum nesting behaviour during this period (Arey, 1997; see also Jarvis et al., 1997). Although pregnant sows will work harder for food than straw for the majority of their time (Hutson, 1992), on the day prior to parturition the work rate for these two resources is comparable (Arey, 1992). Pregnant sows also show a peak in work rate for additional space for locomotion (Haskell et al., 1997) and will work for incomplete nest sites such as earth floors (Hutson and Haskell, 1990) that allow some expression of nesting behaviour. These findings from studies of behavioural priorities are supported by studies of the behaviour and physiology which showed that additional space and provision of nesting substrates reduce behavioural and physiological indicators of distress in pre-parturient sows (e.g. Jarvis et al., 1997; Damm et al., 2002).

In conclusion, therefore, there is good evidence that additional food is highly valued by pigs, in particular adults on a maintenance diet. Providing additional dietary bulk, without increasing other limiting factors such as energy may reduce feeding motivation in the short term, but feed restricted individuals remain hungry for much of their time. The only resource to approach the value of food is the value of nesting material, but only prior to farrowing. Both these findings are supported by the pigs' behavioural and physiological responses when these resources are denied. They are also consistent with our expectations of what these animals might require from their free-ranging behaviour and the functional benefits of these behaviours. Other resources such as companionship, foraging or rooting materials and nesting material for non-pregnant sows are also reinforcing so their provision may improve the welfare of farmed pigs. However, thus far, operant studies have concentrated on adults or growers and little work has been carried out on piglets and weaners, which may have very different requirements from older pigs, in particular in their nutritive and maternal environment. Furthermore, comparative studies of behavioural priorities have tended to use a small range of resources, so it is difficult to draw broad conclusions about the value of alternative resources (apart from food and bedding) that we may provide to pigs.

3.4 Studying Emotions

3.4.1 Studying Emotions in Humans and Animals

Most people experience emotions as intense subjective feelings including love, happiness, fear, anger, or sadness. Because of the subjective and sometimes seemingly irrational nature of emotions, they have received less study in animals than apparently more rational learning and cognitive processes. Yet emotional states such as fear and anxiety may have dramatic effects on animal behaviour, health and welfare. In pigs, for example, it is suggested that fear of humans can influence behaviour, stress, growth and reproduction (Hemsworth and Coleman, 1998; see also Chapter 7), all of which have consequences for animal management, welfare and production. A deeper understanding of animal emotion is thus of central importance in animal production and welfare, but how to study it?

Contemporary researchers view emotions as comprising a number of distinct but related elements: physiological and neurological changes, cognitive changes, behavioural expression, and conscious feelings (Parrott, 1996; Scherer, 1996; LeDoux, 1996; Paul et al., 2005). The precise causal links between these elements are beyond the scope of this chapter. Nevertheless, the prevailing view that emotions, in their functional entirety, comprise integrated physiological, cognitive, behavioural and conscious components renders at least the non-conscious elements open to investigation in non-human animals (LeDoux, 1996; Rolls, 1999; Paul et al., 2005). So, without direct access to the conscious component of emotions, how do we decide what aspects of physiology, neural function, cognition and behaviour to focus on in studies of animal emotion?

One approach is to observe responses to events or situations that are presumed to induce emotions. There are differing views as to what these situations are. Psychologists often define them as having 'major significance to the individual' (Scherer, 1996) or being 'personally significant' (Parrott, 1996). For humans, this could include a wide variety of circumstances ranging from threat of attack by another person, to recalling an embarrassing event. In animals it would include dangerous or threatening/novel situations, sexual encounters, or other circumstances including those in which the survival or reproductive success of the organism may be enhanced or under threat. In fact, many studies of animal emotion involve tests or situations designed to induce the complex of behavioural, physiological, cognitive and perhaps conscious elements that comprise the emotions of 'fear' or 'anxiety' (Gray, 1987; LeDoux, 1996). In studies of rodents, responses observed in these circumstances include orientation, escape, avoidance or freezing behaviour, defecation, urination, activation of physiological stress systems (e.g. changes in heart rate, circulating glucocorticoids), alterations in attention and learning, and changes in brain activity in areas such as the amygdala. If rodents experience a conscious feeling of fear, these changes are likely to be associated with it.

An alternative but overlapping view of the situations that induce emotions is provided by Rolls (1999; see also Gray, 1987). He suggests that emotions are elicited by rewards (anything for which an animal will work) and punishers (anything that an animal will work to escape from or avoid), or changes in these rewards and punishers. Thus, the presentation of a reward may induce pleasure or even ecstasy, depending on its intensity, while the presentation of a punisher may induce anxiety or fear. Furthermore, omission or termination of a reward may induce frustration or anger. Measurement of changes occurring in these situations indicates emotional responses. Rolls suggests that the induced emotions serve several adaptive functions, including preparing and motivating the organism for an appropriate response, enhancing response flexibility, and communicating state to other animals. Similar functions are proposed by others (e.g. Scherer, 1996; LeDoux, 1996; Fraser and Duncan, 1998). Again, the importance of the emotional response to organism survival is highlighted.

A complementary approach to the study of animal emotions is to manipulate neurophysiological processes thought to be involved in emotional states, and to observe how this affects responses to test situations. Comparative analyses suggest that structures in the limbic system (e.g. the amygdala) and the orbito-frontal cortex play important roles in emotional responses in humans and other mammals (see LeDoux, 1996; Rolls, 1999). Manipulations of these, more general pharmacological manipulations (e.g. involving anxiogenic or anxiolytic drugs) and imaging studies have been used to further develop an understanding of the links between neurophysiological, cognitive, behavioural and conscious components of emotional responses (e.g. Cole and Rodgers, 1995; Aggleton and Young, 2000; Lane, 2000; LeDoux, 2000).

The above approaches may allow the development of a ‘library’ of behaviours and neurophysiological changes that could be used as indicators of emotion. Whether animals also experience the conscious components of these emotions and, if so, what labels would be appropriate for these (e.g. fear, anger, rage, jealousy?) and how exactly they map on to behavioural and neurophysiological state are subjects for further research. Nevertheless, the possibility that conscious experience accompanies other elements of emotional response makes it clear that the study of emotions is of central importance in animal welfare research. Progress in this field should allow better assessment of emotional states that may affect an animal’s subjective experiences and hence its welfare. Although the focus has principally been on negative emotional states in the past, there is growing interest in positive emotions which are also important from an animal welfare perspective (see Boissy et al., 2007).

3.4.2 Studying Emotions in Pigs

As for many species, studies specifically investigating the nature of emotions in pigs have been few and far between. However, we can identify three general approaches to this issue.

3.4.2.1 Using Emotional Terms to Label Behavioural and Physiological Responses

This approach is the most common and includes studies not principally targeted at assessing emotion. For example, much welfare-related research on pigs has focused on the concept of stress, often measured by changes in the function of the hypothalamic-pituitary-adrenal (HPA) and sympathetic-adrenal-medullary (SAM) systems. Studying stress is scientifically respectable, but there has been some reluctance to associate stress responses with emotional states, presumably because the latter have been viewed as principally subjective in nature and hence inaccessible to direct measurement. Another important but less considered point is that, in humans at least, correlations between a particular stress response profile and a verbally reported emotional feeling may not be very strong (Frijda, 1986; Wagner, 1989; but see Bradley and Lang, 2000). Nevertheless, certain emotional terms such as fear, anxiety, or frustration are used to describe states that might be associated with measured physiological stress responses. For example, elevated heart rates during exposure to vibration may indicate fear, as may the pronounced SAM responses accompanying defeat of a formerly high-ranking pig (Perremans et al., 1998; Otten et al., 2002) and the elevations in HPA activity observed in pigs conditioned to expect negative handling from humans (Hemsworth and Coleman, 1998). Measures such as heart rate variability can provide more detailed information on the relative activity of sympathetic and parasympathetic systems which may allow discrimination between closely related but distinct emotional states (e.g. fear and anger (Marchant-Forde et al., 2004)). In all these cases, emotional terms are being used, perfectly reasonably, as a convenient label to describe the state that we might experience ourselves if subjected to the conditions that the pigs are studied under. These inferences are based on an evaluation of the likely aversiveness of the situation being studied, and our knowledge that stress responses may be associated with subjective states such as anxiety or fear in humans.

Just as emotional terms may be used to label physiological stress responses, they are also used to summarise behavioural responses. So, for example, thwarting access to a resource which a pig is highly motivated to obtain is often described as inducing a state of frustration characterised by a variety of behavioural changes including increases in activity, aggression, adjunctive behaviour and, in the longer term, stereotypies, as well as physiological stress responses (e.g. Arnone and Dantzer, 1980; Dantzer et al., 1980; Dantzer and Mormede, 1981; Lewis, 1999; Haskell et al., 2000). Another common example is avoidance behaviour which is often interpreted as an indicator of fear, for example of a particular person (e.g. Hemsworth and Coleman, 1998).

Other behaviours that may be linked to emotional states include play, exploration, levels of activity or inactivity, and aggression. Fraser and Duncan (1998) propose that behaviours such as play and exploring are associated with positive motivational affective states/pleasure and tend to be expressed when the costs of performing them are low. Other authors have specifically linked the performance of play in pigs, particularly locomotor play, with a positive hedonic state such as 'enjoyment' (see Olsen et al., 2002). High levels of inactivity or apathy are sometimes viewed as an indicator of a depressed state, particularly when linked with a general lack of responsiveness to external stimuli somewhat reminiscent of the phenomenon of learned helplessness. For example, Broom (1987) demonstrated that sows housed in stalls were generally less responsive to a standardised stimulus (water being tipped onto their backs) than those housed in groups. One possible explanation was that they coped with the environment by reduced arousal and attention to their surroundings. Aggressive behaviour is another interesting example. Many studies of pigs have focused on aggression, but few if any have used the term 'anger' to describe the emotional state that might accompany this behaviour. So, while it appears acceptable to describe the behaviour of pigs in emotional terms such as fear, anxiety, frustration, depression and even enjoyment, the term anger is rarely if ever used. Perhaps this is because we view anger as an emotion that is focused on a specific individual or object, may result from a complex social interaction, and even has a vindictive aspect to it, and we are unable to attribute such complexities of emotion to pigs. Likewise, complex emotions such as guilt, jealousy, and embarrassment are rarely attributed to other animals.

Labeling observed behavioural and physiological states with emotional terms can be a useful way of providing a shorthand description of a suite of responses. However, the assignment of labels may be based on limited circumstantial evidence, which can be strengthened by incorporating a more grounded theoretical or empirical approach.

For example, a number of studies of pigs have used tests that present the animal with a threatening or potentially dangerous situation. These include open-fields, elevated plus maze tests, emergence tests, tests of responses to novelty, and restraint or tonic immobility tests (e.g. Fraser, 1975; Taylor and Friend, 1986; Lawrence et al., 1991; Hessing et al., 1993; Forkman et al., 1995; Spoolder et al., 1996b; Thodberg et al., 1999; Erhard and Mendl, 1999; Erhard et al., 1999; Andersen et al., 2000a,b). Often the main goal of these tests is to establish cross-time and cross-test consistency of individual variation in the behaviours measured, and interpretations are made without referring to emotional terms, but instead by reference to concepts such proactive/reactive coping (Koolhaas et al., 1999). However, behaviour, or emergent factors from principal components analyses (PCA), are sometimes labeled as indicating a fear or anxiety state. For example, Andersen et al. (2000a,b) used behavioural observation and pharmacological manipulations (see below) to suggest that low frequency of entries to, and time spent on, the open arms of an elevated plus maze (EPM) were a good indicator of anxiety. PCA also indicated that behaviour in open fields, a test of emergence from a protected dark box into a brightly lit area, and tonic immobility tests were less closely related to anxiety (Andersen et al., 2000a,b; see also Erhard and Mendl, 1999; Erhard et al., 1999). In further studies, PCA of both mouse and pig behaviour in EPM tests revealed that similar, though not identical behaviours loaded on anxiety-related factors in both species (Janczak et al., 2002a). Thus, a number of lines of evidence have been used to bolster the argument that certain behaviours of pigs in the EPM may be indicative of anxiety. Subsequent studies have failed to find any effects of blood sampling and duration of transport in a trolley on these measures of anxiety. Further tests will be needed to evaluate whether these procedures do not affect anxiety levels, or the tests are not sensitive to such effects (Janczak et al., 2000, 2002b).

An alternative theoretical approach to the assessment of internal states such as emotions has been taken by Weary and Fraser (1995a) who have used ideas from ‘honest-signaling’ theory (Zahavi, 1987) in their studies of piglet vocalisations. Honest signals of internal state may evolve under certain conditions; e.g. when signaler and receiver are related, when signalers vary in their need for a response, and when there is some cost to producing the signal. However, under other circumstances, we may not expect animals to communicate honest information about their internal state if it is possible to ‘cheat’ and convey incorrect information to one’s advantage (e.g. that one is healthy when one is actually in pain). Under these circumstances, responses that are detectable by others may not be accurate indicators of internal state. Weary and Fraser (1995b) showed that the calls of young piglets separated from their mothers appeared to be reliable indicators of need. Non-thriving piglets called more, and used longer and more high frequency and rising frequency calls compared to thriving piglets. One interpretation is that the vocalisation produced is an accurate indicator of some emotional state, such as fear, that the piglets experience in response to separation. Further work has demonstrated that the characteristics of piglet calls can be related to specific changes in stress hormones such as adrenaline and cortisol (Schrader and Todt, 1998), and that calls emitted in a context that is likely to be stressful (being held by a human) are clearly different in structure to those emitted in other contexts (Schön et al., 2001).

Another quite different theoretical approach to the study of animal emotion has been proposed by Wemelsfelder (2001). She advocates a first-person perspective that views animals as beings whose experiences are accessible to investigation by careful observation of their behavioural expression. She has devised a method that allows naïve and independent human observers to qualitatively assess and describe the expressive behaviour (e.g. posture, movement, interactivity) of pigs. The method, which involves a technique known as 'free choice profiling' yields descriptive terms such as 'confident', 'excitable', 'calm, 'apprehensive' that show good inter-observer correlations in descriptions of different pigs, as well as good intra-observer reliability across repeated testing (Wemelsfelder et al., 2000, 2001). Wemelsfelder (2001) accepts that familiarity with the subject animal is required to allow accurate assessment, but argues that descriptions of behavioural expression may directly reflect the animal's state, and allow integration of more traditional reductionist measures of behaviour and physiology. This is a much stronger use of behaviour as an indicator of emotion than has been described above. The philosophical basis of this approach remains open to debate. Researchers will vary in how willing they are to adopt a first-person perspective and accept that emotional states can be directly revealed by observation of behaviour. Nevertheless, it is certainly possible to empirically investigate whether particular expressive terms do correlate with profiles of behavioural and physiological measures, and thus provide an integrative summary of these more reductionist data.

3.4.2.2 Manipulating Internal State Pharmacologically and Observing Effects on Spontaneous Behaviour

If we believe that brain states are central to the experience and expression of emotion, then manipulating these brain states using drugs with well-understood actions should provide further information on emotions. In pigs, the drug diazepam has been used in a number of studies. The drug has an anxiolytic action in humans, and causes increases in rodent behaviours that are regarded as indicative of low anxiety (e.g. time spent in potentially dangerous exposed or brightly lit areas (Cole and Rodgers, 1995; Hendrie et al., 1997)). Andersen et al. (2000a) showed that diazepam also had similar effects on pigs, increasing entries to and time spent on the exposed open arms of an EPM. Dantzer et al. (1976) demonstrated complex effects of diazepam on pig behaviour during an avoidance task, including a delayed peak response to a conditioned stimulus predicting the aversive stimulus, and some evidence of enhanced learning and performance of the task. They suggested that anxiety and fear states modulated by diazepam accounted for these changes in cognitive performance.

In other studies, Cronin et al. (1985) demonstrated that naloxone, an opioid antagonist, could prevent stereotypic behaviour in tethered sows. One interpretation was that performance of stereotypies had a calming effect (minimised a previously aversive emotional state) through the release of opioid peptides and, therefore, that blocking the action of these peptides, decreased the benefits of the behaviour. However, the decrease in stereotypic behaviour appeared immediate, whereas an initial increase might have been expected if the pigs perceived any calming state to be linked with performance of stereotypy. It is also possible that the changes in behaviour could have been caused via a completely different route such as a direct effect on activity, or induction of a nauseous state. Parrott et al. (2000) demonstrated that administration of corticotrophin-releasing hormone (CRH), which coordinates behavioural and physiological aspects of the stress response, led to aroused and excitable behaviour in pigs including frequent changes and posture and orientation, high levels of vocalisation and vigorous oral-nasal activity. It was tentatively suggested that these behaviours may correspond to a state of anxiety.

In general, these studies demonstrate that pharmacological manipulations influence spontaneous behaviour in ways that might be expected if the animal is experiencing a particular emotional state. However, it is always possible that the effects are mediated by different mechanisms separate from those involved in emotion.

3.4.2.3 Manipulating Internal State Pharmacologically and Observing Effects on Conditioned Behaviour

Perhaps the most novel and incisive study of emotional states in pigs has been carried out by Carey and colleagues in a series of experiments (Carey et al., 1992; Carey and Fry, 1993, 1995). In these studies, pigs were trained to make one operant response (e.g. press two levers alternately) to get food while in a 'normal' state, and to make another response (e.g. press only one of the two levers) when under the influence of an anxiogenic drug, pentylenetetrazole (PTZ). They were able to learn this discrimination, suggesting that they could somehow distinguish the two different states induced in the presence or absence of the drug – perhaps anxious (drug) or non-anxious (saline). Carey and Fry (1995) went on to show that non-drugged pigs would also make the response indicative of drug presence (or anxiety) following particular events such as exposure to a novel pen structure, novel object, transportation and mixing with an unfamiliar pig. They suggested that these events induced a state similar to anxiety, or whatever state was induced by PTZ, and thus caused the pigs to make the relevant state-dependent operant response. This method is more powerful than those described in the previous section because it asks the animal to take an experimenter-defined arbitrary action in response to a pharmacological state, whereas the previous studies observed changes in spontaneous behaviour which are more difficult to interpret. The arbitrary action can then be used, with a certain degree of confidence to get the animal to 'report' on its state following particular events. Thus, on the basis of this work we can say that following exposure to novelty or transportation, pigs experience a state that is similar to that induced by a known anxiogenic drug, and is probably some form of anxiety. Approaches such as this are likely to represent the most productive way forwards in understanding emotional states in pigs.

A related approach has been developed by Harding et al. (2004) based on the knowledge that emotional states and cognitive function are closely inter-related (Mendl and Paul, 2004; Paul et al., 2005). Emotions can influence cognitive bias, and cognitive appraisals can influence emotional responses. One example is that humans in a negative emotional or mood state show enhanced expectation of negative events – or pessimism (e.g. Wright and Bower, 1992; see Mendl and Paul, 2004; Paul et al., 2005). Harding et al. (2004) developed a method to investigate whether rats also show a tendency to appraise events in a negative light when they are in a stressed state relative to when they are in a control state, and found results that support this hypothesis. This approach has been developed further for rats (Burman et al., 2008a) and extended to other species (starlings: Bateson and Matheson, 2007), and other tests reflecting links between cognition and emotion have developed (Burman et al., 2008b). Such methods could also be used in pigs, and in conjunction with anxiogenic or anxiolytic drugs, to further develop our understanding of their emotional states.

3.5 Conclusions

Over the past decade, there has been renewed and rising interest in the mental and emotional lives of farm animals, including pigs. Our aim in this chapter has been to give an overview of research into pigs that focuses on those aspects of their 'mind' that seem particularly relevant to their welfare in conventional, modern housing systems. We have also highlighted some individual studies and methodological approaches which appear especially fruitful. Particular recent advances have been in the study of the pigs' spatial and social cognitive abilities, and of their behavioural priorities. While our knowledge of these and other aspects of the pigs' 'mind' has steadily grown, there remain considerable gaps. Some of these are flagged up as important areas for future research in the respective sections of this chapter.

One big challenge remains the scientific study of the pigs' emotional state as highlighted in Section 3.4. Another challenge is to develop methods for investigating the cognitive development and behavioural priorities of piglets and weaners, or to adapt methods developed for older pigs. Laughlin and colleagues, for example, are currently modifying the water-maze procedure originally designed for rats to investigate spatial learning and memory in nursing and newly-weaned piglets (Laughlin et al., pers. comm.). Finally, relatively little seems to be known at present about pigs' understanding of certain physical properties of their environment. We do not know, for example, how numerically competent they are or how they perceive time. A better understanding of their perception of time intervals would help us to assess, amongst other things, whether pigs can anticipate the end of aversive, but common, husbandry procedures (Duncan and Petherick, 1991; Spinka et al., 1998).

Overall, our overview indicates sensory faculties, cognitive abilities and behavioural priorities in domestic pigs that would have helped their wild ancestors survive and reproduce optimally under natural conditions. In intensive husbandry systems, the adaptive value of many of these abilities may be less obvious. Yet pigs used today for pork production seem to have retained many of the faculties of their wild ancestors, and may therefore be behaviorally, cognitively and emotionally at odds with the husbanded environment they spend their lives in. Understanding the cognitive abilities, behavioural priorities and emotions of commercial pigs therefore lies at the very heart of improving their welfare.

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Chapter 4
Welfare of Dry Sows

Jeremy N. Marchant-Forde

4.1 Introduction

At any one time, a female breeding herd comprises both dry sows and farrowing/lactating sows. The term 'dry sow' encompasses all gestating sows, sows awaiting service and barren sows within the herd. There is a great diversity of dry sow housing systems currently in use. Over the last few decades, sow housing has generally seen a move from somewhat extensive systems towards intensive systems, although this trend is reversing within Western Europe and a reversal is also beginning to show emergence in the pig industries of other developed countries, such as the U.S.A., Canada and Australia.

Until this recent reverse, the major factor behind sow housing design was that of economics of production. Since World War II, there have been steady reductions in the number of individual pig producers, but increases in the size of herds. The trend away form extensive systems with small herd numbers towards larger intensive units was initially fuelled by price incentives in the late 1940s, when the production of cheap, plentiful food to meet post-war demand was often supported by governments. The intensification accelerated in the 1950s as new system-based technology was applied. The cyclical, profit-loss nature of the pig industry also accelerated the decline of the small producer. It made economic sense to increase herd size, increase stocking densities and decrease labor costs by mechanising where possible.

The ultimate developments, in terms of gestation housing, were those of stalls and tethers. Keeping the sows in permanent confinement gave the farmer a number of advantages over less intensive systems. For example:

1) Stocking density. A larger number of sows could be housed in a given area compared with loose housing systems
2) Cost effectiveness. Housing sows on concrete with incorporation of a mechanized slurry handling system reduced both straw and labor costs

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3) Ease of management. The stockperson was able to monitor individual sows more easily and adjust husbandry regime where necessary.

However, it has since become apparent that such intensive systems may also have a number of disadvantages in terms of welfare for the sow, which has led to European legislation banning stalls and tethers and increased scrutiny of these systems elsewhere. The aim of this chapter is to summarise the effects of different housing systems on the welfare of the dry sow during gestation.

4.2 Natural Behaviour

Natural behavior is covered in Chapter 2, where the pig's wide behavioral repertoire is dealt with in detail. However, it is appropriate to give a summary of salient aspects of natural behavior here, as when the individual housing systems are examined in detail later in the chapter, they are related to the sow in her 'natural' habitat. Also, as has been previously noted, there is a school of thought which defines welfare in terms of the extent to which an animal can behave in a natural way (Rollin, 1993).

In terms of social behavior, feral sows typically form small herds or 'sounders' of between 2 and 4 related adult females and their most recent litters. Group size will be influenced by habitat type and the availability of resources, most importantly food (Mauget, 1981; Graves, 1984; Gabor et al., 1999). Their home range again depends on resource availability and population density, but can be as large as 6000 hectares (Janeau and Spitz, 1984), although within any given 24 h period, the group may only utilize perhaps 1% of this area. Different sounders may have overlapping ranges, but sounders tend to actively avoid open confrontation with each other (Gabor et al., 1999).

Within sounders, aggression is similarly rare. The group usually maintains a simple linear social hierarchy, which is relatively stable over time. Position within the hierarchy is mostly determined by size and age, with large, mature, physically strong adult sows being dominant over smaller sub-adults and juveniles (Mauget, 1981). Aggression does occur during competition for resources, such as food, but most often, subordinate animals actively avoid conflict with dominant animals (Jensen and Wood-Gush, 1984). Adult boars may associate with the sounder at mating time, and are dominant to all sounder members. As the litters mature, the sub-adult females may form sub-groups within the sounder or separate off to form a new sounder. Sub-adult boars likewise form sub-groups, eventually becoming solitary as mature adults.

In terms of daily behavior patterns, there are typical peaks in activity in the morning and in the late afternoon/evening, with a rest period in the middle of the day. Activity is usually separated into long periods of activity separated by long periods of sleep. However, typical activity levels during daylight are much higher than those seen in housed pigs. In a study conducted in the Edinburgh Pig Park, it was found that during 75% of daytime observations, sows were engaged in foraging-related activities (Stolba and Wood-Gush, 1989). In housed pigs, this figure is typically between 19 and 24% (Gonyou et al., 1992; Broom et al., 1995; Day et al., 2002). Daily activity patterns can shift in response to changes in seasonal temperature and also due to external influences, such as during hunting of wild boar (Kurz and Marchinton, 1972). Behavior within a sounder is socially facilitated, i.e. the actions of one animal are influenced by the presence or actions of another animal, and the group members appear to synchronize with the behavior of the dominant sow (Stolba and Wood-Gush, 1989).

Wild boar thrive in a wide range of habitat types – farmland, scrubland, forest and swamp – and climatic zones – from tropical to sub-arctic. They prefer vegetation that affords cover from the weather and potential predators and use behavioral mechanisms to aid thermoregulation, huddling together when cold and wallowing when hot. They use different parts of their home range for different activities, often having discreet lying or nesting areas, areas for foraging and areas for performing comfort behaviors. Thus, where available, pigs utilize environmental choice.

4.3 Welfare Assessment, Values and the Limitation of Comparisons

As discussed in Chapter 1, the overall assessment of the welfare of an animal within a given system is fraught with difficulties, largely associated with the relative importance that is placed upon the various measures of welfare. Different people place different emphasis or value upon different measures – ethologists may value behavior, veterinarians may value health, animal scientists may value productivity. Thus, agreement on what constitutes the 'best' and 'worst' dry sow housing system in terms of welfare will not be forthcoming.

Although there have been some useful attempts to review the literature in the past (SVC, 1997; Barnett et al., 2001), the welfare of dry sows in different systems still remains somewhat confusing. It is virtually impossible to conduct a 'comparative' approach to the literature, with so many different systems and different genotypes being examined, limitations in what constitutes the experimental unit and thus replication differences in the data, etc. The approach taken in this chapter is to initially approach the topic from a different angle – looking at the salient features of the systems in use today and discussing their relative advantages and disadvantages, whilst concentrating on those welfare issues that are perceived to be the real drivers behind the debate on gestation housing – i.e. aggression between sows kept in groups versus the lack of opportunities for sows kept in close confinement. Historically, there has been too much readiness to classify sow housing as 'individual' or 'group'. The real picture is far more complicated than this and this chapter will reflect this diversity of housing systems. The comparative data will be summarised, but also presented it in an impartial way, rather than including value judgments as to which system is better or worse.

4.4 Dry Sow Housing Systems

The major salient features of a dry sow housing system to consider are:

a) Building type
   a. Indoor
   b. 'Hybrid'
      i. Hoops
   c. Outdoor
      i. Arks
      ii. Tents
b) Grouping
   a. Individually-housed or grouped
   b. If grouped, group size and stocking density
   c. If grouped, static or dynamic group
c) Feeding system
   a. Individual control
      i. Feeding stall
      ii. Electronic sow feeder
   b. Group control
      i. Floor feeding
         1. 'Dump' feeding
         2. 'Spin' feeding
      ii. Trickle feeding
      iii. Trough feeding/Partial stalls/Free-access stalls
d) Floor and floor coverings
   a. Indoors
      i. Bedded
      ii. Non-bedded
         1. Fully-slatted
         2. Part-slatted
         3. Solid floor
   b. Outdoors
      i. Pasture
      ii. Dirt lot

As soon becomes obvious from the above, the various combinations mean that there is a very wide variety of different types of system available and it is impossible to carry out a single comparative experimental study to identify the 'best' system in terms of sow welfare.

4.4.1 Elements of Building Type

Housing of sows occurs in all climates from hemiboreal climates such as central North America and Northern Europe, through temperate, sub-tropical and tropical. There is, therefore, a full range of housing types from fully-enclosed, climate-controlled buildings, through partially-enclosed, open-sided buildings, partially-enclosed shelters with access to outdoor runs of concrete or dirt, temporary covered 'hoop' structures to pasture-based outdoor systems with arks.

In the industrialized world, sows are predominantly housed indoors with varying degrees of 'intensity'. Fully-enclosed, climate-controlled buildings enable the farmer to maintain the animals in a relatively constant environment, regardless of the external climatic extremes, but require relatively large financial investment to construct, with reliance on automatic heating and cooling systems to maintain the thermal environment. These systems are usually slurry-based and bedding-free. In many temperate regions, sows are kept in less enclosed buildings, often with straw as bedding and perhaps with access to outside concrete pens and indoor kennels. These systems are less reliant on automatic heating and cooling systems, and tend to offer the sow a degree of environmental choice by incorporating different thermal zones. They are cheaper to construct but still represent a significant financial investment. In both of the above cases, there is no 'typical' building size.

A more recent housing development is the 'hoop' structure. These are 'temporary' buildings with wooden or concrete side-walls about 1.5–2 m high and with a reflective canvas or polythene roof spread over tubular metal frames. They are ventilated naturally and bedded with deep straw. They often incorporate concrete platforms for mounting of feeding stalls but the bedded area is usually soil-based. Unlike permanent buildings, the width of the hoop is somewhat limited by the weight that the unsupported span can support. Widths of up to 20 m are possible, but most hoops are around 10–12 m wide. Sows do not generally have access to outside, but there may be an element of environmental choice inside, with deep-bedded areas and concrete platforms offering different thermal properties.

Keeping sows on dirt lots or pasture involves basically similar housing – that of temporary, moveable shelters. Pasture-based systems rely on lower stocking density and rotation of sows through paddocks, with rest periods to allow pasture to recover. Dirt lots usually have higher stocking densities and are more permanently in use. Most commercially-available dry sow shelters are made out of corrugated metal and are usually single-skinned and non-insulated.

They may have wooden floors and are usually straw-bedded. During hot weather, they are open at both ends for maximum airflow. Portability limits the size, but sizes typically range from 2.5 m × 4 m up to 5 m × 8 m. Also used in Europe are 'tents' made with canvas or polythene stretched over walls made from big straw bales. These allow larger group sizes than conventional arks.

4.4.2 Grouping

4.4.2.1 Individually Housed or Grouped

If sows are to be housed individually, the choices are individual pens, gestation stalls (otherwise known as gestation crates) or tethers. The commercial reality dictates that individual pens for gestation are virtually non-existent, being used only occasionally by back-yard, small-scale farmers. This is because they are very costly in terms of construction (materials and space per sow) and management as to make them non-viable for serious commercial production. The other methods, however, are extremely common and have been the focus of a great deal of attention in terms of welfare considerations across the pig industries of the developed world, including the enactment of legislation specifically opposing their use.

In its simplest form, the sow stall is basically a pen designed to encompass the minimum space required for a sow to stand and lie down (see Fig. 4.1). Stalls are most typically constructed of tubular metal frames with a feed trough and drinker at the front. Typical dimensions are about 2.1 m long, 0.6 m wide and 1.0 m high, although there are slight variations on these dimensions on commercial farms, largely depending on the age of the stall and the age profile and/

Fig. 4.1 Conventional gestating sow stalls
(Photo source: JNMF)

or genotype of the sows that are housed within them. What must be borne in mind is that the stall is designed to fit one aspect of the space requirement of the sow – that is, its *static* space requirement, which can be defined as the amount of space used by the sow when she is standing or lying stationary. As far back as the 1980s, the space requirements of sows were documented by studies on farrowing crates both in the U.K. (Baxter and Schwaller, 1983) and the U.S. (Curtis et al., 1989). Both these studies found that when changing posture normally from standing to lying and vice versa, sows showed a degree of sideways, forward and backward motion outside the bounds of static requirements. This has been termed their *dynamic* space requirements and it is considerably larger than their static requirements.

Tether systems are not as widespread as stalls, but can consist of two types – either neck tethers or girth tethers. The tether itself is either a strong webbing strap or a metal chain (sometimes plastic-coated) fixed around the neck or girth of the sow and then fixed to a point either on the floor or on the front of the sow's stall. The length of the tether gives the sow the ability to change posture, much as she would in a full stall, but she cannot turn round or physically interact with her neighbours.

The alternative to keeping sows individually is the practice of keeping sows in groups. With grouping, there are a number of other elements that come into play, such as the number of sows in the group, the amount of space available, whether the group should be formed once and kept stable or whether the group composition will change on a weekly or monthly basis. These elements are covered in more detail below.

4.4.2.2 Group Size and Stocking Density

As previously described, the natural behaviour of the sow is to exist in a group. The core group size may be between 2 and 4 adult females but in commercial production, this type of small group management is just one option. To some extent, the size of any given group will also depend on the overall size of the farm – i.e. the total size of the sow herd. Over the last few decades, and on a global basis, the number of farms has been decreasing and the average size of a sow herd has been increasing (see Table 4.1). In North America especially, farms with over a 1000 sows are commonplace.

Table 4.1 Changes in average number of breeding sows per farm

Region	Breeding sows per farm	
	1976	**2001**
Alberta, Canada	13	124
	1994	**2001**
Queensland, Australia	77	154
	1990	**2002**
United Kingdom	61	92

With this disparity in herd sizes, the distinction of small group versus large group becomes unclear. In the UK, small groups would traditionally be anywhere between 4 and 10 sows and large groups 25+. In N. America, however, groups of 45–50 may still be considered small, with large groups being over 100.

4.4.2.3 Static and Dynamic Groups

A further element of grouping is whether the group composition remains unaltered after initial formation – i.e. is static, or whether there are sows entering or leaving the group on a regular basis – i.e. is dynamic. As seen in Chapter 1, a breeding sow is basically cycling through three housing systems during the course of a single reproductive cycle. It firstly enters the service house, where it is served when exhibiting oestrus. From there it moves to the gestation house and then on to the farrowing house prior to farrowing. At weaning, the cycle is repeated. Farms will operate either a continuous farrowing schedule, moving sows between the accommodation types on a weekly basis, or they will operate batch farrowing, usually moving sows between accommodation types on a monthly basis, but this may be influenced by the length of the lactation period.

Most sows that are group-housed during gestation continue to be housed individually during farrowing and thus, they undergo a period of physical separation from their herd-mates. Weaning will likewise occur on a weekly or monthly basis and it is at this point that the farmer will encounter management choices. Service accommodation may be stall-based until embryonic attachment has been confirmed. Alternatively service accommodation may be in group pens. In this case the farmer can either elect to form a group at weaning that will then stay as a static group and not be subject to the introduction of additional sows, or form a 'sub-group' which is then introduced as a group into a larger, already existing group of sows at different stages of gestation. This larger group would be classed as a dynamic system, as within it, there would be groups of sows at different stages of gestation. As one 'sub-group' leaves to enter the farrowing house, another would enter from the service house.

To illustrate the choices available, it is useful to consider a hypothetical 200-sow farm, weaning piglets at 3 weeks of age. After weaning, sows will enter the service house, where they may be expected to come into oestrus about 5 days post-weaning. They are served and then held in the service house until 3 weeks post-mating. They then move across to the gestation house for around 12 weeks, before moving back to the farrowing house 1 week prior to expected parturition date. The cycle is then repeated. The total cycle is therefore about 20 weeks. To have a single batch of 200 sows all farrowing at the same time would obviously be impossible in terms of building investment. The farm would need 200 farrowing places, 200 service house places and 200 gestation house places, all of which would only be occupied for some of the time.

Table 4.2 Hypothetical scenarios of gestation housing based on weekly or monthly batches

	Weekly farrowing	Monthly farrowing
	Batch size	
	10	40
Range of sow numbers in a static group	2–10	2–40
Maximum number of sows in a dynamic group	120	120
Number of mixings in largest dynamic group	12	3
Mixing frequency	Weekly	Monthly
Number of times introduced	1	1
Number of times resident	11	2

Ideally, there would be continual flow through the three systems with as much occupancy as possible. Either a weekly or 4-weekly schedule could be implemented (Table 4.2). With a weekly schedule, the herd could be split into 20 batches of 10 sows, each separated by a week. With a 4-weekly schedule, the herd would consist of 5 batches of 40 sows. These different batch sizes present different scenarios for gestation housing. For example, if static groups are desired, then the range of group sizes under a weekly schedule is 2–10 sows; under a 4-weekly schedule it is 2–40 sows. If dynamic groups are desired, the weekly schedule gives a maximum group size of 120 by mixing twelve times – once each week; the 4-weekly schedule also gives a maximum of 120 sows but mixing only three times – once every 4 weeks.

From this hypothetical example, it is evident that the way that sows are grouped could greatly influence the social behaviour within the group. Ideally, the number of mixings would be kept to a minimum, and from the above, it looks likely that a weekly farrowing schedule would cause a number of problems. There are, however, other factors that will lend support to a weekly schedule. Firstly this schedule should give continual output of around 90–100 piglets a week, which may fit the farmer's follow-on operation better than 360–400 piglets every four weeks. Secondly, there are major capital investment reasons. Here, the number of available farrowing places and any legal requirements for lactation length influence the farmer's decision. With the above scenarios in both cases it would be possible to run the system (at maximum stretch), with 40 farrowing places, 40 service house places and 120 gestation house places. However, there would be no 'rest' periods for any of the buildings. This is particularly important in the farrowing house, where there should be time between batches to thoroughly clean and disinfect the room or building to prevent disease build-up. To rest a farrowing building or room using the weekly schedule, it is only necessary to add 10 more expensive farrowing places to make a total of 50, assuming 1 weaning occurs at three weeks. For the 4-weekly schedule (2), it is necessary to add a whole 40 more places to bring the total to 80 and they will be spending a greater proportion of time not in use. If weaning is at 4 weeks, then the weekly schedule needs another 10 more places to make a total of 60 farrowing places; the 4-weekly schedule still has capacity and the total is still 80.

A farmer running a weekly schedule is unlikely to operate a single 120-sow dynamic group, but it is quite feasible to run 2 dynamic 60-sow groups (6 × biweekly mixings or 6 × weekly mixings followed by 6 weeks with no mixing), 3 dynamic 40 sow-groups (4 × 3-weekly mixings or 4 × weekly mixings followed by 8 weeks with no mixing) or 4 dynamic 30 sow-groups (3 × 4-weekly mixings followed by 9 weeks with no mixing) which in each case would reduce the number of mixings to which each sow was subject.

4.4.3 Feeding systems

4.4.3.1 Floor Feeding

This system of feeding is the simplest system available and encompasses the delivery of feed by spreading or dumping it directly onto the floor either in an inside housing system or an outside lot or paddock. Feed delivery can be achieved manually, by the stockperson dispensing feed from the feed cart with a scoop or bucket. Alternatively, a specialized feed-dispensing trailer can be used outdoors to deliver a uniform line of feed by 'throwing' it over the perimeter fence or indoors, auger-fed holding containers suspended above each pen indoors can either drop the feed straight down (dump – see Fig. 4.2) or throw

Fig. 4.2 Dump feeder used in a small group, straw bedded housing system (Photo source: Xanthe Whittaker)

the food out in a wide circle (spin) onto the floor. There are usually 6–8 sows per dump or spin feeder.

All of these floor feeding systems require animals that have similar feed requirements as there is no control over an individual animal's intake. The total amount of feed delivered to the pen needs to be around 10% higher than the total feed requirements of all the individuals within the pen, to ensure that each animal receives near to its individual requirement.

4.4.3.2 Trough Feeding/Partial Stalls/Free Access Stalls

A more refined method of the above is the delivery of feed into a trough situated at the front of the pen. This contains the feed within a given area and reduces wastage, but also potentially makes feed a more defendable resource, unless there is sufficient trough space available for each sow to access the feed. The amount of aggression that sows encounter during feeding can be influenced by further design modifications to incorporate either 'head and shoulder'-length stalls or full body-length stalls thus reducing the number of displacements – the longer the stalls, the lower the aggression – or by moving to a liquid feed rather than a dry feed. Delivery of feed in a liquid form (Fig. 4.3) probably reduces the variation in eating speed and thus most sows within a group finish eating at the same time, again reducing the displacement of slow eaters by fast eaters. However, there is still a lack of individual control of feed intake.

Fig. 4.3 Gestation pen system using trough and liquid feed (Photo source: JNMF)

4.4.3.3 Trickle or Bio-Fix Feeding

The overall aim of this system is to deliver feed into the trough at a rate near to the feeding rate of the sows, thus ensuring that the sow is 'fixed' to her feeding place and not displacing her pen-mates. Partial stalls are included between each feeding place to provide protection to the sow's head and shoulders from her neighbors (Fig. 4.4). Feeding takes place once a day and the feed is generally delivered at around 80–120 g per minute, based on the slowest eating sow in the group. The sows within the group need to be at a similar stage of gestation and body condition as all feeding places deliver the same amount of feed at the same rate. Ideally, they will also have similar feeding rates, as slow-eating sows can be displaced by fast-eating sows towards the end of the feed delivery period. Group sizes are typically small (4–8) because of the factors needed to make the group as balanced as possible, but on large units, group sizes of 40–60 have been used.

Fig. 4.4 A trickle feeding system for a small group housed in a fully-slatted pen

4.4.3.4 Individual Feeding Stalls

Individual feeding stalls, into which the sow is shut during feeding, have been a traditional, 'low-tech' feeding system in many countries (see Fig. 4.5). They consist of metal, tubular stalls, around 70–80 cm wide, with an integral trough at the front and a gate at the rear, which is usually closed by the stockperson at time of feed delivery. Feed may be delivered sequentially and manually by the stockperson as he/she moves down the passageway with barrow and scoop, in which case each sow can be given an amount suited to her individual

Fig. 4.5 Sows locked in to manually-controlled, individual feeding stalls (Photo source: JNMF)

requirements. Alternatively, feed may be delivered simultaneously to all sows by pulling a lever releasing feed from pre-filled hoppers situated above each trough. In this case, the stockperson can also add feed manually to the troughs of those sows that require more feed based on individual circumstances. Sows are also easy to observe individually.

After the sows have eaten, the gates can then be opened and the sows given access back to the pen. The system can be designed so that each sow has a feeding stall within the given enclosure or the same set of feeding stalls could be accessible sequentially to different groups of sows. The advantage of this is that there is lower capital investment and less space required to house the same number of animals. The disadvantage is that there is an increased labor component to move sows to and from the feeding area and feeding a large number of groups sequentially is extremely time-consuming.

4.4.3.5 Electronic Sow Feeders

All of the above feeding methods enable all the sows to eat simultaneously, reflecting natural feeding and foraging behaviour. Another system that has been developed over the last twenty years is that of a single feeding station delivering feed to each sow sequentially – the Electronic Sow Feeder (ESF). Following considerable development and some problems during early on-farm application, these systems now comprise a fully-enclosed feeding stall, with rear entrance and front exit, and an integral feed hopper and computerized delivery system (see Fig. 4.6). Each sow is fitted with an individual transponder, either contained within an ear tag or attached to a collar around the neck, which is

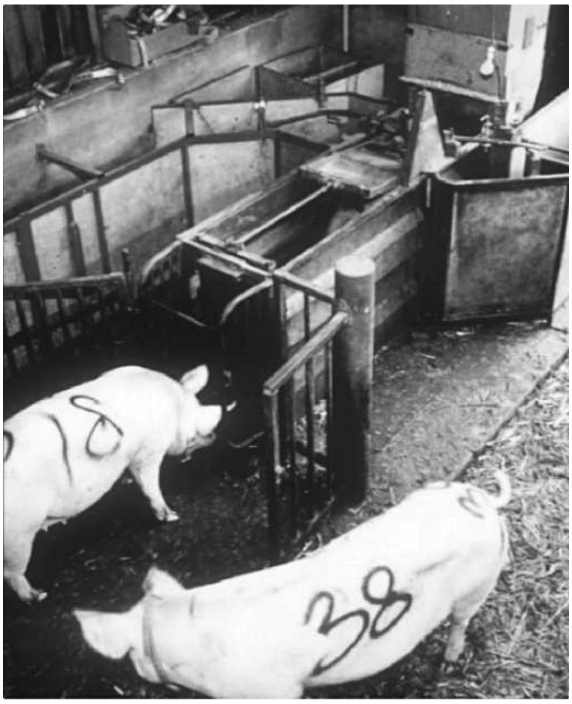

Fig. 4.6 A rear-entry/front-exit electronic sow feeder station showing sows queuing at the entrance

read by the receiver unit mounted by the feed trough. The information within the transponder is read and relayed to a central computer which then controls the amount of feed to be delivered to the sow, depending on her identity. Feed is delivered at a rate of between 200 and 300 g per minute and, typically, all of the sow's daily allocation is delivered and eaten in one visit, although sows can chose to spread their ration over multiple visits at different times of day.

It is usual to have one feeding station per 40–60 sows, enabling all sows to comfortably enter and feed within a 24 h period. If the number of sows increases above this, there is a danger that the feeder will be occupied throughout each 24 h period, without subordinate sows being able to gain access. Usually, sows can circle through the feeder as many times as they want in a day, even if they have eaten that day's allocation. However, some systems avoid this by incorporating a computer-controlled access gate, which will only permit sows with remaining feed allocation to enter either the feeder directly, or a 'holding area' in front of the feeder.

As feeding occurs sequentially, each group will establish a fairly consistent feeder order, based largely on social hierarchy. Thus, dominant sows will be first to enter the feeder station immediately after the new daily allocations are made available. Subordinate sows sometimes feed at night, thereby avoiding possible agonistic interactions around the feeder entrance during queuing.

The major advantages of this system are the complete control of individual feed intake, depending on each individual's requirements and the lack of space taken up by the station relative to perhaps 40 individual feeding stalls. Using multiple hoppers, it is also possible to deliver different rations to different sows within the group and thus animals of different sizes and stages of gestation can be kept together with easy feed management. Whilst in the station, the sow is free to eat without attention from pen-mates and can choose when and how often to eat.

The major disadvantage, from a management perpective, is an over-reliance on technology. If the system fails without being noticed, sows will go without feed. For example, transponders may become lost, the dispenser may stop delivering feed or power may fail. Sows require training to ensure that they are able to use the system and thus training pens have to be built into the design and labor is required to carry out the training. With large groups, daily inspection by the stockperson of each sow individually becomes difficult.

4.4.4 Floors and Floor Coverings

Indoors, there is the option to have systems in which the floor is either bedded or not, in which case they are likely to use solid, part-slatted or fully-slatted floors. The choice of system type is again tied in with the elements of the building type. In a fully-enclosed, climate-controlled environment, there is not the need to provide the sow with a different microclimate, as the whole building should be maintained at the appropriate temperature for sow comfort. Thus, there is not the need, at least from a thermal point of view, to have bedding. Conversely, a hoop structure (Fig. 4.7) would not have any heating system installed, and thus with changing temperatures outside, there would be a need to provide warmth inside, as provided by a composting deep bed.

Fig. 4.7 Inside view of a hoop structure showing deep bed

Outdoors, the housing system usually comprises some form of temporary or semi-permanent shelter placed within an enclosure. The enclosure can range from scrub/woodland, through grass pasture to bare dirt lot. Outdoor sows can therefore be exposed to enriched or barren environments. Sows with outdoor access may be prevented from conducting natural exploration of their substrate by nose-ringing, designed to prevent the sows from using their snout to perform rooting behavior and thereby damage the paddock.

4.4.4.1 Bedding

The most commonly-used bedding is straw. Primarily this is barley or wheat straw, but it can also be oat straw, soybean straw or cornstalks. Other organic bedding material includes grass hay, ground corn cobs, rice hulls, wood shavings and saw-dust. Shredded paper can also be used. Bedding may be supplied either sparingly, and removed and replaced at regular intervals, or may be used in large, or deep-bedded, quantities. With this type of system, the bedding is usually added to on a regular basis, and then removed and wholly replaced only infrequently. In this way, the bed begins to compost and may be a major source of heat in certain systems. Bedding is often added in such a way that it provides an element of enrichment within the pen. For example, in Swedish deep-bedded systems, the straw is often added as a round bale, which pigs can distribute themselves over time, and which also serves the dual purpose of forming a visual barrier behind which they can hide to escape aggression (Fig. 4.8).

Fig. 4.8 Swedish deep-bedded multisuckling room, showing use of straw bale as a visual barrier
(Photo Source JNMF)

4.4.4.2 Non-Bedded Systems

Intensive gestation housing systems are usually non-bedded with either fully-slatted (Fig. 4.9), part-slatted or, occasionally, solid floors. The concept of slatting is to separate the sows from their faeces and urine and thus maintain an element of hygiene. However, within the European Union, welfare concerns over the link between lameness and fully-slatted floors has led to a recent directive (2001/88/EC) that around 60% of any floor area must be 'continuous solid floor'. Thus, gestating sows within the European Union must only be kept on solid or part-slatted floors. If they are not bedded, they must also have access to some other manipulable material.

Fig. 4.9 Fully slatted flooring for sows

Fig. 4.10 Outdoor-housed sows, showing the denuded paddock and large bale tent housing

4.4.4.3 Outdoors

The majority of outdoor production is carried out on dirt lots (Fig. 4.10). Although initially, the area may indeed be grass-covered paddock, unless the sows are discouraged from rooting by nose-ringing or stocked at very low density, the grass cover will be both eaten and rooted up. It is recommended that outdoor production should be carried out only in areas of relatively low rainfall and on soil with good drainage otherwise the dirt paddock could become extremely muddy.

4.5 Welfare Concerns

Although a great deal of research has been carried out on dry sow housing systems in relation to welfare and summarized elsewhere (SVC 1997, Barnett et al. 2001), where the debate continues, it is really less involved in much of the scientific minutiae of many of the measures we take as welfare scientists. The reviews of the literature have addressed such measures as stereotypies and other abnormal behavior, aggression and other injurious behavior, circulating stress hormone concentrations, abnormal pathologies, brain receptor densities, immunological and disease incidence measures, reproductive problems, body function and injuries, growth and piglet production and management conditions for the stockperson.

However, at its most basic there are two opposing positions:

Pro-individual housing – sows in groups are subject to unacceptable levels of aggression.

Pro-group housing – sows in close confinement systems are subject to unacceptable restriction.

This is an over-simplification, however, for the remainder of this chapter the evidence supporting and challenging these statements will be examined.

4.5.1 Housing and Aggression

Examining the natural behavior of the domestic pig, it is clear that the core group consists of 2–4 related adult females and their litters. There is no mixing with unrelated animals, group size remains small and there is plenty of space in a complex environment. Food will be scattered but available ad libitum, as long as the sows forage. Observations of natural behavior indicate that core groups avoid each other (Gabor et al.,1999) but when they do come into contact, agonistic interactions will occur. Within a core group, the social hierarchy is established and stable. Overt aggressive interactions are extremely rare and most likely to happen during conflict over resources such as food.

Contrast this with breeding sows kept on a commercial operation and it is evidently different. On a commercial farm, there are a large quantity of unrelated adult females, they may be housed individually (but in close proximity to others) or in groups ranging from small (4–5) to large (200 +). There will be limited space, a relatively simple environment and they may encounter frequent remixing. They will usually be fed a restricted diet, once per day. Aggression is therefore much more prevalent on commercial systems relative to the natural situation, but just how prevalent will largely be influenced by: (1) degree of mixing/remixing, (2) method of feeding, and (3) amount and quality of space.

4.5.1.1 Aggression and Mixing

When sows are housed in groups, they will be mixed with unfamiliar animals. The amount and frequency of such mixing will depend very much on the system in which they are kept. As covered in Section 4.4.2.3, group systems can be static or dynamic. Static groups will be formed at weaning or after mating, and thus the sows in this system will be subject to a single mixing per gestation cycle. With dynamic systems, sows may be subjected to between 3 and 12 mixings per gestation cycle, depending on whether farrowing is batched monthly or weekly (Table 4.2). Some aggression during mixing is unavoidable but is usually short-lived, with the amount decreasing rapidly over 24–48 h to a basal level. However, it is likely that sows kept in a dynamic system with weekly mixings will be subject to a high degree of social stress relative to monthly-mixed groups, static groups or individually-housed sows.

Although aggression at mixing is unavoidable, it is usually intense only over the first few hours as social hierarchies are being established. Levels should decrease very quickly over the first few hours post-mixing, reaching baseline levels within 1–2 days. However, the amount and duration even over this time period may be influenced using a variety of methods. Methods that have been used are reviewed in detail elsewhere (Marchant-Forde and Marchant-Forde, 2005) and there are some that clearly have an effect over the longer term, some that have an effect over the short term and some that have no measurable effect, although a great many of the studies actually fail to measure aggression over the long-term, but instead concentrate on immediate post-mixing behavior.

Aggression at mixing can be influenced by design of the system and by management techniques. In the first category, the design of the pen can have both short- and long-term effects on aggression. Firstly, the shape of the pen can affect aggression in the short-term, in which case circular pens have been shown to result in higher levels of aggression (Wiegand et al., 1994). Addition of a solid barrier within the pen has been shown to reduce the total number of aggressive interactions over a 12 h post-mixing period in sows (Edwards et al., 1993), but this has also been shown to have longer-term benefits in weaners (Olesen et al., 1996). In a long-term study of three different dry sow housing systems, sows housed in a large group with a solid partition sited in the center of the pen were often observed using the partition to avoid or terminate aggressive interactions (Mendl, pers. comm.). In dynamic systems, in which sub-groups of sows are mixed in the resident group, the division of the pen into distinct lying bays, with one assigned to each sub-group as it was introduced, may have long-term advantages in reducing aggression (Bünger and Kallweit, 1994).

A number of management techniques have been tried, and many again have shown some degree of success in reducing aggression. Among those showing short-term benefits are time of day, chemical intervention and boar presence. There is evidence to suggest that if pigs are mixed after sunset, aggressive interactions are decreased over the short-term (90 minutes post-mixing) but by the next morning, aggression levels are the same as if pigs are mixed during daylight (Barnett et al., 1994, 1996). Similar effects have found using anti-aggression (amperozide – Barnett et al., 1993a,b, 1996) and sedative (azaperone – Luescher et al. 1990, Csermely and Wood-Gush, 1990) drugs. With both of these compounds, aggression appears to be reduced in the short-term for as long as the drug has efficacy, but once the effects of the drug have worn off, aggression rebounds back to that seen with untreated animals. In the most complete study on boar presence, it was found that aggressive interactions, skin damage and flight distance were all reduced by at least 28% over a 28 h post-mixing period by the presence of a boar (Docking et al., 2001).

For longer-term solutions to reduce aggression at mixing, influencing the early social experience of the sows may be effective. Mixing as piglets prior to weaning has been shown to benefit social skills in the longer term. Socialized piglets are able to form stable dominance hierarchies during future encounters with unfamiliar pigs quicker than piglets that are not mixed until weaning (D'Eath, 2005). Early socialization also increases consistency of behavior during social encounters (D'Eath, 2004). However, even if this very early social skill development has not been practiced, the amount of aggression at mixing can still be reduced later in life by practicing repeated mixing, pre-mixing or pre-exposure. With repeated mixing, it has been demonstrated that gilt piglets that are re-mixed three or four times post-weaning subsequently showed reduced aggression when mixed at 5 months of age, compared to pigs mixed just once or twice (van Putten and Buré, 1997). With dynamic systems, pre-mixing is commonly practiced, whereby, rather than introducing several individual sows into a large group at once, the individual sows are grouped first to establish a hierarchy amongst themselves, and then mixed as a sub-group into the large group. This practice does strengthen sub-group behavior and reduce aggression between new and resident sows (Durrell et al., 2003) over the 5 week post-mixing observation period. Lastly, pre-exposing pigs to each other prior to mixing can also reduce aggression. Kennedy and Broom (1996) placed groups of 5 gilts in a small pen within a large pen and let the resident sows have olfactory, auditory, visual and limited physical contact with them for 5 days prior to mixing. Once mixed, aggression was consistently reduced by 60% over the course of the mixing day and the following 2 week observation period compared with gilts that were mixed into the resident group without pre-exposure.

4.5.1.2 Aggression and Feeding

Under natural conditions, sows synchronize feeding and actively forage for many hours during the day, with crepuscular peaks in activity. Under most commercial systems, sows are fed a limited amount of feed (usually around 2–2.5 kg) which is invariably delivered and eaten in one single meal, lasting 15–20 minutes. The fact that sows are fed a restricted diet suggests that they are experiencing a degree of hunger throughout a large part of the day (Barnett et al., 2001, Rhodes et al., 2005). In many 'intensive', concrete-based housing systems that do not have alternative foraging substrate, such as straw, feeding is the major event of the sows' day and thus it is not surprising that access to feed plays a major role in determining the amount of aggression that may be displayed within a system. Where that feeding system promotes competition for access, such as floor feeding, aggression can be relatively high. Where the feeding system reduces competition either by enclosing the sows in feeding stalls or by being more freely available, such as in ad libitum feeding, then aggression is relatively low.

Floor feeding has the advantage of being cheap and relatively low technology, in terms of equipment. However, it is highly competitive and gives rise to aggression around feeding time (Csermely and Wood-Gush, 1986, Arey, 1999), with dominant sows able to monopolize the feed if it is not widely distributed (Csermely and Wood-Gush, 1990, Gonyou, 2005). With sows that are naïve to floor feeding, depositing feed into straw results in more aggression than floor feeding on to concrete, perhaps due to the feed becoming partially hidden by straw and thus resulting in increased perceived value (Whittaker et al., 1999). The aggression elicited by floor feeding can be manipulated by ensuring that feeding area is widespread, that group size is relatively small, that the group is stable, similarly-sized and that group members have similar nutritional needs (Gonyou, 2005), as individual feed intake cannot be readily controlled and lower-ranking sows are susceptible to reduced weight gain (Brouns and Edwards, 1994).

Trough feeding is another system in which sows are fed simultaneously as a group. At its most basic level, the trough runs down one side of the pen without division and each sow has a nominal amount of space to feed (length of trough ÷ number of sows in the pen). However, with this type of arrangement, similar problems to floor feeding can be encountered, with high levels of aggression and dominant sows monopolizing large lengths of the trough, displacing subordinate sows. This is especially the case if feed distribution along the trough is uneven (Olsson et al., 1994). Aggression at the trough can be decreased by improving distribution (using wet instead of dry feed – Andersen et al., 1999) or by using dividers to separate the trough into individual feeding spaces. This can be achieved by inserting stalls of either shoulder or full-body length – both of which decrease aggression compared with non-divided troughs, and full-body stalls proving advantageous over shoulder stalls when used with dry feed (Andersen et al., 1999).

A method developed to address the problem of displacement from the trough has been trickle or 'biofix' feeding. The principle of this system is that each sow in the group has a feeding space separated by short shoulder stalls at which feed is delivered in a slow rate no faster than the slowest eater within the group. Thus, each sow is effectively tied to her feeding place as she is now unable to quickly eat her whole ration and move on to displace a slower eater, which could be the case if all feed is delivered in one drop. Again, this system works best if the group size is relatively small and is stable (Gonyou, 2005).

One of the most common feeding systems for group sows is the individual feeding stall into which the sows may or may not be shut over feeding. Its major advantages are that it allows sows to be fed simultaneously, but also enables the stockperson to check sow body condition and alter individual feed allocations appropriately (Edwards, 1985). Its major disadvantage from an economic viewpoint is that it requires considerable space, with each sow in the pen having her own stall, thereby taking up about 1 m^2 per animal, in addition to the space requirement for resting. If the sows are not shut in, then the opportunity arises for slow eating subordinate sows to be displaced by quicker eating, more dominant sows. Feeding in stalls reduces aggression compared to floor feeding (Barnett et al., 1992) and if the groups are kept small and stable, and sows are matched for size, body condition and feed levels, then shutting the sows in during feeding becomes unnecessary (SVC, 1997).

To the stockperson, the ability to control feed intake at an individual level is extremely important. Over the last two decades, the technology has become available for sows to carry individual electronic transponders which can be read to enable a computer-linked feeding system to deliver a precise, pre-programmed quantity, based on the sow's identity. Early versions of this Electronic Sow Feeder (ESF) system, had reliability issues and problems with vulva-biting (van Putten and Burgwal, 1990), but these have largely been addressed by component design improvement. As the cost of this equipment is relatively high, a single feeder is usually expected to be used by around 40–60 sows. On large farms, it would be possible to have sows housed in static groups, but in many cases, the ESF system is used with a large dynamic group and it is not unusual for group size to be 300 sows, incorporating 5 feeders.

Obviously, with one feeder per 50 sows, feeding is sequential and the feeder may be occupied for as much as 18 h of the day. Usually a feeding order develops, with dominant sows accessing the feeder soon after the 24 h cycle begins. In static groups, this is likely to be fairly stable, but with dynamic groups it is more flexible and is related to time since introduction, with the last introduced sows being later in the order (Bressers et al., 1993). The consequence of sequential feeding is that the entrance to the feeder can become a focus of activity for large parts of the day, and where there is activity combined with limited access to a resource, there is likely to be aggression. Indeed, it is the entrance to the feeder that is one of the main areas for agonistic interactions to occur (Marchant et al., 1995, Hodgkiss et al., 1998). There is also the possibility of dominant sows making repeated non-feeding visits (i.e. visits after they have eaten their allocated daily ration), thereby restricting access to lower ranked sows (Hunter et al., 1988) although this can be reduced by installing a computer-controlled gate at the rear of the feeder which only allows sows that have not received their ration to enter. The amount of aggression within an ESF system can be reduced by provision of long-stemmed straw in the lying area and by starting the feeding cycle overnight (Jensen et al., 2000). Also, the additional feeding of roughage to appetite can decrease the risk of vulva-biting (Gjein and Larssen, 1995a).

As long as access to feed is restricted, competition for feed will occur. Recently, there has been an increase in interest in ad libitum feeding. The major problems with this are that sows consume more than is needed to maintain body weight/condition, which in turn may affect productivity, and that the more they eat, the more waste is produced. The first problem can be mostly overcome by altering the diet to increase the content of dietary fibre, such as sugar beet pulp, which adds bulk and lowers energy concentration. In general, increasing fibre in the diet doubles the amount of time that sows spend eating, reduces stereotypic behaviour (repetitive, relatively invariant behavior with no obvious function) by 7–50%, decreases general restlessness and aggression (Meunier-Salaun et al., 2001) and reduces rooting (Martin and Edwards, 1994) and foraging behaviour (Braund et al., 1998), indicating improved satiety. In a dynamic large group system, there is also some evidence to suggest that intensity of aggressive interactions post-mixing is decreased (Whittaker, unpublished results).

4.5.1.3 Aggression and Amount and Quality of Space

The amount of space that pigs have, and the quality of that space, can have a large impact on their behavioral repertoire, including agonistic social behaviour. As such, it is perhaps surprising that there is a paucity of comparative studies on gestating sows that examine these factors directly. Most of the comparative studies on gestating sows compare systems that vary in a wide number of different factors and thus it is not possible to determine the effects that space or environmental complexity alone may have.

The minimum amount of space given to sows in current commercial housing systems is that encompassed by the gestation crate or stall, which at about 1.25 m^2 encloses the sow's static space requirement (Baxter and Schwaller, 1983). Within this space, the sow is usually housed on a slatted floor without bedding but with a metal trough, a drinker and the metal bars of the crate, and perhaps with a chain attached for the sow to chew on. Obviously the sow enclosed within this space has no pen-mates and thus, it is commonly assumed that she is free from the aggression attributed to group housing systems. In reality, this may be quite erroneous. Evidently in a crate or stall, she is free from the physical effects of aggression – i.e. the skin lesions that group-housed sows commonly show are not apparent. Several studies have in fact shown that aggressive interaction between neighboring sows in gestation crates can be high (Jensen, 1984, Barnett et al., 1987a, Broom et al., 1995). The initial attack is more often followed by retaliation in crates resulting in escalation in the intensity of aggression (Jensen, 1984, Barnett et al., 1987, Broom et al., 1995), rather than the withdrawal and cessation of interaction most often seen in group housed systems. For example, Barnett et al. (1987) observed a total of 55 aggressive interactions in stalls of which 25 (46%) resulted in retaliation. In groups over the same observation period, they observed over twice as many aggressive interactions (136) but only 7 resulted in retaliation and overall free corticosteroid concentrations were nearly twice as high in the stalled sows, perhaps indicating that the consequences of the interaction (i.e. the escalation) may be more important than the number of interactions per se. We also know from studies on group-housed sows that social defeat can elicit quite a strong, psychologically-induced heart rate response, even in interactions that involve immediate withdrawal (Marchant et al., 1995). It is postulated that the psychological component of non-resolvable aggressive interactions for sows in stalls is probably a considerable and chronic stressor.

Once placed in groups, the amount of space given per sow does impact on aggression. The most comprehensive study (Weng et al., 1998) examined the effects of space alone, on the behaviour of small, established groups of six sows. Their pens were bedded and included individual feeding stalls into which the sows were closed during feeding and which were then closed off for the rest of the day. Sows were given different space allowances of 2.0, 2.4, 3.6 and 4.8 m^2 per sow. As space allowance decreased, the total number of aggressive interactions increased. In the smallest pen, the number of interactions involving biting was greater than at the other pen sizes, and the avoidance index was lowest, indicating that the sows had difficulty getting away from an aggressor. At 4.8 m^2, there were indications that the sows were able to better utilize the pen as these sows spent the least time sitting and standing inactive and spent just over 50% more time rooting compared to sows stocked at 2.0 m^2. However, Weng et al. (1998) were at pains to emphasize that these results are only valid for stable groups of six sows housed in this particular system and that they should not be generalized to other housing systems. In particular, these groups were stable, bedded on straw and did not have to compete for food. Short-term studies investigating space allowance at mixing down to 1.4 m^2 might suggest that decreasing space actually suppresses aggression (Barnett et al., 1993a,b), but this study only looked at 90 minutes post-mixing and most other longer-term studies have seen the highest levels of continuing aggression at the lowest space allowances, once the hierarchy is formed.

In other studies that have compared different space allowances, other environmental and social factors have also been varied, making it difficult to interpret effects due to space allowance alone. For example, Boyle and Tergny (1999) examined space allowances of 2.0 and 2.8 m^2 per sow, in pens with fully-slatted floors and free-access feeding stalls – systems designed to show possible conversion designs from existing gestation crate facilities. However, group size also varied with 4 sows per group at the large space allowance and 8 sows per group at the smaller space allowance, and the sows were not in stable groups when entered into the pens. The results showed that there was no difference in the frequency of aggressive interactions between the two systems but at all time-points up to 28 days post-mixing, skin damage scores were lower for the sows housed at 2.8 m^2, indicating lower intensity of interactions or the ability of attached sows to withdraw from the encounter. Jensen (1984) also investigated space allowances of 2.3 and 3.0 m^2, and found more aggression at the lower space allowance but again there were differences in system design, with sows accessing cubicles at the lower space allowance but having access to separate lying, dunging and feeding areas at the higher space allowance. Durrell et al., (2002) examined group-housed sows in two different systems: one with a constant space allowance of 4.1 m^2 per sow, and another with a variable space allowance of between 1.5 and 3.4 m^2 per sow. They found more aggressive interactions in the variable space allowance treatment, but this was perhaps expected as this system was a dynamic split yard system with 33 sows, compared with the static group system of 4 sows. In contrast to these results a study by Seguin et al. (2006) on stable groups found no effect of space allowance on aggressive behavior of 2.3, 2.8 or 3.2 m^2/sow, but this was also confounded by different group sizes ranging from 11 to 31 sows.

As well as the amount of space, the quality of the space can also have an effect on aggression. Much of the current research into group housing in North America involves the conversion of existing stall-house systems into fully-slatted or part-slatted, non-bedded group housing (e.g. Harris et al, 2006). The major qualitative differences in the environment for sows in these converted systems are a greater freedom of movement and the ability to interact socially with other sows – which may or may not be a good thing in such systems. Usually, space is fairly restricted and the environment could still be termed ‘barren’ – with fully- or part-slatted concrete floors and no bedding. Housing sows in groups in these types of converted systems has often resulted in an increase in lameness and skin damage, as a consequence of exposure to agonistic interactions (Harris et al., 2006), although it must also be noted that the systems are often being managed by stockpeople who are inexperienced with group housing. However, aggression within group housing systems can also be influenced by the quality of the space – i.e. aspects of the environment that allow sows to satisfy other behavioral needs such as foraging. For example, Durrell et al. (1997) examined groups of four sows housed in either barren or enriched housing – the pens being the same apart from the enriched environment having mushroom compost suspended on racks for the sows to root in. The enrichment reduced aggressive behavior and injuries. Similarly, Jensen et al. (2000) found that aggression in ESF systems was highest in a part-slatted system without bedding than in three other ESF systems with solid floors and straw-bedded lying areas.

4.5.1.4 Housing and Aggression Summary

Whereas there is evidence to suggest that aggression in group housing systems cannot be eradicated completely, there is also considerable evidence to show that aggression can be kept at a minimal level by a combination of environmental and management factors. Low levels of aggression are facilitated by using a non-competitive feeding system, establishing stable groups where possible and housing the sows in plenty of space with access to straw. When mixing occurs, pre-exposing sows prior to mixing is advantageous, as is having a design of pen that allows sows to avoid aggressive interactions as much as possible, or to readily escape if an agonistic interaction is initiated.

4.5.2 Housing and Space Restriction

For those advocating group housing, the major argument is based around the restriction that is imposed by close confinement in a gestation crate. The visual image of a sow 'imprisoned in a metal cage' is an emotive one and consumers may correctly or otherwise regard space as a necessity, which should not be compromised under any circumstances. Scientific evidence may indicate that space is not as important as other resources, e.g. food availability, but this does not tell us that they are wrong in requiring sows to have adequate space if they are going to buy the product. From a producer's point of view, the crate does offer some very important advantages – it protects the sow from aggression (although as we have seen in the previous section, this may be misleading) and allows her to receive individual attention. She can eat her own food without fear of displacement and her ration can be individually tailored to meet her nutritional requirements. Observation is relatively easy and her health status can be monitored more easily than that of sows housed in groups. Many producers therefore believe that crates are beneficial for sow welfare. In the light of the European Union banning the crate on welfare grounds, the evidence will be considered in three sections; behavior, physiology and health.

4.5.2.1 Space Restriction and Behavior

The Brambell report of 1965 into the welfare of animals kept in intensive farming systems proposed a number of 'freedoms' against which animal welfare could be benchmarked in the various systems examined. These have undergone some modification subsequently, but are now commonly known as the Five Freedoms:

1. **Freedom from Hunger and Thirst** – by ready access to fresh water and a diet to maintain full health and vigor.
2. **Freedom from Discomfort** – by providing an appropriate environment including shelter and a comfortable resting area.

3. **Freedom from Pain, Injury or Disease** – by prevention or rapid diagnosis and treatment.
4. **Freedom to Express Most Normal Behaviour**– by providing sufficient space, proper facilities and company of the animal's own kind.
5. **Freedom from Fear and Distress** – by ensuring conditions and treatment which avoid mental suffering.

From a behavioral perspective, the gestation crate should in particular be examined relative to Freedoms 2 (does the crate provides an appropriate environment in which to rest and be free from discomfort?), 4 (it is obvious that the gestation crate compromises the sow's ability to express her normal behavior) and, 5 (as a consequence of 4, mental suffering may occur). The extent to which her normal behavior is compromised depends on what benchmark of 'normal' is used, her behavior in a loose housing system or her behavior in a semi-natural environment? The original conceptual framework of the Five Freedoms was based on natural behavior and thus the housing system in relation to how the sow would behave without environmental limitations should be examined. For sows there is information on free-ranging domestic sows in semi-natural enclosures against which to compare (Stolba and Wood-Gush, 1989). Under natural conditions, the sow's daily behavioral routine would be as seen in Table 4.3 (Stolba and Wood-Gush, 1989).

As shown below, the daily routine involves considerable foraging-related activity, with multiple changes in location and relatively little time spent resting.

Table 4.3 Behavioural routine of free-ranging domestic sows in a semi-natural environment

Early morning	► Leave communal nests ► Eliminative behavior ► Positive social behavior
Morning	► Change location ► Forage by rooting ► Change location ► Forage by browsing
Forenoon	► Change location ► Drinking ► Change location ► Continue foraging
Non	► Siesta ► Marking and positive social behavior ► Change location ► Wallowing
Afternoon	► Change Location ► Foraging by rooting ► Foraging by browsing
Evening	► Change location ► Marking ► Occupy communal nests

Indeed, considered as a percentage of daylight hours, sows in semi-natural conditions spent 31% of time grazing, 21% rooting, 14% walking and 11% engaged in social behavior – the vast majority of which is positive social contact rather than agonistic (Stolba and Wood-Gush, 1989). Only 6% of daylight time was spent lying inactive.

In a gestation stall, a sow can stand up and lie down. She can have some contact with her neighbors so can engage in limited social behavior. She is likely to have limited ability to forage as she will be on part- or fully-slatted concrete floor. She will have ad libitum access to a drinker and feed will be present for typically about 20 minutes once per day. She can rub herself against the metalwork in lieu of scratching, so can carry out limited comfort behavior. She will urinate and defecate where she stands. In terms of a daily routine, the main events in the sow's behavior primarily occur around the timing of the feeding event. This is usually in the early morning and the sow will show a peak in activity before and after feeding. However, this is fairly short-lived and it has been reported that over 24 h, sows in gestation stalls spend between 70 and 81% of time lying inactive (Holt et al., 2006). Even allowing for sows spending 100% of night-time inactive, this would still equate to spending 50–60% of day-time inactive, which more or less corresponds with the 66–72% figure of inactivity from another study which just looked at day-time behavior (Harris et al. 2006). However, Broom et al. (1995) reported that gilts housed on concrete in stalls spent 79% of daytime observation periods lying inactive.

The disparities between the amounts and types of sow activity in stalls and sow activity in a semi-natural environment is quite evident, and there is sufficient evidence that sow stalls do not give the sow the freedom to express her normal behavior. However, it is necessary to examine how she spends her time in other types of system, before dismissing stalls in this way. The study by Harris et al. (2006) also examined the behavior of sows kept in small group systems with individual feeding stalls – an easy conversion of a stall system by removing the rear of the stalls and fencing off the rear passageway to provide a communal lying area. The sows in this system showed no differences in the time spent lying compared with the stalled sows and there were no differences in time spent sitting, standing, eating or drinking. This is not too surprising, as the physical environment of the two systems varied very little. The group system provided the sow the opportunity to have some choice in her location; allowed her to interact with other sows; and gave her space to change posture and move around. However, there was no substrate for foraging and although her overall behavioral repertoire – i.e. the number of different behaviors carried out – may have increased, her time budget as measured by scan sampling using a limited ethogram did not show any changes from those of stall-housed sows. In both systems the sows spent between 65 and 75% of their time lying inactive. Other types of group housing systems show different results – some lower than stalls, but others quite comparable. For example, sows in small groups with free-access stalls, fully-slatted dunging area and solid floored kennel area spent 60% of their time lying inactive, whereas sows housed in a large dynamic group with

ESF, fully-slatted dunging areas and solid-floored kennels spent only 29% of their time lying inactive (Durrell et al., 2002). Broom et al. (1995) found that small groups with individual feeders and bedded on straw still spent 63% of daytime lying inactive and gilts in a large dynamic group with ESF and straw bedding spent 79% of daytime lying inactive.

It can be concluded that on the basis of time spent lying inactive, group systems have little advantage over confinement in stalls. However, rather than using this particular behavioral element as an indicator of well-being in isolation, it is necessary to examine the whole time budget. It is more important to focus on ethogram complexity and use focal sampling rather than using a basic ethogram to look at time budgets using scan sampling, i.e. 'the devil is in the detail'. When a detailed analysis is attempted, differences in the systems can be identified in terms of their ability to accommodate the sow's natural behavioral repertoire. The study by Broom et al. (1995) examined behaviour of gilts of the same genetic strain and with the same caretaker team in non-bedded stalls, small groups and a large group and then looked at the same animals again after they had been in the systems for four parities. As well as scan sampling, they also included focal sampling. Generally, they found that differences in behavior that existed as gilts had increased in magnitude by the 4th parity (i.e. after about 2 years in the systems).

From the scan data during parity 1, gilts in small groups spent less time lying inactive than stall-housed or large group-housed gilts (63% vs. 79% & 79% respectively). However, by parity 4, stall-housed sows had become the least inactive (30%), followed by the small group sows (46%) then the large group sows (70%). Stall-housed sows were now spending more time rooting and chewing at pen fittings (24% vs. 3% & 1%), sham chewing (10% vs. 3% & <1%) and performing the maintenance behaviors drinking, scratching and eliminating (12% vs. 3% & 3%) than sows in the group housing systems. The focal behavior analysis also showed that stall-housed sows spent 500 seconds per hour engaged in obvious oral stereotypic behavior, compared with 100 s/h for small-group sows and 10 s/h for large-group sows. Other studies have also demonstrated an increase over time in stereotypic behavior for sows in stalls (Stolba et al. 1983, Cronin and Wiepkema, 1984). Although the significance of oral stereotypies continues to be debated (Mason, 1991, Dailey and McGlone, 1997, Marchant and Pajor, 2003), the general consensus of scientific opinion is that these behaviors often develop in situations where the animal is frustrated by unfulfilled needs. A major difference between the stall and the group systems in Broom et al.'s (1995) study was the absence of straw or foraging substrate in the stalls, probably resulting in an inability for these sows to have a full stomach and thus re-directing natural rooting/foraging behavior to the pen fittings and concrete floor. Indeed, Fraser (1975) demonstrated that giving sows in tether-stalls access to straw greatly reduced stereotypic behaviors. There is some evidence that the sham-chewing and bar-biting behaviors are not stereotyped, in that they have a function to buffer stomach acidity by stimulating saliva production (Marchant and Pajor, 2003) – a function that is not necessary when sows have access to roughage (straw) in the group systems.

Perhaps the most basic behavioral need of the sow is to change posture without difficulty. This can be described in terms of the sow's ability to stand up, turn around, lie down and roll over. Without needing to carry out a scientific study, it can immediately be seen that a gestation stall does not allow the sow to turn around or to roll over. The gestation stall encloses the sow's static space requirement (Baxter and Schwaller, 1983). However as a sow stands up or lies down, she moves backwards and forwards, and from side to side. The area encompassing these movements is her dynamic space requirement. The average sow stall currently in use on commercial farms does not come even close to meeting the dynamic space requirements, and with the increasing size of the commercial sow (Whittemore, 1994), many now are coming close to the static space requirements (McGlone et al., 2004). As the sow becomes larger in relation to the stall in which she is kept, she has increasing difficulty in standing up and lying down (Marchant and Broom, 1996, Anil et al., 2002a) and she becomes more prone to injury (Anil et al., 2002b, 2005).

4.5.2.2 Space Restriction and Physiology

Physiology is the study of the mechanical, physical, and biochemical functions of living organisms. In relation to housing systems, the majority of work has focussed on endocrinology and, more specifically, stress hormones related to the Hypothalamic-Pituitary-Adrenal (HPA) axis. Corticotropin-releasing hormone (CRH) is released by the paraventricular nucleus (PVN) of the hypothalamus, in response to the stress. CRH then acts on the pituitary gland, causing it to release adrenocorticotrophic hormone (ACTH), which in turn causes the adrenal cortex to release cortisol. Normally, cortisol production is circadian with an acrophase (peak) in late morning (Ekkel et al., 1996), corresponding with circadian rhythmicity in behavior (Marchant-Forde, 2003). This property in itself causes difficulties in interpretation of results, where single samples are collected and overall, difficulties are present in terms of identifying the level at which a cortisol concentration indicates a welfare challenge (Mendl, 1991). However, it still remains the most widely-used physiological measure when assessing the welfare of sows housed in different systems.

Close confinement by tethering elicits an acute cortisol response, which declines after 24 h (Cariolet and Dantzer 1985). However, of greater concern are the long-term or chronic effects of close confinement. A series of Australian studies found that sows in tethers or gestation stalls had higher cortisol concentrations than sows that were group-housed (Barnett et al., 1984a,b, 1985, 1986, 1987a,b), as did a more recent study in the U.S.A. (Estienne et al., 2006). Bergeron et al. (1996) compared cortisol levels in gilts housed in conventional stalls and gilts housed in turn-around stalls and found that cortisol levels were higher in conventionally stalled gilts. Another technique that has been used is to look for responses in cortisol secretion either by subjecting the animal to stress or by injecting the sow with ACTH to elicit a maximal cortisol response – the theory being that the response will be higher in those animals which have had increased HPA activation in response to stress. Using this methodology, Jensen et al. (1995) showed that stalled sows had greater cortisol response to blood sampling than sows housed in a large group with and ESF. Janssens et al. (1994) found that cortisol responses in tethered gilts increased with prolonged tethering, but did not increase in control gilts that were group-housed over the same time-period. Using a CRH challenge, Janssens et al. (1995) found that tethering increased sensitivity of the adrenal cortex to ACTH.

However, there are other studies that find either no differences in HPA activity due to housing or differences in the other direction – i.e. greater HPA activity in group-housed or non-confined sows versus confined sows. For example, Barnett et al. (1991) compared horizontally-barred stalls with groups and tethers and found that sows in the stalls and groups had similar plasma free cortisol concentrations, though both were lower than those of sows in tethers. Von Borell et al. (1992) and Broom et al. (1995) carried out ACTH challenge studies and found no differences in cortisol responses between sows housed in various group-housing systems and gestation stalls. Soede et al. (1997) measured cortisol in sows housed in tethers or individual pens and again found no differences. Some more recent studies have demonstrated higher cortisol concentrations in sows in group housing systems compared with sows in stalls (Anil et al. 2005 – stalls vs. ESF, Karlen et al. 2007 – stalls vs. hoop structure, Jansen et al. 2007 – stalls vs. large group with trough feeding).

HPA activity would therefore appear to be very difficult to make any firm conclusions, as results from the various studies show inconsistency. As explained previously, methodology of sample collection is important as the intra-individual variation in cortisol concentrations can be large, depending on time of day, stage of gestation (Anil et al. 2006) and also time of sample relative to activity, or feeding time or exposure to incidental stress. Also, there is usually large inter-individual variation in cortisol levels between sows housed in the same system. For example, sows housed in a large group with ESF had different cortisol concentrations, depending on relative social rank. The middle-ranking sows – the sows engaged in high levels of aggressive interaction with limited success – had significantly higher cortisol levels than the high-success sows and the no-success sows (Zanella et al., 1998). Similarly, differences have been found in stall-housed sows in some studies dependent on whether the sows carry out a high level or a low level of stereotypic behavior (Dantzer and Mormede, 1981, Von Borell and Hurnik, 1991), or whether the stalls are long, short, wide or narrow (Barnett and Cronin, 2005, Cronin et al., 2005) or have vertical or horizontal bars (Barnett et al., 1991).

Other aspects of physiology that have been investigated include cardiovascular function and neurotransmitters. With group housing allowing the sow a greater or lesser degree of exercise, it might be expected that this would impact cardiovascular function in terms of fitness. Over the short- to mid-term, there appears to be no impact on basal heart rate. Harris et al. (2006) compared basal heart rates of gilts housed in stalls or small groups and found no difference through the first gestation. Over the long-term however, cardiovascular fitness may be affected. Marchant et al. (1997) investigated the long-term effects of housing system on basal heart rate, and found that sows which had been stall-housed for 7 parities had significantly higher basal heart rates than sows housed in small groups and in a large group with ESF. Stall-housed sows also had heightened cardiovascular responses to feeding, an observation that has also been reported in tethered sows (Schouten et al., 1991). This has been interpreted as indicating the importance of feeding to sows with little other sensory stimulation.

Opioid receptors in the brain have been investigated in sows housed in restricted and loose housing systems and attempts have been made to relate receptor densities to behavior, especially inactivity/unresponsiveness and performance of stereotypies. Zanella et al. (1996) showed that tethered sows had greater μ receptor density in the brain than group-housed sows and that the density was positively correlated with time spent inactive. The duration of stereotypic behavior, however, was negatively correlated with both μ and κ receptor densities. In a further study, Zanella et al. (1998) found that stall-housed sows had higher levels of dynorphin (κ receptor agonist) in the frontal cortex than group housed sows. Loijens et al. (1999) also showed a negative correlation between intensity of stereotypy performance and density of opioid receptors in the hippocampus and hypothalamus in sows that had been tethered for 2 months. Thereafter, the correlation seemed to disappear with increasing duration of tethering. They suggest that differences in the density of opioid receptors in pigs showing high and low levels of stereotypy may well be already present prior to tethering (Loijens et al. 2002).

4.5.2.3 Space Restriction and Health

The studies carried out looking at the effects of gestation housing on health can be roughly divided into three groups; (1) leg strength and lameness, (2) immune status and disease, and (3) skin lesions. Whereas the first two categories can have a direct effect on survivability of the sow, skin lesions, which are often extremely obvious even to the untrained eye, may have less serious implications for the sow's future. That is not to underestimate their impact on the welfare of the affected individual, but in terms of resulting in either spontaneous mortality or euthanasia, skin lesions will fall behind the other two categories. They have, however, been subject of more study than the other categories, mostly in relation to aggression, but also lesions attributable to other elements of the physical environment.

Unfortunately, many studies report only a form of total injury score – i.e. they make a count of all lesions, regardless of their cause. Lesions are notoriously difficult to qualify (degree of severity) and therefore, simple quantitative counts are most often used. Compared with sows in groups, confined sows have been shown to have either more skin lesions (Gloor, 1988; Boyle et al., 2002; Anil et al., 2005), similar amounts (Hulbert and McGlone 2006) or fewer lesions (Gjein and Larsson, 1995; Backus et al., 1997; Anil et al., 2003; Harris et al., 2006, Estienne et al., 2006; Karlen et al., 2007). These discrepancies are due to a number of factors. Firstly, as stated, most scoring systems are count only and do not attempt to differentiate between size, depth or placement of the lesion. Secondly, there are differences in group size, flooring substrate, feeding system etc. in the group systems evaluated, and lastly, the timing of scoring in relation to introduction to the system and stage of gestation varies between studies.

By looking in more detail at these studies and combining their information with other studies that are more detailed, it is possible to identify consistent differences between confinement and group systems. The time-course and type of lesions seen in confined and grouped sows are clearly different. In group systems without sustained aggression, there should be a peak in lesion scores just after introduction to the system. Thereafter, lesion scores decrease as aggressive interactions fall dramatically after establishment of the social structure and the lesions begin to heal (Seguin et al., 2006). Where comparisons are made between confined and group-housed sows, many of the differences are only seen in the post-mixing phase and not later in gestation (e.g. Stamer and Ernst, 1992; Estienne et al., 2006; Karlen et al., 2007). The relationship between the number of lesions and the amount of aggression is indirectly highlighted by a study that shows that as sow bodyweight increases in an ESF group system, the total injury score decreases (Anil et al. 2005). Heavier sows are likely to be more dominant and less involved in sustained aggressive interactions.

As aggression-related skin lesions lessen, longer term injuries, ulcers and calluses are mostly recorded. The incidence is higher in confined sows (Gloor, 1988; Stamer and Ernst, 1992; Gjein and Larsson, 1995a; Cleveland-Nielsen et al., 2004). Sows with poor body condition score (Boyle et al. 1999) and large, heavy sows (Anil et al., 2003) are more likely to have increased injury scores in confinement systems, due to decreased fat cushioning over pressure points such as the shoulder and hip and perhaps being forced to lean against parts of the stall. The total injury score of stalled sows would appear to increase over gestation (Anil et al., 2006) as body mass increases.

So, although it would seem possible to differentiate between the types of lesions seen in different housing systems, it is still extremely difficult to rank systems from a welfare perspective. Is it worse to have, say, 20 aggression-related lesions that will heal over time or one decubital ulcer that remains present for the whole of gestation? It would be necessary to devise a welfare index that takes into account the degree of physical and psychological trauma endured by the sow and the length of time over which it is applied and the proportion of sows that are affected. Within this scenario, it may well appear that a system with 5% of sows having open ulcers for 16 weeks has worse welfare than the system with 40% of sows having mild skin lesions for 3 weeks. This is, of course, another situation where an ability to assess both the degree of pain associated with the lesion and its psychological impact on the sow would be extremely beneficial to help draw up a valid welfare assessment, devoid of human bias.

Under U.S. husbandry systems, spontaneous sow mortality comprises 4.3% of sows per year (NAHMS, 2006). A further 19.5% are culled on an annual basis, but this figure is highly variable from farm to farm. For example, a study carried out on farms in Minnesota, U.S.A., found that annual culling rates varied between 15 and 85% (D'Allaire et al. 1987). Within the NAHMS (2006) culling rate, the major reasons for culling are either based on a management decision to cull the sow when she reaches a specific parity (36.6%), or on the basis of productivity (39.3%), which includes a failure to conceive (26.3%) or poor performance (13.0%). A further 15.2% are culled on the basis of lameness. Extrapolating the culling due to lameness rate to the U.S. breeding herd of just over 6 million sows, means that over 180,000 sows are culled each year due to lameness issues. This figure does not include clinical and non-clinical lameness incidence of surviving sows and therefore, lameness can obviously be seen to have both a large financial impact on the producer and a large welfare impact on the sow.

The causes of lameness are diverse. They can include broken bones, osteochondrosis, arthritis, claw lesions and infected skin lesions. As with the lesions issue, the disparity seen in comparative studies of confined and group housing may be attributed to timing of data collection and different measuring methodologies. However, we may firstly pose the question of whether confinement and the inability to exercise weakens aspects of the locomotor apparatus and leaves them more prone to injury. Examining the musculo-skeletal system within the limbs, Marchant and Broom (1996) found that the femur and humerus of sows housed long-term (7 parities) in stalls were significantly weaker than those of group-housed sows. The muscles associated with locomotion were also reduced in size. Over the shorter term – one parity – taking gilts out of their stalls for short daily exercise also increases bone mineral density and breaking strength (Schenck, 2007). Whether these results have welfare significance or not is debatable, in the absence of any differences in actual lameness incidence between the two studies. However, with weakness, potential injury risk is increased and thus, biological fitness could be reduced. This has been cited as an outcome due to failure to cope with stress, using the definition of stress being that 'which over-taxes (an animal's) control systems and reduces its fitness or seems likely to do so (Broom and Johnson, 1993), leading to pathology (Broom, 2006)'.

In comparative studies, sows in stalls have been shown to have more traumatic injuries caused by flooring and metalwork (Bäckström, 1973), have more claw lesions with increasing incidence over parity (Gjein and Larssen, 1995a,b) and have higher incidence of lameness compared with hoop-housed sows (Karlen et al., 2007). Conversely, sows in groups have been found to have more hoof lesions (Backus et al., 1997), higher lameness incidence (Anil et al., 2005), higher lameness scores (Estienne et al., 2006) and worse gait scores

(Harris et al., 2006). Studies that showed groups to be better had straw bedding (Gjein and Larssen, 1995a; Karlen et al., 2007) perhaps emphasizing that the quality of flooring is a major factor that effects incidence of lameness. Overall, there are large gaps in our knowledge regarding lameness in breeding sows in relation to housing. There is little information on the effects of housing on the different causes of lameness and there would appear to be a need to for an epidemiological approach to provide such information.

The relationship between stress and immune function is complex (Blecha, 2000), but there is evidence to suggest that, in general, stress decreases immunity and leaves an animal more prone to disease. If restricting a sow by confining her in a stall or tether is stressful, both reduced immune function and increased morbidity would be expected. Unfortunately, there is relatively little information on the effects of housing on immune function in sows. Some studies have failed to show any differences in immune function between confined and group-housed sows. Hulbert and McGlone (2006) found no differences between sows in pens and sows in stalls. Bergeron et al. (1996) compared sows in conventional crates with sows in turn-around crates, and again detected no differences. Lastly, von Borell et al. (1992) compared sows in the group Hurnik-Morris system with sows in stalls without finding differences. A recent study in Australia comparing sows in deep-bedded hoop structures with sows in conventional stalls did indicate that the neutrophil:lymphocyte (N:L) ratio was higher for the stalled sows – a measure that has been linked to animals being under greater stress. Similarly, sows in tethers had a greater N:L ratios than sows housed in both indoor and outdoor groups (Leverino et al., 2003). Tethering has also been shown to lower the immunoglobulin responses to *E. Coli* challenge compared with grouped sows (Barnett et al., 1987a,b).

The information on disease incidence is also sparse. Early studies indicated that sows in stalls showed a higher total morbidity and incidence of mastitis, metritis and agalactia (MMA) at farrowing (Bäckström, 1973) and appeared to present with more urinary disorders than grouped sows (Tillon and Madec, 1984). More recently, Hoy and Rathel (2002) have reported an increased incidence of puerperal disease in sows confined during gestation (24.0%) versus loose housed sows (16.9%). Confinement has been implicated in increasing the odds of Postweaning Multisystemic Wasting Syndrome (PWMS – Rose et al., 2003).

4.5.2.4 Housing and Space Restriction Summary

Looking at all the data combined in these sections, the conclusions that can be drawn are definitely not obvious. The biggest danger is making the false assumption that it is a simple confinement versus group comparison. Certainly confinement restricts the sow's behavioral repertoire and may increase the incidence of stereotypic behavior, but the latter is also attributable to barren environments and thus where the quality of space in a group is equivalent to a typical stall, behavioral differences will be small. The physiological assessment of the sow's welfare has contradictory data. Again, the picture is complicated by different group systems and different methodologies making direct comparisons difficult. With health, it would appear that the balance of data favors group housing. If aggression can be minimized, skin lesions should not be sustained through gestation. Lameness issues appear to be lower in groups, especially where sows are bedded on straw. Immune function and disease incidence also favors group housing, but hygiene management will be a crucial factor.

4.6 Housing and Productivity

It has recently been re-emphasized that measures of animal performance afford the most objective measure of an animal's welfare (Curtis, 2007). This is not the viewpoint of the majority of animal welfare scientists. Indeed, it has even been stated by the same author that welfare assessment 'must take into account all possible physiologic, immunologic, behavioral, anatomic, and agricultural-performance indicators of stress and distress' (Curtis, 1987). It has long been argued that examination of production measures alone is a dangerous practice, particularly when taking a herd, flock or system average (e.g. Fraser, 1993). Furthermore, we should remember that animal welfare is about the welfare of an individual animal, not a system (Fraser and Broom, 1990; Rollin, 2002). Animal agriculture over the last few decades has intensified and productivity has increased greatly. Does this mean that the welfare of the animals within our current systems has likewise increased greatly?

When it comes to gestation sow housing, the major measures of productivity include the percentage of returns to service, the litter size, the litter weight and the number of piglets reared per sow per year. However, these figures may be misleading unless they are combined with measures of morbidity, mortality and longevity as these will influence the biological fitness of a given population of sows. The sow's natural lifespan is probably about 12–15 years (Pond and Mersmann, 2001). In commercial production in the U.S., the sow's average lifespan would be about 3.5 parities (about 2 years old). As noted above, in the section on space restriction and health, sows will leave the herd for a variety of reasons, including death (mortality), reproductive failure, age, lameness etc. Looking at the sow replacement rate and causes of replacement, in conjunction with the measures of productivity, will be better than just looking at productivity alone. If a sow averages 11.0 piglets weaned per litter, but only lasts 2 parities, is her welfare is better than a sow that averages 10.0 piglets per litter, but lasts for 6 parities?

The problem in considering productivity in experiments comparing group and stall housing systems, is that invariably data is recorded over a limited number of parities and not 'lifetime reproductive performance'. There is therefore not enough long-term information on productivity available to make a balanced judgment as to the real advantages or disadvantages of one over the other. The other major limitation of experimental studies, certainly in places where confinement housing is normal, is that there may be a real lack of stockperson experience in managing the group housing system. Poor results in the group system may be more due to poor husbandry skills rather than poor system design. A large-scale Danish producer talking to the American Society of Animal Science meeting in 2003 commented that although they had been running group housing systems for around 10 years, and they were still learning how to manage them and improving their productivity, yet getting more than 26 piglets per sow per year (J.V. Hansen – pers. Comm.)

The available productivity data is also fairly ambiguous. Marchant (1994) compared the productivity of sows housed over 8 parities in stalls (12 sows), small groups of 5 with individual feeding stalls (15 sows) or a large group of 38 sows with ESF. The animals were assigned as gilts to one system and remained in that system for 8 parities, with no culling procedure applied except for medical reasons. Thus, sows with multiple returns to service or small litter size remained in the systems. The weaning to conception interval was shorter for stall-housed (12.8 days) and small group-housed sows (15.1 days) than sows in the ESF system (22.3 days) – but these high figures are indicative of the management decision not to cull those sows experiencing reproductive difficulties and are skewed by a few individuals who had multiple returns to service. The average litter size over eight parities was significantly greater for the stall-housed sows (11.7 piglets) compared to both the small group sows (10.6 piglets) and the ESF sows (10.7 piglets), but larger proportions of small group sows (100%) and ESF sows (95%) remained in their respective housing systems for all eight parities than did the stall-housed sows (67%). ESF (12.9%) and small group-housed sows (10.2%) also had improved pre-weaning mortality compared to the stall-housed sows (14.3%), with the result that numbers of piglets weaned did not differ between systems.

In shorter-term experimental studies, results are varied, but group housing systems show better productivity than confinement housing systems in more studies than *vice versa*. There are consistent results for litter size, with larger litters seen in an ESF system (Bates et al., 2003), a hoop structure (Lammers et al., 2007), small groups of 5 or 6 (Salak-Johnson et al., 2007; Cronin et al., 1996), the Hurnik-Morris system (Morris et al., 1998) and static groups of 11–31 sows (Seguin et al., 2006), when compared with stalls. Seguin et al. (2006) also noted heavier piglets from group-housed sows and Morris et al. (1998) showed increased lifetime production. There are also a number of studies that report no differences between group housing and individual stalls (Von Borell et al., 1992; Stamer and Ernst, 1992; Gjein and Larssen, 1995; Backus et al., 1997; Hoy and Rathel, 2002; Boyle et al., 2002; Hulbert and McGlone, 2006; Harris et al., 2006).

Conversely, a few studies have demonstrated higher productivity in stall-housed systems. Backus et al. (1991) found that sows in stalls had a lower replacement rate and higher numbers of piglets/sow/year than group-housed sows. Karlen et al. (2007) determined that sows in stalls had fewer returns and more piglets/100 mated sows than sows housed in a large group hoop-based system. Finally, McGlone et al. (1989) found that sows in stalls performed better than sows in a pasture-based system and an indoor group system. However, sows in tethers performed worse.

4.7 Conclusions

The welfare of sows during gestation remains a contentious issue in some parts of the world. The most important aspects to consider are firstly, that aggregating housing systems into simple categories such as groups and stalls is not beneficial in understanding the welfare of gestating sows, and secondly that no matter what the system, the management of that system will have the greatest impact on the welfare of the sows. Each specific system has to be looked at individually and different systems have different advantages and disadvantages in terms of animal welfare. The minimum recommendations for a gestation system should include the following key features:

- A design that minimizes aggression and competition for all individuals
- A design that allows sows to express normal patterns of behavior
- A design that protects from environmental extremes and potential sources of injuries, pain and disease
- A design that is safe for the stockperson and is relatively uncomplicated to manage successfully

Finally, there is a growing realization that ultimately the issue of sow welfare in confinement systems may be outside the welfare scientists' sphere of influence. It is an emotive subject for the general population and ethical and/or moral viewpoints can greatly affect the evaluation of different systems and the associated scientific data.

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Chapter 5
Welfare of Pigs in the Farrowing Environment

Anna K. Johnson and Jeremy N. Marchant-Forde

5.1 Introduction

In the U.S.A., housing for the lactating sow and her piglets can be divided into five main areas. Total confinement, defined as the farrowing crate, houses the highest number of sows at 83.4 ± 4.0%. Remaining operations house fewer sows with open buildings that have outside access at 12.4 ± 4.1%, open building with no outside access, 2.9 ± 0.5%, lot with hut or no building, 0.6 ± 0.2% and pasture with hut or no building the lowest at 0.7 ± 0.3% (NAHMS, 2000). In the U.K., it is estimated that around 70% of sows farrow in crates, 27% farrow outdoors in farrowing arks and only 3% farrow in loose-housed indoor systems (BPEX, 2004).

Farrowing crates have become widely accepted by the industry for numerous reasons: it has made sow management easier, it allows for a higher stocking density of sows/unit of land and it can help to reduce piglet mortality (Fraser and Broom, 1997). However, the farrowing crate has received criticism due to potential detrimental effects it may inflict on the welfare of the sow. The prevalence of decubital ulcers (Davies et al., 1996; Rountree et al., 1997), behaviours considered maladaptive (Cronin and Wiepkema, 1984; Rushen, 1984; Haskell and Hutson, 1996), and a limitation on allowing the sow complete postural adjustments are a few considerations. The development of an alternative, economical farrowing system that retains the advantages of the conventional farrowing crate could be beneficial to the industry (Collins, 1987).

Alternative outdoor swine operations for the gestating sow are increasing in popularity in some countries. In 1975, only 6% of the U.K.'s national herd was housed outdoors. This trend can be seen in other European countries, France now houses 10% of its herd outdoors, and Denmark and Sweden are conducting feasibility studies to determine if their cooler climates would permit

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successful swine performance (Huijben and van Wagenberg, 1999; Riart, 2000). However, for the sow and her litter during farrowing and lactation in the major pig producing countries of the European Union (EU), an estimated 95% of pork producers are using farrowing crates.

5.2 Overall Welfare Assessment for the Sow and Her Litter

The assessment of overall welfare within farrowing systems presents a unique challenge for pork producers, veterinarians and animal scientists. Welfare assessment within all other phases of swine production, involves pigs at a single stage of their productive life. Within the farrowing environment, the sow and her piglets are at two very different stages of their life and have different requirements in regards to their thermal, social and physical (the production system) environments. For example ambient temperature requirements differ for the sow and her litter and in addition change over time (Johnson, 2001). Temperature requirements for the lactating sow ranges from 15 to 26°C but individual newborn piglets prefer a higher temperature of 34°C (Curtis, 1995; FASS, 1999; Swine Care Handbook, 2003). At birth, piglets are poorly equipped to deal with the environment outside of the sow. They are especially susceptible to cold stress due to a lack of coat hair, a large surface area to body weight ratio, lack of suitable energy reserves and poor body thermostability at birth (English and Morrison, 1984). When the environmental temperature falls below 34°C the newborn piglet is subjected to cold stress and will begin to mobilize its glycogen reserves in the liver and skeletal muscles and nutrients supplied through the sows' colostrum to increase its heat production (Johnson, 2001). While undergoing cold stress, the piglet reduces its locomotive vigor, it can soon become weak through starvation and will be less able to avoid the restless movements of the sow (Aumaitre and Le Dividich, 1984; Arey, 1992). Litters can and will huddle and this can effectively increase the thermal insulation and conduction (Mount, 1963; Bel Isle, 1978). Once the piglet has huddled and raised its hair, it is up to the caretaker to provide warm, dry bedding or even additional heat. Therefore, a system that may be ideal for the welfare needs and requirements of the sow may be far from optimal for her piglets and *vice versa*.

In addition, the skills, competency, experience and dedication of the caretaker working daily with the sow and her piglets (McGlone and Johnson, 2003) must be factored in. Designing a welfare-friendly farrowing system with disregard for the person who has to care for the pigs within that system, can result in the pigs' welfare being good in theory but bad in practice.

In order for objective and science-based assessments to be conducted on swine farms we must have an appreciation of the sow's and her piglets' welfare during farrowing and lactation. This chapter will discuss the natural behaviour of the sow and her piglets around farrowing. Next a variety of different commercially-available farrowing systems will be addressed. Finally, each farrowing system will have their opportunities and challenges discussed in relation to sow and piglet welfare.

5.3 Natural Farrowing Behaviour

To determine the best practices for providing good sow and litter welfare in the farrowing accommodation, a good starting point is to re-examine the behavioural patterns that have been documented around farrowing and during lactation, in a natural or semi-natural environment. As discussed in Chapter 2, there is a complex series of behaviours carried, with sows and piglets undergoing various phases of isolation and community integration and living. Jensen (1988) has proposed that maternal behaviour can be divided into six distinct parts: (i) isolation and nest site seeking, (ii) nest building, (iii) farrowing, (iv) nest occupation, (v) social integration, and (vi) weaning.

5.3.1 Isolation and Nest-Site Seeking

Outdoor wild, feral and domestic sows all proceed through three phases 48–24 h prior to the birth of the first piglet. The sow will leave the social group and seek isolation. The importance of this isolation may be gauged by the distances that sows are willing to walk, reported to be between 2.5 and 6.5 km (Jensen, 1986, Jensen et al., 1987). Many potential nesting sites are investigated with one finally being chosen. Jensen (1986) noted that the sites were often situated away from the usual "home range" of the sow, and were often chosen to provide a degree of both vertical and horizontal protection and some form of a slope (Jensen, 1986; 1989).

5.3.2 Nest Building

Next pre-farrowing nest building behaviour begins, which involves an organized sequence of activities. Jensen (1986) concluded that feral sows, when choosing a suitable nesting site, preferred: (1) to use a variety of substrates for nest construction, (2) that the nest walls were structurally sound with well-formed sides, and (3) for the ground to slope. The chosen site is hollowed out to a depth of 5–10 cm by rooting. Grasses, roots and leaves are collected and are used to line the nest. Larger branches are arranged over the nest and grass and other fine materials form a roof over the branches. The effort that can be made to construct the nest can perhaps be illustrated by the fact that a single nest of a free-ranging sow in Brazil contained 255 kg of plant material (Zanella and Zanella, 1993).

5.3.3 Farrowing

Farrowing often begins a few hours after the end of nest-building. The sow is unusually passive for an ungulate, and once parturition is underway she carries out very few postural changes. Sows often stand, turn and sniff the first piglets born (Jensen, 1986), but this behaviour declines as more piglets are farrowed. Sows do not get up to help the neonates from their foetal membranes and the umbilical cord is normally torn when the piglet moves around to the udder. Jensen (1988) proposes that this passivity may be due to the fact that the sow gives birth to a large number of precocial young, and that to engage in maternal behaviour individually as the piglets are born, may place them at unnecessary risk of accidental crushing. After farrowing is complete, sows are inactive for 90–95% of the time during the first 48 h. This inactivity may be a behavioural adaptation by the sow to reduce crushing and to allow the establishment of a teat order.

5.3.4 Nest Occupation

Nest occupation occurs over the 7–10 days after farrowing is complete. Maternal behaviour has a very complex organisation mainly revolving around the suckling event. Nursing can be initiated either by the sow lying on her side and presenting her teats or by the piglets squeaking at her head and (or) massaging the teat area. Eventually the whole litter vigorously butts and jostles for position at the mammary glands, with or without attaching themselves to the nipples (Johnson, 2001). Often at this time piglets vocalize intensely and continually (Appleby et al., 1999). Götz (1991) reported that sows spent most of their time in farrowing crates in lateral recumbency (62 to 85%), but this decreased over the lactation period. Ellendorff and Poulain (1982) reported that during nursing the sow's grunts became rhythmical, the frequency of grunts was low at first becoming rapid (3.8 ± 0.2 s). While rapid grunting was still in progress, the whole litter became quiet, with each piglet suckling a nipple. This period lasted between 7 and 38 s (average 15 s) and was followed by another phase of active stimulation with predominant piglet behaviours involving butting and nosing at the udder. This later period ranged from less than 1 min up to several minutes, until piglets either detached themselves from the teat, fell asleep, engaged in other activities, or the sow ended the nursing period by standing up or rolling onto her sternum to hide her teats (Johnson, 2001).

5.3.5 Social Integration

In a free-range situation, the sow and piglets stay away from the rest of the herd for at least the first week postpartum (Jensen, 1988). During the first one or two days, the sow forages very little and stays in close proximity to the nest site (Johnson et al., 2001b). Later, she leaves the nest for longer periods and forages further away, and eventually rejoins the herd for morning feeding, on average seven days after parturition. The litter remains using the nest for a further two to three days, until the nest is eventually abandoned. Thereafter, the litter is gradually introduced into the herd. The behaviour of the sow and litter during this stage of nest occupation probably establishes the sow-offspring recognition that is important once social integration has occurred (Jensen and Redbo, 1987). Social integration for the sow and her litter occurs gradually over the next few days. Free-range sows begin integrating their litter into the herd towards the end of the second week (Jensen, 1988). This allows time for family bonding to become complete before introduction to other litters. This introduction results in a shift of social interactions away from litter-mates towards other piglets of a similar age (Petersen et al., 1989). The frequency of these interactions gradually decreases to a steady low level after about eight weeks. These results have important consequences for the design of group farrowing accommodation. It would seem to be appropriate to allow mixing of litters prior to weaning, but not before about 14 days postpartum (Rudd, 1995; North and Stewart, 2000).

5.3.6 Weaning

Weaning is likewise a gradual event. In effect, natural weaning starts early on in lactation. The frequency of suckling declines gradually from the first week, and the number of suckling events terminated by the sow increases perhaps indicating that the sows become less inclined to nurse (Jensen et al., 1993). Piglets begin to consume solid food from around 4 weeks postpartum and by 8 weeks, solid food constitutes a large part of the piglets' diet (Jensen, 1995). The number of piglets missing from suckling also gradually increases and weaning is completed anywhere between 8 weeks (Newberry and Wood-Gush, 1985) and 19 weeks postpartum (Jensen and Stangel, 1992), and there can be quite large variation in weaning age occurring within a given litter (Jensen, 1995).

5.4 Current Commercial Farrowing Systems

Seen in the context of natural behaviour, it is hardly surprising therefore, that it is essentially impossible to design a farrowing system for use in commercial production that does not come into conflict with one or more aspects of natural behaviour. Every farrowing system in commercial use or in experimental development will contain a greater or lesser degree of compromise. There are a wide variety of options available for housing the farrowing and lactating sow and her litter, ranging from housing in conventional crates, through to housing in outdoor paddocks. The sow can be kept individually housed throughout, individually housed in early lactation and grouped in late lactation or kept in a group throughout (Fig. 5.1). Likewise, superimposed on the choice for the sow, there are options to keep litters segregated throughout lactation or segregated for the early part of lactation only and able to mix later in lactation. Allowing piglets to mix from birth does not work well for reasons that will be explored in the following sections. In terms of grouping, this can occur as part of a single housing system that covers the whole of the farrowing and lactation periods, such as various, mostly experimental, communal farrowing systems (e.g. van Putten and Buré, 1997; Marchant et al., 2001) and commercial systems such as group outdoor paddocks or the Swedish Thorstensson system (Bradshaw and Broom, 1999a). Alternatively, farrowing and lactation systems can be separated, with sows farrowing in one location and then moving later in lactation into a multisuckling system, such as seen with the Swedish Ljungström system.

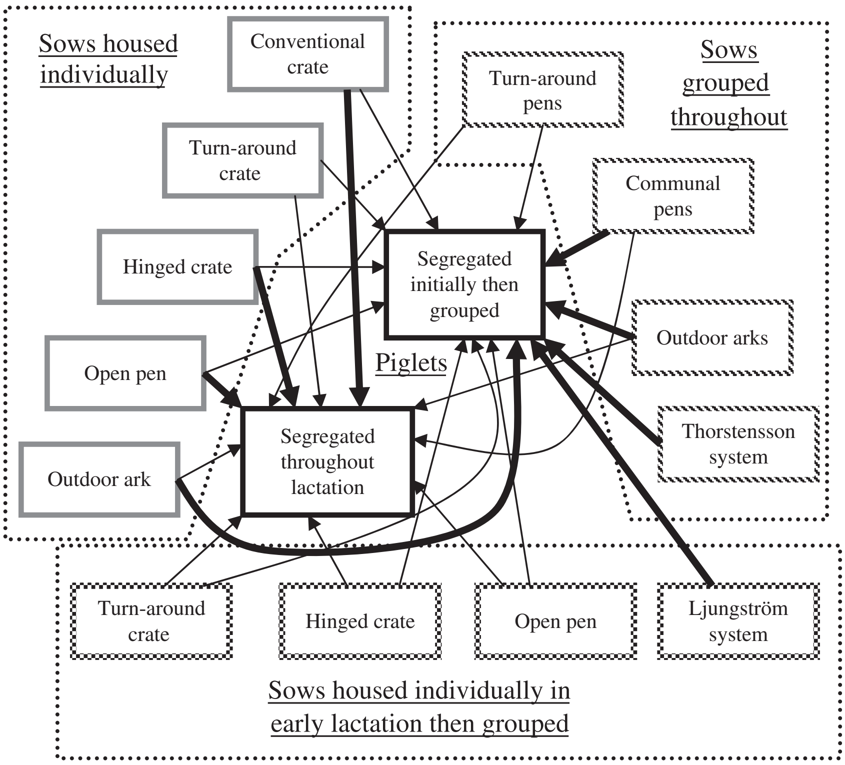

Fig. 5.1 Diagrammatic representation of possible combinations of farrowing and lactation systems. Most common combinations joined by thick arrows

5.4.1 Standard Farrowing Crates

The standard farrowing crate is usually a tubular metal construction fixed within a pen of about 2.2 m x 1.5 m, with recommended dimensions of around 2.2 m long, 0.6 m wide and 1.0 m high – Fig. 5.2. According to Whittemore (1994) producers are still using crates that are smaller than this, irrespective of the fact that sow size continues to increase. There are a wide variety of designs, but most have common features in that they have a built-in feed trough with a water supply for the sow and her piglets at the front, metalwork running horizontally the whole length of the crate with some bars running across the width over the front two-thirds to prevent the sow from escaping by climbing upwards. The rear usually has a removable frame, the position of which is adjustable depending on the length of the sow. The flooring substrate may be solid concrete, with some slatting at the rear of the crate, or fully-slatted. Solid flooring can be augmented with bedding, such as straw, sawdust or shredded paper. Slatted floors greatly reduce the labor required to remove manure and provide drainage for urine and soiled drinking water.

Over the years a variety of floor types have become available to the producer, bare woven wire, metal, plastic coated metal and plastic (Stanislaw and Muehling, 2002). There is usually a creep area (circa 0.5 m^2) set to the side or front of the crate which provides a warm lying area for the litter, with the heat source either from a heated mat or an overhead heat lamp. Crates are usually placed in rows within a room; the number of crates per room is dependent on the farm size. Good disease management practice dictates that all sows should

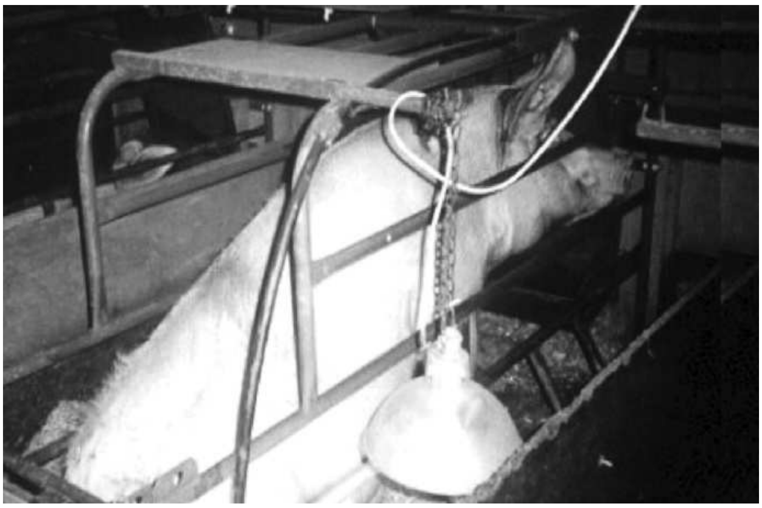

Fig. 5.2 Conventional tubular metal farrowing crate, with forward creep area and supplementary piglet heating lamp
(Photo source: JNMF)

enter and leave the farrowing accommodation at the same time (all in – all out) and thus the number of farrowing places in a room should be related to the number of sows that are due to farrow in a given cycle. The partitions between the pens are usually about 0.5 m high, i.e. high enough to prevent piglets escaping but low enough to allow a standing sow to see her neighbour.

5.4.2 *"Turn-Around" Crates*

Designs of note in this category include ellipsoid farrowing crates (Lou and Hurnik, 1994 – Fig. 5.3) and modified triangular farrowing crates (McGlone and Blecha, 1987; Heckt et al., 1988). These systems also attempt to take up an amount of overall space only slightly larger than that used by a conventional crate with pen; the above designs utilize an overall pen size of 2.0 m x 1.75 m (ellipsoid) and 2.6 m x 1.5 m (triangular). Turn-around systems are similar to conventional crates, in that they are made out of tubular metal and the system incorporates a piglet creep area. The systems would usually be installed on a fully-slatted floor as maintaining hygiene would be difficult if used on a solid

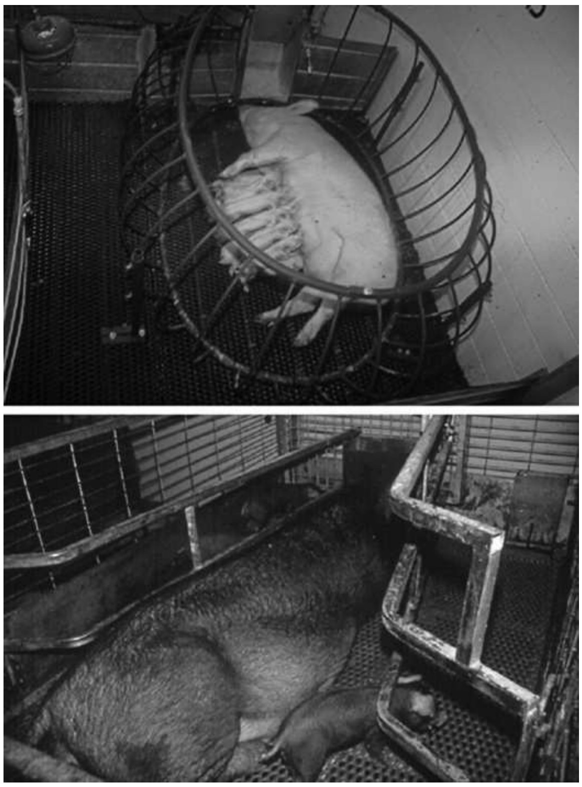

Fig. 5.3 Ellipsoid and "turn-around" farrowing crates (Photo source: J.J. McGlone)

floor with bedding, due to accessibility problems for cleaning given that the sow can potentially eliminate at both ends of the crate.

5.4.3 Hinged Crates

Another design that has become increasingly popular over the last few years within Europe is a system that is essentially a compromise between a conventional crate and an open pen. As much of the piglet mortality due to crushing occurs in the first few days after parturition, systems have been developed in which the sow is crated around farrowing, but the crate can then be hinged open, a common practice is to open this at 5–7 days after farrowing, to allow the sow space to turn around for the remainder of lactation – Fig. 5.4 (MLC, 2004). However, the caretaker still has the ability to restrain the sow if necessary for his or her own safety when carrying out routine husbandry tasks. As with turn-around crates, these systems also try to take up space similar to a conventional crate with pen. The systems incorporate a piglet creep area and can be installed with solid floors and bedding or on a fully-slatted floor (MLC, 2004).

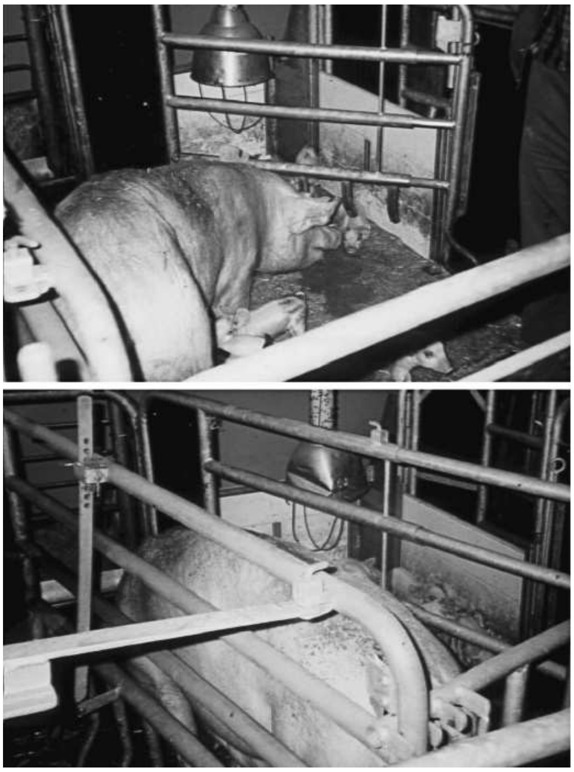

Fig. 5.4 Tubular metal hinged farrowing crate, showing crate in open and closed positions (Photo source: JNMF)

5.4.4 Open Pens

Before the development of farrowing crates, indoor-housed sows gave birth in simple open pens, that were basically rectangular in shape, straw-bedded and which may have incorporated a heated creep area in one corner. Over recent years, the open pen has been subject to a great deal of research in the search for alternatives to close confinement. As live born piglet mortality has been an acknowledged problem in open farrowing systems, the major emphasis has been towards modifications that afford the piglet a greater degree of protection.

Many open pens now contain rails that run around the pen perimeter, usually about 15–20 cm up from the floor and out from the wall (McGlone and Blecha, 1987; Blackshaw et al., 1994), giving the piglets an escape area should they become trapped between the sow and the floor when she uses the wall to lie down (Fig. 5.5). Other designs incorporate sloping walls which again have in-built escape areas at the bottom (e.g. Cronin et al., 1996; Marchant-Forde, 2002 – Fig. 5.5). Heated creep areas are commonplace, either in one corner, along one of the pen short sides or occasionally centrally placed in pens that are divided into nesting and dunging areas. Many systems are still straw-based, as using bedding

Fig. 5.5 Open pens showing rail and sloping wall protection system (Photo source: JNMF)

tends to fit with the ethos of alternative farrowing pens, but open pens have been developed with fully- or part-slatted floors (Heckt et al., 1988).

5.4.5 *Outdoor Arks*

Several farrowing hut designs are available to the swine producer: plywood and plastic A-frames, steel English style arks and plastic and plywood models. Each hut differs in shape, for example the A frame is taller and shaped in a flattened triangle. The 'A' frame arks are usually constructed of plywood or tin over a wooden frame, with sloping sides and a flat roof (Fig. 5.6). Dimensions are about

Fig. 5.6 Outdoor farrowing arks, showing 'A'-frame, semicircular tin and insulated plastic designs

2.1 m wide × 2.1 m long × 1.2 m high, in comparison to the English style hut which is lower and forms an arc (Penner et al., 1996; Honeyman et al., 1998a). As the name suggests, the semicircular ark is essentially a near half-cylinder, usually of corrugated tin over a wooden frame, with the ends filled in (apart from the entrance) by plywood (Fig. 5.6). Dimensions are usually about 2.5 m wide × 1.7 m long × 1.1 m high. For all types, some versions have a solid plywood floor, others have no floor. In both cases, it is usual to use fairly large amounts of straw as bedding.

There is no heated creep area and no water supply for either sow or her litter. Some arks do incorporate rails to help prevent piglet crushing and some may have double skins with insulation, in order to try to reduce extremes of temperature, although research is lacking on the benefits of insulation (Edwards and Furniss, 1988; Johnson and McGlone, 2003). Some producers have each farrowing ark in its own paddock, some put perhaps up to eight arks per paddock, depending on the paddock size.

Fenders are fixed onto the front of farrowing arks, and (1) serve to keep the piglets close to the farrowing ark, (2) keep the straw in the huts for longer, and (3) allow unrestricted movement of the sow (Honeyman et al., 1998b; Johnson and McGlone, 2003). Two fender designs that are currently used commercially are a low, wooden fender that fixes underneath the front of the farrowing hut doorway and the second is a taller, metal structure. The taller metal fenders can have two types of front, wooden boards or a plastic polyvinyl chloride roller. Fender design may influence the length of time that piglets are confined to the hut and the work efficiency for the stockperson carrying out routine tasks (i.e., litter processing; Johnson and McGlone, 2003).

5.4.6 Communal Pens

Communal indoor systems have undergone a fair amount of study over recent years (Stolba and Wood-Gush, 1984; Kerr et al., 1988; Arey and Sancha, 1996; Pedersen et al., 1998; Weary et al., 1999a; Marchant et al., 2000a; Marchant et al.,2001). Although the notion of keeping farrowing sows in a group throughout farrowing and lactation does not appear to relate to what we know of the sow's natural behaviour, there are reasons for supposing communal farrowing systems could work commercially, by reducing the amount of mixing of sows after segregation in conventional farrowing systems and increasing the social skills of the piglets. In terms of design, many of the pens themselves incorporate the types of features seen in the development of single open pens, but with addition of barriers to contain piglets within the pen, yet allow the sow to come and go from communal areas. Figure 5.7 shows three experimental communal pen systems developed in the U.K. (top), Denmark (middle) and The Netherlands (bottom). There are some common features, in

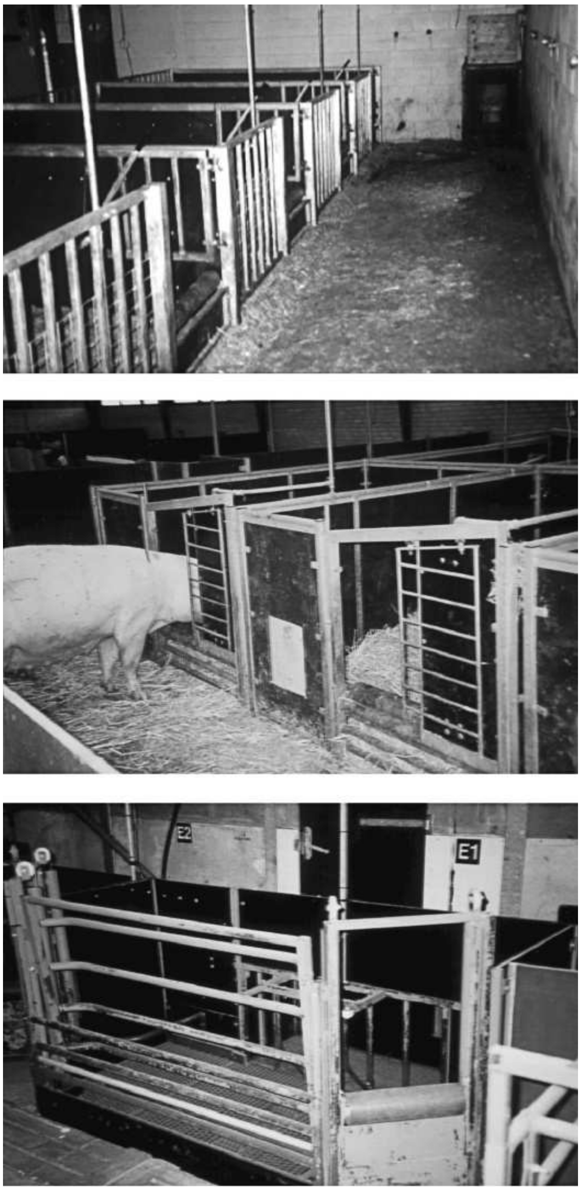

Fig. 5.7 Experimental communal pen farrowing systems from U.K., Denmark and The Netherlands (Photo source: JNMF)

terms of piglet-retaining barriers but also differences in terms of bedding, creep areas and piglet protection designs. Group sizes are usually between 4 and 8 sows and the system usually combines individual farrowing areas with communal lying, feeding and dunging areas for the sow, and later, their litters.

5.4.7 Swedish Style Multisuckling Pens

There are two main types of multi-suckling management systems, which are in commercial use in Scandinavia (Algers, 1991) but have also been tried as a specialist system in other countries including the U.K. (Bradshaw and Broom, 1999a) and the U.S.A. (Larson and Honeyman, 2000; Honeyman and Kent, 2001). The first type is the Ljungström system, which involves farrowing sows in individual open pens, and keeping sows and litters individually until around 14–21 days of age (Ebner, 1993). Then several sows, usually 6–8, and their litters are moved together into a large straw-bedded multi-suckling pen (Fig. 5.8) and kept here up to weaning at 5–6 weeks post-farrowing, when the sows are then moved out to the service area, leaving the piglets behind as a group usually until they reach a weight of 25+ kg. The second type of system is called the Thorstensson system. This system also utilizes a large multi-suckling room, but in this instance, the sows are already grouped before farrowing (Ebner, 1993). Temporary farrowing pens are placed down each long side of the room on the day the sows enter the system. These pens allow the sow to come and go, but a barrier prevents the piglets from leaving the pen before they are about 7–10 days old.

Before farrowing, the only straw in the system is within the pens, in order to encourage the sows to farrow inside, but once all sows have farrowed straw is placed throughout the room. The pens contain no heated creep area and no protection rails, placing the emphasis for piglet survival largely on the maternal qualities of the sow. Once piglet escape has become commonplace, all of the partitions are removed and the system becomes a single large multi-suckling

Fig. 5.8 Ljungström multisuckling pen for 8 sows and litters (Photo source: JNMF)

pen. As with the Ljungström system, at weaning, only the sows are removed and the piglets remain in place for a few more weeks.

5.4.8 Economic Considerations of Farrowing Systems

A major factor to be considered in the choice or conversion of farrowing systems is the effects on cost of production. Outdoor housing is well-suited to the vagaries of the economics of pig production, which has notorious profit and loss cycles, because it requires minimal capital investment. FAWC (1996) estimated that the capital cost for outdoor production, including gestation and farrowing, was between £ 250 and £ 350 per sow place, compared with an estimated £ 1500 per sow place for conventional indoor systems. However, these figures do not include the capital cost of the land and more extensive systems usually have increased variable costs, such as higher feed costs and higher bedding costs (Bornett et al., 2003).

Alternative indoor systems also require substantial capital investment and system elements that mean fewer pigs in the same given space, use of bedding, changes in labor requirements etc., will have additional ongoing costs when compared with standard crates in a non-bedded system. For example, the amount of extra space needed for an alternative system may be as little as 9% or as much as 147% (Table 5.1).

Although there is very little fully-costed economic evidence of welfare systems, there have been attempts made to model the changes in cost of production (e.g. SVC, 1997; den Ouden et al., 1997; Krieter, 2002) and these do yield some potentially useful information.

The SVC (1997) report carried out a modeling exercise on the ‘typical’ European farm of 165 sows housed intensively. In the basic farrowing model, the sows are housed in conventional farrowing crates on slats and the piglets are

Table 5.1 Size of alternative farrowing systems relative to typical commercial farrowing crate of 2.2 × 1.5 m

Alternative	Size (Metres)	Increase in floor space needed (%)	Reference
Turn-around	1.5 × 2.6	21	McGlone and Blecha (1987)
Sloped pen	2.1 × 2.1	40	McGlone and Morrow-Tesch (1990)
Family pen	1.7 × 2.3 + 0.4 × 1.0	30	Arey and Sancha (1996)
Werribee pen	2.3 × 3.5	147	Cronin et al. (2000)
Ellipsoid crate	2.0 × 1.8	9	Lou and Hurnik (1994)
Outdoor english-style hut	2.8 × 1.7	41	Johnson et al. (2001a)
Average	–	48	–

(source: J.J. McGlone, 2006)

contained within the pen. In the increased welfare model, the crates are removed and the sow and piglets are loose-housed on slats. The major cost component is pre-weaning piglet mortality, which is set in the basic situation as 13.2%. The model was then also run with the alternative system at 13.2%, and at 14.2%, 15.2% and 16.2%. Lastly, the 16.2% mortality model also had a straw component added. In terms of farmer income, just moving to the alternative system reduced income by 9% over the basic system. Then, if piglet mortality increased (as most studies on loose-housed sows at farrowing show) there would be an additional 12% reduction for every 1% increase in mortality over 13.2%. Lastly, if straw was added as a cost to the worst-case scenario 16.2% mortality, the total reduction in income was 60%, made up of 36% due to 3% increase in mortality, 9% due to housing cost increase for loose housing and 15% due to extra labor and housing cost increase due to straw.

Krieter (2002) compared costs of production using fully-slatted systems, including crates for farrowing but groups for gestation, with straw-based systems, including groups for both farrowing and lactation. His model calculated that moving to the 'high welfare' system would increase costs by 24.4%. Thirty-nine percent of this increase was attributed to the change in lactation system – i.e. an overall 9.5% increase in end production cost was directly as a result of moving from slatted crates to strawed groups during farrowing/lactation.

Another study has similarly examined cost of moving from intensive system to a more extensive system, but has not teased apart the different stages of the sow cycle into gestation system and farrowing system. However, these authors still show similar economic trends. Den Ouden et al., (1997) used a different method by which they calculated the change in cost per feeder pig produced for the addition of 13 different factors into basic crate farrowing accommodation with slatted floors. At this basic level, total chain cost of production per pig from farrowing to slaughter was 357 Dutch Gilders (Dfl). If weaning age was increased to 6 weeks from 4 weeks, this added 8.76 Dfl or 2.5% to cost per pig. Adding straw to the sow herd at the rates of 1.4 or 7 kg per sow per week, added 3.20 (0.9%) and 5.89 (1.7%) Dfl. respectively

So, there is strong evidence to suggest that any move from a basic set-up of a farrowing crate on a slatted floor will incur increased cost, dependent on the extent to which change is introduced.

5.5 Challenges with Different Farrowing Systems for the Sow and Her Litter

As previously stated, the farrowing system presents unique challenges and opportunities due to the presence of pigs with two very different sets of requirements, namely the sow and her litter. The wide variety of system types and their various combinations also means that it can be quite difficult to generalize the challenges and opportunities across systems.

5.5.1 Challenges with Isolation and Nest-Site Seeking

We know that under natural conditions, the sow will separate herself from the herd and seek an 'ideal' nest site. Under commercial conditions, we are housing the sow, with other pre-farrowing sows, in a given space. The space may range in size from a farrowing crate to an outdoor paddock, but nonetheless, the space from the sow's point of view, is restricted. Thus, we can state that:

- Most commercial and experimental farrowing systems do not allow the sow to seek and achieve isolation to the degree seen in semi-natural enclosures

Outdoor paddocks can at least afford the sow a degree of isolation, with each farrowing space (ark) being self-contained and designed for a single sow only. If the outdoor farrowing system utilizes a single paddock per ark, then the sow can fully isolate herself. Indoors, the degree of isolation varies very little. Some of the communal-type systems do offer both individual farrowing 'sites' coupled with group-living areas, but the sow cannot achieve total isolation from her group-mates. Individual open pens and the various crate designs give sows isolation from physical contact, but multiple sows will be housed within the room, so that there will be no auditory, visual or olfactory isolation. What effect this lack of isolation has on the welfare of the pre-partal sow has not yet been experimentally determined. There are data that show that as parturition approaches, aggression between pre-farrowing, pair-housed sows increases (Arey et al., 1992), even when the sows are well-acquainted with each other. The hypothesis being that aggression may increase owing to frustration caused by the inability to attain isolation (Arey et al., 1992).

However, it is not yet possible to tease apart the effects of lack of isolation from the effects of lack of nest-site choice and seeking behaviour restriction. This is because:

- Most commercial and experimental farrowing systems do not offer the sow multiple nest sites spread over a large area and sows are highly motivated to cover large distances seeking a nest site during this stage of the farrowing process.

Research on free-ranging sows suggests that they may travel between 2.5 and 6.5 km (Jensen, 1986; Jensen et al., 1987). These types of distances are really only possible in outdoor production systems. In group paddocks, there will also be one ark per sow and thus, the sows within the group that farrow early relative to their group-mates, will also have a degree of 'nest-site' choice. Although all 'nest-sites' (arks) will essentially have the same physical characteristics, placement relative to resources, such as feeding site or wallow, may mean some nest-sites are more preferable than others. Sows housed in indoor group farrowing systems will have a little space in which to travel, and again, the early-farrowing sow will likely have some nest-site choice. Sows farrowing in indoor individual farrowing systems, such as open pens and crates, will have very little space and little or no choice in farrowing site. However, even sows housed individually in a

6.5×7.0 m pen have been shown to cover over 350 to 500 m per day during the nest-site selection period (Haskell and Hutson, 1996). Again, the degree to which these restrictions impact the welfare of the sow is not known.

Another challenge with providing an element of nest-site choice is that:

- Sows may select a nest-site that is inappropriate – i.e. within the communal or dunging area

This is particularly a problem in group farrowing systems, where sows may choose to farrow in parts of the system designed for other uses such as the communal lying area or feed area, or they may 'double-up', i.e. two sows farrow in the same farrowing space (Rudd, 1995). This then forces the stockperson to move the sow back into the designed farrowing area even though the sow has clearly shown preference to nest-build elsewhere. Open farrowing systems may be designed incorporating the key-features of nest-site choice, such as a degree of visual protection, comfortable flooring substrate and ready availability of nesting materials, but sows often choose not to farrow in the designated place. When housed singly, they may take bedding from the 'nest' to build their own nest elsewhere (Haskell and Hutson, 1996) or when housed singly, they will also do likewise and/or choose to farrow with other sows in the same nest (Arey et al., 1992). Farrowing outside of the designated area can cause subsequent problems for the welfare of the litter, as the piglets may now be away from supplementary heat and away from in-built piglet protection elements. Moving the sow when she has clearly chosen a nest-site is likely to have an impact on her physiological and psychological welfare, but again, this has not been quantified.

5.5.2 Challenges with Nest-Building

The sow is highly motivated to build a nest. The initiation of nest-building is mainly hormonally controlled (Widowski and Curtis, 1989; Boulton et al., 1997a,b; Gilbert et al., 2001) whereas its performance and completion seem to be regulated both hormonally and via environmental feed-back (Jensen, 1988; Jensen, 1993: Arey et al., 1991; Damm et al., 2000). The extent to which a sow is able to nest-build will obviously be greatly dependent on the housing system in which she is kept. The major elements are freedom of movement and presence of appropriate nesting substrate. Thus we have a challenge that:

- Close confinement and bedding-free systems greatly restrict nesting behaviour, which may result in increased stress and altered behaviour during the nesting phase

We know that ordinarily a great deal of behavioural effort goes into building the nest. If the sow is unable to move during this phase and does not have access to nesting material, which might be as basic as straw or shavings, then her behaviour is altered. Nesting is more elaborate in open pens than in crates

(Thodberg et al., 2002; Damm et al., 2003a) and less fragmented (Damm et al., 2003a). Without access to a nesting substrate, sows usually direct rooting and pawing behaviour at pen fittings and flooring (Hartsock and Barczewski, 1997) and crated sows in particular, show increased posture-changing and more sitting (Jarvis et al., 2001). The peak in substrate-directed behaviour is closer to the birth of the first piglet in crated sows with no access to straw, then in penned sows with straw (Jarvis et al., 2001) and plasma cortisol is also higher for these sows (Jarvis et al., 2001). Jarvis et al. (2002) then carried out a 2 $\times$ 2 factorial experiment looking at straw/no straw and crate/pen and found that cortisol and adrenocorticotrophic hormone (ACTH) levels were higher in all crated sows, regardless of presence of straw. Thus, behavioural restriction rather than lack of access to nesting substrate activated the hypothalamic-pituitary-adrenal (HPA) axis. The difference in plasma cortisol is greater in gilts than in sows with prior experience (Jarvis et al., 1997), indicating at least some degree of adaptation to stress over this period.

Without bedding, sow behaviour is altered. However, does a paucity of nesting material or the inability of the sow to build a nest to her satisfaction, have a knock-on effect on subsequent behavioural elements of farrowing?

- The sow may actually need to build a quality nest in order to switch-off the sequence and prepare for the next phases. Does an inadequate nest building phase result in aberrant farrowing and post-farrowing behaviour?

There has been relatively little work carried out in this specific area, but there have been some studies that have attempted to relate disturbed or inadequate nesting to subsequent events. For example, Damm et al., (2000) investigated differences between loose-housed sows with access to straw and branches and loose-housed sows with access to straw only. The straw only sows continued nest-building much closer to the birth of the first piglet and then 71% of these sows carried out further nest-building after parturition was underway, compared to 38% of the straw + branches group. If nests are physically removed, then this increases cortisol response and heart rate in sows as parturition approaches, relative to sows with undisturbed nests (Damm et al., 2003b) and it also makes the sows more reactive after farrowing, when calm behaviour is advantageous, and it takes their piglets longer to access the udder and suckle after being born, which may affect viability (Pedersen et al., 2003).

5.5.3 Challenges with Farrowing

Once parturition is underway, the sow is usually fairly passive. Close confinement and/or lack of bedding *per se* during this particular phase, may not be a welfare concern for the sow, as she may well not change posture during the whole of this phase, and there is no hormonal evidence to suggest that confinement during the parturition process is stressful (Lawrence et al., 1997). However, if she does stand up during farrowing, the fact that she is confined may theoretically increase the likelihood that she could crush one or more of her piglets. As each piglet is born, it stays in very close proximity to the sow and makes its way round to the udder to begin sucking. As soon as the sow stands, she needs to locate her piglets and make sure they are not in the danger area when she subsequently lies back down. This is much more difficult for her to achieve in a crate than in an open system, and thus the piglets are potentially at greater risk of being overlain if this aspect of sow maternal behaviour is important for piglet survival. There is also conflicting evidence that parturition is slowed and stillbirths are increased in confinement farrowing systems. Conversely, however, if the sow is aggressive either towards her litter or towards a caretaker confinement may be advantageous (Marchant-Forde, 2002). We therefore have potentially conflicting challenges at the time of farrowing:

- Confinement during parturition places piglets at greater risk of stillbirth and may increase crushing risk

A number of studies have demonstrated that as the mean interbirth interval between piglets increases, or the variation in interbirth interval increases, then the incidence of stillbirths increases (Zaleski and Hacker, 1993: van Dijk et al., 2005; Pedersen et al., 2006). Therefore, it follows that any environmental effect that may influence interbirth interval may have an effect on stillbirth incidence. There has long been a hypothesis that the length of parturition is related to the amount of activity and/or exercise that the sow is able to carry out immediately prior to parturition (Bäckström, 1973; Hansen and Vestergaard, 1984). However, the relationship is unclear. Wulbers-Minderman et al. (2002) reported that duration of parturition is shorter for sows housed in outdoor huts (157 min) compared with sows housed in indoor pens (234 min). Biensen et al. (1996) and Thodberg et al. (2002) have both reported shorter interbirth intervals for sows farrowing in indoor pens (13 and 19 min respectively) compared with sows farrowing in indoor crates (18 and 30 min respectively). Cronin et al. (1993) studied sows only in crates, but gave some access to sawdust whereas others had no access to a bedding substrate. They found that parturition was quicker for those sows with sawdust (159 min) compared to those without (201 min). Other work in this area has found no effect of increased space, albeit increased space in widened crates (Fraser et al., 1997) and a contrary effect of bedding, with the provision of straw actually increasing duration of parturition of sows housed both in crates and open pens (Jarvis et al., 2004). The effects of confinement on stillbirth incidence are not clear-cut.

In terms of posture changing, we have good evidence that the risk of crushing is much greater for piglets if the sow changes posture during parturition itself (Weary et al., 1996; Marchant et al., 2001; Andersen et al., 2005) but not many studies have investigated the effect of environment on posture-changing during parturition. Sows in conventional crates have been shown to carry out more postural changes during parturition compared with open penned sows (Damm et al., 2002a) and at least during the early part of parturition compared with sows housed in wider crates (Fraser et al., 1997). Boyle et al. (2002) examined the effects of gestation housing system on responses to farrowing in crates and found that sows that had gestated in loose-housing carried out more posture changes during parturition than sows that had gestated in confinement. When farrowing in confinement, bedding can effect postural changes, with sawdust decreasing posture-changing incidence and the number of piglets crushed (Cronin et al., 1993). As detailed in the previous sub-section, if nest-building is not completed to the sow's satisfaction prior to parturition starting, she may continue to carry out nesting behaviour with piglets present (Damm et al., 2000). Where nesting occurred during parturition, sows carried out an average of 16 posture changes, compared to an average of only 5 posture changes carried out by non-nesting sows (Damm et al., 2000)

- Loose housing during parturition places piglets at greater risk of death due to savaging and makes intervention more difficult.

Savaging is much more common in first time mothers than in experienced sows (English et al., 1977; Harris et al., 2003) but the true incidence of potentially infanticidal behaviour is probably under-estimated due to lack of data. On commercial farms and many experimental studies, savaging is used to describe the interactions between dam and piglet that result in death of the piglet, rather than offspring-directed aggression that does not result in mortality. The percentage of gilts that savage piglets to death has been quoted in various studies as 3.4% (Harris et al., 2003), 8.1% (Marchant-Forde, 2002) and 18.7% (Cronin and Smith, 1992). These differences can probably be explained in part by the fact that the Harris et al. (2003) study is reporting a large farmer-entered database using crates, whereas the other two studies are reporting relatively small scale experimental studies using a mixture of open pens and crates. In terms of the percentage of gilts that show savaging behaviour, including non-fatal savaging, figures are significantly higher, with reported incidences ranging from 21.1% (Ahlstrom et al., 2002), through 42.1% (McLean et al., 1998) to 88.9% (English et al., 1977).

Our understanding of the causes of this offspring-directed aggression is still rather vague, and the incidence relative to confinement or loose housing is equivocal. There is some evidence that gilts that are likely to savage piglets can be identified before savaging occurs. Behavioural testing and observations during gestation suggests that savaging gilts are more likely to exhibit 'shy' behaviour towards humans (Marchant-Forde, 2002) and show low aggression towards pen-mates (McLean et al., 1998). During the expulsive phase of farrowing, savaging gilts have been shown to be more restless and more reactive towards their piglets (Ahlstrom et al., 2002).

If we had to predict whether savaging would be greater in confined or open systems, we could in fact argue in both directions. In an open system, the gilt can get at the piglets, no matter where the piglets go in the pen. Therefore, a gilt wishing to attack her litter, could readily do so, but the ability to move may enable her to investigate and familiarize herself with her piglets before resorting to aggression. In confinement, the gilt can only attack piglets if they venture near her head, but maybe the inability to move makes familiarization difficult and makes the gilt more susceptible to spontaneously attack her litter. The results from various studies reporting savaging mortality do not support either prediction clearly. Marchant-Forde (2002) reported that 12.9% of gilts in pens savaged piglets compared to only 3.2% in crates. McLean et al., (1998) found that incidence of savaging was not related to treatment, but other studies have found that savaging was more likely to occur with gilts in crates (Jarvis et al., 2004) and especially gilts in crates with no access to straw (Cronin and Smith, 1992). This result perhaps highlights the influence of a frustrated nesting phase on susceptibility to savage. Beattie et al. (1995) carried out a 2 × 2 factorial experiment, with gilts moving between barren (B) and enriched (E) gestation and farrowing systems and found that savaging incidence was 14% with gilts moving from an enriched, peat- and straw-based gestation system into slatted standard farrowing crates with no access to bedding (EB treatment). Savaging in the other three treatments was 4% in the BB treatment and 0% in BE and EE treatments.

For human caretakers around the time of parturition, care of sows in crates is relatively easy – the sow is locked in an accessible position and manipulations can be done without much danger to the carer. In an open pen system, access can be difficult and the carer can be in danger if the sow is aggressive and protective of her litter. This aspect is largely anecdotal, but Marchant-Forde (2002) reported that 8.1% of 62 gilts on trial were dangerously aggressive towards humans, but these were all in an open pen system, so incidence in this system was in fact 16.2% compared with 0% in the crates. Worryingly, aggression increased with age, so that 2nd parity sows were more aggressive than gilts and 3rd parity sows were more aggressive than 2nd parity sows. However, aggression towards the carer also showed a degree of consistency both across time within lactation and across parities. It was also related to some measures of human approach recorded during the first gestation, with 'bold' sows being more predisposed to carer-directed aggression (thus a different population to sows which savage piglets). Therefore, potentially aggressive sows could be identified even before entering the farrowing accommodation and precautions could be taken, either by only putting these sows into a confinement system, or subsequently removing them from the herd.

5.5.4 Challenges with Nest Occupation

In some respects, the challenges associated with the nest occupation phase are the crux of the welfare issues regarding farrowing systems. Over the last few decades it has become an issue of the welfare effects of confining the sow versus the welfare impact of increased piglet mortality in open systems. Confinement of the sow is an issue for the whole time the sow is in the farrowing room – i.e.

from entry prior to nest-building to exit at weaning, covering all six phases, but piglet mortality is really an issue at this time-point only – the nest occupation phase. Once the piglets have been born, sows in a natural environment continue to occupy the nest-site without integrating the litter with the herd for about 7–9 days, although they themselves may spend time away from the litter interacting with herd-mates. At this time, the piglets are still very vulnerable to nutritional and thermal deficits and are not very mobile. We know that regardless of the type of farrowing system, the majority of piglet mortality occurs in the first few days post-parturition and around half of total pre-weaning mortality occurs within the first 24 h of life (English and Smith, 1975; Cronin et al., 1996; Marchant et al., 2000a, 2001). The total amount of mortality and the cause of death are influenced by environmental, management, nutritional and genetic factors but behaviour is also a factor. In the first few days after parturition, the behaviour of the sow and the piglets is extremely important for piglet survival and it can be greatly impacted by the farrowing system. However, first let us address the thermal and nutritional environment. At birth, sows and piglets have very different thermal requirements of around 18–20°C for sows and 30–34°C for piglets. In all farrowing systems, we have the challenge that:

- A farrowing system that fails to meet the thermal needs of the sow and litter during nest occupation may impact piglet survival and growth

The widely different thermal needs at birth are usually handled indoors by the use of whole house heating to meet the sows' requirements plus additional localized heat sources in a creep area to meet the piglets' requirements. Ideally, having a large differential between house and creep temperatures will work to draw piglets away from lying in contact with the sow and thus, keep them away from where they could be prone to crushing (see below). Where the house temperature has been reduced relative to the creep temperature, piglet use of the creep area is maximized (Farmer et al., 1998; Schormann and Hoy, 2006). With crated systems, sow location is predictable and thus supplementary heat sources can be placed where the caretaker wants. Often, extra heat lamps are suspended by the crate for the first few days post-farrowing, but their location may have little effect on the piglets' preference to lie close to the sow (Hrupka et al., 1998) and recently, an epidemiological study has found that infra-red heat lamps actually increase the risk of pre-weaning mortality compared to other forms of heat (O'Reilly et al., 2006), though the reason for this is unclear. In open farrowing systems, sow location may be less predictable and thus, heat is usually provided in a single area, which is only accessible to the piglets. The heat source may be in the form of suspended heat or infra-red lamps, or a heated mat. More recent research has involved the development of simulated udders (Lay et al., 1999) or heated water beds (Ziron and Hoy, 2003).

In outdoor systems and 'low-tech' indoor systems, such as the Thorstensson system, there is no supplementary heat provided for the piglets. The thermal environment is therefore dependent on the provision of substrates to build a nest. Nests are built to protect piglets from predators, to reduce the risk of piglets being crushed and to keep them warm (Curtis, 1995). Algers and Jensen (1990) recorded the temperatures in 16 farrowing nests built by free-ranging domestic sows during two winters for the first wk post partum. Measurements were made approximately 5 cm from the piglets. Nest temperatures were virtually unaffected by outer climatic conditions and by the number of animals in the nest. Algers and Jensen (1990) reported that nest temperatures varied between 11 and 26°C (average 20.3°C) and outer temperatures at the same time varied between –17 and 7°C (average –1.5°C). So even in challenging ambient temperatures, the thermal requirements of the piglets can be met in a well-built nest. However, the thermal success of a nest will be influenced by the maternal behaviour of the sow – firstly in building a good nest and secondly by spending time in it.

Another primary challenge for the piglets after birth is to gain adequate nutrition:

- A farrowing system that impacts the suckling behaviour of the sow and litter during nest occupation may impact piglet survival and growth

Immediately after parturition, it is vitally important for the piglets to find the udder and to begin accessing colostrum. Those piglets that take longer to reach the udder and suckle colostrum have lower antibody titers (Damm et al., 2002b), greater drop in body temperature (Hoy et al., 1995) and greater risk of mortality (Hoy et al., 1995). Given this importance, it is surprising that there has been relatively little attention given to this aspect in relation to housing system impacts on time taken from birth to first suckling. There is some evidence that piglets in a group pen farrowing system have a shorter birth to suckle interval (Bünger and Schlichting, 1995) and this may in part be due to accessibility of teats. For example, Lou and Hurnik (1994) showed that teat access was better in ellipsoid crates compared with conventional crates and when Rohde Parfet et al. (1989) examined the interval from birth to first udder contact, they found that crate design did have an impact, with piglets born to sows housed in short, wide crates with the bottom rail only 20 cm from the floor taking the longest to take teats into their mouths. In open farrowing systems, piglets should be relatively able to gain udder access as there is no metalwork to potentially physically block teat availability. However, aspects which affect the sow's posture-changing behaviour during and immediately after parturition may play a role in delaying the birth to first suckling interval, as has been demonstrated in farrowing crates (Rohde Parfet and Gonyou, 1988). In an open pen system, sows which underwent disruption of their nests subsequently carried out more nest-building behaviour during parturition and their piglets took significantly longer to suckle after birth (Pedersen et al., 2003).

Later in the nest occupation phase of some farrowing systems, sow behaviour can still impact whether or not the piglets obtain sufficient nutrition. There are a number of indoor experimental farrowing systems that have been designed to allow the sow to get away from her litter, as would happen in the natural nest occupation phase, and indeed, farrowing arks used in outdoor production also usually have a fender to retain piglets within the ark while the sow can access the paddock. However, for these systems to work, there is a reliance on good maternal motivation from the sow to return and suckle her litter and good barrier design to prevent early piglet escape (Rudd, 1995). If the sow spends too long away from the litter then the piglets may become undernourished, which puts them at increased risk of mortality, either as a primary cause (starvation) or a secondary cause (crushing). Sows with access to get-away areas show wide variation in the amount of time they spend away from the litter (Pitts et al., 2002) and this can effectively become abandonment if the piglet area is sub-optimal or if the sow is content to suckle those piglets which escape into the get-away area (Marchant et al., 2000a).

Having got to the udder and suckled successfully, the newborn piglet still has a high risk of dying but this risk is greatly increased if suckling is unsuccessful. Crushing or overlying by the sow remains the major cause of early piglet mortality in all types of system both indoors (Marchant et al., 2000a) and outdoors (Edwards et al., 1994) but it is closely tied to nutritional status and thermal environment (Edwards, 2002). We have the challenge that:

- A farrowing system that impacts the behaviour of the sow and litter during posture changes may impact piglet survival due to crushing

The risk of a crushing event happening is dependent on the type of posture change that the sow makes, the type and amount of behaviours that the sow carries out before she makes the posture change and the location of the litter relative to the sow and to each other (Marchant et al., 2001). For the piglet, the fatal/non-fatal outcome of the crushing event may then depend on how responsive the sow is to its distress calls.

The most dangerous posture changes for the piglets are the sow lying down from standing, lying down from sitting or rolling over (Weary et al., 1996); Bradshaw and Broom, 1999b; Marchant et al., 2001; Damm et al., 2005; Johnson et al., 2007). The way the sow lies down has been described in detail (Baxter and Schwaller, 1983) but what appears to be critical is the amount of control that the sow exerts over the final stage, where the hindquarters make contact with the floor (Marchant et al., 2001). Ordinarily, sows seem to prefer to lean against a vertical surface to help control lying down, both during gestation (Marchant and Broom, 1996) and post-farrowing (Damm et al., 2006). If a sow lies down without leaning, the risk of piglet crushing increases (Marchant et al., 2001). Farrowing crates work advantageously by preventing this type of sudden, uncontrolled descent of the hindquarters. Farrowing crates have been shown to have more crushing deaths associated with lying down from a sitting position compared to open pens (Edwards et al., 1986), but the frequency of sitting is increased in crates relative to pens and thus, the number of sitting to lying transitions is higher. Also, generally, this crushing increase is more than offset by increased crushing due to other posture changes in pens. For example, in open pens, rolling by the sow can be the cause of as many as half of all crushing deaths (Weary et al., 1996, 1998; Bradshaw and Broom, 1999b;

Marchant et al., 2001), whereas this posture change is effectively prevented by farrowing crates. Rolling is especially prevalent by sows housed on hard floors (Herskin et al., 1998) and may be pain-related, being reduced in sows given analgesia (Haussman et al., 1999).

Before she changes posture, especially lying down from standing, the sow is often seen to carry out some pre-lying behaviour, hypothesized to ensure that the area into which she is lying, is clear of piglets (Marchant et al., 2001). The behaviour may involve looking around to locate piglets, rooting, nosing and pawing at any substrate and pushing piglets away with her snout. In crates, these types of behaviour are greatly restricted and the sow can only locate piglets near her head. In open pens, there is strong evidence to show that sows which engage in more of this behaviour before lying down have reduced rates of crushing (Marchant et al., 2001; Valros et al., 2003; Andersen et al., 2005), emphasizing the importance of the quality of maternal behaviour needed for open farrowing systems to work successfully. However, the context in which pre-lying behaviour is carried out is also important (personal observation). If the litter is resting together away from the sow, it may be better for the sow to lie down quickly without disturbing her piglets, in which case, carrying out little or no pre-lying behaviour is better. If, in this scenario, she performs a lot of pre-lying behaviour she risks the litter getting up and entering the area into which she is about to lie down, thereby increasing the risk of a crushing event.

This brings us to crushing in relation to the location of the piglets. Obviously, crushing can only occur if the piglets are near to the sow when she changes posture. However, "nearness" by itself is not necessarily a risk factor (Marchant et al., 2001). If the piglets are clustered and near to the sow, crushing risk is relatively low, but if piglets are spread out and near to the sow, then this poses problems for the sow in her ability to successfully locate all her piglets, and the risk of crushing is much higher (Marchant et al., 2001) even in an open system, where she is able to turn round. In early lactation, the piglets have high nutritional and thermal demands and are often found in close proximity to the sow to meet both these demands. Piglets with low weight-gain are especially more likely to spend time in contact with the udder, and this places them at proportionally higher crushing risk than their littermates (Weary et al., 1996). Most farrowing systems incorporate a creep area – an area accessible only to the piglets and which usually has a supplementary heat source – in order to draw piglets away from the sow and thus, reduce the risk of crushing. Other developments to influence piglet behaviour have included the design of a simulated udder (Lay et al., 1999) and the use of air blowers to encourage piglets away from the sow when she changes posture (Jeon et al., 2005).

If a piglet becomes partially trapped by the sow, it usually screams to alert the sow, who should then change posture again to release her piglet. This maternal responsiveness is a protective behaviour which often appears to be lacking or blunted in modern commercial sows with large between-sow variability reported by many authors (Harris and Gonyou, 1998; Herskin et al., 1998; Marchant et al., 2000b; Held et al., 2006). However, within-sow, there has been documented consistency in responsiveness to piglet screams both within parity (Marchant et al., 2000b) and across parities (Held et al., 2006). There has also been documented consistency in crushing rates across parities (Rudd and Marchant, 1995; Jarvis et al., 2005), with over 40% of sows on an experimental unit especially being consistent in crushing no piglets over three parities in open pens (Rudd and Marchant, 1995). These facts indicate that this aspect of maternal responsiveness and crushing rates may be subject to selection, to improve piglet survival in open systems where maternal ability is of greater importance for system success (Grandinson, 2005).

5.5.5 Challenges with Social Integration

Under natural conditions, the sow begins to leave the piglets alone in the nest a couple of days post-partum and then on average around 10 days after farrowing, the nest site is abandoned (Petersen et al., 1989) and the sow begins to process of integrating her litter into the family group, where they come into contact with piglets from other litters, anywhere between 7 and 15 days post-partum (Newberry and Wood-Gush, 1986; Petersen et al., 1989). Under standard commercial conditions, piglets do not interact with non-littermates until they are removed from the sow and mixed at weaning – apart from those litters where cross-fostering may occur in the first few days immediately post-partum. However, there are experimental and commercial systems that do expose litters of piglets to each other prior to weaning and this could potentially expose piglets to aggression from non-littermates and competition for access to their dam's udder at milk let-down due to cross-suckling. So, firstly, we have the challenge that:

- Social integration places piglets at risk of social stress due to aggression

When unfamiliar pigs are mixed together, aggressive encounters will ensue, to a greater or lesser degree. The duration and severity of the encounter will most likely depend on the relative sizes of the pigs to each other (Rushen, 1987), their previous social experiences and perhaps their age (Pitts et al., 2000), but also the environment in which the encounter takes place. Some farrowing systems in commercial use do allow piglets from different litters to mix prior to weaning – for example, most outdoor systems and the Swedish Ljungstrom and Thorstensson systems. A number of experimental communal farrowing and/or multisuckling systems also allow piglets to mix or co-mingle, prior to weaning in the presence of their dams (de Jonge et al., 1996; Wattanakul et al., 1997a; Olsson et al., 1999). Other researchers have modified individual farrowing systems to allow just piglets to mix by removing partitions between pens or crates (Pluske and Williams, 1996; North and Stewart, 2000; D'Eath, 2005).

In most cases, researchers have concentrated on the effect of mingling pre-weaning on the piglets' subsequent behavioural responses to weaning itself and post-weaning mixing. Generally, studies have consistently found that if piglets are mixed during lactation, their welfare is improved at weaning, with reduced aggression compared to previously unmixed control piglets and better post-weaning growth rates (Wattanakul et al., 1997a; Weary et al., 1999a, 2002; Bünger et al., 2000; North and Stewart, 2000; Cox and Cooper, 2001; Hotzel et al., 2004; Hessel et al., 2006). However, many studies have failed to look what happens to the piglets at the time of mixing during lactation. Wattanakul et al. (1997b) found that when piglets were mixed at 11 days of age, skin damage scores were higher than unmixed controls. Also at mixing at 11 days of age, Weary et al. (1999a) reported little aggression and no sustained fighting, but in another study with mixing at 14 days of age, reported twice as much agonistic behaviour in mixed pigs compared with unmixed controls (Weary et al., 2002). Parratt et al. (2006) showed aggression increased around fourfold in piglets mixed at 16 days of age compared to unmixed controls in the 90 min post-mixing. The apparent differences may be due to differences in age at mixing and the environments into which piglets are mixed. Under natural conditions, piglets are mixed at a relatively young age, in the presence of their free-moving dams and in a great deal of space. For the above studies, sows may be confined, piglets may be slightly older and space may be limiting.

However, notwithstanding these limitations, the reduction in post-weaning aggression appears to be greater than any increase in aggression seen at co-mingling pre-weaning and there are other benefits too. Weary et al. (2002) reported that piglets mixed at weaning were involved in roughly 8 times the amount of aggression that co-mingled piglets were. Hotzel et al. (2004) reported a fivefold reduction in post-weaning aggression for co-mingled piglets. North and Stewart (2000) and Wattanakul et al. (1997a) recorded 5–8 times fewer skin lesions on co-mingled pigs when remixed at weaning. Other studies have also shown that co-mingling bestows long-term benefits in terms of improved social skills (Olsson et al., 1999; Hillmann et al., 2003; D'Eath, 2005), with co-mingled piglets able to establish hierarchies quicker (D'Eath, 2005) and weight gain post-weaning seems to be improved (Wattanakul et al., 1997a; North and Stewart, 2000; Hessel et al., 2006).

The other big challenge with social integration during lactation, is that piglets from other litters may be competing for milk at suckling events. Thus, our second challenge during this phase is:

- Social integration places piglets at risk of being displaced from the udder at milk let-down by piglets of other litters

When lactating sows and their litters are mixed, cross-suckling does occur. Reported incidences of 'alien' piglets present at a suckling event range from 4% (Götz et al., 1991) to 29% (Maletinska and Spinka, 2001), but differences in group size and day of observation in relation to lactation length are thought to influence these numbers. The extent to which cross-suckling occurs is influenced by the exact system design and management techniques employed in the pre- and post-mixing environments. In most commercial and experimental farrowing systems that practice multisuckling, sows farrow individually and mixing of sows and litters occurs around day 10 to day 14 of lactation, either in the same room by removal of pen barriers or by movement to a specifically designed multisuckling pen. If sows are able to get-away from the litter prior to entry into a multisuckling system, then cross-suckling can be reduced (Dybkjaer et al., 2001). Similarly, if sows and litters have some familiarity with the multi-suckling environment prior to being able to mix, then again cross-suckling can be halved relative to groups of sows and litters moved direct into the multi-suckling environment on day 14 (Wattanakul et al., 1998a). Moving and mixing on the same day also reduces the number of suckling attempts and the number of successful milk let-downs (Wattanakul et al., 1998a).

When we look at individual piglets, it has been found that 34 to 38% of all piglets cross-suckle at least once (Olsen et al., 1998; Maletinska and Spinka, 2001). However, within this fairly large number, there appears to be two populations – those that are occasional cross-sucklers and those that are habitual cross-sucklers. Olsen et al. (1998) reported that in fact only around 5% of piglets were habitual cross-sucklers and 29% were occasional. Maletinska and Spinka (2001) reported 15% habitual and 23% occasional. Cross-sucklers are more likely to come from sows with relatively low milk yield (Olsen et al., 1998) and from large litters (Maletinska and Spinka, 2001) and also cross-suckle from sows with relatively large litters themselves, perhaps ensuring access to a functional teat (Maletinska and Spinka, 2001).

The presence of 'alien' piglets can disrupt the suckling event, especially on the day of mixing, and a number of studies have reported decreased successful sucklings post-mixing (Wattanakul et al., 1997a, 1998a,b; Pedersen et al., 1998). To reduce cross-suckling, sows can show aggression towards alien piglets (Olsen et al., 1998) but widely reported is synchrony in nursing, where sows in a group have milk let-down simultaneously (Bryant et al., 1983; Wechsler and Brodmann, 1996; Wattanakul et al., 1997a; Maletinska and Spinka, 2001), so that piglets nurse at their dam's udder without excessive competition from alien piglets. Thus, although cross-suckling does occur in group lactation systems, it need not result in disadvantages for the piglets, with a combination of management and sow input controlling the extent to which it occurs and ameliorating potential negative outcomes such as disrupted nutrient intake and growth patterns,

5.5.6 Challenges with Weaning

Weaning is the time of final cessation of nursing and suckling activities (Counsilman and Lim, 1985). In wild boar and free-ranging domestic pigs, weaning occurs around 3–4 months post-parturition (Newberry and Wood-Gush, 1985; Jensen and Stangel, 1992) and is a gradual process. Under commercial conditions, weaning may occur anywhere between 2 and 8 weeks post-partum, depending on the system.

Regardless, we have the challenge of weaning at an early age relative to 'nature' and we often have the challenges of abrupt change in diet from milk to solid feed, movement to a different environment and mixing with piglets from other litters.

- Weaning at an early age influences piglet welfare

The biggest problem with addressing this issue is that researchers have invariably chosen to compare two or more weaning ages that are both or all effectively 'early' when compared with 3–4 months. The incidence of belly-nosing or pen-mate manipulation has garnered a lot of attention and its performance has been hypothesized as being related to suckling motivation and redirected feeding attempts (Weary et al., 1999b; Worobec et al., 1999). Recent work appears to highlight a relationship with post- rather than pre-suckling behaviour (Torrey and Widowski, 2006). Belly-nosing is still considered to be indicative of compromised welfare for the performer but it can certainly have health and welfare implications (umbilical lesions) for those pigs that are recipients (Main et al., 2005). The amount of belly-nosing is related to age at weaning, being seen more frequently in piglets weaned at 1–2 weeks of age than in piglets weaned at 3 weeks of age or later (Gonyou et al., 1998; Worobec et al., 1999; Hohenshell et al., 2000; Main et al. 2005). However, even looking among later-weaned piglets, more nosing is seen in piglets weaned at 3 weeks, compared to piglets weaned at 4 (Colson et al., 2006), 5 (O'Connell et al., 2005) and 6 weeks (Bøe, 1993). Belly nosing incidence can be reduced by weaning into enriched pens (Dybkjaer, 1992, O'Connell et al., 2005; Bench and Gonyou, 2006) and especially by providing enrichment devices that are designed specifically to satisfy or attract nosing behaviour (Bench and Gonyou, 2006).

Other issues with very early weaning – i.e. at or before 2 weeks of age – include increased aggression at mixing in later life (Hohenshell et al., 2000; Yuan et al., 2004; Colson et al., 2006), decreased immune function and increased mortality in the post-weaning period (Davis et al., 2006), depressed feed intake and poorer growth rates (Gonyou et al., 1998; Colson et al., 2006) and changes in the expression of genes regulating glucocorticoid response (Poletto et al., 2006), which may have long term effects on the pig's ability to cope with stress later in life.

- The change from milk to solid feed influences piglet welfare

When the sow and her litter are kept intact and separated from others, there may be temporal changes in certain parameters of nursing, such as a decrease in total nursing duration and an increase in the percentage of nursings terminated by the sow (Valros et al., 2002). However, there is no change in the total number of successful nursings per day, over a 4–5 week post-partum period (Valros et al., 2002). This is quite different from what occurs in the 'natural' situation and in other farrowing systems such as those that allow the sow to get away from her litter or which allow sows and/or litters to mix prior to weaning. In a semi-natural enclosure, weaning is a very gradual event, beginning within the first few weeks after parturition and ultimately being completed at 13–17 weeks (Newberry and Wood-Gush, 1985; Jensen, 1988). Over that time period, the number of suckling events per hour decreases steadily from the 2nd week of lactation until the 10th week and drops more steeply (Jensen and Recén, 1989). The number of suckling events initiated by the piglets and terminated by the sow increases and more suckling events occur with piglets missing (Jensen and Recén, 1989).

With 'get-away' systems, the sow will increasingly choose to spend time away from her litter (Bøe, 1994; Rantzer et al., 1995; Weary et al., 2002). However, these systems do not mirror nature as in the 'natural' situation, the sow cannot isolate herself from her litter. Thus, in many of these 'get-away' or sow-controlled systems, certain individual sows (and there is considerable variation) may spend inappropriate amounts of time away from the litter resulting in litters being effectively abandoned and weaned early (Bøe, 1994, Rantzer et al., 1995). Those that do not abandon the litter completely may still spend an average of 14 h a day away from the litter by the 4th week of lactation (Weary et al., 2002) and not surprisingly, the number of suckling events per day in these systems begins to reduce quite considerably as lactation progresses. In systems with mixing of sows and litters prior to weaning, there is some evidence that nursing frequency reduces over lactation compared to individually housed sows and litters (Arey and Sancha, 1996; Weary et al., 1999a).

These differences in nursing behaviour will subsequently impact how the piglets react to weaning when it is imposed. For those piglets with high reliance on nursing, the abrupt change from milk to only solid feed will have the greatest impact, resulting in a marked growth check as piglets' energy intake drops drastically albeit temporarily. Associated with weaning are marked changes in the histology and biochemistry of the small intestine, such as villous atrophy and crypt hyperplasia (Pluske et al., 1996). The use of creep feed for piglets prior to weaning is contentious and may have little effect for post-weaning feed intake or make the transition from milk to solid feed at weaning any easier. This is probably because of the different circumstances under which it may be offered. If it is offered to piglets in conventional individual farrowing systems weaned at 2–3 weeks of age, it is unlikely to be of much benefit as milk availability is likely to be consistently high up to the point of weaning. However, where piglets may be weaned at a later age or where the nursing frequency declines over lactation, creep feed may well help piglets contend with weaning. Pajor et al. (1991) measured creep feed intake in piglets from day 10 to day 28 of lactation and found that up to day 21, average intake was less than 5 g per day, with large variation both between and within litters. From day 21 to day 28 average intake increased quite rapidly up to 63 g per day, but it was the larger, more physically mature piglets which ate most and there was no direct relationship between pre-weaning intake and post-weaning gain. This variability and post-weaning effect was also reported by Fraser et al. (1994). Other studies where access to the sow may be limited have shown that piglets eat more feed pre-weaning and post-weaning compared to piglets with ready access to the sow at all times (Cox and Cooper, 2001; Weary et al., 2002).

- Movement from the lactation environment at weaning influences piglet welfare

Usually at weaning, piglets are moved and mixed to standardize size and/or gender and free up the expensive farrowing accommodation for the next batch of sows. The idea that piglets stay where they are at weaning, with only the sows being moved out is not a new one (Charlick et al., 1968) but is rarely used, except perhaps in the Swedish multisuckling systems, where it is usual practice to remove the sows at weaning and keep the piglets in the multisuckling pen up to about 25 kg weight. There are few experimental studies available to determine the effects of movement at weaning on piglet welfare. Although Rantzer and Svendsen (2001) have highlighted concerns with hygiene and morbidity when leaving piglets in the home pen at weaning, all other studies have shown advantages compared to moving. Both Bøe (1993) and Puppe et al. (1997) compared leaving litters in the farrowing pen with moving to flat decks at weaning and found that moving resulted in more pen-mate manipulation including tail-biting (Bøe, 1993) and higher aggression, decreased immunity and elevated glucose levels (Puppe et al., 1997). Furthermore, moving at weaning resulted in welfare being more compromised compared with mixing at weaning (Puppe, et al. 1997). Comparisons of the 'Specific-Stress-Free' (SSF) system, which raises pigs from birth to slaughter in the same pen has also demonstrated better growth rates, lower cortisol concentrations, decreased aggression and better immune system activity compared to moving and mixing piglets at weaning (Ekkel et al., 1995; Ekkel et al., 1996).

The final major challenge with weaning in most commercial systems is mixing with other piglets. The advantages/disadvantages of mixing at weaning compared to mixing during lactation have been covered in the previous section.

5.6 Overall Assessment of Welfare in Different Systems

In the above section, we have taken the approach of in-depth investigation of each of the separate phases of time spent in the farrowing house, for the sow and her litter and discussed these individual elements in relation to aspects of system design. In this final section, we will now tie some of this together with respect to hypothetical systems in use in commercial practice. This will give a clearer indication of how current systems may interface with the welfare requirements of sows and litters during their time in the farrowing house. However, we must also issue some caveats – we will be dealing with generalizations to illustrate concepts based on information presented in the chapter, which in turn is derived from papers published to date on research often carried out in very specific situations. On any given farm, welfare within a farrowing system will be influenced by many things including system design, herd health, genetics, feeding system, gestation system and the skill of the carers. Extrapolation of the discussion below to a specific system not described would not be applicable and is therefore ill-advised. For the scoring system, we will also make the assumption that the sows exhibit good maternal behaviour, so that the limitations of the system, rather than the sow, are highlighted.

5.6.1 Hypothetical Systems Descriptions

1. **Conventional Crates.** Conventional tubular metal farrowing crate on slatted floor. No bedding but heated creep area for piglets. Litters kept intact with sow throughout 2–3 week lactation. No creep feeding. At weaning, piglets are moved and mixed with unfamiliar piglets.
2. **Modified Crates.** Conventional tubular metal farrowing crate on solid, long-stem straw bedded floor. Heated creep area for piglets. Litters are kept intact for 10 days and then partitions between 3 pens are removed allowing litters only to mix. Weaning occurs at 4 weeks of age and piglets given access to creep feed from 2 weeks of age. Piglets are moved at weaning but are not mixed with any unfamiliar piglets.
3. **Hinged Crates.** Hinged tubular metal crates on solid, long-stem straw-bedded floor. On entry to the system crate is open and is not closed until nesting has finished. Sow is kept in closed crate until litter is 7 days of age, then crate is opened. Heated creep area for piglets. Litter kept intact with sow throughout 3–4 week lactation, but sow may have limited communication with sows in neighboring pens. No creep feeding. At weaning, piglets are moved and mixed with unfamiliar piglets.
4. **Open Pens.** Open pens with solid, long-stem straw-bedded floor and piglet protection rails around perimeter. Heated creep area for piglets. Litter kept intact with sow throughout 3–4 week lactation but sow may have limited communication with neighboring sows. No creep feeding. At weaning, piglets are moved and mixed with unfamiliar piglets.
5. **Single Ark.** Insulated farrowing ark in paddock for single sow, ringed by an electric fence. Paddock has some grass cover and ark is bedded with deep long-stem straw. Sow is kept singly throughout 3–4 week lactation but sow may have limited communication with sows in neighboring paddocks. Piglets are contained within the ark for 7–10 days by a fender and then released into the paddock. Piglets can move under fence and mix with piglets in other paddocks. No creep feed, but sow is floor fed and piglets can access sow feed. At weaning, piglets are moved but not mixed with unfamiliar piglets.
6. **Ljungstrom System.** Swedish Ljungstrom system, with sows housed individually in straw-bedded, solid-floored pens with piglet protection rail around perimeter. Heated creep area for piglets. Sow and litter kept intact for

14 days and then moved together to a deep-bedded multisuckling pen with 9 other sows and litters. Piglets can access creep feeder from 14 days of age, up to weaning at 6 weeks. At weaning, sows are removed, piglets remain in the multisuckling pen.

7. **Thorstensson System.** Swedish Thorstensson system, with 8 sows group-housed in a large, deep straw-bedded pen with 8 individual temporary pens down one side. Sows are grouped before and during a 6-week lactation period. Piglets are retained in the home pens until 10 days of age by a barrier, but are then mixed by removal of all the pens and the system becomes a multisuckling system. Piglets can access creep feeder from 21 days of age up to weaning at 6 weeks. At weaning, sows are removed and piglets remain in the pen.
8. **Grouped Arks.** Insulated farrowing arks in a group paddock for 6 sows ringed by an electric fence. Paddock has some grass cover and ark is bedded with deep long-stem straw. Sows are grouped before and during a 3 to 4 week lactation period. Piglets are contained within the arks for 7–10 days by a fender and then released into the paddock. Piglets can move under fence and mix with older and younger piglets in other paddocks. No creep feed, but sows are floor fed and piglets can access sow feed. At weaning, piglets are moved but not mixed with unfamiliar piglets.
9. **Communal Pens.** Communal farrowing system for 4 sows with individual, deep-strawed, open farrowing pens incorporating sloping walls with piglet escape area underneath, communal sow passageway and communal outdoor lying/dunging area. Heated creep area for piglets. Sows are grouped before and during 4 week lactation. Piglets are kept within home pen for 10 days by a barrier which is removed to allow litters to mix. No creep feeder but piglets may access some food from sow feeder. At weaning, piglets are moved but not mixed with unfamiliar piglets.

5.6.2 Welfare Assessment of Hypothetical Systems

The pluses and minuses of each of the systems are given in tabulated form below (Table 5.2). The rationale behind the scores given can be summarized as follows:

1. **Conventional Crates.** Sow cannot isolate or seek nest site. Inability to nest-build can result in disturbed farrowing, placing newborn piglets at risk of crushing or stillbirth. But crate perhaps helps newborn piglets locate udder more easily. During nest occupation, sow cannot move around or leave the litter but her piglets are protected from early mortality by the crate. All social integration is thwarted. Sow has decreased control over nursing frequency and piglets are weaned early and abruptly and moved and mixed.
2. **Modified Crates.** Sow cannot isolate or seek nest site. Can carry out limited nest-building with bedding, and this may be sufficient to prevent disturbed

Table 5.2 Quantitative sow and litter welfare scores for each hypothetical system over six separate phases of farrowing

System	Isolation & Nest-site seeking		Nest-building		Farrowing	
	Sow welfare	Litter welfare	Sow welfare	Litter welfare	Sow welfare	Litter welfare
1. Conventional crates	✘✘		✘✘		✘	–
2. Modified crates	✘✘		–		–	–
3. Hinged crates	✘		–		–	–
4. Open pens	–		✓		✓	✓
5. Single ark	✓		✓✓		✓	✓
6. Ljungstrom system	–		✓		✓	✓
7. Thorstensson system	✓		✓✓		✓	✓
8. Grouped arks	✓		✓✓		✓	✓
9. Communal pens	✓		✓✓		✓	✓
System	Nest occupation		Social integration		Weaning	
	Sow welfare	Litter welfare	Sow welfare	Litter welfare	Sow welfare	Litter welfare
1. Conventional crates	✘✘	✓✓	✘✘	✘✘	✘✘	✘✘
2. Modified crates	✘✘	✓✓	✘✘	✓	✘	✓
3. Hinged crates	✘	✓✓	✘	✘✘	✘✘	✘
4. Open pens	–	✘✘	✘	✘✘	✘✘	✘
5. Single ark	✓	✘✘	✘	✓✓	✓	✓
6. Ljungstrom system	✓	✘✘	✓	✓	✓	✓✓
7. Thorstensson system	✓✓	✘✘	✓✓	✓✓	✓	✓✓
8. Grouped arks	✓✓	✘✘	✓✓	✓✓	✓	✓
9. Communal pens	✓✓	✘✘	✓✓	✓✓	✓	✓

✓✓ large positive effect on welfare ✓ positive effect on welfare.
– neutral effect on welfare ✘ negative effect on welfare.
✘✘ largenegative effect on welfare.

farrowing. But crate perhaps helps newborn piglets locate udder more easily. During nest occupation, sow cannot move around or leave the litter but her piglets are protected from early mortality by the crate. Sow's social integration is thwarted but piglets are able to mix. Due to multisuckling, and creep feed presence, sows may have some control on nursing frequency. Piglets have a degree of solid feed intake and are not mixed at weaning.

3. **Hinged Crates.** Sow cannot isolate or seek nest site but can move around the pen. Can carry out nest-building with bedding, and this may be sufficient to prevent disturbed farrowing. But crate perhaps helps newborn piglets locate udder more easily. During most of nest occupation, sow cannot move around or leave the litter but her piglets are protected from early mortality by the crate. After 7 days, crate is open and sow can move around the pen. Piglets' social integration is thwarted but sows may carry out limited social interactions with neighbors. Sow has decreased control over nursing frequency and piglets are weaned abruptly and moved and mixed.
4. **Open Pens.** Sow cannot isolate or seek nest site but can move around the pen. Can carry out nest-building with bedding, and this may be sufficient to prevent disturbed farrowing. During most of nest occupation, sow can move around but not leave the litter and her piglets are relatively unprotected from crushing. Piglets' social integration is thwarted but sows may carry out limited social interactions with neighbors. Sow has decreased control over nursing frequency and piglets are weaned abruptly and moved and mixed.
5. **Single Ark.** Sow can isolate but nest site is pre-assigned. Can carry out nest-building with bedding and paddock vegetation, and this may be sufficient to prevent disturbed farrowing. During nest occupation, sow can move around and leave the litter but her piglets are relatively unprotected from crushing. Piglets can socially integrate but sows may carry out only limited social interactions with neighbors. Sow has some control over nursing frequency, piglets have a degree of solid feed intake and are not mixed at weaning.
6. **Ljungstrom System.** Sow cannot isolate or seek nest site but can move around the pen. Can carry out nest-building with bedding, and this may be sufficient to prevent disturbed farrowing. During most of nest occupation, sow can move around but not leave the litter and her piglets are relatively unprotected from crushing. Social integration of sows and piglets is sudden and involves moving to new environment. Sow has some control over nursing frequency, piglets have a degree of solid feed intake and are not mixed or moved at weaning.
7. **Thorstensson System.** Sow can achieve limited isolation and has some choice of nest sites. Can carry out nest-building with bedding collected inside and outside of pens, and this may be sufficient to prevent disturbed farrowing. During most of nest occupation, sow can move around but not leave the litter and her piglets are relatively unprotected from crushing. Piglets and sows can socially integrate. Sow has some control over nursing frequency, piglets have a degree of solid feed intake and are not mixed or moved at weaning.
8. **Grouped Arks.** Sow has choice of nest sites and may isolate herself. However, her chosen nest-site may already be occupied meaning she has to take a non-preferred site or 'double up', which is a management challenge. Can carry out nest-building with bedding and paddock vegetation, and this may be sufficient to prevent disturbed farrowing. During nest occupation, sow can move around and leave the litter but her piglets are relatively unprotected from crushing. Piglets and sows can socially integrate. Sow has some control

over nursing frequency, piglets have a degree of solid feed intake and are not mixed at weaning.

9. **Communal Pens.** Sow can achieve limited isolation and has some choice of nest sites. However, as with grouped arks, her chosen nest-site may already be occupied meaning she has to take a non-preferred site or 'double up', which is a management challenge. Can carry out nest-building with bedding collected inside and outside of pens, and this may be sufficient to prevent disturbed farrowing. During nest occupation, sow can move around and leave the litter but her piglets are relatively unprotected from crushing. Piglets and sows can socially integrate. Sow has some control over nursing frequency, piglets have a degree of solid feed intake and are not mixed at weaning.

Although hypothetical, the description of these system designs illustrates the type of features that impact sow and piglet welfare during the various different stages of farrowing system occupation. No single system has positive effects on welfare for sows and litters across the board, so even the 'best' system has an element of compromise. Under the nominal scoring scheme used, the overall worst is Conventional Crates (see Table 5.3) and the overall best are the Thorstensson system and the Grouped arks (Table 5.3).

However, this is purely a quantitative assessment and does not attempt to assign different qualitative weightings to different factors. The most important aspects that this exercise highlights are perhaps the fact that conventional crates rank poorly for both sow and piglet welfare, based on the review of the scientific literature, but that modifications including bedding, mixing of litters pre-weaning, increasing weaning age slightly and offering creep feed can certainly improve piglet welfare within the system. For the sows, group-housing appears to offer welfare advantages, but these systems certainly increase the management skills needed by the stockperson and without these, welfare scoring could be considerably lower. Also, and the real crux of the welfare assessment problem, where the sow is loose-housed, piglet welfare during the nest occupation phase tends to be

Table 5.3 System ranking based on the relative number of advantages and disadvantages in welfare terms for sows, piglets and overall

System	Sow welfare ✓:✗	"Rank"	Litter welfare ✓:✗	"Rank"	Overall welfare ✓:✗	"Rank"
1. Conventional crates	0:11	9	2:4	8	2:15	9
2. Modified crates	0:7	8	4:0	1	4:7	6
3. Hinged crates	0:5	7	2:3	7	2:8	8
4. Open pens	2:3	6	1:5	9	3:8	7
5. Single ark	6:1	4	4:2	3	10:3	4
6. Ljungstrom system	5:0	4	4:2	3	9:2	4
7. Thorstensson system	9:0	1	5:2	2	14:2	1
8. Grouped arks	9:0	1	4:2	3	13:2	2
9. Communal pens	9:0	1	4:2	3	13:2	2

disadvantaged, with the disadvantage being an increase in early pre-weaning mortality. This remains the key problem with alternative farrowing systems as it represents a major economical loss to the producer as well as a welfare issue.

5.7 Conclusions

The assessment of welfare within farrowing systems remains a difficult area of study due to the conflicting needs of the sow and her litter. Conventional farrowing crates can safeguard piglet welfare during the nest occupation phase of farrowing, especially limiting early pre-weaning mortality; an extremely important factor for the welfare of the individual piglet and also for the profitability of the commercial producer.

However, conventional crates also have a number of disadvantages with respect to sow and piglet welfare during other stages of lactation, and maybe throughout other stages of production. Many alternative systems exist albeit at an economical cost to the producer and most confer welfare benefits during some of the farrowing stages.

For increased piglet mortality not to be a problem which currently it is, there needs to be a greater reliance on the selection of our gilts and sows for positive maternal traits (i.e. rooting, pawing and being responsiveness to their piglets) and a greater reliance on caretaker skills to manage the farrowing and lactating systems optimally.

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Chapter 6
Housing the Fattening Pig

Niamh E. O'Connell

6.1 Introduction

It is likely that pigs have been confined to some extent for several thousand years (Zeuner, 1963). Early confinement systems probably consisted of rudimentary pens or dwelling houses, and it was not until the time of the Greek and Roman civilisations that specialist pig houses were developed (Baxter, 1984). It appears that pig husbandry methods were relatively slow to develop thereafter. For example, slatted flooring systems for pigs did not appear to develop to any great extent in Europe and the US until the 18th and 19th centuries (Baxter, 1984). During the 20th century, however, pig housing systems underwent somewhat of a 'revolution' that led to the development of modern-day, intensive houses (Brent, 1986). This revolution reflected a number of factors including a move from mixed-enterprise to specialist pig production. This more business-like approach to pig production resulted in increased confinement of pigs in highly capitalised, specialist houses, where emphasis was placed firmly on production efficiency. Some of the methods adopted to maximise production efficiency included minimising space allowance per animal, widespread use of slatted floors, and automation of feeding systems, temperature control and ventilation.

Emphasis on production efficiency is essential in order for pig production systems to remain viable. However, increasing public concern in relation to intensive livestock systems means that other factors must also be taken into consideration. For example, pig housing systems should be designed in such a way as to safeguard the welfare of pigs, and to minimise the environmental impact of pig production. Thus, modern housing systems for pigs must attempt to achieve a number of different objectives simultaneously. Often these objectives appear at odds with each other. For example, promoting welfare through allowing pigs to perform natural, species-specific behaviours invariably means increasing environmental space and complexity, and thus increasing capital

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cost of housing. An important role of research is to determine how best to achieve appropriate balances between production efficiency and animal welfare within intensive pig production.

6.1.1 Variation in Housing Systems

The range in pig housing systems is vast and is determined by a number of different factors. As Smith (1987) points out, production systems evolve gradually and represent 'an amalgam of national and local constraints, personal preferences, state of knowledge and fashion'. In general, all housed systems may be classed as intensive, however within housed systems, production systems may be viewed as more or less intensive (SVC, 1997). Intensive housed systems generally consist of specialised buildings where all or part of the floor is slatted, and pigs are housed at low space allowances (Brent, 1986). Less intensive housing systems generally involve solid floors and provision of bedding, for example in a deep litter system. Scraped systems also exist, which consist of solid floored pens where lying and excretory areas are structurally distinct, and where excreta is removed via scrapers (SVC, 1997). Within these systems, Straw-Flow® systems may operate, where straw is provided and gradually moves down a sloped floor to an excretion area (Kelly et al., 2000; Fig. 6.1).

In many cases, pigs are housed in different accommodation depending on stage of life. For example, most commercially-reared pigs are weaned at an unnaturally early age (for example, at 3 or 4 weeks of age). These early-weaned

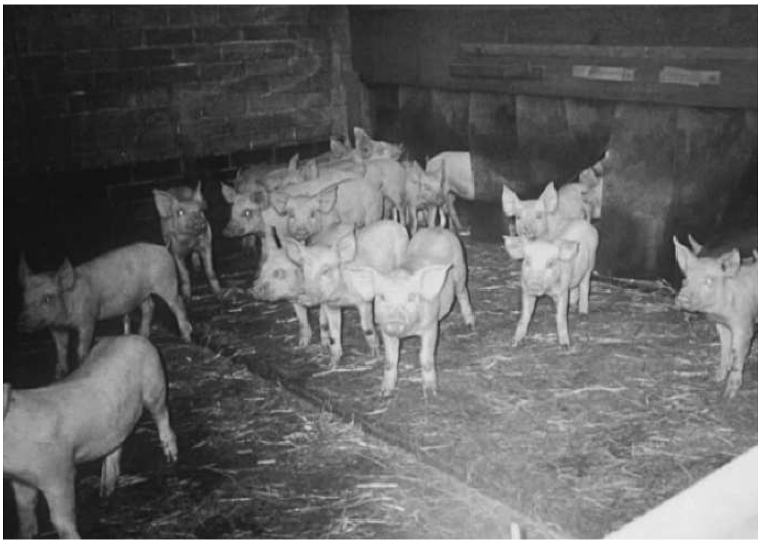

Fig. 6.1 A sloping bed nursery pen, in which straw is added to the top of the slope and progresses down to the dunging channel at the bottom as the pigs move around the pen

pigs have specialist environmental requirements in terms of factors such as temperature, hygiene, ease of observation and method of food presentation. The younger the weaning age of the pig, the more critical the housing environment. A number of different housing systems are used for weaned pigs. These include flat deck systems with fully-slatted floors and controlled environments (Fig. 6.4), kennel systems where resting areas are separated from exercise/dunging areas (Fig. 6.3), and straw yard systems (Fig. 6.5). Tiered cages with wire mesh floors have also been used to house weaned pigs (Brent, 1986). Environmental factors are not as critical with older growing and finishing pigs, which can tolerate greater fluctuations in factors such as temperature (English, 1987). Diagrammatic examples of some common housing systems for weaner, grower and finishing pigs are presented in Fig. 6.2.

Production systems not only vary in terms of physical characteristics but also in terms of management practices. For example, producers may operate 'all in/all out' or 'continuous flow' systems between houses at different stages of life. In addition, pigs are increasingly being produced within combined 'wean-to-finish' houses in order to reduce stress and labour associated with moving and regrouping pigs. Many producers also operate large group systems for pigs (i.e >50 pigs) in order to make more efficient use of resources. A wide variety of

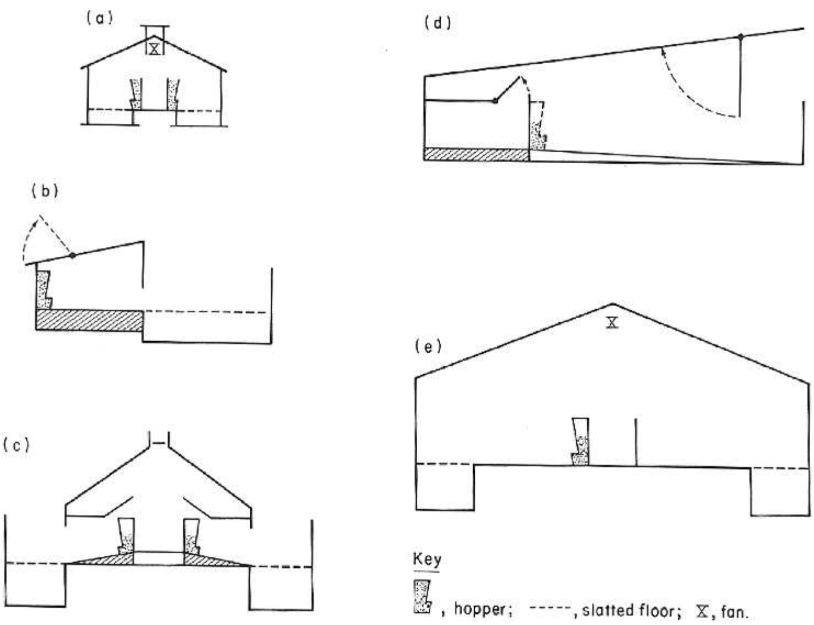

Fig. 6.2 Diagrammatic representation of some common housing types for pigs at different ages (not to scale). (**a**) Flat deck rearing pens with slatted/perforated floors, (**b**) Weaner kennel with hinged roof, (**c**) Kennel pens with veranda, (**d**) Weaner pool which may be straw based and which includes a kennel with hinged lid and a pop-hole for pigs to enter, (**e**) finisher accommodation with slatted/perforated flooring
(from UFAW, 1988)

feeding systems are also employed, ranging from liquid-, to wet-, to dry-feeding systems, which may be fed through a variety of different feeder types. This variation in production systems means that it would be impossible to discuss welfare implications of each system individually. This may also be pointless as Brent (1986) suggests that there 'is no one right way to accommodate a pig at each stage of life'. The approach adopted in this chapter is to break down the environment of the pig into a number of key components that are likely to have significant implications for welfare. The list of components covered in this chapter is by no means exhaustive, and is limited to some topical physical and social factors. The aim is to discuss the impact of these components on pig welfare, and to discuss possible ways in which components can be manipulated to maximise welfare.

6.2 Physical Factors

6.2.1 Space Allowance

In commercial pig production, efficient use of space is central to the successful management of resources. However, a fine line exists between efficient use of space and provision of insufficient space. In reality, where welfare problems exist within fattening herds, many of them can be attributed, either directly or indirectly, to inadequate space allowance. The relationship between animals and space can be defined in different ways, for example as space allowance per animal (m^2/animal), or in terms of stocking density (number of animals/m^2) (Petherick, 1983). As has been highlighted previously (SVC, 1997), both measures are mathematically equivalent but may differ substantially in terms of ethological impact. Increased stocking density invariably means increases in group size, and this latter factor is likely to be a significant factor contributing to perceptions of 'crowding' (Petherick, 1983).

Pigs require space for a number of different reasons, with requirements for physical occupation (body space) being the most obvious factor (Petherick, 1983). Space is also required to allow pigs to achieve a certain quality of life. This means providing pigs with sufficient space to be able to lie down in a fully recumbent position when desired, and to be able to freely access resources such as feed and water when required. In addition, ability to maintain discrete pen areas, such as feeding, lying and dunging areas is also important to pigs (Baxter, 1984). Quality of life is also enhanced by providing pigs with sufficient space to be able to perform species-specific exploratory and play behaviours, and to escape aggressors.

6.2.1.1 Consequences of Inadequate Space

It has traditionally proved easier to determine effects of inadequate space allowance through assessing effects on production performance. In terms of physical effects, reductions in space allowances can make it difficult for pigs to gain access to the feeder, and thus have negative effects on growth performance (Petherick, 1983). Kornegay and Notter (1984) manipulated data from a number of different trials in order to determine the magnitude of space allowance effects on feed intake by pigs of different ages. The magnitude of these effects are as follows: for weaner pigs at a floor space of 0.18 m^2 per pig, daily feed intake increased by 7% for every 0.1 m^2 increase in floor area; for grower pigs housed at a space allowance of 0.3 m^2, daily feed intake increased by 3.2% for every 0.1 m^2 increase in space; and for finisher pigs housed at a space allowance of 0.7 m^2, daily feed intake increased by 2.3% for each 0.1 m^2 increase in space. Corresponding increases in growth performance equated to 8.6, 5.2, and 2.6% respectively for the weaner, grower and finisher phases (Kornegay and Notter, 1984).

Physical restrictions imposed by small space allowances may also cause psychological stress (Baxter, 1984), and consequently adversely affect the food conversion ratio (Barnett et al., 1983). This is supported by research with growing and finishing pigs which showed reductions in growth performance associated with reduced space allowances which were not attributable to reduced feed intake (Randolph et al., 1981; Hyun et al., 1998). It is also possible however, that poorer food conversion associated with reduced space allowance may have occurred through increased spillage of feed due to increased aggression at the feeder (Walker, 1991). Effects of space allowance on food conversion ratios appear to be important at all stages of the growing cycle. For example, Kornegay and Notter (1984) found that for weaner pigs at a floor space of 0.18 m^2 per pig, the food conversion ratio decreased by 1.2% for every 0.1 m^2 increase in floor area; for grower pigs housed at a space allowance of 0.3 m^2, the food conversion ratio decreased by 1.6% for every 0.1 m^2 increase in space; and for finisher pigs housed at a space allowance of 0.7 m^2, the food conversion ratio decreased by 0.4% for each 0.1 m^2 increase in space.

Research shows that reductions in space allowance also adversely affect welfare-related parameters in pigs. For example, Pearce and Paterson (1993) observed that finishing pigs housed at low rather than high space allowances spent longer standing and sitting motionless, and exhibited higher plasma cortisol responses to exogenous adrenocorticotrophin (ACTH). Reduced space allowances also appear to be a significant contributor to episodes of harmful social behaviour such as tail-biting (Petherick, 1983). Aggressive behaviour by growing and finishing pigs is also significantly increased when space allowance is reduced (Randolph et al., 1981; Simonsen, 1990; Anil et al., 2007). This increased aggression may reflect a number of factors including an inability of pigs to clearly establish dominance relationships at mixing (Baxter, 1987), or a long-term inability to escape aggressors (Turner et al., 2000). It is also possible that pigs are more aggressive under restrictive conditions due to increased stress levels (Dantzer et al., 1980).

Increased aggression and stress associated with low space allowances may contribute to observed adverse effects on health-related parameters. For example, reduced space allowances led to increased aggression-related skin lesion scores (Turner et al. 2000; Anil et al., 2007) and reduced humoral immune responses to an antigen challenge (Turner et al., 2000). In addition, Wolter et al. (2003) found that low floor space allowance also increased the rate of removal of pigs from pens due to injury, poor health, or death.

6.2.1.2 Determination of Space Allowance

It is important to specify minimum space allowances for pigs in order to safeguard the welfare of pigs whilst promoting production efficiency. Policy directives often specify space requirements for pigs in a banded fashion, whereby a particular space allowance is recommended for all pigs falling within a particular weight band (e.g. Council Directive 2001/88/EC). However, it has been suggested by several authors that recommended space allowances for pigs should more closely relate to the actual body weight of the animal. For example, Spoolder et al. (2000) suggested that space allocations should be based on an allometric equation which relates total space requirements (A) to average pig weight (W) by some appropriate factor (a), for example: $A\ (m^2) = a \times W^{0.67}\ (kg)$.

The next step is to determine the appropriate magnitude of the factor 'a'. As pigs spend approximately 80% of their time resting (Ekkel et al., 2003), this factor should be calculated to allow sufficient space for pigs to lie down. According to Petherick (1983), factor 'a' equates to a value of 0.047 when pigs are lying in the fully recumbent position, and to a value of 0.019 when lying in the sternal position. Even under warm conditions, however it is rare for all pigs to lie apart simultaneously in a fully recumbent position (Petherick, 1983). This is supported by Ekkel et al. (2003), who found that although growing and finishing pigs prefer to lie in a recumbent position, they prefer to lie together rather than apart. These authors suggested that space allowances for growing and finishing pigs in slatted systems should be determined with factor 'a' equating to a value of 0.033. This corresponds well with earlier research which showed reductions in growth performance of pigs in slatted systems when factor 'a' values were reduced from 0.034 to 0.030 (Edwards et al., 1988).

The requirements for space are greater in solid floor/bedded systems than in slatted systems (Kornegay and Notter, 1984) due to a greater need to distinguish dunging from resting areas. In addition, it is likely pigs in straw-based systems require more room for activity than in slatted systems. Although minimum space allowances for more extensive systems do not appear to have been determined, research suggests that effects of reduced space allowance are similar to those observed in slatted systems. For example, Turner et al. (2000) found that when space allowances of growing pigs on deep-litter straw systems were reduced from 32 to 50 kg/m^2 (expressed in terms of liveweight per square metre of floor space), pigs showed increased skin lesions and reduced humoral immune response to an antigen challenge.

6.2.2 Flooring, Bedding and Enrichment

6.2.2.1 Variation in Floor Types

Choice of flooring for pigs often appears to involve a choice between what is optimal for the pig, and what is optimal for the producer. Baxter (1984) suggested that pigs are likely to prefer variable and organic flooring; however this would appear to be at odds with producer requirements in terms of pen hygiene and labour efficiency. Within housed systems, flooring is either solid or slatted/perforated, or a combination of the two. In most cases, solid floors are made from concrete, and slatted floors from either concrete or metal. Some slatted systems use plastic-coated or galvanised metal flooring for younger weaned pigs, and then concrete slats for older pigs during the growing and finishing phases. Slatted floors have benefits in terms of separating the animals from their excrement, thus leading to improvements in pen hygiene and reduced labour requirements. Improvements in pen hygiene in slatted rather than solid floor pens have been shown to lead to improved health status in young, weaned pigs (Rantzer and Svendsen, 2001). These factors may account for the fact that slatted floors (either partly or fully slatted) have become one of the most popular floor types for growing/finishing pigs within Europe (SVC, 1997).

The impact of flooring systems on other aspects of pig welfare must also be considered. Floors should be comfortable for pigs to lie, stand and walk on (Lean, 1988), and should not contribute to injury or distress (Baxter, 1984). In many cases a balance must be struck between pen cleanliness and pig comfort. Increasing the solid:void ratio in fully-slatted floors means improvements in comfort and safety, but also reductions in pen hygiene. An important factor determining potential floor-related injuries is void width in relation to foot size (Lindemann et al., 1985). Baxter (1984) suggested that the width of the void should not exceed half the width of the narrowest dimension of the contact area between the foot and the floor. Similarly, the solid area should not be less than the width of the foot, and if possible should be greater than this. Current EU legislation states that maximum void width for weaner and rearing pigs must be 14 and 18 mm respectively, and that minimum slat width for weaners and rearing pigs must be 50 and 80 mm respectively (Council Directive 2001/88/EC). Quality of manufacture of slats is also important in terms of minimising injuries. Key factors include the absence of sharp or jagged edges, and the provision of non-slip, non-abrasive surfaces (Smith, 1981). In accordance with this, research with weaner pigs has shown that foot injuries were reduced substantially by the use of plastic coating compared with uncoated expanded metal and woven wire flooring (Lindemann et al., 1985; Brennen and Aherne, 1987).

Injuries to the foot, and leg weakness problems, are reduced if pigs are housed on solid rather than slatted floors (MAFF, 1981; Jørgensen, 2003; KilBride et al., 2008). In addition, pigs show a preference for resting on solid rather than slatted floors (Aarnink et al., 1994). These factors suggest that there may be some welfare benefits associated with moving from fully slatted to either

Fig. 6.3 Pen system for finishing pigs, showing straw bedded kennel and minimally bedded, solid-floored dunging/loafing area

partly, or fully solid floors. There may also be production benefits associated with this move. For example, pigs appear to show improved growth rates when housed on solid rather than slatted floors (Verstegen and van der Hel, 1974). Increasing the solid proportion of the pen floor may also reduce adverse environmental impacts of pig production through reducing ammonia emissions (Aarnink et al., 1994). However, if fully solid floors are used, research suggests that bedding should also be used. For example, KilBride et al. (2008) showed that the risk of capped hock was lower in deep bedded, solid floored pens than in pens with little straw over a solid floor or part- and fully-slatted floors. The same authors also found that bursitis incidence increased in a similar way to a dose response: deep straw < little straw < part-slatted < fully-slatted. Jørgensen (2003) showed that claw disorders, and incidence of sole and white line lesions were greater with unbedded fully-solid floors, than with bedded solid floors or slatted floors. It was suggested that some of these injuries may have reflected traumatic injuries associated with slipping on wet and dirty floors. These problems may also be reduced by use of slatted areas in the pens. Aarnink et al. (1994) found that incorporation of a slatted area covering 25% of the pen was sufficient to prevent fouling of the solid part of the pen.

6.2.2.2 Bedding and Enrichment

In addition to reducing injury levels, provision of bedding also has benefits in terms of improving the physical comfort of the pigs (Baxter, 1984). This is evidenced by the fact that pigs take less time to lie down, and spend more time lying laterally, in bedded rather than unbedded pens (Böhmer and Hoy, 1993). In addition, pigs show a marked preference for spending time in bedded rather than unbedded pens (Beattie et al., 1998). One of the most important functions of bedding, however, is to increase levels of environmental complexity. In general, increased intensification of pig housing systems has led to the development of relatively sterile and unstimulating environments. Research suggests that this contributes to 'apathy' in pigs (Ruiterkamp, 1987), and also to chronic stress (Beattie et al., 2000; de Jong et al., 2000a). In these intensive environments, pigs often show high levels of behavioural inactivity (Wood-Gush and Beilharz, 1983; Beattie et al., 2000), which is thought to reflect a 'cut-off' strategy to enable pigs to distance themselves from their environment (Pearce et al., 1989). These barren environments also appear to have more fundamental effects on the welfare of pigs in terms of leading to impairment of cognitive function (Sneddon et al., 2000), and increased fearfulness (Pearce et al., 1989; Beattie et al., 2000). Recent research suggests that barren rearing environments also adversely affect maternal behaviour of gilts, and that this can lead to increased levels of harmful social behaviour among offspring (O'Connell et al., 2005a).

One of the most common criticisms of barren rearing environments for pigs is that they do not provide an outlet for highly motivated exploratory behaviours. Pigs have a natural instinct to perform manipulative or 'rooting' behaviour with the snout (Beattie and O'Connell, 2002), and will spend significant proportions of daylight hours in natural environments performing this behaviour. When housed in barren environments without access to substrates, pigs often redirect this rooting behaviour towards pen fittings (Petersen et al., 1995; Guy et al., 2002) and pen-mates (de Jong et al., 1998; Beattie et al., 1995, 2000). This increased manipulation of pen-mates contributes to increased levels of injurious behaviours such as belly-nosing and tail-biting (Petersen et al., 1995; Beattie et al., 1995), and also to increased aggression (Beattie et al., 1995). The provision of enriching substrates in the pen therefore has benefits in terms of providing an outlet for exploratory behaviour, and thus reducing adverse social behaviours. Additional benefits are also shown when enriching substrates are provided, in the form of increased levels of play behaviour (Beattie et al., 1995).

The type of environmental enrichment which is provided must be compatible with the housing system used. The provision of bedding has inherent physical and thermal comfort values (Arey, 1993), but is not suitable for fully-slatted systems. In addition, commonly-used bedding substrates such as straw may be in short supply in some locations. In these cases, localised enriching devices are often used, which may consist of either substrate dispensers or troughs, or 'toys' which are either hung in the pen or placed on the ground. A wide variety of toys can be used, and may range from blocks of wood to chains (Fig. 6.4), car tyres or plastic rods. The success of these toys as enriching devices has been variable, and in some cases they appear to lose their stimulus value over time (Schaefer et al., 1990). Newberry (1995) suggested that in order to be effective, enriching

Fig. 6.4 Flat-deck weaner accommodation, with plastic-coated, woven wire floor and 'enrichments' including chain and destructible plastic ball

devices should be functionally relevant to the animal. Research has shown that enriching devices that stimulate foraging or exploratory behaviour are successful in this respect (Beattie et al., 2001, Van de Weerd et al., 2003). Characteristics which stimulate this type of behaviour and which should therefore be included in enriching devices include being 'ingestible', 'odorous', 'chewable', 'deformable' and 'destructable' (Van de Weerd et al., 2003). Replacing long-stemmed or short-stemmed straw with chopped straw can adversely affect the ability of the pigs to manipulate it, and can result in greater incidence of tail-biting (Day et al., 2008).

6.2.3 Feeder Design

6.2.3.1 Weaned Pigs

It could be argued that the requirements of pigs in terms of feeder design are more critical in the post weaning period than at any other period in life. Under natural conditions, weaning is a gradual process which may not be complete until pigs are 17 weeks of age (Jensen and Recén, 1989). Under commercial conditions, however, pigs are often weaned abruptly at a much younger age (for example 3 or 4 weeks of age). This practice often leads to significant reductions in feed intake by the pigs (Pluske et al., 1997), which not only affects growth performance, but also has negative welfare implications. For example Beattie et al. (1999) showed that, on average, pigs weaned at 28 days of age consume as little as 15 g of dry pelleted feed during the first 24 hours post weaning. This low feed intake may reflect a number of factors, including difficulty adapting to a completely solid diet (Fraser et al., 1998), and to using a feeder for the first time (Pluske and Williams, 1996). In addition, stress caused by social and environmental changes at weaning is also likely to contribute to reduced feed intakes.

It has been suggested that feed intake by weaned pigs may be stimulated by allowing pigs to feed simultaneously as in the situation prior to weaning, and to mix feed with water in the trough (Fraser et al., 1998). These factors have led to the widespread use of 'communal' feeders for weaned pigs, which allow a number of animals to feed simultaneously from the same trough, and to mix feed with water. However, encouraging pigs to feed and drink from the same trough may lead to increased levels of competition at the feeder (Baxter, 1983). This is supported by research which showed increased levels of aggression, and altered diurnal feeding patterns in 'communal' rather than traditional 'dry multi-space' feeders (O'Connell et al., 2002). 'Multi-space' feeders have benefits in terms of allowing pigs to feed simultaneously from the same trough, but from different feeding spaces within the trough. Research shows that this leads to greater levels of feed intake than with some commonly used 'communal' feeders (O'Connell et al., 2002). In addition, feed intake levels do not appear to be improved by the presence of drinkers in the trough, which allow pigs to mix feed with water. In fact, research suggests that young, weaned pigs may have difficulty learning to operate these drinkers, and that this leads to the accumulation of wet, unpalatable feed (Pluske and Williams, 1996; O'Connell et al., 2002). Other aspects of feeder design that can influence feed intake of weaned pigs includes depth of trough, size of feeder gap, lip height and side panels (Laitat et al., 2005).

6.2.3.2 Growing and Finishing Pigs

Providing sufficient access to feed is a fundamental factor affecting the welfare of growing and finishing pigs. As Baxter (1983) points out, a significant proportion of the aggression that occurs amongst established groups of pigs occurs at the feeder. Access to feed is of primary importance when pigs are fed using a restricted feeding regime (Vargas et al., 1987). Baxter (1984) suggested that under these conditions, sufficient feeder space should be provided for all pigs to feed simultaneously. In communal feeders, individual trough space requirements for Large White $\times$ Landrace pigs can be calculated using the following equation: W (width cm) $= 6 \times$ live weight (kg)$^{0.33}$ (Baxter, 1984). However, many pigs are now sufficiently genetically improved to be fed on an ad libitum basis without becoming overly fat. Even within ad libitum systems, however, sufficient access to feed must be provided. Baxter (1984) recommended that one feeding space should be provided for every four pigs that are being fed on an ad libitum basis. It has even been suggested that one feeding space should be provided for every two to three pigs (Bogner, 1981). Conventional 'single-space' feeders require pigs to place their head inside an enclosed trough while feeding. These feeders thus have benefits in terms of protecting the head and ears of the pig from attack while feeding (Baxter, 1989). Research suggests that one 'single-space' feeder should be provided for every 10 pigs in order to maximise welfare and performance (Walker, 1991; Morrow and Walker, 1994).

Reducing the feeder space per pig has fairly predictable effects on pig performance and behaviour. For example, Hyun and Ellis (2001) found that feed intake and growth rate were reduced when the number of growing pigs per single-space feeder was increased from 2 to 12. Reduced feeder space per pig also leads to increased variability in performance, with small pigs being penalised in terms of gaining access to the feeder (Hansen et al., 1982; Georgsson and Svendsen, 2002). This corresponds with the concept of 'social workload' discussed by Walker (1995). 'Social workload' was the term used to describe the 'effort required and aggression encountered in negotiating a route through penmates to a feeder and dislodging pigs which are either feeding or obstructing the feeder'. Walker (1995) suggested that subordinate pigs may be discouraged from using the feeder in situations when the social workload is likely to be high.

Diurnal feeding patterns are also affected by levels of feeder access. Under normal conditions, pigs show a fairly typical diurnal feeding pattern with two peaks in feeding activity, a smaller one before and a larger one after midday (Morrow and Walker, 1994; O'Connell et al., 2002). These peaks may be related to the beginning and end of the light cycle (Feddes et al., 1989), or to stockperson activity (Morrow and Walker, 1994). When feeder space is restricted, these peaks in demand for the feeder become less distinct, and pigs show an overall increase in feeder occupancy (Laitat et al., 1999; O'Connell et al., 2002). Whether or not altered diurnal feeding patterns actually reflect poorer welfare in pigs is difficult to determine (Laitat et al., 1999). However, the increased levels of disturbance caused to resting animals due to higher levels of activity during resting periods must also be taken into account. In addition, it is not only diurnal feeding patterns, but also individual meal characteristics that are affected by access to feed. For example, research has shown that group-housed pigs make fewer, longer visits to the feeder when fed from individual electronic feeders than from multi-space feeders (Nielsen et al., 1996). In addition, pigs also appear to show an increased rate of eating when access to feed is restricted (Nielsen et al., 1995; Gonyou and Lou, 2000).

In addition to feeder space per pig, positioning of feeders in the pen is an important factor determining access to the feeder. Georgsson and Svendsen (2002) suggested that in order to maximise performance and welfare, feeding systems should be designed to prevent dominant animals in the pen excessively occupying the feeder. This is likely to be a more important problem in systems where pigs are fed using 'single-space' rather than 'multi-space' feeders due to reduced number of feeding spaces per pig. Previous research suggests that this problem may be reduced by placing 'single-space' feeders at a distance of at least 2 m apart in the pen (Walker et al., 1993).

6.3 Social Factors

6.3.1 Group Formation

Commercially-reared pigs are often regrouped at least once during the production cycle to create groups of pigs of the required size or weight uniformity. In practice, this regrouping often occurs at weaning, and possibly also again at the start of the finishing period. It has become evident from research that the post regrouping period represents a difficult time for pigs. In addition to having a negative effect on productivity (Tan et al., 1991; Stookey and Gonyou, 1994), regrouping unfamiliar pigs also leads to increased injury (Gonyou et al., 1988) and stress hormone levels (Moore et al., 1994). This stress is often attributed to the physical aggression that occurs during the post regrouping period as dominance relationships are established. For example, individual fights among growing pigs during the initial period after regrouping may last for 20–30 minutes (Meese and Ewbank, 1973). In addition, this heightened aggression may remain evident for a number of days (Stookey and Gonyou, 1994) or even weeks after re-grouping (Tan and Shackleton, 1990). However stress at regrouping is not only due to physical fighting but also to more subtle psychological factors such as social strangeness (Zayan, 1991).

Different management regimes may be adopted in commercial practice to reduce aggression among regrouped pigs. For example, fighting between unfamiliar pigs may be motivated by uncertainty about relative fighting ability (Rushen, 1990). Evidence suggests that this uncertainty is reduced if pigs from different litters are allowed to socialise prior to regrouping at weaning (Weary et al., 1999). In addition, uncertainty about relative fighting ability may also be reduced through forming groups of pigs that are dissimilar in weight (Rushen, 1987). However, recent research suggests that relatively large dissimilarities in weight are required to reduce aggression between regrouped pigs (O'Connell et al., 2005). Environmental factors may also be manipulated to reduce aggression among regrouped pigs. For example, aggression is reduced if pigs are regrouped in pens that contain enriching devices or 'toys', which appear to act as a diversion to the pigs (Schaefer et al., 1990). In addition, providing areas in the pens where regrouped pigs can 'hide' their head and shoulders can also lead to reduced aggression (McGlone and Curtis, 1985). At a more fundamental level, rearing pigs in complex and/or spacious environments has benefits in terms of promoting social development, and consequently in reducing aggression between pigs (Lammers and Schouten, 1985; O'Connell and Beattie, 1999).

6.3.2 Social Status

As previously stated, the aggression that occurs after regrouping of pigs is associated with the establishment of social hierarchies. Evidence suggests that social status within these hierarchies has a marked effect on the subsequent welfare of growing pigs. For example, Meese and Ewbank (1972) referred to the 'harassment and reduced weight gain at the lower end of the dominance order'. Similarly, recent research showed that growing pigs with low social status suffered greater injuries and had greater difficulty gaining access to resources such as the feeder than pigs with high social status (O'Connell et al., 2004a). These factors may contribute to the increased physiological stress (Ruis et al., 2002) and reduced immune capacity (McGlone et al., 1993) observed in growing pigs with low social status. Research has also shown that pigs with low social status also show increased responsiveness to certain acute stressors (Hicks et al., 1998; de Jong et al., 2000b). It is possible that this increased responsiveness may reflect increased fearfulness, as previous work with poultry found that lower ranking birds were more fearful than higher ranking animals (Cunningham et al., 1988).

It is possible to influence the welfare of pigs with low social status through altering management and housing factors. Systems that are restrictive in terms of access to resources such as feed or space tend to exacerbate the negative effects of low social status (Baxter, 1984; O'Connell et al., 2004b). In addition, research by de Jonge et al. (1996) and Olsson et al. (1999) suggest that it is possible to reduce the negative effects of low social status on the welfare of growing pigs by rearing pigs under extensive conditions. The conditions used in these studies involved allowing pigs to socialise with animals from different litters in free ranging environments prior to weaning. While it is likely that these types of conditions during rearing may specifically improve the development of social skills among pigs, they may not always be commercially viable. More recent research has shown that it is also possible to improve the welfare of commercially-reared growing pigs with low social status through rearing them in more complex environments (O'Connell et al., 2004a).

6.3.3 Group Size

Housing fattening pigs in large groups (Fig. 6.5) has potential advantages for producers in terms of leading to more efficient use of resources, such as space, pen divisions, feeders and drinkers, and also to greater ease of management. For these reasons, large group systems for pigs (i.e. groups of more than 50 pigs) appear to be becoming increasingly popular with producers. However, a common concern associated with increasing group size is the effect that it will have on levels of social unrest and aggression, and consequently on health status. Baxter (1984) suggested that in order for social stability to be maintained, each pig within a group should be able to recognise every other pig and remember their relative social status. It is estimated that the number of pigs that can be recognised by an individual is between 20 and 30 animals (Fraser and Broom, 1998). This suggests that when group sizes are increased above this number, there will be chronic aggression associated with permanent social instability.

Fig. 6.5 Weaners housed in a group of approximately 100 in a deep straw-bedded Swedish multisuckling pen, following sow removal

However, this does not appear to be the case in practice, and evidence suggests that varying group sizes (at standard floor and feeder space allocations) has little effect on welfare and health parameters. For example, recent studies found no adverse effects on aggressive behaviour when group sizes were increased from 10 to 60 pigs (Turner et al., 1999; O'Connell et al., 2004b). In addition, immune status parameters in growing pigs were not affected by increasing group sizes from 10 to 80 animals (Schmolke et al., 2003).

The fact that increasing group size does not automatically lead to increased levels of aggression may be related to a number of factors. Firstly, it is likely that mechanisms of social regulation are different within larger rather than smaller groups of pigs. Research carried out by Turner et al. (2001) suggested that social regulation was mediated through aggression to a greater extent in smaller than in larger group systems. These authors suggested that within larger group sizes, pigs may adopt more energy-efficient social strategies that do not involve high levels of aggression. In addition, when group sizes are increased, pigs also experience an increase in available or 'free' space. The relationship between 'free' space and group size can be expressed by the equation $Y = 0.179 + 0.002092X$, where Y is free space and X is the number of growing/finishing pigs per pen (McGlone and Newby, 1994). The increase in free space associated with increasing group size may contribute to reduced aggression through allowing pigs to perform active behaviours without disturbing other animals in the group, and through providing a better ability to escape aggressors (Turner et al., 1999).

The effect of increasing group size on production performance has yielded conflicting results, with some authors finding no adverse effects on performance and others showing reduced growth performance with increasing group size. Where negative effects are found due to increasing group size, they tend to be shown with younger as opposed to older animals. For example, Wolter et al. (2001) found that increasing group size from 25 to 100 animals had adverse effects on growth performance during the growing phase, but not the finishing phase. In addition, analysis of data from 20 studies involving 22,000 pigs housed in group sizes from 3 to 120 pigs found decreases in performance in weaner and growing pigs, but not in finishing pigs, when group sizes were increased (Turner et al., 2003). It was suggested that decreases in performance in grower pigs may have reflected increased energy expenditure associated with having to walk greater distances to access feeders and drinkers in larger groups (Turner et al., 2003). It has also been suggested that younger pigs are less sophisticated in feeding behaviour than older animals, in terms of their ability to adapt feeding behaviour to suit large group situations (Hyun and Ellis, 2001; Wolter et al., 2001).

6.4 Conclusions

It is evident that physical and social factors associated with pig production have significant implications for welfare and productivity. Research over the last 30–40 years has been pivotal in terms of quantifying these effects. There is no doubt that a shift in emphasis has occurred within pig housing systems, and that it will continue to occur over the coming years. Emphasis is increasingly being placed on welfare requirements of pigs, and is being enforced through legislation and quality assurance schemes. In many cases, welfare requirements are based on allowing pigs greater behavioural freedom, for example to lie comfortably or to perform natural exploratory behaviour. The challenge for researchers is to find ways to allow producers to meet these requirements for welfare, while simultaneously maintaining high levels of production efficiency. This work is already underway. For example, research discussed in this chapter has highlighted methods of increasing environmental complexity, and of deter-mining space allowances within intensive production systems. In addition, management techniques aimed at reducing problems relating to aggression and social stress have also been highlighted.

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Chapter 7
Pigs and Humans

Hans A.M. Spoolder and Susanne Waiblinger

7.1 Introduction

The human is an important part of the pigs' environment: he or she is impacting upon the animals both directly, by working with them or being in close proximity, and indirectly via management decisions on the production process or on housing design (Schlichting, 1974). Professional characteristics (e.g. knowledge, experience) as well as personal ones (e.g. empathy, attention to detail) contribute to differences between stockpeople in their way of interacting (Grommers, 1987). Additionally, situational variables such as time constraints or family problems, influence the behaviour of humans (Schiefele, 1990). Maintaining good welfare and productivity relies on understanding how and which stockpeople perform best, as well as understanding and catering for the needs of the animals. Solving problems with human-animal interactions (particularly when it involves handling) is easier if it is clear how the stockperson as well as the animal perceive the situation.

This chapter examines reasons for a stockperson's behaviour towards pigs, the way pigs perceive their environment, the effects of human behaviour on the animals and possible ways to improve human-pig interactions. An overview of the main variables discussed and their interrelationships is presented in Fig. 7.1.

7.2 What Makes a Good Pig-Person?

A good relationship between humans and the animals under their care is crucial for good animal welfare, health and production. The mutual perception of humans and animals then involves mainly pleasant emotions and motivations and few unpleasant ones such as fear or frustration (Waiblinger et al., 2006a). In a good relationship, humans are more patient with the animals, they show more

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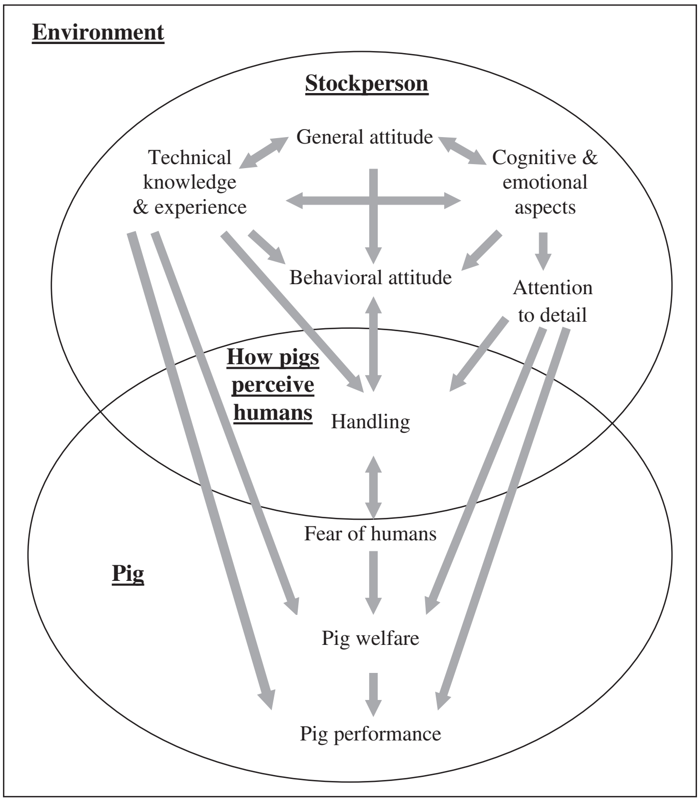

Fig. 7.1 Simplified diagram of the interplay and effects of attitudes, knowledge and experience on stockpeople behaviour and subsequent pigs' welfare and performance

gentle interactions, they like interacting with the animals and they perceive animals as sentient beings with individuality and with physical and psychological needs which they try to and often do understand. But not every stockperson thinks and acts like this. Humans differ considerably in how they interact with animals and in their management style and decisions. We will review the most important underlying factors.

7.2.1 Attitudes and Other Personal Variables

Personality and attitude are the major concepts used in psychology in explaining behaviour in humans (Rotter and Hochreich, 1979; Ajzen, 1988; Schiefele, 1990).

Personality can be defined as an individual's unique system of traits that affect how he or she interacts with the environment. Personality characteristics are relatively stable over time (Costa and McCrae, 1986). The personality of a stockperson is related to their management, to their human-animal interactions, and to animal productivity (e.g. Seabrook, 1972; Seabrook, 1995; Waiblinger, 1996; Waiblinger et al., 2002). When measured using a personality inventory questionnaire, higher scores in the "implied non-aggression level" – meaning that the person shows a lower disposition to be aggressive – was negatively correlated to mortality and positively to the number of reared piglets per sow (Seabrook and Darroch, 1990). Similarly, high performance in sows was positively correlated to warmth, emotional stability and self-discipline from the stockperson (Ravel et al., 1996). Different personality characteristics may influence different aspects (i.e. management, handling) of stockmanship. Patient and agreeable humans interacted with their animals more positively (talking with them calmly, stroking them) and less negatively (shouting at, hitting strongly), while confidence was related to good management, showing understanding for the animals' needs (Waiblinger, 1996). Some personal characteristics may have a direct effect on behaviour (agreeableness), while others act indirectly by influencing attitude formation (Waiblinger et al., 2002).

Attitudes are learnt, object-related and changeable by new information or experiences (Ajzen, 1988). They are often seen to be the most important causal factor of a person's behaviour towards social objects (Schiefele, 1990) and this seems to hold true also for human-animal interactions. The formation of (general) attitudes, including attitudes towards animals, starts in childhood. Attitudes towards specific behaviours are also built and modified by experience. The influence of stockpersons' attitudes on their interactions with the animals and on subsequent behaviour and productivity of the animals, has been shown in pigs (Hemsworth et al., 1989, 1994; Coleman et al., 1998, 2000) and cattle (Hemsworth et al., 2000; Lensink et al., 2000; Hemsworth et al., 2002; Waiblinger et al., 2002). Recently, positive correlations were also found between positive cognitive, emotional and behavioural attitudes and the degree to which the housing was designed and managed to fulfil the animals' needs (Waiblinger et al., 2006b). Together with work on management styles (Van der Ploeg, 1994) and results in veal calf production (Lensink et al., 2000), this suggests that a broader influence of the stockpersons' attitude towards the animals is not only limited to the direct interactions but also acts on the indirect aspects of stockmanship, such as attention to detail, readiness to solve problems and decisions in management and housing. Moreover, attitudes may be related to general aspects of work, such as job-satisfaction, work motivation and motivation to learn, which together influence the stockperson's work performance and, subsequently, the welfare and productivity of the animals (Coleman et al., 1998; Hemsworth and Coleman, 1998). This relationship is not unidirectional: attitudes might act on job-satisfaction, but also vice versa (Hemsworth and Coleman, 1998; Seabrook, 2001). Furthermore, the behavioural situation feeds back on attitudes (Hemsworth and Coleman, 1998).

Some other characteristics of the stockperson may also have effects on his or her behaviour. Empathy with animals may influence the development of beliefs about pigs themselves and about handling pigs (Coleman et al., 2000, 2001).

Gender seems to have an effect on attitudes and behaviour to animals, with women showing more positive attitudes and interactions than men (Hills, 1993; Lensink et al., 2000) and, by this pathway, probably bear fewer risks of accidents (Mack, 1979). Hills (1993) reported higher empathy scores for women in agriculture.

7.2.2 Knowledge and Experience

Positive attitude and empathy alone are not sufficient for good stockmanship. Inexperienced people with positive attitudes might quickly learn about the behaviour of the animals and the best way to handle them, but basic knowledge about animal behaviour and handling techniques will support this process. In gaining experience, preformed attitudes towards pigs and behaviour towards pigs are modified. If the first experiences are made more successful, a positive attitude is instilled, while failures at the beginning may develop the attitude in the opposite direction. This interacts also with knowledge and experience: an experienced pig handler will almost intuitively know how a pig will respond when trying to get past him in a corridor. He will also know when to give up trying to stop it. Calming a stressed pig down by letting it pass and then quietly but determinately collecting it again is sometimes the best option. If and when to let it pass is a matter of experience with handling.

7.2.3 Situational Variables

Personal and professional variables determine the intention to perform a behaviour, but the actual behaviour is further influenced by variables of the actual situation. These are, for example, the possibilities to perform a behaviour and the possibilities for alternative behaviours, the perceived consequences of a behaviour, the perception of the situation and influences of colleagues. Seabrook (2001) describes how the positive attitudes of new staff towards pigs might be challenged and changed (adapted to the actual situation) by a system where they found pigs being treated as machines. The same author highlights the important role that the colleagues or manager takes for the behaviour of (new) staff: the level of aggression on pig units was affected by the actions of role models. High aggression managers tend to have high aggression staff.

Higher workload may negatively affect human-animal interactions. Lensink et al., (2000) found fewer positive interactions in larger farms and inferred that this can be explained by the perceived workload. On dairy farms, the total working time estimated by the milkers, was positively correlated with the number and percentage of negative interactions during milking, and negatively correlated with the percentage of positive interactions (Waiblinger et al., 2003). In both cases, the attitude variables did not differ, but only the behaviour. Thus, lack of time or level of pressure seems to directly act on the behaviour. Time pressure is mentioned by stockpeople as reason for aversive actions (Seabrook, 2001). In abattoir personnel, the beliefs about the importance of moving the pigs as quickly as possible to the stunner were related to their behaviour towards the pigs (Coleman et al., 2003).

7.3 Think Pig: How Does a Pig Perceive the World?

A good stockperson understands pigs. With this statement much more is implied than just understanding what the best type of feed is or the first signs of a particular health problem, although these technical issues are equally important. A good stockperson knows consciously, or subconsciously, how pigs perceive the world. This enables him to anticipate pig behavioural responses and to attend to their needs.

Wild pigs live in woodland, often with dense undergrowth. They live in small groups of 1–4 sows with their offspring (Signoret et al., 1975). Adult boars leave the group and lead a solitary life. For communication and exploration, pigs rely primarily on olfactory and auditory signals: hearing and smell are well-developed senses. Their natural habitat does not allow visual cues over long distances. Hutson et al. (1993) lists visual cues among the least interesting when trying to stimulate sows. In contrast, olfactory (Eucalyptus oil), auditory (play back of grunting) or tactile (water/slap) cues were more effective in inducing a response. To understand how pigs respond to these different cues, a stockperson first has to have some general idea how pigs perceive their environment.

7.3.1 Olfaction

Pigs use their highly-developed sense of smell to find food and to recognise other individuals Fig. 7.2. The substances which convey information from one pig to another are called pheromones (Albone, 1984). Primer and releaser pheromones have been identified (see Sommerville and Broom, 1998). Primer pheromones exert a medium to long term effect. An example in pigs is androstenone (an androgen metabolite, 5a-androst-16-en-3-one; the first pheromone to be chemically identified), which is present in boar saliva. It advances and synchronises puberty in immature gilts, and may induce lactational oestrus in sows which have recently farrowed. It is suspected that there are also female pheromones actively inducing sexual development of the immature boar (Sommerville and Broom, 1998). Releaser pheromones exert an immediate effect on the recipient. Androstenone (as well as androstenol) affects the behavioural responses of sows in heat immediately: within a few seconds of smelling these substances from a spray can or the saliva of a mature boar an oestrous female will show a standing response, or lordosis, (Booth, 1975).

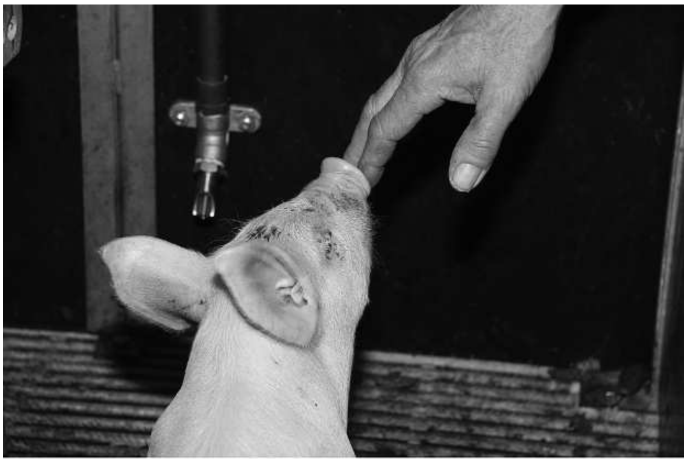

Fig. 7.2 Olfaction is arguably the most important of the pig's senses (Photo source: Marrit van Engen, FarmulaOne)

Olfaction is also used to recognise other individuals of the same species. Kennedy and Broom (1994, 1996) effectively reduced aggression on introduction of unfamiliar gilts to a group by allowing the animals to smell each other prior to grouping. Olfaction is important for hierarchy formation (Ewbank et al., 1974; Meese and Baldwin, 1975). Anosmic pigs show less aggressive behaviour during feeding and new encounters. Identification between sows and piglets just after parturition is by olfaction (Horrell and Hodgson, 1992). There are a number of other pheromones which have yet to be identified chemically, but which are assumed to influence aggression, either by reducing it (showing submission to the winner) or by increasing aggression in other pigs through emission of pheromones by a stressed animal (Sommerville and Broom, 1998). Fear pheromones in the pig have yet to be identified, although their existence is suspected in other mammals such as rodents (Mackay-Sim and Lang, 1981).

7.3.2 Hearing and Vocalization

Communication of gregarious animals living in forested areas requires good vocalisation and hearing skills. The hearing range of pigs is between 42 Hz and 40,500 Hz (compared to humans between 31 Hz and 17,600 Hz), which is a wider range than those of horses, cattle and goats (Heffner, 1998). They also have a highly developed ability to localise sound (Heffner and Heffner, 1989). Pigs communicate vocally in many different ways, using a range of different sounds. Kiley (1972) distinguishes 14 different vocalisations, most of which are associated with a range of situations. However, some (long grunts, barks, squeals) appear to be more specific for certain situations. Marchant et al.

(2001) relates short, single grunts to exploratory behaviour, although a third of the short grunts observed in their study was related to other types of behaviour - arousal, warning, contact or greeting. Long single grunts were associated with locomotor behaviour. Three-quarters of long grunts appear to be contact calls, perhaps related to social isolation. Squeals are related to distress, and short rapidly-repeated grunts may serve a ‘greeting’ function (Marchant et al., 2001).

7.3.3 Vision

The pig’s retina, pupil and lens are very similar to those of humans, even more so than for any of the other common farm animal (Klopfer, 1965; Graf, 1976). Pigs and humans have similar eyeball size and retinal area. This suggests similar light gathering capability. However, pigs have far fewer cone cells than humans. This implies that their vision is poorer than humans (Graf, 1976). Zonderland et al. (2008) investigated the visual acuity of pigs, i.e. their ability to distinguish details and shapes. In their study they tested the pigs ability to discriminate between an ‘O’ and a ‘C’, at different shape sizes and light intensities (from 0.5 to 80 Lux). They concluded that the illuminant level is less important for the pig’s ability to distinguish visual cues, compared to the size of the visual cue.

Pigs can see different colours, as they possess rods and cones which would indicate that they could identify different wavelengths of light (Lomas et al., 1998). Demonstrating the ability to distinguish colours is difficult as light intensity has to be taken into account. Tanida et al. (1991) suggest that pigs

Fig. 7.3 The pig has a wider field of vision compared to humans, but at the same time, is a poorer judge of distances
(Photo source: Marrit van Engen, FarmulaOne)

may be red-green colour blind, but can distinguish blue from grey. Mayhew (1994) could not demonstrate blue-green discrimination in piglets, although pot-bellied pigs show electroretinogram peaks in blue and green light areas (Mayhew, 1994).

Adult pigs have an angle of view of approximately 310° (Prince, 1977). This allows them to keep a constant visual check on their environment, but it may reduce their ability to assess distances to objects (Grandin, 1980). In 23-week-old pigs, Tanida et al. (1996) estimates the angle to be less (about 250°), on the basis of flight zone. Pigs have a low viewpoint: their head is close to the ground most of the time Fig. 7.3.

Their natural habitat places less demands on vision than it does on smell and hearing. Evidence for this is that the formation of stable group hierarchies do not rely on the animals being able to see (Ewbank et al., 1974).

7.4 A Pig's Perception of Humans

We can, of course, not be sure how pigs perceive humans. We can only describe how pigs respond to human presence, both behaviourally and physiologically. Their responses tell us something about how they perceive stockpeople and their specific actions.

To understand a pig's perception of humans, it is important to understand that human-animal relationships are both interactive as well as dynamic. The relationship is strongly influenced by the nature of the interactions and vice versa (Estep and Hetts, 1992). By improving the human-pig relationship, the perception of the human by the pig changes. Fear of humans may therefore be reduced through improvement of human-animal interactions (Hemsworth and Coleman, 1998), but this may even be taken a few steps further: humans may be perceived by the animals in a positive way. Every stockperson knows that sows and boars which are used to being stroked actively seek human contact and relax when positively interacted with (e.g. scratching, talking, stroking). Work with sheep also suggests humans can be perceived as a source of pleasure or social support (Korff, 1996; Boivin et al., 2000). In sheep and cattle, stress reducing effects have been shown through the presence of familiar humans or by positive interactions during aversive situations like isolation or veterinary procedures (Korff, 1996; Waiblinger et al., 2003). It is likely, that this can apply also to pig husbandry systems, where regular positive contact occurs.

7.4.1 The Signals that Humans Send

Hediger (1965) describes five different kinds of roles or meanings of the human for an animal that are most often observed: (1) the human as predator, (2) the human as prey, (3) the human as part of the environment without social significance, (4) the human as symbiont, and (5) the human as a conspecific.

These perceptions are not exclusive, but an animal probably perceives any given human as a member of a combination of these (Estep and Hetts, 1992), depending on previous experience.

The animal perceives the human by smell, voice and other sounds, touch and behaviour, including complex pattern recognition (Seabrook, 1986). Tanida et al. (1996) showed that posture, distance, type of movement and direction of approach affects a pig's fear response. Piglets approached a dummy lying face down significantly quicker than dummies bending forward or standing up. Pigs also appear to come closer to people in quadrupedal posture. The amount of body visible over a partition (face, upper half body, from knees up) did not affect behavioural response: the overriding signal seems to be the fact that the person is standing and taller than the animal. Hemsworth et al. (1986b) confirms that a low posture (squatting) reduced the latency of 8–12 week old animals to approach the human. The pigs were also quicker to interact when the observer did not approach the animals or tried to initiate interaction. When the observer wore gloves, pigs were slower to approach as opposed to an observer with bare hands. The authors suggest that olfactory cues may be related to this.

Animals generalize their experiences with one human to other humans (e.g. Tanida et al., 1995; Hemsworth et al., 1996b), but they also discriminate between people (Tanida and Nagano, 1998; Koba and Tanida, 1999). Identification is possibly based on size and posture, and less likely via facial characteristics (Koba and Tanida, 2001). Therefore, although pigs can discriminate between humans and apparently use visual over olfactory cues, they need strong extra cues to do so. It is likely that under commercial conditions they do not receive these (Hemsworth, 2000).

The signals that humans send, knowingly or not, directly influence a pig's perception of humans. From the pig's perspective, the relationship with the stockperson can range from affectionate to fearful, depending on its previous experience of the human-animal interactions.

7.4.2 Using Approach Latencies to Measure Fear or Affection of Humans

Gray (1987) described fear as a hypothetical state of the brain, or neuroendocrine system, arising under certain conditions and eventuating in certain forms of behaviour. This definition probably applies to any motivational state, so the challenge is to find methods in which this hypothetical state can be identified and quantified in relation to conditions and behaviours involved. Hemsworth and co-workers have pioneered the way in which fear of humans by pigs is assessed in a functional way. They use the approach behaviour of the animal to a human observer in a standard arena (e.g. Hemsworth et al., 1994). This involves an arena of approximately 2.4 × 2.4 m with 1.2 m high walls and a concrete floor. The arena is preferably situated near the animal's home pen. Each animal is introduced individually into the arena and the experimenter enters after a two minute familiarisation period. The experimenter stands at the mid point of the wall opposite the entrance. During the next three minutes a number of observations are made: the time taken by the pig to enter the area within 0.5 m of the observer, the total time spent in this area, the number of physical interactions with the experimenter, the time to first physical interaction with the experimenter. This standard approach test was adopted by several other groups studying fear in livestock animals.

More recently, Marchant et al. (1999) have addressed some of the issues relating to the design of the test. In particular the confounding effects of fear and exploration on approach behaviour of pigs when they are tested in a novel environment were investigated. In a novel arena, pigs spend more time investigating the periphery, which is where the unfamiliar human is standing, meaning that contact with the human in some cases may be incidental rather than purposeful (Marchant-Forde, unpublished results).

Using approach latencies to humans as a measure of fear, Hemsworth et al. (1986a) found significant litter effects in young pigs (8–12 weeks) and concluded that there might be a genetic component involved. Later work confirmed there was a moderate hereditary effect on fear responses in an approach test ($h^2 = 0.376$; s.e. = 0.19; Hemsworth et al., 1990). However, the frequency and nature of the interactions between humans and pigs appears to have considerably more effect on approach latencies Fig. 7.4. Evidence for a strong and predictable relationship between prior handling experiences and fear of humans

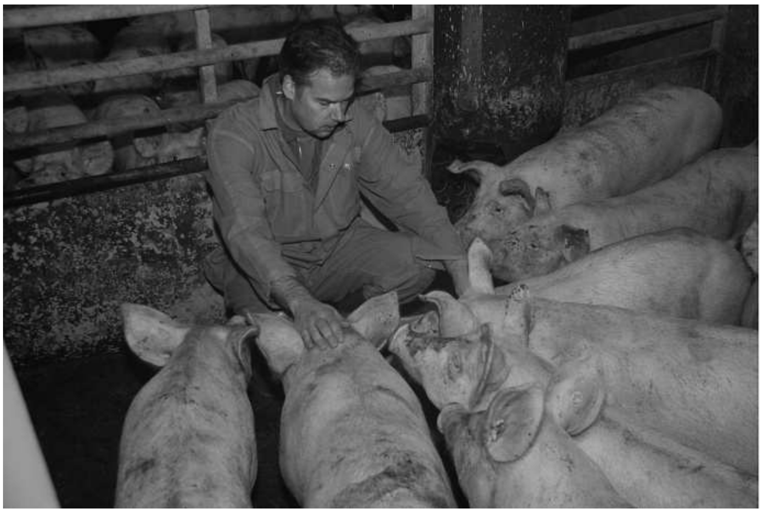

Fig. 7.4 Squatting reduces the approach latency by pigs considerably compared to standing up (Photo source: Marrit van Engen, FarmulaOne)

Table 7.1 Effects of previous handling experience in pigs on time to approach an experimenter in a standard approach test (based on: Hemsworth and Coleman 1998). Different superscripts in the same row indicate significant differences ($P<0.05$)

Study	Positive	Minimal	Negative	Significance
Hemsworth et al., 1981a	119	–	157	NS
Gonyou et al., 1986	73^{a}	81^{ab}	147^{b}	*
Hemsworth et al., 1986a	48^{a}	96^{b}	120^{c}	**
Hemsworth et al., 1987	10^{a}	92^{b}	160^{c}	*
Hemsworth and Barnett, 1991	55^{a}	–	165^{b}	*

* $P< 0.05$
** $P< 0.01$

has been generated in abundance by Hemsworth and co-workers (e.g. Hemsworth et al., 1981a, 1986a; Gonyou et al., 1986). Almost all of these studies showed that negative behaviours (sudden movements, slapping, kicking, using electric goads) increase the latency for pigs to approach an observer in a standard test, as opposed to positive behaviours (calm movements, stroking, talking quietly). Table 7.1 lists the main results of a number of studies.

Visual, tactile and possibly auditory and olfactory cues during human – animal interactions affect the animal's perception of the handler. However, pigs appear adaptive enough to change this perception, based on new experiences. Hemsworth and Barnett (1992) handled pigs regularly from birth to 8 weeks and tested them between 10–24 weeks. Although the authors found clear effects of their handling treatments on piglet responses up to 18 weeks, the differences disappeared in later tests. Similar findings were reported in other studies (e.g. Hemsworth et al., 1981; van der Mheen and Spoolder, 2003).

It can be concluded that the perception that pigs have of humans depends to a large extent on the frequency and nature of human – animal interactions. Fear of humans can potentially be reduced or even changed into a positive perception of the stockperson through positive handling and by creating circumstances in which fear is not unnecessarily enhanced.

7.5 Fear of Humans in Relation to Pig Physiology and Performance

Fear causes stress. Pigs will attempt to cope both behaviourally and physiologically with stressful situations. Short term responses will aim to avoid or escape the fearful stimulus. If this is impossible, long term coping strategies are adopted which may negatively affect pig welfare and performance.

7.5.1 Physiological Responses

Cannon (1914) first described how animals cope when confronted with a stressful stimulus through the so called 'fight-or-flight' response. This immediate reaction involves autonomic and neuroendocrine elements which mobilise the body's

Fig. 7.5 Fear of humans due to negative handling reduces pig performance (Photo source: Marrit van Engen, FarmulaOne)

reserves so it can respond adequately to the challenge. It may include elevated levels of adrenaline, increased heart rate, blood pressure and body temperature. If the stressor persists the physiological responses move into a second phase, which is still relatively short term but predominantly corticosteroid mediated. Hemsworth et al. (1981a) suggest that pigs handled unpleasantly (and therefore likely to be more fearful of humans) respond to human exposure with a brief but significant increase in plasma corticosteroid concentration within about 10 minutes following exposure. No such response was measured in the pleasantly handled animals.

The increased levels of corticosteroids allow extra energy (glucose) to be generated from, for example, muscle proteins. If the stressor is still not removed and cannot be avoided, a long term or chronic stress response ensues. This response also involves corticosteroids and has a negative effect on the animal's physiology. Pedersen et al. (1998) found lower concentrations of free plasma cortisol in tethered sows handled pleasantly (as opposed to unpleasant or minimal) after human contact, but also before. This suggests that the quality of interaction not only affects pig stress hormone levels during handling itself, but has longer term effects. Chronic stress may result in reduced reproductive performance, reduced growth (through poorer efficiency) and impaired immunity (e.g. Clark et al., 1992) Fig. 7.5.

7.5.2 Performance of Fearful Pigs

Hemsworth and Coleman (1998) list a number of studies in which performance of poorly handled pigs is reduced in comparison to positively handled animals (Table 7.2). In all studies reduced growth rates were observed when pigs have

Table 7.2 Effects of previous handling experience in pigs on their growth rate, in grams per day (after: Hemsworth and Coleman 1998). Different superscripts in the same row indicate significant differences (P<0.05)

Study	Age of pigs (weeks)	Positive	Minimal	Negative	Significance
Hemsworth et al., 1981a	11–22	709	–	669	NS
Gonyou et al., 1986	8–18	897^{a}	881^{a}	837^{b}	*
Hemsworth et al., 1987	7–13	455^{a}	458^{a}	404^{b}	*
Hemsworth and Barnett 1991	From 15 kg for 10 weeks	656	–	641	NS

* $P < 0.5$

been handled negatively. Minimally handled pigs appear to grow at the same rate as pigs which have been handled positively. It can be argued that although positive handling may not improve growth rates, the opposite is true: negative handling reduces the speed at which pigs grow. However, there is some conflicting evidence around as Hill et al. (1998) found improved performance of minimally handled pigs compared to positively handled animals. It is difficult to draw an overall conclusion on this.

In addition to this, data from the Australian group suggest that reproductive performance can also be affected negatively. In their study of gilts (Hemsworth et al., 1986a) they found that the pregnancy rate at 40–60 days post mating differed significantly: 33.3, 55.6 and 87.5% for unpleasantly, minimally and pleasantly handled animals (P<0.05). The same study suggested that testicle size of boars at 23 weeks of age was greater when the animals had been handled pleasantly, and that these boars also attained a fully coordinated mating response at an earlier age compared to the unpleasantly handled boars. Although proof for a direct causal relationship is lacking, the authors suggest that these effects on reproductive physiology are associated with differing levels of circulating stress hormones in the handling treatments. However, Paterson and Pearce (1989) appeared to find an opposite effect: unpleasantly handled gilts attained puberty quicker following first exposure to the boar (21 vs. 27 days; P<0.05). They concluded that unpleasantly handled gilts were more sensitive to acute stress making them more responsive to boar stimulation. Other work by these researchers (e.g. Pearce et al., 1989) also fails to confirm the 'chronic stress' theory, although in these studies the negatively handled animals were highly fearful of humans. Differences in genotype are unlikely to explain these effects, but it is possible that situational differences in treatments or housing circumstances may have ameliorated some of the detrimental effects in the studies by Pearce and co-workers. Hemsworth and Coleman (1998) suggest that if behavioural responses to handling treatments allow animals to cope with the stressor, they are unlikely to develop chronic physiological stress responses. This would imply that, depending on circumstances, pigs can be very fearful of humans although their performance is not negatively affected.

Hill et al. (1998) confirm this possibility. Their handling treatments (which included minimal handling and positive handling, but not negative) and two levels of enrichment had no effect on meat quality, pig performance or ease of handling. However, time to interact with the observer of groups handled minimally was significantly greater compared with the other groups. Van der Mheen and Spoolder (2003) found that their 'roughly' handled pigs had similar growth rates to 'calmly' handled pigs, but less back fat. The latter were less active and the authors suggest that the calmly handled animals had a better energy conversion ratio. Approach latencies to humans confirmed existing hypotheses: they were longer in 'roughly' handled animals. In both studies mentioned above, the pigs appeared not chronically stressed, but fearful of humans.

It seems that fear and performance are related. However, pigs are very adaptable and will resort primarily to behavioural responses to cope with handling stress before physiology and (ultimately) performance and health are affected. Reduction in performance can therefore be considered a serious signal in relation to handling quality.

7.6 The Professional Pig Handler

The important effects of the stockperson on the pig's welfare and performance raise the question of how stockperson behaviour and work performance can be optimised in pig husbandry. The three main points are stockperson selection, training and the provision of adequate working conditions. In this section we will deal with these issues, and provide suggestions on solving handling problems at the abattoir and at the farm.

7.6.1 Selecting Adequate Staff

During selection, personal factors that cannot or can only very slightly be changed may be taken into account, i.e. gender, personality characteristics or empathy scores. However, no tools for such a selection procedure exist at present (Hemsworth and Coleman, 1998). Some progressive businesses (e.g. feedlots, livestock auctions) are hiring more women because they are thought to be gentler and more careful with animals than men (Grandin, 1993). Small farms may use a subjective assessment of the applicant in the handling of animals. However, selection possibilities are limited and as discussed before, the actual behaviour is not fixed.

7.6.2 Training Stockpeople

Therefore, training of stockpeople is the way to improve work performance and handling of pigs. Attitudes, the antecedents of behaviour, are changeable by new information or experiences (Ajzen, 1988), and thus offer the opportunity to improve handling via changing attitudes towards the handling process and towards the animals. Providing stockpeople with knowledge, and probably practical experience, about consequences and possibilities of interactions is the basis for building or changing the attitudes and subsequently the behaviour of the stockpeople. Hemsworth et al. (1994) successfully used cognitive-behavioural intervention methods to change attitudes and subsequent behaviour of stockpeople in the pig and dairy industries in Australia. In their 'Prohand' course, they combine science-based knowledge with practical examples of human-pig interaction and the consequences on ease of handling and pig performance. The main message from the course (expressed in statements such as 'Maximise your positives & minimise your negatives') is reinforced by spreading the course material over two days separated by a few weeks, and by follow-up leaflets and other materials which can be used in the office as well as in the pig building. However, changing attitudes and behaviour is not an easy task: the developers of the course estimate that about 25% of trainees will not have their work influenced by the information offered through Prohand (Hemsworth, 1998, personal communication). Hemsworth and Coleman (1998) review the factors affecting resistance to attitude change, for example the strength of attitudes held, specific personality characteristics (authoritarian, dogmatism), characteristics of the message and its source. They conclude that all of these factors should be taken into account when developing and implementing a successful training package. Their data show that attitudes and behaviour can be improved despite, for example, peer pressures on most large farms.

7.6.3 Handling on Farm

The average intensity and frequency of interactions between humans and pigs as part of routine husbandry practices depend to a large extend on the age of the pig. Stockperson-pig interactions are most frequent in the farrowing house and in the mating area. The least interaction occurs in the finishing pig barns. Many of the interactions which occur have negative or unpleasant consequences in terms of pain or discomfort to the animals (e.g. tail docking, teeth clipping, vaccinating). However, most interactions, including some of the painful ones, can be carried out in such a way that they do not put a heavy strain on the human-animal relationship. There are also opportunities to reinforce a positive relationship Fig. 7.6.

The activities in the farrowing house which involve some degree of pig-human contact are numerous. Checking the sow before, during and after parturition, drying off piglets, making sure colostrum is taken up by the whole litter, cross fostering, teeth clipping, castration, tail docking and iron injecting all involve handling of the animals by the caretaker. Brent (1982) lists

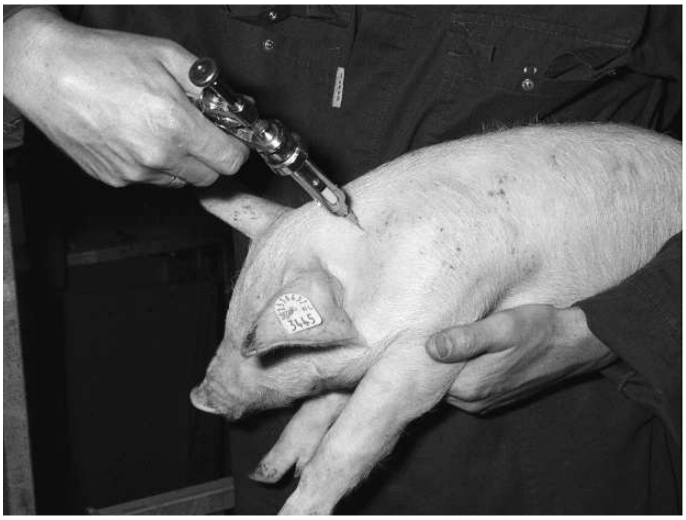

Fig. 7.6 Painful procedures need to be carried out skilfully to minimise stress and should also be accompanied by positive interactions
(Photo source: Marrit van Engen, FarmulaOne)

all these activities and more, and addresses a clear and practical way that these can be performed to improve piglet survival as well as the productivity of the unit. A combination of technical skill and attention to detail (a 'motivation to observe departures from normal' – Hemsworth et al., 1995) is crucial. Caring for the sow and piglets around parturition and during lactation is particularly sensitive to positive reinforcement. A high motivation to improve performance will have immediate and tangible results, as the turnover in the farrowing barn is relatively fast. Good results will not only enforce good practices, they also stimulate a desire to learn new skills and knowledge of the care of pigs (Hemsworth et al., 1995). Holyoake et al. (1995) conclude that good and sufficient supervision in the farrowing rooms not only improves piglet survival rates, but does so in an economically-viable way: extra time spent in the farrowing room pays for itself.

Finishing pigs are only handled occasionally, during movement to new accommodation, for veterinary treatment and when sold. Daily inspections usually do not involve physical interactions with the animals. The lack of interaction does not necessarily affect fear of humans or performance (e.g. Gonyou et al., 1986; Hemsworth et al., 1987): minimally handled animals have growth rates similar to positively handled animals. They have slightly longer latencies to approach humans (e.g. Gonyou et al., 1986; Hemsworth et al., 1986a, 1987), but significantly shorter than those of negatively handled individuals. Abbott et al. (1997) found that willingness to leave the pen was affected by the amount of handling pigs had received, in particular by previous experiences of leaving the pen. They found that pigs which had been allowed to leave their pen voluntarily before, would be easier to move when taken out for slaughter. Without doubt this effect relies heavily on the quality of the pig's experiences when the pen is left for the first time. However, it is not just the quality of the handling which affects responses, but also the predictability of how humans behave. Inconsistent handling appears as bad as negative handling. Hemsworth et al. (1987) compared inconsistently handled pigs (an unpredictable mixture of positive and negative interactions) with positively handled and negatively handled animals. Behavioural responses of the inconsistently handled animals were significantly different from the positively handled finishers (e.g. Time to interact with experimenter: 160^a, 10^b, 175^a and 92^c seconds for Unpleasant, Pleasant, Inconsistent and Minimal treatments; different superscripts indicate differences at $P<0.05$). In their study, growth rate over the 6-week observation period was different between Positive and Negative treatments ($P<0.05$), with Inconsistent being intermediate (but not significantly different). In summary: daily inspections with adequate follow-up if necessary, in combination with minimal handling of finishing pigs does not appear to be detrimental to pig welfare nor pig performance. However, combining daily inspections with frequent positive interactions appears better.

Interactions with dry sows occur at different stages before and during pregnancy. The effects of handling on reproduction were discussed above. There is evidence that handling gilts positively will result in better reproductive performance, but the results appear situation-dependent. In some circumstances gilts appear to cope behaviourally with negative human interactions without having to resort to physiological responses, which in turn may affect fecundity and fertility (Hemsworth and Coleman, 1998). However, good stockmanship and pig-human interactions in the service area require more than calm and positive handling alone. Getting sows in the right physiological condition and in heat requires a good eye and attention to detail during the daily interactions with the animals. In particular, when artificial insemination is used the behaviour of the stockperson is crucial. Provoking a solid standing response has been shown to improve conception rate (e.g. Signoret and Bariteau, 1975). The stockperson can help to induce this response by pushing the sow's side and applying pressure on her back. In addition to other stimuli, for example by a vasectomised boar, these are essential to check if the sow is receptive enough, and to get her to stand still.

Boar performance is positively affected by good handling: testicle size is greater and the age at which a fully-coordinated mating response is attained is lower in positively handled boars (Hemsworth et al., 1986a). In general, when dealing with boars, the advice is not just to be 'positive', but to be patient and to be careful (Brent, 1982). Patience is needed when acclimatising and settling the animal, but also when training him to do his work. Care is needed to keep him in good condition and to avoid injury, for example through inappropriate design or maintenance of the service area (wet floors, protruding pen components). Finally, boars need to be treated with respect: their behaviour towards humans is far less predictable than that of sows. They should not be handled without the use of a board, and preferably two people should be present when moving boars or during the service routine.

Sows and gilts housed in stalls are not handled routinely, although they are in regular visual, olfactory and auditory contact with caretakers who do their daily inspection rounds. Handling is limited to moments when the animals are moved to and from the stall, when they are treated for illnesses or when they are checked for pregnancy or oestrus. Although one may expect that the effects on sow performance of poor human-animal interaction may not be noticeable so much under these circumstances, research has shown that badly handled sows show high fear responses to humans and may have a chronic physiological stress response (Pedersen et al., 1998). Furthermore, Hemsworth et al. (1981b) investigated over 1200 sows on 12 farms in the Netherlands and found significant negative correlations between fear of humans by sows and the number of piglets born per sow per year on the farm. Although this may not prove a causal relationship between the quality of human-animal interaction and sow productivity, there appears to be a strong link between them. Even if direct handling is rare, regular interactions occur during daily control and can vary largely in number and quality from giving negative signals to the pigs (quick, sudden movements, shouts, unpredictability) to positive ones such as calmly talking to sows and scratching or stroking them gently while passing individual stalls. In group-housed sows the situation is similar, albeit it that the quality of the stockperson's eye and ease of interaction with his/her sows is put to the test a bit further. Group-housed sows cannot be inspected daily as easily as individually-housed sows. Depending on the type of group housing system used, their feed intake may be more difficult to monitor. Treatments such as vaccinations or pregnancy testing will involve more direct interaction between pig and stockperson. The first will be painful, the second does not have to be negative at all. The consequences of painful treatments can be ameliorated if these can be associated by the animal with some pleasurable experience. This is made easier if a positive relationship exists due to the good quality daily interactions. Hemsworth (2000) refers to earlier work in which they conclude that a treatment of daily injections was perceived by young pigs as 'moderately aversive' because of positive circumstances around injection. They refer to the presence of the experimenter and the opportunity to investigate novel stimuli (Hemsworth et al., 1996a). Positive handling, even under these circumstances, appears to be extra rewarding. Moving sows to and from other buildings provides further opportunities for good handling. The general principles apply. Calm but consistent handling, using a stock board instead of a stick, putting your hand on the back of a sow whilst moving instead of kicking its heels, all add to reduction in stress levels of both the sow and the handler. 'Think pig' when moving sows. Some practical suggestions can be found in the next paragraph. A number of different group housing systems are currently used world wide, and for some of the above issues solutions have been found through technical improvements of the system. However, technical solutions will aid, but never replace the skills and sympathetic handling by a good stockperson (Edwards, 1992) Fig. 7.7.

Fig. 7.7 Ultimately, calm and consistent handling saves time
(Photo source: ASG)

7.6.4 Handling Before Slaughter

Transport and handling involve a lot of human – animal interactions. To the naïve, minimally handled finishing pig this period puts the greatest strain on its ability to cope with changes. The welfare of the animals is predominantly considered in terms of stressors just before slaughter and on post-mortem muscle acidification (Faucitano, 1998). Stress levels due to poor handling and poor facilities affect the animal's physiology and may result in reduced meat quality. Pork can either become dark, firm and dry (DFD meat) or pale, soft and exudative (PSE). DFD pork is a result of muscle glycogen depletion prior to slaughter, leading to a low lactic acid concentration and a high ultimate pH (Tarrant, 1989). The meat has a higher susceptibility to microbial spoilage than normal pork. Depletion of muscle glycogen can occur when the animals have not had time to recover from chronic stress through, for example, exercise or fighting during mixing (e.g. Karlsson and Lundström, 1992; Sather et al., 1995). PSE, the 'opposite' meat quality problem, occurs when animals are exposed to high levels of stress just before stunning. The pH falls rapidly after slaughter and reaches a low level while the carcass temperature is still high. Protein denaturation results in meat that is watery and pale. PSE meat has a reduced acceptability to consumers and processing is poor. There are several authors who have demonstrated a relationship between stressful handling techniques prior to slaughter (i.e. by using electric goads) and PSE pork (e.g. D'Souza et al., 1999; Grandin, 1980).

Fig. 7.8 Clearing corridors prior to moving pigs will reduce distraction to the animals and save time
(Photo source: ASG)

Mixing should be avoided as much as possible. It not only increases the occurrence of DFD pork, but also the level of skin blemishes on the carcass (e.g. Guise and Penny, 1989; Faucitano, 2001). The latter is not just an indicator of reduced welfare, but also has economic implications: Faucitano (2001) quotes UK Meat and Livestock Commission figures showing a 6% downgrading of carcasses in Britain due to a poorer appearance. If mixing cannot be avoided, it should take place prior to transport. The novel environment and small area inside the truck reduces aggression levels temporarily (Lambooij, 1988), but they are then expressed after unloading prior to slaughter. Pigs should not be mixed in lairage if at all possible.

Loading pigs poses a number of different challenges to the animal. The quality of the materials used as well as the skills of the stockperson are of primary importance when minimising stress during loading. On the day of sale pigs will have to be moved a number of times. The route from the home pen to the truck should be free from any obstacles and distractions to avoid baulking as much as possible; think from the pig's perspective. The eyesight of pigs is relatively poor: sharp contrasts in black and white on the floor distract or cause a fear response (Tanida et al., 1996). Pigs will move towards light, but not if it is too bright. Light should be even and diffuse (Grandin, 1980). Shadows and darkness also affect behaviour. The position of the eyes of a pig may also reduce their ability to judge distance (Grandin, 1980), so a relatively small step down may cause a problem. The same applies to, for example, drain grates, puddles of water and gutters. Steps up are easier because their nose is close to the ground and they are likely to judge the height by touching. Moving towards a corner may be difficult if the animal cannot see a way forward. If possible, a barred gate may help. Pigs are curious animals and will stop at novel smells (feed spills, urine) and other distractions (tools or equipment) Fig. 7.8. Solid pen walls, as opposed to barred gates, will reduce distraction from pigs in other pens along the route. Loading ramps should not be too steep to avoid pigs baulking. They should have an angle of 20° maximally (e.g. van Putten and Elshof, 1978) and solid walls so that the animals do not see the elevation. Although a hydraulic lift loading pigs in groups of 8–10 is said to be better at reducing shoulder haemorrhages and PSE meat (Faucitano (1998) quoting Nanni Costa et al. (1996)), this is still insufficiently substantiated and more likely to be an effect of poor ramp design (Nanni Costa et al., 1999). Pigs are social animals, and their need to stay in close contact with the rest of the group (Van Putten and Elshof, 1978) can be used to herd them. The race should be about 1 m wide so that pigs can see others moving ahead (Grandin, 1990), which agrees with Lambooij et al. (1995) who suggest a width of 4–5 animals.

Throughout the whole moving process the actions of the stockperson are of vital importance to reduce stress. Shouting and excessive noise should be avoided. Pigs should be handled quietly and firmly. A stock board should be used to prevent the animals from turning back. Ideally the board is about the same width as the corridor. No electric goads should be used. Several alternative devices (such as soft foam pipes and flags) are in use on commercial farms to move pigs calmly. Providing the animals are not too excited or agitated, tapping pigs on a shoulder is often sufficient to make them turn in the opposite direction (Grandin, 1986). Smacking and shouting will cause pigs to become agitated and stressed, resulting in sudden movements, baulking and panic. Calm handling in an environment which has been designed with the pig's perception of the world in mind, will improve pig welfare, provide better quality meat and be less stressful to the pig handler as well as the pig.

7.7 Conclusions

The quality of human-animal interactions depends to a large extent on the ability and the willingness of handlers to reduce stress in their animals. The development of good handling skills is essential. However, these are not only achieved through sound technical training. What is needed as well is a positive attitude towards livestock, attained for example through improved awareness of the effects which every day interactions have on the animals. They can also be improved by 'thinking (like a) pig'. Imagining how a pig perceives the world will enhance understanding of the pig's responses to humans and its environment. This will not only make handling easier, it will also facilitate the design or improvement of handling facilities on the farm, during transport and in lairage. Good quality interactions improve the welfare of the pig, but also that of the handler.

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Chapter 8
Balance Between Porcine Disease and Welfare

Wim J.A. Boersma, Jan van der Meulen and Theo A. Niewold

8.1 General Introduction

In this chapter, we will discuss the relationship between disease and welfare. Whereas welfare and its assessment have been defined in previous chapters, we need to define disease and health more precisely. Subsequently, the systems that are involved in maintenance of welfare and disease will be discussed.

Obviously, management in animal husbandry is focused on maintenance of health for economic reasons. The tools that are used may be preventive or curative. The choices made in disease control depend on legal measures and trade considerations. For example, food additives such as anti-microbial growth promoters (AMGP's) may be very effective but their use can be prohibited because of consumer concerns. As a result of domestication, modern commercial pigs are quite different in some ways from their natural counterparts in the wild. As a consequence, humans are responsible for maintaining a certain level of pig welfare for which standards differ in various geographic and/or climatic areas in the world, dependent on human prosperity and welfare. In this chapter, we will refer to European Union (E.U.) regulations on animal care. However, also in the U.S.A., lobby groups argue for the implementation of similar rules. Therefore, in animal husbandry, the level of welfare is to a large extent determined somewhere in the battlefield between economics and compassion. In this chapter, we will try to evaluate to what extent health contributes to welfare and where the conflicting demands are hard to reconcile.

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8.2 Welfare and Disease in Pig Farming

8.2.1 Extremes in Farming Conditions: Pig's Health and Welfare

Two opposing tendencies may be distinguished in pig farming. On one hand, the more extensive/outside/natural farming aimed at supposed high welfare and on the other hand, intensive farming aimed at the prevention of disease in enclosed/indoor farms with high pig density.

Though most conventional farming is intensive, in various parts of the world, mainly the E.U., there is a trend towards keeping pigs more extensively. This is driven by welfare concerns and by the expectation that some consumers are willing to pay more for products from animals that have been bred and reared in a rather extensive way. In the U.S.A., there is a different type of natural farming that is based on the economics of husbandry. There appears to be a tendency to think that animal welfare is best warranted in a more natural or extensive form of husbandry since intensive farming limits species-specific behaviour. The romantic view of animals roaming the fields results in a better image for the farmer. However, not only the loss of coat and the fat layer but also other physiological traits may make the present domestic, highly-selected production pig not suitable for what can be harsh conditions of free-range farming, depending on the climatic extremes to which it is exposed. Extreme conditions can lead to increased losses especially in young animals (MacKenzie, 1999).

Whether conditions intended to improve welfare are also favourable for animal health is a question we should address and contradictions often arise. For example, within free-ranging systems regarded as conferring high welfare, health control may be less well guaranteed (e.g. Jolie et al., 1998). However, in guaranteeing adequate health control, the level of care for the animals may be more important than the level of the intensiveness of farming (Coleman et al., 1995; Swanson, 1995; Kertz, 1996). Intensive husbandry aims to optimize health as far as it supports production and for the pigs, optimal production brings the advantages of 'optimal' feeding and human supervision to control disease. However, once a disease enters an intensive farm, transmission of disease may be hard to control due to high animal densities. In addition, the housing and floor conditions limit the expression of species specific behaviours. Pigs are housed in separate age categories that restrict or redirect social behaviour. In recent years there has been increasing interest in the impact of positive and negative social behaviours in intensive pig farming which has led to the re-emergence of concepts such as group housing of sows and enrichment of barren environments. Such concepts are included not only in the E.U. but are even beginning to emerge in U.S.A. legislation. E.U. regulations state that for good welfare, the absence of hunger and starvation is a primary requirement. But in free-ranging pigs, the control of feed intake and the provision of a balanced diet (trace elements) may require more care to prevent metabolic diseases than in well-controlled intensive husbandry systems. Similarly, whereas welfare may be optimal for extensively-reared pigs over most of their lifetime, when such pigs come into contact with humans this will be a stressor for them since they are not used it and yet human contact is necessary for health control, vaccination and transport.

8.2.2 How to Define Health and Disease

The short outline above indicates that the perception of health varies and is related to different forms of pig husbandry. A better definition of health is needed which is independent of the management system that is applied and based on thorough knowledge of underlying mechanisms of action. Furthermore, a clear definition of health and disease is needed to unravel and discuss the mechanisms underlying the welfare/health/disease relationships. As is the case for welfare (see other chapters), many definitions are used for health. The present definitions of swine health and welfare are biased by different perceptions of the people involved in pig husbandry and of the public in general and also by politics. Feed producers refer to healthy fattening pigs as those animals that show high feed conversion and rapid growth. Reproduction aspects of the sow (litter size, weight/litter, weight per piglet, farrowing rate) and the vitality of the young piglets are also used as criteria. The veterinary views on health are based on the presence or absence of clinical signs of disease. This partly overlaps with criteria for welfare, as used in the E.U. regulations on animal welfare such as freedom from pain. However, the absence of clinical disease cannot be defined as health. Subclinical disease may be the cause of suffering and behavioural deviations.

Diseases that are caused by a specific pathogen may be relatively easy to prevent and treat. However, many diseases in modern breeds have a multifactorial nature – e.g. post-weaning diarrhoea – and as a consequence, adequate prevention and treatment is complicated. Emerging multifactorial diseases may be the result of selection and the domestication process, but the suggestions in that direction need further investigation.

New diseases will emerge continuously in the co-evolution of animal/host and pathogen. Not all diseases result from infections, but also from quite different aetiology that includes feed metabolism and physiology. In addition, somatic disease comes in different qualities. In its mildest form, it is sub-clinical. That means we are not aware that an animal is ill. With other diseases, clinical symptoms remain at the level that we take together as sickness behaviour (e.g. anorexia, vomiting, and fever). Some diseases may develop to disable the animal in such a way that it becomes apparent to its caretaker or even results in death. In individuals, diagnosis of sub-clinical disease stages is difficult and costly. Absence of disease is almost impossible to assess.

Is it then true that where disease begins, health ends? Definitions of health vary from absence of disease to more sophisticated descriptions, as even a 'healthy' animal runs the risk of once being ill. Therefore we propose that *'a healthy animal should be sufficiently robust that it can cope with the causative agents of disease and be healthy again in a short period without remaining disabilities'*. In addition, in the case of infections, the disease adds to the education of the immune system and improves immunological memory and protection potential. Thus, transient diseases may still be compatible with 'health'.

Disease resistance is the combination of susceptibility to disease and the capability to withstand disease. Susceptibility is in part determined by intrinsic genetic factors, such as the receptor for a certain viral pathogen, and environmental factors modulating this. Individuals that lack such factors are disease resistant but in a passive way. *Active disease resistance includes the capacity to overcome a primary infection and may be better expressed as resilience. This indicates that the individual that is affected by a disease is still able to maintain a certain level of productivity in the face of this disease challenge* (Albers et al., 1987; Coop and Kyriazakis, 1999). *Therefore resilience of disease resistance might be a better measure for 'health'.*

As absence of disease cannot be guaranteed easily, nor indeed wanted. Animal husbandry requires great care and attention and should be devoted to minimising the risk for disease to maintain a status of healthiness. In addition, the animals should be kept to allow optimal resilience adapted to the conditions of management (Fig. 8.1). Below, we will discuss what factors may be important therein. Clinical disease is incompatible with good welfare. In addition, disease development stages that are accompanied by sickness behaviour are not regarded as a state in which good welfare is experienced. In this chapter therefore, we will essentially use resilience as a measure for health. Any attempt to separate health and welfare is artificial. In addition, the interactions between systems that maintain disease resilience and systems involved in expression of welfare are interdependent even at the molecular level. Against this background, we will discuss some aspects of strategies to control health, such as housing and management style, preventive measures such as isolation and vaccination, effects of genetic make-up and other predisposing conditions, effects of feed and its composition and the effect of prohibition of AMGPs and possible alternatives such as probiotics. None of these items can be discussed separately or comprehensively because most of these aspects are interconnected.

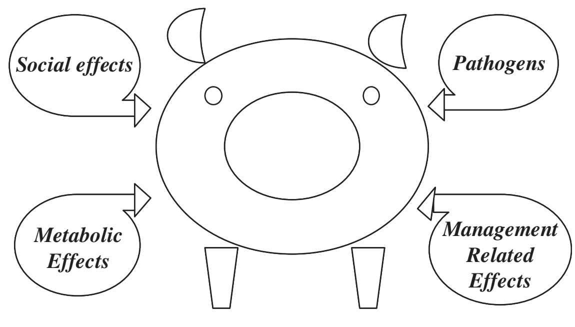

Fig. 8.1 Diagrammatic representation of the modulators of porcine health and welfare

8.2.3 The Welfare Concept in Development: New Rules

Though quite different in various geographical areas, animal welfare has received increasing attention from government and public. Ethics of animal husbandry have been reviewed in recent years and generated discussion by the public, in general spearheaded by various animal rights movements. As a consequence, legislation has been proposed and introduced and with it the need for verifiable and objective criteria for welfare has arisen. However, animal welfare is a concept that is not easily defined, described or assessed in an objective manner. Wiepkema and Koolhaas (1993) defined welfare as the state of an individual that can reliably predict or control relevant events by means of species-specific signals. Broom and Johnson (1993) defined welfare as ‘a state as regards an animal’s attempts to cope with its environment’ which leads to questionable levels of welfare in any state of disease. For a domestic animal in an environment that it cannot control, this may lead to insufficient adaptive responses. In general, such a state is regarded as a stressful situation leading to negative emotions such as fear, distress or pain (Duncan, 1996). The level of effort in any physiological system that is required to cope with, or to adapt to, an imbalance in these systems, is a relative measure for welfare. Animals differ in adaptation capacity. Adaptation includes physiological responses of the neuroendocrine system and stress responses, autonomic responses such as heart rate and body temperature and behavioural responses.

The E.U. in 1998 not so much gave a definition, but indicated that welfare may be maintained: (1) when animals are kept: such that they have free access to water and a diet that supports full health and vigour; (2) when freedom from discomfort is warranted by appropriate environment, shelter and a comfortable rest area; (3) when animals are kept free from pain and injury and diseases should be prevented or adequately treated; (4) when animals are free to express species-specific behaviour in sufficient space and facilities with companions of the animal’s own kind; and (5) when animals are kept such that they are free from fear and distress. This indicates that the animal caretaker is obliged to ensure that the conditions and treatments in animal husbandry are such that animal suffering is avoided (E.U., 1998). Disease and animal welfare according to these regulations are mutually exclusive.

At the same time, the E.U. has banned several efficient forms of disease prevention such as some vaccinations, which has a low priority when it comes to the improvement of welfare. Introduction of the E.U. principles should, in a relatively short time, lead to sows that will be kept in social groups, pigs that are kept in at least statutory minimal pen size and in pens where permanent access to material that stimulates exploratory behaviour is warranted. In addition, regulations were developed for noise levels, light and ventilation, the time of weaning and the prohibition of mutilations such as clipping of teeth, tail-docking and castration without anaesthesia. Furthermore, rules are being developed for limitation of transport time including an authorised travel plan, maximum loading densities, and control of ventilation, humidity and temperature by on board registration and warning. These were based on experimental evidence that showed that stress related to transport and mixing led to changes in heat and energy distribution (Schrama et al., 1996; Heetkamp et al., 1995).

Western European countries have developed welfare regulations that also include 'on-farm rules' for hygienic housing, the density of animals, management and quality of feeding, water and treatment of animals, the use of vaccines, antibiotics, chemotherapeutica, and the fight against disease vectors such as rodents and birds. Finally, rules are being developed for the consultation of veterinarians and, in the future, a license will be required for animal caretakers. In addition, new rules are being developed to safeguard animal welfare at market, at exhibitions/agricultural shows and in the slaughter process. However, the development of new rules is only effective when the parameters used both for welfare and for health, are well defined and can be measured reproducibly.

8.2.4 The Intricate Relationship Between Health and Welfare

Health and welfare, due to their intricate relationship, cannot be discussed independently. *Welfare is the state of the body in which a relatively low level of adaptation to changing environmental conditions is required or in which the adaptation to the environment is still under control*. The neuroendocrine system and the brain are involved in the regulation of processes important for the organisation and expression of behaviour that includes adaptive processes. Health is modulating welfare in various ways. Opportunistic-pathogens form a constant threat to the health of an individual. The reaction of the body to pathogens can lead to dysfunction, subsequent disease and eventually death. Disease is accompanied by all kinds of features that are not compatible with welfare, such as fever (uncontrollable temperature), pain from various sources (brain, stomach, GI-tract, respiratory tract, head/brain), vomiting, loss of appetite and loss of the urge to move: i.e. sickness behaviour; which is *the behaviour of an animal that is anomalous as compared to the normal animal species specific behaviour as a result of disease symptoms*. Events or experiences that lead to sickness behaviour may be of somatic origin but may also be the result of modulation of psychosomatic effectors. Sickness behaviour therefore, is an expression of an individual behaviour that indicates discomfort and for the purpose of this paper this state will be considered as diminished welfare. Body and mind are not separate entities, therefore also the care for pig health and welfare are inseparable (Fig. 8.2).

8.2.5 Requirements for Health

As the absence of disease is pivotal for welfare, the management of animal husbandry should focus on the prevention of disease and, if necessary, the treatment of disease. Diseases may be the result of interactions with infectious agents. Furthermore, there are diseases that are the result of an imbalance between the environmental demands and the adaptation capacity of the individual. This may be

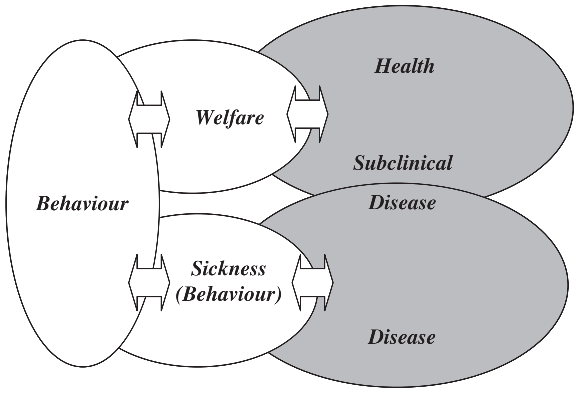

Fig. 8.2 Interactions between neuroendocrine regulated features and disease

observed at any level of its physiological or neuroendocrine systems. Inferior genetic make up of the animal may lead to insufficient adaptation to demanding environmental conditions such as stress, inadequate housing and feed. Alternatively, human interference may be such that the environmental demands may overstretch the physiological potential of the individual such as increasing animal growth over the physiological limits (e.g. production diseases in broilers). The latter conditions, in addition, may be the basis for inadequate interactions between the resilience, the surveillance systems and the neuroendocrine systems that lead to new (secondary) opportunities for infectious agents. The genetic make-up of animals in part determines the level of vulnerability to any of the above conditions (Visscher et al., 2002).

Disease resistance and resilience is the result of the genetic make-up of an animal and the iterative immune education. The education material is formed by pathogens and other 'foreign' substances (antigens) that come into the animal's environment in all life cycle phases. Different factors can modulate responses to exposure of the animal to challenges of the disease resistance system. Such factors include feed, logistics and management, hygiene and climate control as part of housing quality. Ecological aspects are represented by e.g. the confrontation with other animals such as their number, the density, the level of relationship, the unexpected or unwanted encounters with unrelated previously unknown individuals (mixing), the continuous need for participation in the social ranking process but also the interactions with caretakers.

As in humans, for prevention of disease the level of hygiene, climate control, clean water and feed and vaccines are major decisive factors. Once a disease has been diagnosed, an adequate treatment is not always possible. For viral diseases the farmer mainly relies on preventive use of vaccines. Bacterial and parasitic diseases are treated with antibiotics and other drugs. Most have considerable side effects and the worst of all being the induction of resistance to treatment of the pathogen. Management factors such as the induction of acute or chronic stress that have their effects either in social, metabolic or physiological factors should be avoided. Alternatively animals adapted to husbandry conditions could be selected.

The immune system plays a vital role in disease resistance and resilience and interacts with other systems in maintenance of animal welfare. Severe immune deficiencies are incompatible with life. Below we summarise how the immune system responds to challenges of resilience. The quality of the immune system determines to a large extent an individual's health and hence also its welfare. We will evaluate how the immune system participates in the complex interactions at the level of the neuroendocrine axis.

8.3 Resilience

8.3.1 Intermezzo: The Role of the Immune System

Skin and epithelia protect the outer surface of the body and body cavities. In addition, physico-chemical conditions such as pH, secretions (sweat), enzymes and mucus form a barrier that protects these outer surfaces. The immune system represents the second line of defence under the surfaces. The breach of this line of defence leads to generation of a so-called 'danger-signal' for the immune system (Matzinger, 2002; Gallucci & Matzinger, 2001) that consists of two major interrelated parts: the innate immune system and the adaptive or specific immune system (Fig. 8.3). Danger signals are generated at the actual site of first encounter of the foreign entity with cells from the immune system (Matzinger, 2002). Directly under the skin is a network of cells that, upon encounter of foreign antigens, transport these to the regional lymph nodes where a specific immune response is initiated upon presentation of the antigen. A similar surveillance system is found along the mucosal surfaces but in a more localised form. A third level of defence is observed along blood vessels. Here, endothelial cells express functions related to danger signalling. The danger signal leads to recruitment of mainly monocytic cells by chemotaxis and they start locally with clean-up actions. Such cells include resident tissue macrophages, neutrophils and thrombocytes. The immune system consists of cells that communicate and are in contact with each other and deliver signals via multireceptor systems and humoral factors, of which the most important are chemokines and cytokines. Cytokines are humoral factors that consist of small proteins that act locally and systemically within the immune system and have a hormone-like function. They have pleiotropic functions for which there exist receptors within the immune system but also within the neuroendocrine system and the brain. Fever, anxiety and reactions of the GI-tract (diarrhoea, vomiting) are examples of such functions that do not necessarily involve actions of the immune system.

Both parts of the immune system aim to maintain homeostasis. The innate part of the immune system will already reach an adult reaction pattern early in life. The adaptive immune system reaches adult response levels only when pigs are about 8 weeks old (Bianchi et al., 1999). The system is then ready to respond to its environment and starts to build up immunological memory. A relatively long period is required to allow proper immune education and to develop a full

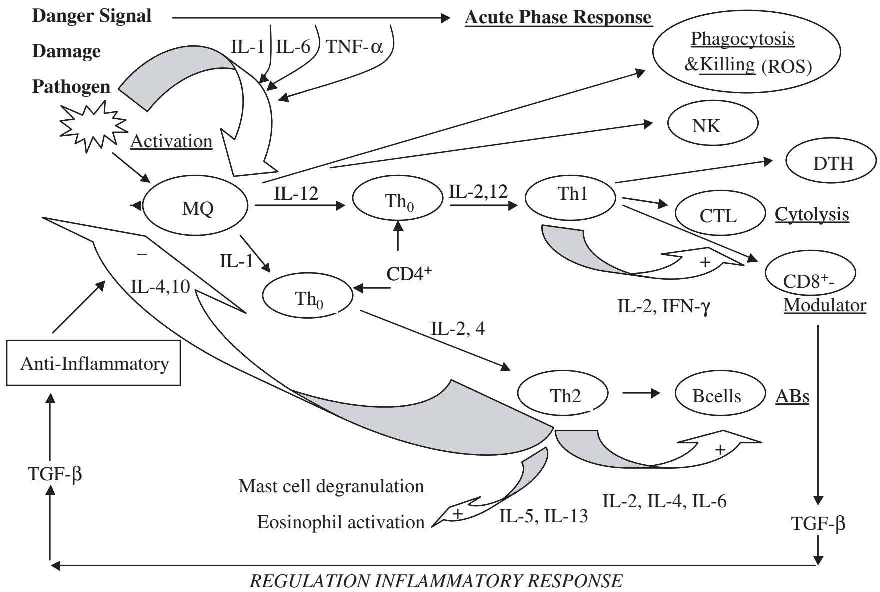

Fig. 8.3 Regulation of inflammatory responses. Danger signals lead to production of cytokines (IL-1, IL-6, TNF-α) that in turn activate e.g. macrophages. Activated macrophages present antigen and induce differentiation of Th0 cells into Th1 (IL-12) and Th2 (IL-4) type helper cells. Helper cells induce effectors at different levels such as Natural killer cells (NK), Delayed type hypersensitivity (DTH), Cytolysis of infected or aberrant cells (CTL) and antibody production (ABs). Th2 cells in addition lead to activation of mast cells. The cytokines that are involved in these processes are indicted. Down-regulation of responses is induced by anti-inflammatory cytokines (IL-4, IL-10, TGF-β) dependent on the presence of antigen

immune response repertoire. Apart from sows and boars used for reproduction, most other pigs reared for meat do not reach full adult maturity. That means that in general, the porcine adaptive immune system will be in a state of homeorhesis.

8.3.2 The Frontiers of Defence: The Innate Immune System

The innate immune system in part consists of cells that react directly with pathogens and damaged or infected cells. Other cells are recruited by signals generated by cells from the adaptive immune system that specifically recognise a danger situation created by intruding pathogens (Gallucci & Matzinger, 2001). Danger-signals lead to production of Interleukin-1 (IL-1), Interleukin-6 (IL-6) and tumour necrosis factor alpha (TNF-α). Macrophages are activated in response to these signals. In addition, at the level of the brain, these signals are recognised to induce fever and to stimulate the hypothalamus-pituitary-adrenal (HPA)-axis to produce cortisol and catecholamines. The effects of cortisol and its metabolites as inhibitors of inflammation have been described in detail (Rook, 1999). Cortisol down-regulates the production of pro-inflammatory cytokines and the level of damage caused by the inflammatory response. Catecholamines redistribute the blood flow so that muscle and brain receive a larger part of circulating blood, whereas the circulation in which the GI-tract is involved, is reduced. This can lead to the changes in the GI-tract surfaces and decreased barrier function (Niewold et al., 2000).

The main functions of cells from the innate immune system include: (1) The induction of an acute phase response in which proteins, prostaglandins, leukotriens and other factors are produced that have regulatory functions, reduce available micro-nutrients for pathogens (Fe, Cu) and generate antimicrobial activity (cytotoxins, granzymes, perforins). In addition, they have a function as scavengers, transport and binding proteins that take part in inactivation of potentially harmful substances derived from pathogens (LPS), or produced in the anti-pathogen reactive process. The exact functions of many acute phase reactants are not known. (2) Innate immune functions comprise phagocytosis and killing or destruction of the foreign agent. The activity of NK cells, which kill infected cells and cells that have an abnormal 'appearance' in an aspecific manner, is enhanced. (3) The production of cytokines that can induce and regulate the specific immune responses. Both the resident cells which are active in distant surveillance functions and the cells in lymph nodes, spleen and bone marrow, need to proliferate. As a consequence of its immune surveillance function, the triggering of the innate immune system leads to activation of the adaptive or specific immune system.

8.3.3 The Actions of the Adaptive Immune System

The specific or adaptive immune system reacts to foreign antigens that are detectable by the sets of receptors of the cells in this system. The cells generally need more than one signal to exert their functions. The first decisive signal is the recognition of a part of the foreign molecular structure by the T cell. This recognition occurs in an indirect way. T-cell antigen recognition requires involvement of tissue specific antigens (MHC molecules). Therefore, antigen recognition is a process which is individually specific to a high extent. Following the recognition of the antigen, a process of differentiation and cell growth starts as depicted in Fig. 8.3. It shows that depending on the cell cytokines that are produced, two main response types can be distinguished of which the Th1- and Th2-cells and the cytokines that are involved are the mediators. The choice of the pathway is related to the nature of the antigen and its route of entry. For example, anti-viral responses will require not only antibodies but also clearance of the virus from infected cells. In such responses, Th1 cells are involved which enhance lysis of infected cells by cytolytic T-cells. In addition, Th1 cells mediate delayed type hypersensitivity responses by monocytes (local reactions). Th2 cells mainly induce humoral or antibody mediated responses. In addition, they enhance mast cell degranulation and the activity of eosinophillic cells. Th2 cells mainly have a function in anti-parasitic responses and antibacterial responses. Feedback regulation occurs via cytokines such as TGF-β, IL-4 and IL-10 which mediate the down-regulation of the response by activated macrophages (Mosmann and Sad, 1996). In pigs, the cytokines that induce Th1 or Th2 type responses have all been identified. However, formal proof for development of these cell lineages in polarisation experiments has not yet been demonstrated.

Does this knowledge of immunology contribute to our notion of welfare? We have discussed that sickness behaviour is expressed in the beginning of the disease process. From this it was anticipated that there is a relationship between disease and behavioural characteristics that follow from the disease process (review Konsman et al., 2002). Recent investigations demonstrate that systems involved in control of health and welfare use, in part, the same signalling processes and mediators. This is an indication that these signals might be used as early warning systems to detect emerging disease. Below we will discuss the present state of knowledge with respect to sickness behaviour (Fig. 8.4).

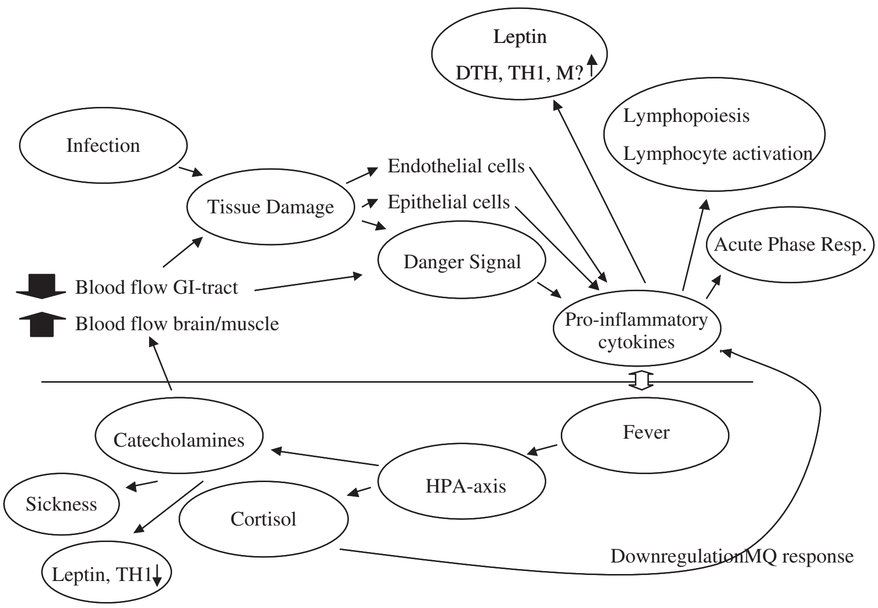

Fig. 8.4 Immune and neuroendocrine interactions. Infection leads to tissue damage and danger signals. The proinflammatory cytokines that are produced in this response lead to activation of the leptin related interactions, activation of the immune system and to acute phase responses. At the level of the neuroendocrine system, this leads to fever, HPA-axis activation and subsequent responses at the level of Cathecholamines, Cortisol and Leptin resulting in sickness behaviour. Cathecholamines enhance blood flow to brain and muscle but reduce blood flow to the GI-tract. This may lead to ischemia and epithelial damage etc. In this way, an inflammation process may lead to considerable damage if it is not downregulated e.g. by cortisol that interferes with macrophage and epithelial cell activation

8.3.4 Sickness Behavior

It is important to understand how sickness behaviour and disease may be related, as it seems to connect behavioural aspects of welfare with the impact of disease on welfare. A whole set of non-specific symptoms are induced by inflammatory cytokines in an infected individual such as hypophagia, adipsia and reduced social interest. The group of Dantzer worked out the idea of sickness behaviour, which in their definition represents 'the expression of the adaptive reorganisation of the priorities of the host during an infectious period' (Konsman et al., 2002). This behaviour is triggered by pro-inflammatory cytokines like Interleukin-1 (IL-1) which are produced by peripheral phagocytic cells as a result of contact with pathogens. In the brain, the microglia cells and other cells with macrophage-like activities and structure, produce cytokines whereas other cells have cytokine receptors. IL-1 receptors have been identified in the hypothalamus as well (Hammond et al., 1999). The peripheral cytokine signal is relayed to the brain in two ways: Via a fast neural pathway, it generates a signal in the brain that leads to the expression of inflammatory cytokines and via a slower humoral pathway for local induction of cytokines (Luheshi et al., 2000).

The cellular and molecular mechanism that relays a physiological sense of awareness of an infection to the central nervous system (the brain) using a peripheral immune mechanism is rapidly unravelled. In absence of IL-1-receptors TNF-α takes over the HPA-axis modulation. Intracerebral IL-1-receptors mediate sickness behaviour induction (Bluthe et al., 2000). Inflammatory cytokines are potent modulators of the HPA axis. Studies in humans make clear that sickness behaviour is not only expressed in case of infectious disease alone but may also be the result of a 'brain disorder' (for a review see Leonard, 2001). Experiments in rodents indicate that this is most probably the case. Rats injected with *E. coli*-derived LPS showed an increased anxiety level compared to controls that could be reversed using melatonin (Nava and Carta, 2001). Thus, a molecular structure that is related to infection generates a clear-cut danger signal in animals and also leads to an effect at the level of behaviour. Alternatively, antibiotic or G-CSF treatment in septic rats reduced the sickness behaviour. Interleukin 1(beta) released during the initial phase of an immune response can directly stimulate the release of corticotropin releasing hormone and in this way, can modulate HPA-axis activity and mood disorders in humans (Owen et al., 2001). Based on these observations, Bauhofer et al. (2001) suggest that analysis of sickness behaviour may lead to a measure of animal/pig welfare equivalent to the human quality of life. Bluthe et al. (1995) found differential effectors for social deviations and anorexia (measured as weight loss). Intraperitoneal administration of IL-1 beta led to body weight loss and behavioural disorders. The subsequent addition of IL-1 receptor blocked the effect on behaviour but not on anorexia. Central administration of IL-1 beta-receptor reduced social behaviour disorders while the effect on anorexia remained intact. This indicates that for IL-1, different receptor mechanisms are present at the CNS level. Aubert (1999)

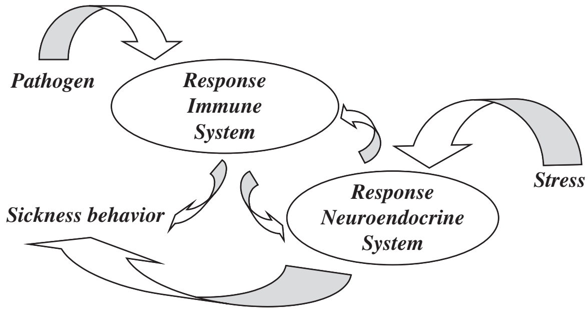

Fig. 8.5 Neuroendocrine immune interactions (generalised)

concluded that behavioural changes induced by cytokines are not merely the consequence of degraded state but also reflect motivational reorganisation that may have consequences for all kinds of processes that occur in a stable where groups of animals are in interaction. When the new set-up of priorities includes a general decrease of activity (immobility, sleepiness, reduced food and water intake), the sick animal still is in an open system where it can, and sometimes needs to, respond to external stimuli. But sickness behaviour can be interrupted only when important strong stimuli are received e.g. for the sow from newborn piglets. Anorexia is the most common feature during the early phase of infection. According to Exton (1997) the function of the anorexic phase lies in the reduction of further invasion of the body by pathogens via the GI-tract as a result of reduced food uptake and increased integrity of the epithelia.

The present state of knowledge with respect to the relationships between sickness behaviour, welfare and disease has been summarised above (Fig. 8.5). In evolutionary terms, one might conclude that disease, physiological evolution and cultural evolution interact. Social behaviour influences disease and is influenced by it (transmission, genetic). Danger signals lead to expression of sickness behaviour, which form a negative contribution to welfare. Alternatively, stress may have consequences for the function of vulnerable organ systems such as the gut and predisposition for disease. In such conditions the immune system may be severely challenged while it is down-regulated due to stress.

For pigs, sickness behaviour is also an important indicator for health and welfare. Monitoring pigs' sickness behaviour may contribute to the management of welfare in pig farming. Selection for the effectors of sickness behaviour can be included in selective breeding but may mask symptoms of disease.

8.4 Management of Disease

8.4.1 Trends in Pig Farming

In the past, animals with the best exhibited features suitable for intensive production purposes have been selected. This has led to pigs that display fast growth, optimal use of nutrients and modulation of the distribution of muscles and fat. In some countries, these processes are even enhanced by the use of growth hormones and other metabolism modulating substances. Since vaccination, antibiotics and anthelmintics could be used freely until recently, there was little need to include health and disease resistance in parameters for selection of production animals. A relatively high hygiene standard aims to prevent exposure of animals to pathogens. Together, these measures have led to a selection of animals in which the natural immunity, either innate or specific, is not a major characteristic. Inclusion of resilience in selection might contribute not only to animal health but also to animal welfare. Recent developments have led to reorientation of animal husbandry at least in Europe, but also in the U.S.A. where similar tendencies can be observed. Some of these tendencies, e.g. free range or natural farming, will lead to increased risk for animal disease in contrast to tendencies such as SPF (specified pathogen free) breeding. These developments can be summarised as follows:

Hygiene determines the risk for attracting a disease, as it influences the level of exposure and the quality of the innate and specific immune system. Two extremes develop in management. Large-scale intensive husbandry systems develop in which exclusion of pathogens is minimised. The level of containment aims at ultra-high hygienic standards (almost lab-animal SPF level). On the other extreme of the spectrum, is extensive farming with small-scale systems in the E.U. and larger systems in the U.S.A. with natural exposure to pathogens.

Consumer concerns with respect to welfare have led to quite different effects. A strong tendency has developed to decrease the preventive use of chemotherapeutica and antibiotics (AMGPs) in order to prevent development of resistance of pathogens and to minimise the supposed risk of resistant infections in the consumer and of drug residues in animal products. At the same time, the public expresses increased preference for decreased intensity of husbandry, with this smaller-scale farming using a more ‘natural’ type of management.

Politics In Europe in recent years, the discussions on the backgrounds of outbreaks of Foot and Mouth Disease and Classical Swine Fever have led to changes in policy regarding husbandry systems. Transport and inter-farm contacts have been firmly restricted. Closed farming systems develop in which the all-in/all-out principle is applied, which allows the maintenance of hygiene and limits the spread of pathogens and disease. The high hygienic standards aim to protect the consumer who wants predictable quality and an almost zero risk of contamination with human pathogens (zoonoses).

Welfare regulations, in western oriented societies, tend to aim more specifically at an increased level of pig-specific natural behaviour. These include, area for free ranging, specific feed components such as non-digestible fibres, limitation of animal density, group housing, use of specific bedding, etc. Changes to systems that allow a higher level of species-specific behaviour at high animal density will lead to intensive use of the area available for husbandry. Obviously, the risks of disease will increase as animals in the field can be exposed to all kinds of pathogens. For example, parasitic diseases with life cycle stages that survive relatively well in the topsoil are expected to increase over time. The increased risks of infection together with the reduction in use of preventive medicines (including vaccines) has revived the question of breeding of animals with a better disease resistance, i.e. a resilient animal that is able to withstand the conditions of extensive farming without much help.

For the pig farmer, the factors discussed above present difficult, complex choices. Withdrawal of AMGPs may lead to increased losses especially in young pigs. Pig production efficiency and product volume and quality can be greatly increased by reducing disease losses. Breeding for disease resistance and/or resilience can play a significant role alone or in combination with other control measures including disease eradication, vaccination and medication. Taken together, the above tendencies with respect to farm animal management both in public and in politics all aim to reach a higher level of the behavioural aspects of welfare but pose new challenges for the contribution of health to welfare.

8.4.2 Prevention of Disease

8.4.2.1 Prevention of Disease by Vaccination

For known pathogens, vaccination is the method of choice to eliminate the risk of disease but in general, it is only effective as a preventive measure. Vaccines should be administered to the majority of animals when they are in a healthy state, because protection time is needed to build immunological memory. Live vaccines are most effective but their safety depends on the level of attenuation. In principle, most live vaccines lead to transient disease symptoms, such as fever and local inflammatory effects. Vaccinations especially with safe, inactivated vaccines have to be repeated often to increase the response above threshold values or to maintain protection in the short life of a pig (Van Oirschot and de Leeuw, 1985). The injection of a killed vaccine, with adjuvant, may also have negative aspects. Due to the formulation with adjuvant it may be painful and will cause a brief local inflammation.

For bacterial diseases, vaccination is applied to neutralise virulence factors and toxins. Prevention and treatment of parasitic diseases is based on pharmacological approaches, as efficient vaccines are generally not available or are of poor quality. However, pharmacological approaches have a drawback in that they contaminate the meat, environment and manure and may result, over time, in resistance. Nevertheless, the parasite burden in animals may be such that well-being is compromised.

Both for disease prevention and animal welfare, vaccination is a most powerful tool but trade and export regulations often lead to restricted use. Antibodies specific for the vaccine pathogen will circulate in vaccinated animals for a long time and, in general, do not allow the distinction between infected and vaccinated animals. However, newly developed marker-vaccines lead to immune responses that at least in one easily diagnosed aspect differ from the response to infections (e.g. CSFV and PRV) (Van Oirschot, 1999; De Smit, 2000).

This will allow us to efficiently protect animals from diseases for which a ban on vaccination currently exists.

The balance between optimal veterinary practice and the commercial aspects of husbandry, often leads to vaccination when the first pigs express diseases symptoms. Vaccination of pigs that are not healthy is a sub-state-of-the-art treatment and in addition may lead to side effects due to circulating antibodies (Osterhaus et al., 1998). Vaccination in sick pigs is a last resort measure which may only reduce suffering of those pigs in a population that are not yet infected.

Some vaccines cannot be used in pregnant and diseased pigs. It is important to realise therefore, that induction of maternal immunity in sows requires accurate planning. For various diseases in many countries a post-eradication, non-vaccination policy still exists. When outbreaks of these diseases occur, such as foot and mouth disease or classical swine fever, the reaction in general is culling of animals not only on the farms where outbreaks occur but also in a wide area around. However, public support for the killing of healthy animals (sometimes millions) to prevent disease spreading is rapidly decreasing. Ring vaccination using marker vaccines around farms where primary infections have been diagnosed may reduce the numbers of animals that are culled and thus contribute to animal welfare.

8.4.2.2 Prevention of Disease by Isolation

Pathogens can travel over long distances by aerogenic transport, by animals of the same species but also by birds, foxes, cats, dogs and other animals that are found on or around farms or indeed by humans. Isolation may be effective in disease prevention, however, all materials with which the animal may come into contact have to be decontaminated and/or sterilised. Import of animals into such systems is limited, needs high quality quarantine and has a built-in risk of in-breeding with all the accompanying complications for health and well being that this entails. For small laboratory animals (rodents) double barrier maintenance in SPF systems is readily attainable. For larger animals in theory this may also seem feasible, but it is rather costly not only in terms of housing but also especially in labour.

However, due to the high standards of disciplined application of hygiene that is needed, these systems in general have not been shown to be sufficiently robust to be stable over long periods of time. This is in part due to the unbalanced microflora that may develop in such 'sterile' environments. This has been shown in Scandinavia and elsewhere where *Mycoplasma* in cleaned SPF farms rapidly re-appeared (Sorensen et al., 1992). Rotavirus and influenza cause infections of pigs that are mainly human-derived. New farming concepts with indoor slaughter may satisfy the consumers need for assurance of food safety. As new farming concepts such as SPF offer a non-natural environment and barrier maintenance, they may be counter to good welfare due to severe restriction of species-specific behaviour (such as wallowing, rooting, etc.). The super-clean environment may

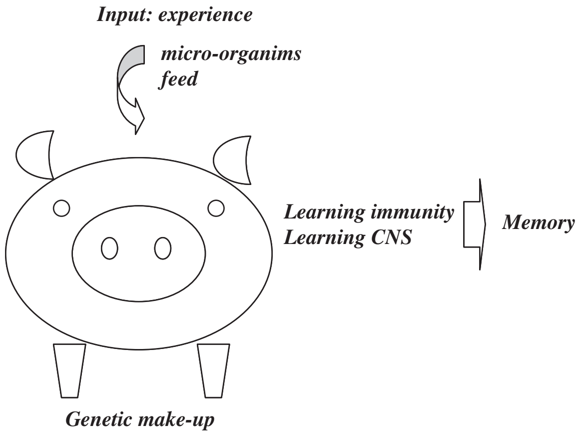

Fig. 8.6 Learning by doing. The interactions of the pig and its environment, infection, and social experience. Both at the level of the CNS, neuroendocrine system and immune system a memory is build up. The genetic make up and experience is conserved in memory that contributes to the pig's resilience

only be maintained in rooms with smooth, easily-cleaned surfaces, regular cleaning and disinfections of rooms, disinfections of manure etc.

Another drawback of SPF farming needs to be mentioned here. The isolation of pigs may lead to an inadequate education of the immune system (see Fig. 8.6) and aberrant reactivity later in life, might have its origin earlier during development of the system (Rook and Stanford, 1998). There is ample evidence that in neonates, there is a tendency to react to immune stimulation with Th2-biased responses (Morein et al., 2002; Bonney and Matzinger, 1998). This effect may be the result of an imprint by the maternal immune system which, during pregnancy, shows a similar bias (Wegmann et al., 1993; Mosmann and Sad, 1996; Raghupathy, 1997). It was hypothesized therefore that the absence of exposure to environmental pathogens and natural infections and the use of vaccines with adjuvant that direct responses into the Th2 trajectory, may lead to an increased prevalence of Th2-associated deviations of correct responsiveness (Rook and Stanford, 1998). Apart from an inadequate, unbalanced immune system that is deficient in Th1 reactivity, this also introduces a risk of yet unnoticed consequences for animal welfare due to ineffective immune–neuroendocrine interactions (Griffin, 1989; Kelley, 1985).

8.4.2.3 Resilience as Selection Criteria in Breeding

A genetic make-up that leads to immunodeficiency either in a quantitative or qualitative way, is a threat to porcine health. Also, the susceptibility to behavioural disorders is threatening to a pig's health and welfare. Therefore, there emerges recently a tendency to select for more robust pigs with a high natural disease resistance and a high grade of vitality. For selection of resilient pigs, the quality of the immune system may be a criterion. But what is a good immune system? For each type of challenge, there is an optimal requirement of reactivity. For bacterial infections, the innate immune system generally takes care of the primary attack. Antibodies neutralise toxins, aid in complement-mediated lysis, in phagocytosis and subsequent killing. Some viral diseases develop so rapidly that the immune system is not able to react adequately in time. Only those pigs which are vaccinated or which are not vulnerable to the attack (e.g. foot and mouth disease virus) will survive. For viral diseases, specific T-helper cells that modulate cytotoxic cells and pathogen specific cytotoxic T-cells are required for the final clearance.

Immune responses that lead to destruction of infected cells cause a lot of tissue damage. This leads to the exposure of many 'self' antigens that previously were not exposed to the immune system. In general, this will only lead to transient autoimmune responses. It indicates that in case of massive tissue damage, increased risks for aberrant reactions are present. In tissues that are both highly vulnerable to damage and are vital for the survival of the animal, such as the lungs (oxygenation of the blood) and the gut (exchange of water and nutrients), immune responses need to be sufficient but balanced. The mucosa of the GI-tract and the lungs are essentially one cell layer thick. Firm immune reactivity in lung or mucosal tissues may lead to extensive invasive infections. For that reason, the mucosal immune response is carried out by a specific part of the immune system. This is a gentle one and based mainly on continuous antibody-mediated surveillance, relatively low T-cell responses and as a consequence moderate responses of the recruited part of the innate immune system. Aberrant responses in humans include decreased immune surveillance, with cancer as a result, and in addition include well known examples such as asthma, allergies and autoimmune diseases. In the pig, most of these diseases do not come to expression because of the limitation of the life span. However, examples of feed allergies such as those observed for soya components and other feed components are not uncommon and may cause a considerable decrease in animal welfare (abdominal pain) and also loss in production.

Taken together, it becomes apparent that a balance between various effector systems within the immune system is of pivotal importance. The quality and quantity of the immune responses should be sufficient to protect but should not be hyper-reactive. Selection in breeding should include validated infectious disease models in which the responses can be evaluated at the cellular level. Obviously, the evaluation should include a balanced analysis of a broad array of functional animal models: for bacteria, for viruses and for parasites, based on their difference in requirements for protection. Farm animals in their farm habitat should be used preferentially for such analysis rather than laboratory pigs.

8.4.2.4 Attempts at Selective Breeding

Development of resilience through indirect selection primarily on immune response traits may be the best long-term strategy to generate robust animals. In homozygous miniature swine, boar, sow, parity and litter differences were important determinants of serum IgG and IgM concentrations. Seasonal variations were observed (Mallard et al., 1989). Yorkshire pigs were bred for high (HRP) and low (LRP) responder pigs in response to model antigens e.g. antibody responses to hen egg white lysozyme and DTH responses to purified protein derivative of tuberculin. Mitogenic responses were also determined. After challenge with *Mycoplasma hyorhinis,* low responder pigs developed more severe pleuritis and peritonitis than did the high responder pigs. HRP developed more severe arthritis and less polyserositis than did the LRP. In contrast, LRP were non-responders to a TGEV vaccination (transmissible gastro-enteritis virus) but HRP did react to the vaccine (Wilkie and Mallard, 1999). This suggests that aspecific selection may lead to improved resistance to selected diseases, while production parameters remain stable (Mallard et al., 1998). However, the severe arthritis may be explained as hyper-reactivity of the Th1 type cells in response to the *Mycoplasma* challenge. The development of certain traits requires a subtler, balanced test system for genetic selection. This was confirmed in HRP pigs which showed a similar or lower NK activity than was observed in controls. LRP had lower frequencies of NK cells than the high responder pigs (Raymond et al., 1998). Selection for adaptive immunity traits apparently did not select for innate immunity traits. This was also observed for superoxide anions that are important indicators for the killing capacity of monocytes (Groves et al., 1993). Similarly Krauslich et al. (1983) found that a dichotomy developed between cellular and humoral immunity after selection based on responses to model antigens. Pig lines developed for either innate, or cellular or humoral responses led to line-restricted disease incidences (Joling et al., 1993). Bruininx et al. (2000) observed that genotypes with highest antibody responses (Yorkshire and Dutch Landrace) had lowest growth whereas lowest responses were observed in the animals with most rapid growth (Finnish Landrace). Though not investigated in pigs, for poultry it was observed that selection for antibody responses to a model antigen led to unnoticed selection for certain MHC types (Pinard et al., 1992; Kreukniet et al., 1994; Parmentier et al., 1995). This unwanted selection for MHC haplotypes should be avoided as it is assumed, that exposure to pathogens plays a role in maintenance of MHC diversity. A balanced co-evolution of host and pathogen may be severely disturbed by selection (Mallard et al., 1998; Paterson et al., 1998).

Experiments with *Actinobacillus pleuropneumoniae* bacterins (vaccines) led to quite different qualities in responses as compared to the response to the challenge with live bacteria (Furesz et al., 1997). Therefore health advantages cannot be predicted from selection for disease resistance traits based on single or a few immune response test systems or by using model antigens (Biozzi et al., 1982). Future research should be directed towards developing and applying breeding techniques that will increase resistance to diseases without compromising production efficiency and product quality. This will require co-operation of immunogeneticists, veterinarians and pig breeders. As passive behavioural coping styles were associated with enhanced humoral immune responses also behavioural characteristics are important selection traits (Schrama et al., 1997).

However, it is not sufficient to have an immune system of optimal quality. The system also needs proper education to generate immunological memory (see Fig. 8.6). As the immune system learns in an iterative manner by doing, the quality of the system is in part determined by *'Use it or lose it'*. The pig's environment should allow such immune education. Vaccination methods may complete the response repertoire that is needed. This also leads to reduced shedding of pathogens and transmission in case a disease breaks out (MacKenzie and Bishop, 1999).

The above review indicates that breeding for better resilience is not simply accomplished. However, the development of resilience may be a strategy that with support of modern genomic approaches will gain momentum (Niewold et al., 2005). Those techniques when applied to pigs will also to generate sufficient understanding of resistance mechanisms.

8.4.2.5 Infectious Diseases and Specific Welfare Aspects

A few examples may make clear what detrimental effect diseases may have for pig welfare. Most infections occur unnoticed, as they remain subclinical. Disease is only of advantage for the pathogen if it enhances spreading by e.g. coughing and diarrhoea. Primary infections that result in inflammation of vital organ systems may be life-threatening already early after the infection. Opportunistic pathogens are in equilibrium with the host immune system. Environmental conditions, inadequate management, bad hygiene, bad feed composition or feed contamination, inappropriate housing conditions and co-infections that result in imbalance of the immune system, gut health or gut microflora may lead to development and growth of the pathogens and to increased severity of disease.

Diseases may be of viral, bacterial or parasitic origin. Most frequent infections in pig farming are GI-tract related in young piglets and respiratory tract related in fattening and adult pigs. Taken together, a pig runs a relatively high risk of suffering from diminished welfare due to infectious diseases. We will discuss a few examples just to indicate that such infectious diseases are not only an economical loss, but also indeed lead to diminished welfare of the infected pig.

Parasitic worms mainly have their entrance via the GI-tract. Tape worms like *Teania solium* are not frequently seen in modern pig husbandry, however they may reappear when a more natural way of pig husbandry is reintroduced. *Ascaris suum* lives in the upper part of the gut. In free-ranging pigs, the survival of the egg in the soil is a continuous source of repeated exposure. *Ascaris* infections lead to coughing, fever, diarrhoea and significant sickness behaviour. Lungworm (*Metastrongylus spp*) leads to similar symptoms in pigs as observed for *Ascaris*. The lung condition may lead to superinfections of viral and bacterial origin. *Metastrongylus* may carry influenza virus. *Hyostrongylus rubidus* ends up in the stomach mucosa and stomach epithelium. Various other worms remain in the gut. Dependent on the burden and secondary infections for which they may pave the way, they may lead to sickness behaviour and severe suffering of the pigs.

For most worms, pharmaceutical treatment of the pigs may be very effective. However, for pigs that have access to a limited area of land, repeated exposure and infection may lead to resistance of the parasites. For all pigs, a major threat is the increasing resistance of parasites to the drugs that presently still provide an effective treatment (Roepstorff and Nansen, 1994; Daugschies, 2000; Borgsteede and Jongbloed, 2001).

In general, bacterial infections lead to severe disease when untreated. Co-infections that occur frequently enhance severity. For infections with *E.coli* bacteria, that are the cause of (weaning) diarrhoea, inflammation of the udder and LPS-shock, or infections with *Actinobacillus pleuropneumoniae*, *Streptococcus suis*, *Brucella*, *Leptospira*, *Mycoplasma*, *Salmonella, Campylobacter*, that all cause other diseases, the use of therapeutic antibiotics has been the first choice thus far. However, due to high density farming, spreading of disease is rapid and suffering of animals is almost unavoidable. Antibiotics should only be used when needed, in order to avoid introduction of resistance and residues in products. Most vaccines are of limited value in that they may only be effective when used in a preventive way and for specific serotypes of bacteria. Bacterial diseases in part may be avoided by controlling feed quality and sterilisation.

For the major porcine viral diseases, effective vaccines have been generated. Clinical features and immune response parameters are the basis for diagnosis. Classical swine fever virus (hog cholera) and African swine fever virus have similar clinical features. Pigs start to get fever and diarrhoea and show sickness behaviour. Nasal secretions contain lots of virus. As the virus is also active in lymphoid cells, immunosuppression is the result. Super-infections of bacterial or viral origin lead to death at about 20 days. Pseudorabies virus (Aujeszky's disease), Foot and mouth disease virus and Porcine parvovirus all cause severe and sometimes fatal disease. Porcine respiratory and reproduction syndrome virus leads to increase death in piglets (early and late) with different sets of symptoms.

Some microorganisms may only be mildly pathogenic in pigs, but may be a threat to human health e.g. *Salmonella, Campylobacter*. Those micro-organisms may negatively influence animal health as interaction with the host may lead to physiological stress that in turn leads to activation of the neuroendocrine system. For example, attenuated *Salmonella* in pigs led to enhanced noradrenalin (NorA) levels (Bailey et al., 1999). NorA is known to influence heart rate and blood pressure and in addition has effects on animal behaviour (Dotevall, 1994). Following stress, NorA leads to a reduction of gastric juice production and slows the intestinal transit time (Dotevall, 1994). In this case, the host pathogen interactions modify host physiology and GI-tract activity. The neuroendocrine effects may lead to enhanced toxin production and *E. coli* pilus adhesion (Lyte et al., 1997). Subsequent bacterial growth and translocation may also be the result of enhanced levels of NorA (Bailey et al., 1999; Lyte and Bailey, 1997).

Infections may lead not only to clinical disease that obviously results in reduced welfare, but some micro-organisms may also negatively modulate animal physiology and health in an indirect mode of action. Environmental conditions including housing, stress, feed and transport may enhance the susceptibility to such micro-organisms. Intrinsic animal factors resulting from selection for high production traits may complicate disease. This may be the basis for the multifactorial diseases that seem to be on the increase in pig farming (Niewold et al., 2000).

8.4.2.6 Maternal Immunity and Postnatal Protection

In pigs, the immune system is able to generate immune responses in the prenatal phase of development. However, it takes until about 6–8 weeks after birth for the full repertoire of functions to be available at full strength. Vaccination of young pigs before day 3 can lead to reduced responsiveness compared with later vaccination, but no direct relation was observed to postnatal increased cortisol levels in serum at the time of immunisation (Metzger et al., 1978). During the postnatal period, the piglet is protected from foreign antigens/pathogens that are present in the environment of the sow by antibodies transferred from the sow to the piglet within the colostrum. These antibodies are taken up via the semi-permeable gut and will circulate in all tissues of the young pig. When the repertoire of pathogens in the environment of the piglet and the sow is different, the maternal protection will be deficient. However, sow-derived antibodies have a limited lifespan, as their half-life is about 12–18 days. Therefore, specific antibodies may rapidly decrease below levels that are relevant for protection while an efficient endogenous antibody response cannot and has not yet been generated.

Healthy sows that are immune to micro-organisms in their environment provide antibodies to the piglet that contribute to shaping of the gut microflora (see below) and provide a first line of defence to pathogens. Efficient and broad vaccination of sows will contribute to health of the piglets produced. Under the maternal immunity umbrella, the piglets can safely develop their own immune system while major challenges can be resisted effectively. Early discontinuation of lactogenic protection (weaning) may contribute to the severity of weaning diarrhoea. The consequence of maternal protection in general is an apparent suppression of the response to vaccination in young pigs (maternal immune suppression). This suppression can be observed up to 18 weeks postnatally (Van Oirschot, 1987). Since vaccination under maternal immune suppression may still prove very effective in priming of the pigs, it is assumed that apart from antibody titres, also other immunomodulatory effects play a role in maternal immune suppression. This indicates that for earliest protection of the young pig, it is still worthwhile to start vaccinations even though maternal immunity exists (Boersma et al., 1998). Health care of the sow is the start of health care for the piglets. For education of the sow's immune system vaccines are not only important, but the sow should also be allowed to develop a broad response repertoire to environmental antigens to protect piglets until after weaning. One of the traditional ways to accomplish this is by exposure to manure of healthy animals.

8.5 Production Related Diseases

8.5.1 Introduction

Production diseases may be the result of inadequate management and animal care such as logistics and associated stress, the choice and quality of feeding. Such parameters to a large extent are determined by the economics of production. Health problems may also be the result of selection of pigs for a purpose that does not match the demands of the specific animal in its environment (Niewold et al., 2000). Such diseases may be the result of consumer demands for specific product qualities that are not compatible with the adaptation capacity of animals. For example, the breeding of lean pigs may indicate where breeding may touch the limits of animal health and welfare (see below). Animal housing should be in balance with the adaptation capacity of the pigs. Its welfare-beneficial features may be detrimental for health and vice versa. Some of the aspects summed up here will be discussed just to indicate complexity of farming and the narrow gap between welfare and disease.

8.5.2 Management Factors and Stress

We will restrict our discussion of management-related stress to selected examples that clearly diminish welfare and in addition affect resilience. The relationship between (sickness-) behaviour, stress and disease resistance resides at the level of common messengers and receptors. Apparently, management of pigs will influence health by modulation of behaviour, social relationships and stress factors in pig husbandry.

Young piglets, especially males, go through many stressful events, such as unanesthesized castration, teeth-clipping and tail-docking. Social support by the sow may at least in part reduce the effect of these acute physical stressors (Sachser et al., 1998; Ruis et al., 2001a, b). This stressful period is followed by a change in nature and composition of the feed, separation from the sow, transport and mixing with unfamiliar piglets. This presents a firm challenge to the adaptive capacities of the piglet. As a consequence, all forms of sickness behaviour can be studied during the process of piglet weaning. The well known anorexic period after weaning leads, in general, to a malfunctioning of the GI-tract as a result of the decrease of the available gut epithelial surface area that is measured as the villus length/crypt depth ratio (Nabuurs, 1998; Niewold et al., 2000). In addition, the gut integrity decreases and discontinuation of maternal immunity may result in increased susceptibility to infectious diseases especially of the GI-tract. Though we may compensate for this with feed additives that reduce exposure and enhance endogenic immunity, it may never reach the effectiveness of maternal lactogenic protection.

Coping strategies have an important influence on the outcome of the behavioural and physiological stress response in individuals. The effects of social stress are modulated by social support. Group housing may decrease the effects of ranking in mixed groups and result in better 'health' performance. However, dependent on the representation of dominant and submissive, proactive and reactive pigs in a group, the social stability may be reduced (Ruis et al., 2001a, b). Coping characteristic and social status may have implications for welfare and production. More knowledge is needed to allow the selection of pigs such as to establish socially stable groups that (together) have a physiological adaptation capacity sufficient to respond adequately to challenges via the immune system.

8.5.3 Juvenile Trauma: Enhanced Sensitivity for Stress?

Castration is apparently incompatible with animal integrity and is a cause of diminished welfare (see below). Castration is performed for two reasons mainly: (1) to avoid boar taint in meat, and (2) to avoid aggression and agonistic behaviour among pigs. Boar taint is unwanted by consumers in certain geographical areas although it may be a delicacy in other areas. Castration does not always lead to a decrease in aggressive behaviour. In contrast, the castration of dominant males may lead to increased aggression on the part of the females (Dixson, 1993).

Unanaesthetized castration is painful, increases early deaths in new-borns and is thought to be unethical for those reasons. The welfare aspects include the pre- and post-operation stress, pain, health risk and the interference with the animal's integrity and the interference in social behaviour (White et al., 1995; Horn et al., 1999; Taylor et al., 2001). Health effects thus far have received far less attention, but we know that castration causes production of acute phase proteins (Lackner et al., 2002). In pigs, the testosterone levels in males show a postnatal peak between about days 2 and 20 after birth (Schwartzenberger, 1993). This surge of testosterone is thought to influence sexual and agonistic behaviour and as a result, also involves the response to infections. Castration may prevent the development of sufficient levels of testosterone when castration is performed directly after birth and may have intermediate effects when castration is performed between 0 and 21 days. Also, in humans, levels of testosterone were shown to influence negatively the immune response modulation by cortisol (Rohleder et al., 2002). Cortisol and other neuroendocrine components of the stress response may severely affect the immune system (Griffin, 1989; Kelley, 1980). In pigs, cortisol suppresses the aspecific, proliferative response of lymphocytes *in vitro* (Brown-Borg et al., 1993), but also NK-responses and chemotaxis are negatively influenced (McGlone et al., 1993b).

The traumatic experience of castration may sensitise the pigs to later stressors such as mixing (Bruijnzeel et al., 1999; McGlone et al., 1993a, b). Mixing of dominant pigs led to increased aspecific lymphocyte proliferation whereas, in subordinates, it decreased. De Groot et al. (2001) concluded, that dominants might be more vulnerable to the effect of mixing on the immune response than subordinates at mixing. This was based on the observation, that the post challenge ratio of interferon gamma:IL-10 that was produced in response to pseudorabiesvirus was lower in mixed dominants than it was in subordinates. It may be an indication that in pigs, as in other animals, the skewing of Th1/Th2 responses is under control of neuroendocrine regulation (Chiapelli et al., 1994). Mixed barrows castrated at three weeks of age suffered more from immunosuppression than mixed gilts (De Groot et al., 2001). These results suggest that the trauma of unanaesthetised castration renders the barrow more susceptible to subsequent challenges due to interactions of the immune system and to HPA-axis skewing to higher activity that leads to a reduced immune capacity of the castrated males. This was supported by findings that in 18,000 pigs, inflammation was more often observed in barrows than in gilts (De Kruijf and Welling, 1988). In barrows, there was increased incidence in pneumonia, chronic pleuritis and pericarditis compared with age-matched gilts (De Kruijf and Welling, 1988). It was suggested, that altered hormonal patterns or the post-traumatic increased sensitivity to subsequent stress might be causative.

The stress and the change in hormonal patterns that accompany castration may be the mediators of an increased HPA-reactivity in barrows (De Groot et al., 2001). In addition, De Groot et al. (2001) showed, that antibody responses of barrows and gilts showed differences in the production of IgG1 or IgG2 in antiviral responses which are an indication for Th1 and Th2 responsiveness respectively in pigs. The gilts may be more prone to Th1 responses than barrows, which is analogous to observations in mice (Wilcoxon et al., 2000).

The suffering related to castration should be prevented. Most effective is a worldwide ban on castration. The alternative may be immuno-castration, although the behavioural and health effects of this method have not been investigated in sufficient detail yet (Zeng et al., 2002). Alternatively, insemination with selected semen to avoid the production of males might be explored (Rath et al., 1999; Blecher et al., 1999). Whether this may have consequences for specific traits in breeding also remains to be investigated.

8.5.4 Modulation of Meat Quality May Affect Vital Functions

8.5.4.1 The Role of Leptin

Production animals are sometimes ‘shaped’ to the wishes of the consumer, independent of the consequences for animal health or welfare. For example, the increasing obesity observed in humans and the adverse effect of animal fat on human heart and blood vessels has led to selection of pigs with reduced fat: muscle ratios (Cameron et al., 2000; Barb et al., 2001). Since various hormones are dependent on their distribution in body fat for appropriate functioning, it was expected that changes in body fat distribution in sows might have detrimental effects e.g. on their reproduction capacity and other vital functions.

Leptin is a protein hormone that was first identified (1994) as an adipocyte hormone regulating food intake, energy expenditure and the neuro-endocrine axis. It has been shown to regulate feed intake in several species including pigs. Leptin may be involved in body energy stores, dietary energy intake and reproductive function. Selection for high daily food intake in pigs resulted in higher serum leptin concentration, fat deposition and food intake. Serum leptin and fat deposition were positively correlated. This might enable the use of leptin concentrations as selection criteria for genetic improvement of carcass lean content in pigs (Cameron et al., 2000). Expression of leptin in fully-fed pigs reflects adipocyte size and body-fat mass. Leptin signals the status of body energy stores to the brain, where signals emanate to regulate food intake and whole-body energy expenditure (Houseknecht and Portocarrero, 1998). Expression of the long form of the leptin receptor that is capable of signal transduction was observed in most parts of the brain, adrenals, reproductive organs, liver, kidney, pancreas, immune system, gut, heart, lung, bone marrow, muscle and adipose tissue. The distributions of this receptor in tissues in foetus, newborn and young pigs supported the idea that leptin might play a role in regulating numerous physiological functions (Lin et al., 2000). Leptin inhibits feed intake and stimulated growth hormone (GH) and luteinizing hormone (LH) secretion in the pig (Baratta et al., 2002). Recombinant porcine leptin also modulates the function of these hormones (Barb et al., 1998). Feed restriction affects the reproductive, metabolic, and endocrine parameters in cyclic gilts and may have deleterious effects on ovarian function in the peri-estrous period (Almeida et al., 2001). Insulin mediates changes in porcine leptin. During nutritional deprivation adipocyte function related parameters such as leptin were severely reduced. Leptin concentration changes aim to adjust the energy partitioning in the animal to conserve energy during nutritional deprivation, thereby enabling survival (McNeel and Mersmann, 2000). Leptin is thought to influence whole-body glucose homeostasis and insulin action (Houseknecht and Portocarrero, 1998).

Leptin may also affect the hypothalamo-pituitary-gonadal axis. Leptin receptor mRNA is present in the anterior pituitary and hypothalamus of several species. The leptin receptors in placental tissues are involved in regulating the metabolism of the fetal-placental unit. Leptin and its receptor may play a role during early stages of development of the pig embryo-foetus (Guay et al., 2001; Prunier et al., 2001). Leptin mRNA expression was higher in progeny from mothers provided with more feed. Body weight at birth was negatively correlated with the abundance of leptin mRNA in subcutaneous fat in piglets 59 days of age. Birth weight was a determinant of blood leptin concentrations in adults. This demonstrated that maternal nutrition during pregnancy programs post-natal leptin expression in offspring (Prunier et al., 2001; Ekert et al., 2000). The hypothalamus is the key site of central regulation of energy homeostasis, appetite, and reproduction. The leptin receptor in the hypothalamus along with several neuropeptides is involved in regulation of the neuroendocrine axis. Neuropeptides may serve as messengers that regulate reproduction and energy balance (Lin et al., 2001). In addition to neuroendocrine functions, leptin may affect peripheral tissues by acting on receptors located in sympathetic ganglion neurones (Czaja et al., 2002). The above observations indicate that selective breeding that disturbs leptin expression levels may result in dramatic physiological effects. Insufficient knowledge may lead to skewing of physiological systems such that animal welfare is severely at risk.

8.5.4.2 Leptin and Immunity

Leptin also modulates the immune response. The physiological response to infection includes reductions in tissue concentrations of anabolic growth factors as a means of reducing growth and conserving nutrients for immunological processes. This repartitioning of nutrients is accompanied by anorexia, which has been linked to increased leptin expression. Certain high lean gain swine genotypes have greater sensitivity to pathogen and non-pathogen stressors evident by reduced productivity and increased mortality during disease stress or in suboptimal production environments. In such pigs, LPS induced or enhanced anorexia, fever, and circulating TNF-α, cortisol, and NEFA, but LPS reduced circulating glucose, insulin, and IGF-1. The LPS-induced hypoglycaemia and hypoinsulinemia was significantly greater in moderate lean cross pigs as compared to high lean pigs. Acute phase responses were lower for moderate lean pigs than for high lean pigs. Leptin mRNA in adipose tissue was significantly reduced in both moderate and high lean pigs. Leptin expression was not increased by endotoxin challenge in the pig. Nevertheless, physiological differences in leptin, a potent regulator of food intake and energy metabolism, may be important factors in the genetic variation in sensitivity to environmental stress and sensitive to regulation by consequences of inflammatory responses (Houseknecht & Portocarrero, 1998; Spurlock et al., 1998; Leininger et al., 2000).

Leptin and leptin receptor genetic marker genotypes associate with immune parameters and with production traits (Te Pas et al., 2001). Furthermore, certain high lean gain pig lines have greater sensitivity to environmental stress including pathogens (Leininger et al., 2000), indicating that breeding for production traits alone can threaten resilience. Hypoleptinaemia caused by malnutrition impairs the immune response by reducing the Th1, and DTH response, increasing the Th2 response and alters the innate immune response. Pro-inflammatory cytokines lead to an increased production of leptin, which in its turn enhances PMN and macrophage function. Higher leptin levels result in reduced food intake, associated with inflammatory disease (sickness behaviour). In maintaining the Th1/Th2 balance, a properly balanced leptin response appears to be central.

The example of leptin modulation by changing the body fat distribution shows, that the consequences of selection based on a limited number of selected traits without control of vital functions leads to unwanted and/or unnoticed modulation of several functions that are vital for health and welfare maintenance. As a consequence, feed restriction (welfare) alters reproduction characteristics and has consequences for offspring. Further studies are required to understand details of the role of leptin. This may help to select for those characteristics that maintain sufficient disease resilience capacity and at the same time meet the pigs nutritional demands. In addition, the effects of leptin on HPA-axis activity may lead to an unwanted increased sensitivity to stress. Future genomics-guided-breeding may provide tools to avoid such effects.

8.5.5 Feeding and Health

8.5.5.1 The Gut Flora on the Junction of Complex Systems

Gut and lung together form the major surface area to be protected from intruders. For example, in humans, the gut surface area is estimated to be about the size of a tennis court. As a consequence most pathogens enter the body via these 'portes d'entree'. The gut ecosystem is composed of the microflora, the epithelial lining, the gut associated immune/lymphoid tissue (GALT) and the neuro-endocrine system. They need to cooperate to support and maintain the integrity of the GI-tract. Environmental influences that modulate neuro-endocrine functions will have an effect on the gut eco-system as well (Husband and Gleeson, 1996). All four systems differ in expression along the GI-tract, but at any site and time they need to maintain the delicate balance between opening up for resorption of nutrients and closing carefully for all life-threatening events (Goddeeris et al., 2002). In addition, all four systems are dynamic and they are subject of continuous differentiation and renewal (microflora, gut, GALT) or are subjects of many exogenous modulating impulses (neuro-endocrine system). In most mammals, the complexity of the gut wall as well as of the GALT decreases toward the colon. The gut flora contributes to the barrier that is maintained against pathogenic intruders and toxic substances. Furthermore, the gut flora is important for and is modulated by nutrition and growth, intestinal health and moreover interactions with the host at the level of mucosal immunity. Pig management modulates the gut flora. Early weaning, sterile or barrier maintenance of pigs or contaminated or insufficient feed all influence gut health of the pig and its welfare. Feed composition, diet, pre and probiotics are tools to modulate gut flora in a direction that supports the health of the host/pig.

8.5.5.2 The Role of the Gut Flora in Gut Health

Before birth, the GI-tract is devoid of micro-organisms. It is assumed that in pigs, invasion of the gut by the maternal flora starts during birth. Later on, the maternal faeces and other environmental sources contribute as well (Mackie et al., 1999; Kenworthy and Crabb, 1963). In pigs, in the initial flora, *Lactobacillus* and *Clostridium* (Yurdusev et al., 1985) rapidly follow the development of

E. coli and *Streptococci*. After one day the major flora elements are present in large numbers (10^{10}/gram faeces) and full colonisation occurs in about two days (Ewing and Cole, 1994). The flora develops in a dynamic interaction with the host and in this way induces the development and differentiation of the gut (Lopez-Boada et al., 2000) and simultaneously shapes the functionality and the repertoire of the gut-associated immune system (for review see Moreau and Gaboriau-Routhiau, 2000).

Dependent on feed and other conditions, the flora that develops after weaning is relatively stable with respect to the composing bacteria (Drasar and Barrow, 1985; Harmsen et al., 2000). In most mammals, a largely similar distribution of bacteria is observed along the GI-tract when the host flora relationship is stabilised. The micro-organisms with a resident character form the so called indigenous flora (Dubos et al., 1965). As the gut ecosystem is open, the exchange with new species is normal. New invaders may become resident when they replace strains of similar species or successfully compete for the same niche.

Flora contributions to growth promotion include the stimulation of gut wall development and architecture that influence efficiency of nutrient uptake but also the fermentation of substrates into components that are digestible to the host (Stewart et al., 1993). The production of vitamins and detoxification of food components contribute directly to the pig's health. To facilitate the interactions between host and flora, the digested and undigested food serves as substrate for both. In addition, secretions such as mucus, saliva, gastric and pancreatic juices including enzymes, bile salts and secretory antibodies contribute to the interactions between all flora components of which many still are unidentified. The generation of short chain fatty acids (SCFA) that influences gut cell differentiation, deconjugation and dehydroxylation of bile salts (Bezkorovainy, 2001), and production of vitamin K like metabolites (Falk et al., 1998), all are examples of health aspects that are modulated by various gut flora components.

The daily output of the GALT may be in the order of grams of secretory IgA per day (Brandtzaeg et al., 1999). In the secretions, antibodies are abundantly present that bind to normal flora components (Apperloo-Renkema et al., 1993). Active or passive translocation of flora components across the epithelium plays a role in the education process of the immune system (Moreau et al., 1982; Kramer and Cebra, 1994; Kroese and Bos, 1999; Bos et al., 2000).

In gnotobiotic mice and pigs, development of the mucosal immune system is severely delayed. When such animals are exposed to a conventional environment they attract diseases which have their main porte d'entree via the mucosal surfaces. They generally will not survive this situation without severe precautions being taken. Also the young of SPF animals run a severe risk in attracting fatal diseases in a conventional environment although they do have a selected GI-tract flora, which they received from the maternal animal (Boersma, unpublished observations). This indicates that the flora contributes to development of a healthy GI-tract and that a period of learning precedes the establishment a stable host-flora relationship to the benefit of both. The contribution of the immune system to the shaping of the microflora has long been underestimated. In a healthy individual both innate and specific reactivity are in balance with the alterations in the flora. Immune cell subsets appear at clearly defined time points and in an ordered sequence (Vega-Lopez et al., 1995; Joling et al., 1994). At birth, the pig gut is characterised by a lack of immunological cell types characteristic of the mature gut. The gnotobiotic pig shows a similarly immature architecture (Rothkoetter and Pabst, 1989).

In newborns, it is not the underdeveloped immune system of the piglet but the maternal derived colostral and milk antibodies that contribute most to the primary selection of flora elements. In healthy conditions, the upper part of the small intestines contain relatively few bacteria, but the concentration of bacteria increases in jejunum and ileum and large intestine. The flora however, consists of many bacteria that are harmless only dependent on the conditions of the host. Opportunistic bacteria expand their niche when possible. Factors that control this dynamic balance are host (immune system, gut integrity), nutrient and flora composition dependent. Apart from the natural controlling factors, therapeutic use of antibiotics and immuno-suppression (induced or acquired) may also have a severe impact on the gut ecosystem balance. Infections with *Clostridia, E. coli, Klebsiella, Enterobacteriaceae, Enterococcus* spp and *Staphylococcus* spp are typical examples of imbalances. The primary function of the gut does not allow suffering from prolonged inflammatory conditions. The reactions to pathogens therefore need to be of short duration and local in character. Longer duration leads to severe suffering of the animals and complications at different physiological levels. Harmful side effects of bacteria are triggering of immune reactivity and production of cytokines such as TNF-α, IL-1, IL-6 and reactive agents such as reactive oxygen species and antibacterial peptides. In some cases, the balance of the ecosystem is redressed by administration of the normal flora or inoculation of single strains of bacteria such as probiotic *Lactobacilli* (Blomberg et al., 1993) or non-pathogenic competitor strains (Mulder et al., 1997).

Obviously such a complex ecosystem needs to be analysed using systems that really allow to analyses the multitude of parameters involved. 'X-omics' guided by shrewd bioinformatics is needed to learn to understand the principles.

8.5.5.3 Probiotics for Microflora Stabilization

Antibiotics in sub-therapeutic levels have increased growth rates via a mechanism that is still not fully understood (Yokoyama et al., 1982). Probably it includes the suppression of sub-clinical infections, reduction of production of growth suppressing toxins and reduction of flora elements that have a negative influence on uptake (of essential nutrients). For obvious reasons such as induction of resistance, the use of antibiotic growth promoters has been or will be prohibited in the E.U. and elsewhere (VanBelle, 2001). As a consequence of withdrawal of AMGPs, a search for allowable alternatives was initiated that might contribute to animal health and production, to the same extent.

Probiotics have been reported to improve microbial balance in the gastrointestinal tract through bacterial antagonisms, competitive exclusion and immune stimulation (Havenaar and Huis in't Veld, 1992). When the flora is in disequilibrium, the addition of bacteria that have health improving properties and/or feed components that preferentially give an advantage to such bacteria may restore the host flora relation. Such probiotic (good for health) bacteria were first isolated from faeces of healthy animals. Selected probiotics have been shown to have anti-pathogen effects that are based on competition for nutrients and for adhesion sites in the gut wall (Mulder et al., 1997). Furthermore they lead to enhanced production of volatile fatty acids and antibiotic peptides (bacteriocins). In addition, they stimulate gut architecture and motility but also give an a-specific enhancement to the effectors of the gut-associated and systemic immune system (Falk et al., 1998; Cebra, 1999; Isolauri et al., 1993; Maassen et al., 2000a, b). *Lactobacillus*, *propionibacteria* and *bifidobacteria* species contributed in enhanced growth in piglets (Pollman et al., 1980; Mantere-Alhonen, 1995; Abe et al., 1995). In pigs, the concept of competitive exclusion has been shown for *S.cholera suis* applied to suckling piglets (Fedorka-Cray et al., 1999). A reduction of 50% in gut frequencies of *S. cholera* was obtained in the pigs. Results suggest that this treatment may also be beneficial for young pigs (Fedorka-Cray et al., 1999) and for reduction of *E. coli*, similar results have been reported (Genovese et al., 2000). The capacity of selected probiotic micro-organisms to enhance immune responses has also been demonstrated with a wide variety of antigens including model antigen and oral rotavirus vaccines (Ouwehand et al., 2002). All these effects are probably attributable to the macrophage-activating and IFN-γ inducing properties. Most probiotics analysed have a tendency to bias the immune response toward Th1 cytokine profiles (Maassen et al., 2000a, b).

If the hypothesis of Rook and Stanford (1998) on the 'under-education' of the immune system is true (see 8.2.2), then stimulation of the immune system in the Th1 direction by administration of, or exposition to, exogenic stimuli might be beneficial to the learning immune system – i.e. 'give us this day our daily germs' (Rook and Stanford, 1998). To accomplish this, the use of probiotics as adjuvant and the transformants thereof as live vaccines (Maassen et al., 1999) might be considered, especially in neonates and young. Regular administration of dosages of probiotic bacteria may have an adjuvant effect for the response to any infection. This might help re-install the balance in Th1 and Th2 type reactions and may also be beneficial on concomitant use of non-reproductive or inactivated vaccines that are Th2 biased (Famularo and De Simone, 1998).

Recent experimental evidence in chickens, mice and humans shows that the stimulation of the immune system using probiotics or other means may be a most important contribution to animal health. Yet there is still some hesitation for the introduction of probiotics in veterinary practice. This is in part based on a conservative feed industry whose standard production methods are detrimental to live bacteria. However, especially in pigs, the delivery of probiotics via a fresh fermented feed concept might be very effective and cheap and 'porridge' may fit very well with the eating habits of piglets.

8.5.5.4 Modulation of Gut Health: Functional Foods in Pigs?

The luminal content has a major influence on the functioning of the gut. Parenteral feeding leads to gut atrophy, changes in morphology and an increase in T-lymphocytes which indicates danger signals along the GI-tract (Matzinger, 2002; McCracken et al., 1999). Weaning-associated inflammatory processes along the gut show increased levels of IL-1 and of fibrinogen (Cummins et al., 1988). Also, post-weaning, increased numbers of $CD4^+$ T-helper cells were found (McCracken et al., 1995; Pluske et al., 1999). Apparently the food is of vital importance to initiate and maintain a healthy gut ecosystem. Food can be regarded as functional if it is demonstrated satisfactorily to affect beneficially one or more target functions in the body, beyond adequate nutritional effects. This in a way should contribute to either the state of well-being and health or to the reduction of the risk of disease (Roberfroid, 2002).

Prebiotics include non-digestible food ingredients that target certain components within the microbiota of the intestine. Efficient prebiotics have a specific fermentation and the ability to alter the faecal microflora composition towards a more 'beneficial' community structure. This leads to activities such as the suppression of the growth of pathogens through different regulatory mechanisms (Roberfroid, 2002). In a balanced feed, sufficient non-digestible oligosaccharides (NDO) should be present to support gut health. In some countries this has already been included in welfare regulations. NDO's form a specific category of prebiotics. They assist to maintain a flora composition that controls growth of pathogenic micro-organisms e.g. by means of competitive exclusion. However, at present there is not yet a predictable relationship between the inclusion of specific NDO in diets for pigs and their effects on the microbial ecosystem, digestive processes and on overall performance.

Short-chain fructo-oligosaccharides (FOS) occur in a number of edible plants, such as chicory, onions, asparagus, and wheat. Both inulin and oligofructose are effective prebiotics according to *in vitro* and *in vivo* assessments in different laboratories (Kolida et al., 2002). These carbohydrates promote fermentation in the colon, increasing short-chain fatty acid production and alter bacterial flora in the small bowel and colon (Vanderhoof, 1998). FOS are associated with a decrease in faecal pH, an increase in faecal or colonic organic acids, a decrease in the production of nitrogenous end products in urine and faeces, a decrease in faecal bacterial enzymatic activities and a modification in faecal neutral sterols. FOS enhance magnesium absorption and enhance both colon butyrate concentrations (VFA) and local immune system effectors (Bornet et al., 2002). FOS are typical 'prebiotics' that stimulate bifidobacterial growth specifically while suppressing the growth of potentially harmful species such as *Clostridium perfringens* in the colon. Their effects on the gut ecosystem can lead to a significant reduction in the number of bacteria reported to have pathogenic potential. Moreover, it has also been reported that they improve the bio-availability of essential minerals and that they reduce serum triglyceridemia by lowering hepatic lipogenesis (Roberfroid, 1997).

Fermentable hemicelluloses such as sugar beet pulp lead to a decrease in metabolic cholesterol to a larger extent than hardly digestible fibres, fermentable cellulose or pectin. Some fibres may reduce cholesterol content of pork products by up to 10–25%. The reduction involves mainly HDL and not LDL cholesterol (Kreuzer et al., 2002). Pigs fed a high transgalacto-oligosaccharide (TOS) diet had more caecal volatile fatty acids (VFA) that are beneficial to gut health. Compared to TOS-fed pigs, FOS-fed pigs had a higher proximal colon pH, lower colon VFA concentration and lower portal VFA concentration. Thus, dietary FOSs and TOSs have different effects on fermentation characteristics of gut contents of pigs which deserve further investigation (Kolida et al., 2002; Roberfroid, 1997).

It is evident that in many cases, the enhanced saccharolytic activity in the small intestine of NDO fed pigs cannot be maintained throughout the large intestine due to the fast rate of fermentation of these NDO in the upper part of the GI-tract. For example, prebiotic carbohydrates that can be fermented throughout the gastrointestinal tract, may result in prolonged prebiotic effects in young pigs (Mosenthin and Bauer, 2000; Houdijk et al., 2002). Alternatively, pairing NDO and probiotic strains that have the metabolic potential of fermenting the supplied NDO at a competitive rate compared to the indigenous micro-flora, is likely to be a successful strategy in controlling the intestinal ecosystem. The expected benefits are an improved survival rate during the passage of the probiotic bacteria through the upper intestinal tract to the colonic microbiota. In addition a stimulating effect of the NDO on the growth and/or activity of both exogenous and endogenous bacteria is expected (Zimmermann et al., 2001).

The non-digestible oligosaccharides that are classified as dietary fibre exert their functional effects in the colonic microflora that use them as selective 'fertilisers' for the gastrointestinal physiology, the immune functions, the bioavailability of minerals and the metabolism of lipids. Potential health benefits may also concern reduction of the risk of some diseases like intestinal infections. Feed composition should therefore not only be selected for growth but also for stabilisation of 'health promoting' flora components. However, as known from human studies, adverse effects of high concentrations of fibres (diarrhoea) have been reported and also healthy fibres should be used with care (Marlett et al., 2002).

8.5.5.5 Diet and Immunity

The composition of the diet is mainly based on production parameters such as rapid growth. However, trace elements in the diet determine to a large extent the effectiveness of the innate and specific immune system. Most important for some trace elements are that there exists a narrow bandwidth between beneficial and detrimental effects. High added concentrations might lead to severe toxicity. In addition, the bioavailability of trace elements present in the diet is not well controlled and understood. Effects of some of the trace elements are in a tight balance such as for molybdenum, copper and iron. Copper is important in bactericidal activity of many cells of the immune system. Iron injections are common to prevent anaemia due to rapid growth (Brock 1994). Iron supplementation may lead to a lower incidence of post-weaning diarrhoea (Schrama et al., 1997) but iron effects on immunity mechanisms are not clear (Hershko, 1993). Optimal immune responses were observed usually at normal physiological levels of iron in blood measured as haemoglobin (Bruininx et al., 2000). However, cellular immune responses were reduced in iron deficient pigs (De Sousa et al., 1988, 1991). Iron over-supply may exhaust the iron-binding capacity in the gut and in the circulation. As acute phase proteins play a role in binding of micronutrients, the acute phase response may be negatively influenced. This increases the risk of infection by opportunistic bacteria that may grow out once the surplus of iron becomes available for their expansion. Acute phase responses are sensitive to changes in the bio-available manganese concentration in the diet. Manganese is important for the production of IL-1 and TNF-α. Zinc and copper have a strong influence on immune responses such as DTH reactions, phagocytosis and the acute phase responses (Rink and Gabriel, 2001; Bonham et al., 2002). Maternal and weanling chromium supplementation (200 ppb) led to decreased IgG levels in 4 weeks old pigs about one week after weaning which is typically the most vulnerable phase to attract infections in young pigs (Van de Ligt et al., 2002).

For optimal health maintenance, the balanced representation of trace elements in the diet is of great importance. Though new genetic lines of pigs are developed continuously, adaptation of ration lags behind. In addition, for free range animals, the diet may be dependent on the soil richness with respect to the trace elements. This is quite different in different geographical areas where pigs are reared. This is a typical situation where the consequences of management conditions that allow a higher level of species-specific behaviour have to be brought into balance with the optimisation and/or support of the natural disease resistance, in order to reach a satisfactory level of animal welfare.

The role of the normal mature intestinal lamina propria is to maintain a balance between immune reactivity and the physiological gut function. In neonatal pigs, this balance may develop slowly and is dependent on contact with antigen (Bailey et al., 2001). The stress related to weaning may result in immunological insults and may tip the balance of the developing mucosal immune system of the piglet into excessive effector or regulatory function resulting in transient or chronic allergy or disease susceptibility. Food allergy is characterised by villus atrophy, crypt hyperplasia and reduced ability to digest and absorb nutrients. These phenomena are highly similar to those observed in post-weaning diarrhoea in piglets. The effect is related to the level of specific protein in the diet and may be transient (Li et al., 1990). Such reactions of the intestinal immune system to dietary antigens occurred in the intestine of the post-weaned piglet preceding the proliferation of *E. coli* and the development of post-weaning diarrhoea (Stokes et al., 1987). The transient cell-mediated immune response to dietary antigens might increase the susceptibility to disease.

Though not studied in great detail, gut immune responses have been suspected in food hypersensitivity reactions to soybean proteins (Stokes et al., 1987; Dunsford et al., 1989). Li et al. (1991) showed that pigs fed diets containing soybean meal had a lower rate of gain and villus height but higher serum anti-soy IgG titres, and increased DTH responses to soy-proteins as compared to those fed on dried skim milk. Food contaminants may be a source of infectious disease (*Salmonella, E. coli*). In addition, contaminants with toxic effects may lead to diseases and may have a secondary effect in reduction of immune responses. Pigs may have decreased resilience as a result of gut damage due to reactions to unwanted feed components. Subsequently they may show symptoms of a disease of which the farmer is unfamiliar or does not understand the origin. It is not known how many of these pigs suffer be it transiently from such feed-derived, unrecognised diseases.

8.6 Housing

8.6.1 Housing, Health and Welfare

Today's domestic pigs use an environment that is relatively unnatural and which limits species-specific behaviour. This leads to inadequate adaptive responses, to chronic stress and enhanced risk for animal disease. To avoid such diminished well-being, new formats of housing including the possibility to walk 'freely' outside and to use attributes for expression of species-specific behaviour are being developed, in order to control stress, sickness behaviour and to maximise natural behaviour such as explorative walking, rooting and wallowing, within limited stocking density, greater space and limited group size. As the effect of various stressors may be additive in their negative effect, optimisation of as many factors as possible in animal care leads to best performance (Hyun et al., 1998).

8.6.2 New Housing 'Dirty or Clean': Health or Welfare?

The immune system is a system which builds up memory in an iterative manner: i.e. learning by doing. In this respect, the low exposure to antigens from allergens and pathogens in over-hygienic conditions may lead to an understimulation of the immune system (see previous sections). Such insufficient priming might be the underlying cause for increased frequencies of atopy and allergy in humans (Rook and Stanford, 1998). The latter diseases are not of importance for the pigs. However, an imbalance in immune responses may result in aberrant responses to pathogens as well.

A survey in the Netherlands showed that airway problems were the most common diseases in Dutch pigs. In addition, lung problems are more frequently observed in farmers than in any other occupation (Donham et al., 1986). Organic dust causes airway and lung disease in humans (Cormier et al., 1997). Obviously the aerial environment in certain pig housing systems can be detrimental to animal and human health. For animals, the discussion on best choices for housing systems leads to different outcomes. These may have quite different effects on the immune system and therefore have a considerable impact on the risk of attraction of disease. Animal stocking density and the free-ranging area that is available to the animals will determine the chance to attract and transmit infectious diseases. High animal densities in a limited area increase the risks of continuous re-infection due to survival of the bugs in the environment. Various parasitic diseases are most likely candidates that will take their toll. Air quality may affect animal health in an indirect way. This might be the consequence of the fact that an increased level of dust keeps lung alveolar macrophages busy such, that their pathogen scavenging function is diminished. Thus, an increased level of dust is a predisposing factor for lung infections (Van Iwaarden et al., 2001). Secondly, there is a tendency to keep animals in surroundings varying from a high hygienic standard to almost SPF conditions. These conditions when performed according to state of the art standards will limit the risk of infectious diseases to the minimum. The question remains what will be the effect on animal health if such a system is breached. There are insufficient studies available to properly estimate the risks.

Swine confinement buildings were compared with a wide range of cleanliness that was related to ventilation, air temperature, animal density and room size and assigned a 'dirtiness' score. Furthermore humidity, ammonia, carbon dioxide, total dust and microbiological counts including the presence of spores, moulds and endotoxins were determined. It was concluded, that apart from seasonal variations, the most important contaminants were micro-organisms (bacteria). In general summer dirtiness levels were lower than in winter (Duchaine et al., 2000). Bassaganya-Reira et al. (2001) evaluated the performance of early-weaned pigs in 'clean' and 'dirty' housing. Animals in the dirty housing showed clearly lower health status and retardation in growth. 'Dirty' pig diets that comprised enhanced levels of conjugated linoleic acids were able to enhance frequencies of CD8 cells that are thought to be relevant in protection to pathogens.

The type and amount of bedding material, animal stocking density and size of the pen will influence exposure of animals to factors suspected to interfere negatively with health. However, pigs in barren environmental conditions showed more signs of chronic stress than pigs housed under relatively enriched conditions. Development of appropriate social behaviour is reduced as compared to observations in more enriched housing (Beattie et al., 2000; De Jonge et al., 1996; Olsson et al., 1999). De Jong et al. (1998, 2000) investigated physiological aspects of barren housing such as chronic stress. They observed that enriched-housed pigs had higher baseline cortisol levels than barren-housed pigs. This was in contrast to the behavioural observations. However, at 22 weeks of age the circadian rhythm of enriched-housed pigs was clearly visible whereas the rhythm for barren-housed pigs was blunted. Differences in circadian rhythms were visible from week 15. Blunted cortisol rhythms are also observed in tethered pigs (Janssens et al., 1995) and in human depression (Deuschle et al., 1997). The blunting of cortisol rhythms is therefore considered to be a further indication of chronic stress in barren housed animals. However, De Groot et al. (2000) showed that no effect was observed on humoral immunity and responses to mitogens under conditions of chronic stress according to behaviour and blunting of cortisol rhythms. This deserves further study.

Also group size is of importance and may be related to housing conditions. Wolter et al. (2001) showed that for animal health, a larger group size (50 or 100) might be preferred over smaller group sizes (25). This was based on the relative frequencies of pigs with 'poor' health and injuries. When enrichment is created with bedding that contributes conditions that are harmful for health aspects of the respiratory tract (dust) or directly are harmful by exposure to pathogens (high endotoxin levels), it is necessary to find out where the balance lies between animal welfare and animal health. Though for welfare (De Jong et al., 1998, 2000), a limited level of straw bedding (half the available area covered), may be beneficial in that it reduces stress-related phenomena, a so called deep straw bedding may be less beneficial for health (Turner et al., 2000). Pigs in deep straw bedding in groups of 20 or 80 pigs in two densities showed that the immune response of animals in high density showed an increased frequency of injuries and a reduced humoral immune response as compared to animals in a low density. Both animal interactions (De Groot et al., 2001; Ruis et al., 2001a, b) and a higher level of exposure to dust may explain the harmful effects observed for immune responses.

The perception of animal welfare plays an important role in changes in animal husbandry. In those countries where consumer concern is based on care for animal welfare, there is a tendency to think that welfare is best warranted in a more natural or extensive form of husbandry. However, free range is of quite different quality in various geographical areas. In densely populated areas, pigs will be allowed only to use a small surface area where they can have contact with the soil. In the densely populated area they will have still close contact with human beings and a high level of veterinary control is maintained. In other regions (e.g. U.S.A. or U.K.) animals can freely roam into fields such that they will only seldom come into contact with human beings. Housing that aims to contribute to the prevention of infectious disease may have most problems to provide the means to express natural species-specific behaviour. As long as the barrier is maintained, animals are safe. Once the barrier is broken the animals are prone to rapid spreading of disease. Natural or free-range farming will allow a fuller repertoire of species-specific behaviour, however, health control and optimal feeding is less well controlled. Especially pathogens that survive in outside conditions will more easily find sufficient hosts to reproduce. From the studies cited above, it becomes apparent that ideal situations with respect to housing, climate and animal density are not yet fully developed and cannot be easily predicted. It is of importance that the effects of all such conditions are studied in an integrated manner. The read-out of such multifactorial systems may be approached using modern genomics and proteomics as read-out systems.

8.7 The Future of Health and Welfare?

We started this chapter to make clear that as long as welfare, health and disease are not clearly and precisely defined, different human perceptions of animal welfare lead the decision-making in measures to select for farming conditions. We have given some definitions that may provide a basis for identification of critical parameters that now can be defined and can be measured in an objective way. As the absence of disease is not easily determined, the definitions of health remain relatively weak. For welfare, the definition in qualitative aspects has been proposed. However, also, the decision of which level of welfare may seem appropriate is mainly determined by human perception of the pig's welfare. As we have demonstrated, the mutual influences of health and welfare status the present definitions should be more focused to accomplish that. Further investigation of the parameters on which such a common definition could be based is needed. The concepts of animal health and welfare are still in development.

Various aspects of pig farming were reviewed with respect to their impact on animal health and welfare and we have tried to demonstrate that to distinguish between the two is artificial. The systems that are involved in the control of health and disease i.e. the neuroendocrine system and the immune system, are to a high degree intertwined: messengers and receptors are shared. The same signal with a messenger in one system may initiate an immune response whereas at the same time this same signal may lead to sickness behaviour similar to that observed as a result of diminished welfare and stress and its counterpart disease susceptibility.

The short introduction to the immune system illustrates its importance for maintenance of health. Only an orchestrated response is effective, with balanced input of both Th1, Th2 responses. This leads to a response that is adjusted (1) to the nature of the threat, (2) to the level of danger and (3) to spare the vital functions in the organ systems that are involved such as lungs and GI-tract.

Resilience instead of disease resistance seems a more appropriate measure for the capacity of an animal to adapt to environmental conditions in order to maintain health. The concept of sickness behaviour has been introduced to demonstrate what the impact of health may be for welfare. The role of the microflora and the factors that are involved in the shaping of the flora including the maternal colostrum and milk (delayed weaning), are still underestimated. Feed quality and nature may contribute to improvement of gut health to the benefits of the animal. Pre- and probiotics may contribute to gut health which is pivotal in the maintenance of the pig's resilience.

For the farmers, the complex choices that they have to make should be based on balanced decisions in which animal care is the main issue. The effect of castration on the hormonal level and on the level of increased sensitivity for stress and subsequently for disease are such that it should be high on the list of 'Don'ts' in pig farming. Extreme forms of either intensive or extensive of husbandry, including breeding, housing and feeding, run the risk of derailment either from the aspect of suboptimal welfare or from diminished health. Consumer demands may drive the farmer to select animals that are increasingly vulnerable to disease or behavioural constraints. The example of leptin, a hormone that was only recently described, demonstrates that we still know only little of the complex interactions of nutrition, the neuroendocrine system and other complex systems in the body. It also shows where modern genomics/proteomics/X-omics may contribute to dissect such complex relations. The development of a porcine welfare chip and porcine health chip may in future help farm managers to control the effect of their decisions.

In conclusion: the marriage of welfare and stress is probably best warranted in farming systems that include the best of extremes: expression of optimal species-specific behaviour, preventive health care, feed that supports disease resilience, shelter from harsh conditions and protection from those who try to alter physiological systems without sufficient knowledge of the consequences. We tend to conclude, that welfare and health in different systems meet different demands that sometimes appear to be mutually exclusive or at least hard to reconcile.

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Chapter 9
Welfare into Practice

David C.J. Main

9.1 Introduction

Implementing new knowledge of animal welfare on pig farms is a key challenge for all stakeholders. This chapter will consider the mechanisms available for bringing about welfare improvements. Since implementation of these husbandry improvements is dependent upon stockpeople, it is critical to consider what forces are likely to bring about change. A critical motivation for stockpeople is the level of care for their stock. In a survey of U.K. producers, farmers reported that providing each of the Five Freedoms was important. Indeed at least 87% of respondents thought that each of the Five Freedoms was either of great or extreme importance (see Fig. 9.1).

Even though stockpersons are usually very motivated to care for stock under their care, husbandry changes that improve welfare are more likely to be implemented if there is a positive impact on the profitability of the production system. There is often scope for welfare and profitability improvements (i.e. "win-win") in many pig units without dramatic changes in the husbandry system. For example, in some units a relatively small change in building design with minimal additional costs can reduce respiratory disease thereby improving welfare. The reduced level of disease will also increase profitability by reducing medication costs, increasing feed conversion performance and reducing abattoir losses.

This relationship is well understood by many farmers. For example in the same survey of U.K. farmers, there was a very close relationship between the levels of importance the pig farmers placed on the well-being of pigs and the importance of the disease on profitability (see Fig. 9.2). In other words, farmers perceive that disease can affect both welfare and profitability. In this survey, however, it is interesting to note that farmers believed that tail-biting had more importance for well-being than for profitability. This might suggest that raising awareness of the

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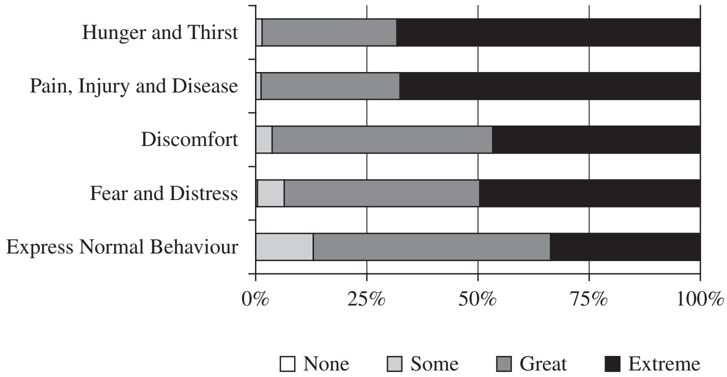

Fig. 9.1 The proportion of pig, dairy and sheep farmers ($n = 488$) that considered the level of importance that animals should be placed on providing animals with each of the five freedoms was either none, some, great or extreme. Survey sent to U.K. farmers supplying a major retailer

financial implications of some welfare problems may be less important for motivating farmers to make husbandry changes.

There are limitations in relying on the farmer's fundamental motivation to care for animals and the link with profitability. For example there may be a lack of knowledge on how to improve the situation. Also the farmer may not be aware of the level of welfare problems on their own farm. In a recent study, dairy farmers appeared to be unaware of the levels of lameness on their own farms. The mean prevalence of lameness as observed by an experienced assessor was 22%; however, the mean level of lameness reported by the farmer prior to the herd assessment was 6% (Whay et al., 2003). Farmers are unlikely to embark on welfare improvements if they have not perceived such a problem.

Husbandry improvements described in previous chapters will need to be implemented by stockpeople, managers or owners. On large units these may

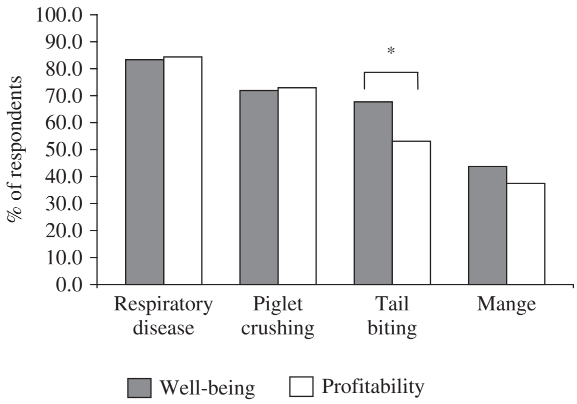

Fig. 9.2 Proportion of pig farmers ($n = 96$) believing that respiratory disease, piglet crushing, tail biting and mange has either great or extreme importance on pig well-being and pig unit profitability

be separate, clearly-defined people. However, for small units, one person may take on one or more of these roles. Different husbandry improvements may necessitate a different level of involvement for each of these participants. For example a change in the daily routine that does not have any time or resource implications can be implemented by the stockperson directly, providing the manager gives ongoing support and training for stockpeople. However, husbandry improvements that require capital investment will necessitate an investment decision from the owner, approval from the manager to implement the change and acquiescence from the stockperson to change the daily routine.

9.2 Motivations Required to Implement Welfare Improvements

Potential welfare improvements that have been discussed in previous chapters will only be implemented if stockpeople, managers and owners are motivated to change the husbandry conditions for welfare concerns. The level of motivation required depends on the particular welfare concern. For those welfare concerns that are inherent in the husbandry system the motivation to change would need to be very considerable. For example, the restriction of freedom of movement in gestation stall and tether systems can only be addressed by substantial investment in a new sow housing system. In the U.K., many pig farmers only introduced these changes in response to legislation prohibiting this particular system.

However, many welfare concerns such as levels of disease, aggression and tail-biting may be managed with lower levels of investment. These more "avoidable" welfare problems are often "win-win" scenarios – i.e. some short-term investment in resource results in both welfare and profitability improvements. If policymakers wish to bring about welfare improvement then the following motivations to change may be considered. In practice, a combination of these mechanisms is likely to be most effective as no one single mechanism would work for all farmers.

9.2.1 Enforcement

Farmers may be required to change their practices in response to either legislation or market-driven standards. In either case, farmers respond either directly to the publication of the new standards or to identification of non-compliances by a visiting official or assessor. For legislative requirements, failure to modify the husbandry resources could result in prosecution. For farm assurance schemes, failure to comply could result in loss of scheme membership, which could lead to loss of premium or denial of access to the market place.

9.2.2 *Education*

A significant limitation for welfare improvements could be the farmer's knowledge of the issues. This knowledge may be lacking even if the stockperson is very motivated to care for the livestock. This lack of knowledge may relate to both awareness of one's own performance or the advice or knowledge on how to improve the situation.

9.2.2.1 Raise Awareness of Their Performance

This can be achieved by an advisor or external assessor reports back to the farmer on their own level of performance. Comparing results with other similar farmers benchmarks this "welfare performance" and this may motivate the farmer to modify husbandry conditions. This may be achieved by simple league tables or inclusion within the report.

9.2.2.2 Advice to Resolve Problems

Clearly some farmers may benefit from external advice on specific husbandry solutions that would be effective on their own unit. Advice may be part of formal training schemes, informal meetings or from an advisor or veterinary surgeon. Although certification scheme assessors are not normally permitted to give advice directly, certification schemes can insist that farmers have available appropriate, advisory literature or insist that the problem is incorporated and acted upon within a veterinary health and welfare programme.

9.2.3 *Encouragement*

Since most farmers are normally very motivated to provide good welfare conditions appropriate encouragement may be very effective. The following are some potential examples.

9.2.3.1 Positive Farm Assurance Reports

In addition to identifying non-conformances, reports can also include positive statements acknowledging best practice in maintaining high welfare state measures.

9.2.3.2 Financial Incentives

In the U.K., the reduction in cell counts associated with mastitis in dairy cattle that followed the introduction of a scheme linked to milk price is an obvious example of the ability of a financial incentive to bring about a change.

9.2.3.3 Promote Competitive Nature of Farmers

Even with no financial incentive, farmers that are proud of their stock will compete to have the highest standards. Compilation of simple league tables of welfare state measures could promote competition between farms.

9.3 Role of the Market

The market place has an increasingly important role in delivering welfare assurances to consumers. If these welfare assurances are meaningful some farmers will be required to make welfare improvements. For many countries, these improvements have been mostly delivered by "enforcement" within certification schemes that control access to the marketplace. The level of welfare improvement will depend upon the particular marketplace and the associated demands of the retailer or consumer.

Consumers have a significant role to play in the welfare standards. Individual consumers are more likely to have a more direct influence on smaller producers and retailers. However, for pig products sold via large retailers, the buying power of a large number of consumers influence the purchasing policy and the associated technical controls of the large retailing companies. For pork products in the U.K., the retailers consider the abattoir as their producer. In practice, this means that abattoirs implement the retailer requirements either by directly visiting the farms or requiring farms to become members of a farm assurance certification scheme.

9.3.1 Market Types

There are three principle types of markets that have very different influences on animal welfare. Different countries will have different proportions of their market in each category.

9.3.1.1 Open Access Limited by Compliance with Legislation and State Enforcement

The traditional market place has been open access to all pig producers. The requirement to follow the necessary legislation has not been checked by the purchaser of the pigs. In this system, the responsibility for enforcement of the legal requirements has remained with the relevant state authorities.

9.3.1.2 Access Limited to Compliance with National Farm Assurance Schemes

For this market place, the purchaser of the pigs places some basic requirements on the producer. The standards expected are usually based upon legislative requirements plus additional criteria that can be achieved by the vast majority of the pig producers. There is usually a system of monitoring compliance with these basic requirements. Although welfare standards are often a significant component of these initiatives, the purchaser often includes food safety and environmental conditions. In the U.K., food safety legislation required purchasers to show due diligence in the production process (including on-farm). In order to implement this legal requirement, retailers have promoted farm assurance schemes that include food safety. In practice, welfare and environmental concerns have then been added to these systems. The certification systems that can deliver the assurances required for these schemes are discussed below.

9.3.1.3 Premium Markets with Additional Welfare/Environmental Standards

Some certification schemes aim to deliver higher welfare standards than the norm. For example, the RSPCA Freedom Food scheme in the U.K. and the Free Farmed program in U.S.A. have been specifically designed to deliver high welfare standards. Organic schemes take a more holistic approach as the aim is to address environmental, food safety and animal welfare concerns. Whatever the particular scheme, the principles of certification (see below) apply. It is, however, important to consider the impact of the schemes on animal welfare.

9.4 Principles of the Certification Process

All types of certification scheme, whether designed for the “mass” or “niche” market, will need to follow similar principles. The key components are the detail of the technical standards and the assessment systems that ensure all farmers within some schemes are compliant with the standard. Farms belonging to schemes will normally receive appropriate certificates. For some farm assurance schemes, the body that administers the scheme is accredited to ISO Guide 65, or its equivalent European standard (EN45011), by the relevant national accreditation body. Hence, the farm is certificated and the scheme is accredited. Accredited bodies have demonstrated a certain level of competency and impartiality. The accreditation process does not set minimum thresholds for the standards although it needs to demonstrate that the standard is developed in consultation with stakeholders such as retailers and farmers.

9.4.1 Standards for Current Quality Assurance Schemes

Farm assurance standards have been developed for most livestock sectors including pigs (Main et al., 2000a). The standards required by each scheme vary enormously in both content and scope; e.g. organic schemes give quite specific detail on the content and origins of the diet while others have more general statements about diet suitability. Some standards deal only with the management of the animals on the farm whereas others include transport and slaughter. For some countries there are mechanisms in place to ensure a certain minimum level in set amongst certification schemes. For example, in the U.K., an Assured Food standard moderates standards for several schemes (www.redtractor.org.uk).

The detailed content of the standard for each scheme usually requires agreement between interested parties (e.g. farmer and retailer). However, as a minimum, certification schemes would include legislation and codes of practice that are relevant to the stated objectives of the scheme. In addition, the standards need to be achievable by at least those operating to "best practice". An unachievable standard will alienate farmers. Also the standards should be clearly definable, understandable and unambiguous. They should be regularly and frequently updated. They should be auditable and enforceable since a standard that cannot be verified on farm is unhelpful and could lead to false claims by the scheme.

For national schemes that are aimed at a large number of producers, the standards would not be able to prohibit a welfare concern that is intrinsic to a common husbandry system. For example, the Assured British Pig scheme, which aims to encompass most indoor pig producers in the U.K., has not prohibited the farrowing crate system although it can address avoidable issues such as ensuring that pen fittings are maintained so as to avoid injuries.

The ability for a scheme to deliver "good welfare" depends on the extent to which welfare can be assured by the husbandry provisions. The standards should include all resources and husbandry practices on a farm that could affect the welfare of any individual of the species covered by the scheme. This should include all types of stock such as the management of cull animals. Most schemes base standards on measures of provision – i.e. the husbandry resources that should be provided to the animal rather than animal-based measures of outcome such as disease incidence, tail-biting prevalence, etc. Although some schemes do include a requirement for a health plan (see Box 9.1), which can require farmers to plan their own husbandry procedures in order to minimise certain welfare concerns, and then monitor their effectiveness by recording and reviewing animal-based measures of performance over time (Pig Veterinary Society, 1999). Thus, a particular health or welfare concern should be detected by the farmer and a specific action plan relevant to that farm instigated.

Previous work investigating the impact of farm assurance schemes on dairy cattle welfare have demonstrated that defining resources alone may be ineffective in delivering high welfare standards (Main et al., 2003). For example, a high mean (22%) prevalence of lameness was observed in farms whatever their assurance status. A management/health plan standard that requires active identification and management of welfare concerns is likely to be more effective in dealing with multifactorial problems than simplistic definitions of husbandry provisions within the standard.

Box 9.1. Management standards
Quality management systems, such as ISO 9000, provide a model for management systems in any industry. However, the key principles of these management systems can be incorporated into more farmer-friendly systems. For example a veterinary health plan, contain the following key elements (Main and Cartledge, 2000):

1. Plan the specific prevention and treatment procedures
2. Record the incidence of key health and welfare parameters
3. Review at regular intervals the levels of these parameters
4. Action plans to modify husbandry conditions in order to deal with specific problems

Health plans may be specifically mentioned in farm assurance standards e.g. Assured British Pigs (2007), which states:

2.5.1 The Participant must have a Veterinary Health Plan (VHP) drawn up and regularly updated by the attending veterinary surgeon. This must be made available to the assessor.
2.5.2 Herd performance data must be monitored for signs of disease or production disorders, including the level of transit deaths and the level and type of condemnations of slaughter stock.
2.5.3 The VHP must be reviewed and revised in the light of current performance in relation to a) identified targets and b) any new DEFRA (Department of Environment, Food and Rural Affairs) Codes of Practice as and when they are introduced.

9.4.2 Implementation of Standards

A scheme cannot deliver an assurance to the consumer unless there is a credible system for ensuring that the producer is complying with the requirements in the standard. There are usually three key stages to this process:

9.4.2.1 Dissemination of Standards

Farmers will only implement standards if they are fully aware of the detailed requirements of the standard, so it is important that they receive updated copies of the standards. Some schemes use a self-assessment system partly to draw the attention of the farmer to the standard requirements and partly to provide evidence that the farmer is complying with the standards since an external auditor can verify the accuracy of the self-assessment. Advisors can assist the producer to comply with the standard. For example, the veterinary surgeon is well suited to perform this task, ideally in association with regular consultations on herd health and preventive medicine.

9.4.2.2 Assessment of Compliance

A representative of the scheme (assessor) will usually need to visit the farm to verify compliance with the standard. In general terms, the assessor is looking to gather evidence (visual, verbal or written) that verifies compliance with the standard. The assessor gathers this evidence from observation of records, resources and management, structured dialogue with stockpersons and, of course, observation of the animals in their environment. Their competency in terms of animal welfare knowledge and assessment are critically important. Also the impartiality of the assessor is important for the credibility of the scheme. The assessor will need inspection and audit skills (see Box 9.2). Inspection is used to assess the husbandry resources that are specified in the standard. Audit skills are needed to assess compliance with the management aspects of the standard such as the veterinary health plan. Increasing the frequency and length of visits can increase the credibility of the assessment procedure. However, this obviously has a direct impact on the cost of the scheme. Assessors with suitable auditing and inspection skills (and suitable access to records) should be able to make some assessment of the management of the unit over a reasonable period such as one year prior to the visit.

Box 9.2. Definitions of inspection and auditing

Inspection is defined in international standards ISO 8402 as "Activity such as measuring, examining, testing or gauging one or more characteristics of an entity and comparing the results with specified requirements in order to establish whether conformity is achieved for each characteristic."

Auditing in the same standard is defined as "Systematic and independent examination to determine whether qualities activities and related results comply with planned arrangements and whether these arrangements are implemented effectively and are suitable to achieve objectives".

9.4.2.3 Management of Non-Compliance

The certification schemes will also need to ensure any failure to achieve specific elements of the standard (non-compliances) are resolved. Usually, membership of such schemes is withheld until evidence is provided or another visit is arranged to demonstrate full compliance. For existing members, the member will usually have a certain defined period in which to resolve the non-compliance. If the issue is very serious or is not resolved the scheme can then expel the farmer.

9.4.2.4 Improvements to the Certification Process

As discussed, most welfare-relevant farm assurance or legal standards define the resources that should be provided to the animals. For some husbandry provisions such as provision of a certain space allowance, welfare requirements can be very specific and directly measurable without reference to any further welfare outcomes. These "engineering-based" requirements (Mench, 2003) can be assessed objectively. However, many requirements in organic, farm assurance and legal standards can only be assessed with reference to the animal outcomes. These have been called "performance-based" as they imply that resources provided to the animals should only be considered compliant if they result in certain minimum outcomes. For example, the provision of "adequate nutrition" requires assessment of the body condition of animals in addition to an assessment of the diet. Several studies have evaluated the use of outcome measures in pigs such as the prevalence of skin injuries (Leeb et al., 2001) and lameness (Main et al., 2000b). Increased reliance on animal-based outcomes measures in certification is likely to increase the welfare assurance provided by such schemes. The E.U. is funding a large-scale project, Welfare Quality (Blokhuis et al., 2003) that aims to produce a European standard for welfare assessment. The University of Bristol has developed an animal-based welfare assessment protocol for pigs, dairy cattle and laying hens in a research study assessing the welfare impact of the RSPCA Freedom Food scheme (Whay et al., 2002).

9.5 Case Example: The Farm Assured British Pigs Scheme

The following example demonstrates the operation of the Farm Assured British Pigs (FAB Pigs) scheme that operated in the U.K. between October 1996 and July 1998. This example outlines the issues that pig farmers were required to correct, either to join or to remain as a member of the original FAB Pigs scheme and is reprinted with kind permission from the Veterinary Record (Main and Green, 2000). This assurance scheme was designed to "reassure purchasers of pigs from registered herds on aspects of medication and animal welfare" (FAB Pigs, 1996). The FAB Pigs standards which were used during the period of this study were replaced with more detailed standards in July 1998 (FAB Pigs, 1998). In November 1999, the Assured British Pigs scheme operated by Assured British Meat superseded the FAB Pigs scheme and a previously separate scheme – the Malton Code Scheme (Wood, 1999).

9.5.1 Overview of the FAB Pigs Scheme

Farms applying for membership of the scheme were inspected by veterinary surgeons from the U.K. State Veterinary Service (SVS). All farms within the scheme were subjected to a system of surveillance monitoring, which consisted of biennial visits from the SVS and quarterly visits from the farm's private veterinary surgeon (PV). Any aspects of the farm or its management identified during the inspections as a non-compliance with the standards were recorded on a veterinary report form. Farms were required to correct all non-compliances identified on the initial SVS visit before membership was accepted. Corrective action was verified either by another SVS visit or by the PV. FAB Pigs also recorded non-compliances identified by private veterinary surgeons during their quarterly veterinary visits. If the same non-compliance was noted at the next quarterly visit then the farm was sent an enforcement notice from FAB Pigs outlining the action required. Confirmation of compliance was normally required from the PV.

The total number of farms accepted for membership by July 1998 was 2,010. Of farms joining the scheme, 16.6% had at least one non-compliance identified during the initial SVS visit and 6.9% of farms had at least one non-compliance on subsequent surveillance visits.

A random sample of reports from farm visits were analysed. These involved 372 non-compliances identified at 222 visits to 177 farms. There was an average

Table 9.1 Number, percentage and type of 249 non-compliances relating to the welfare requirements of FAB pigs standards identified on 177 farms

Type of non-compliance		Number	%
Structural defects	– *Floors*	27	10.8
	– *Not–specified*	23	9.2
	– *Gates*	20	8.0
	– *Arcs*	10	4.0
	– *More than one defect*	9	3.6
	– *Miscellaneous*	7	2.8
	– *Feeders*	6	2.4
	– *Walls*	4	1.6
	Total	**106**	**42.6**
Hospital pens	– *Inadequate number of pens*	12	4.8
	– *Inadequate facilities*	12	4.8
	– *Inadequate use of the pen*	6	2.4
	– *No named responsible person*	1	0.4
	Total	**31**	**12.4**
Health issues	– *Tail biting*	10	4.0
	– *Pigs not euthanased*	5	2.0
	– *Dirty pigs*	2	0.8
	– *Lameness*	2	0.8
	– *Shoulder ulcers in sows*	1	0.4
	Total	**20**	**8.0**
Water	– *Inadequate drinking points*	28	11.2
	– *Insufficient pressure*	3	1.2
	Total	**31**	**12.4**
Other	– *Ventilation alarms / failsafe*	34	13.7
	– *Welfare codes*	16	6.4
	– *Stocking density*	11	4.4
	Total	**61**	**24.5**
Total		**249**	**100.0**

of 2.1 and 1.2 non-compliances identified per initial and surveillance visit respectively. The reduced non-compliance detection in existing members may be due to differences in the inspection procedure or increased compliance by existing members. Welfare-related considerations accounted for 67% of the non-compliances examined (Table 9.1). The remaining aspects primarily concerned the food safety aspects of medication.

Most of the welfare–related non–compliances were related to the specific requirements of Schedule 3 of the Welfare of Livestock Regulations (HMSO, 1994) that was the relevant welfare legislation at the time of the study. Of the welfare–related non–compliances (Table 9.1), 43% concerned structural defects that could be harmful to pigs, 14% concerned the provision of emergency ventilation systems and alarms, 12% were related to the provision and use of hospital pens and 12% were associated with the adequate supply of water. Stocking densities above the legal minimum standard accounted for 4.4% of welfare–related non–compliances. Non–compliances relating to the requirement to have and understand the welfare codes accounted for 6.4% of welfare–related non–compliances. The remaining 8% of welfare–related non–compliances were directly related to various health concerns. In the sample examined, one non–compliance, which concerned a pig that should have been euthanised, was deemed to involve "unnecessary pain or unnecessary distress" by the inspector.

This example has provided evidence that the FAB Pigs scheme, operating under the original standards, identified veterinary medical and welfare–related concerns and ensured that they were corrected. It is reasonable to assume that many of these concerns would not have been identified without the introduction of this farm assurance scheme and associated inspection system.

9.6 Summary

It is very important to recognise that the vast majority of farmers care passionately about the welfare of the animals under their care. It is important to utilise this motivation rather than to patronise or alienate those that are actually responsible for animal welfare. There are, however, still some persistent welfare problems as reviewed in the other chapters so it is necessary to consider what other motivations are necessary to bring about welfare improvements. For example, many welfare problems may require minor husbandry changes but yield significant welfare improvements. These win–win scenarios can often be accomplished by raising awareness of the issue and possibilities for change. In particular, farmers should be encouraged to monitor and manage their own "welfare performance". Health and welfare programmes are a mechanism for ensuring welfare concerns are actively managed.

For issues that require more significant husbandry changes, such as housing–related investments, then other motivations may be required. Education, enforcement and encouragement initiatives should all be considered. Enforcement by marketplace–driven standards obviously has a role to play; however, the role of encouragement initiatives that actually reward good performance is likely to more effective and self–sustaining.

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Chapter 10
Welfare of Pigs During Transport and Slaughter

Jeremy N. Marchant-Forde and Ruth M. Marchant-Forde

10.1 Introduction

At some stage in their lifetime, the vast majority of pigs will be transported, except those that are born and then die or are euthanized on the same farm. The number of times and distances over which they are transported will vary depending on whether they are in the finishing or the breeding herd and the nature of the pig industry within the country or region in which they are being reared. For example, it is not uncommon for herds in North America to employ multi-site production, meaning that at weaning, pigs may be transported to a nursery unit and later on, transported again to a growing and finishing unit. Over the last few decades, slaughter plants have followed a similar trend to pig farms, meaning that they are now fewer in number, more spread out geographically, but larger. This means that the average distances that pigs have to be transported to reach the slaughter plant have increased and thus, average journey time has increased. The maximum journey time in particular has been focus of much recent research with resulting recommendations and legislation in some markets, such as the European Union.

If the process of transportation is too stressful for a pig, the ultimate result can be the death of that pig or the pig becoming non-ambulatory or ‘fatigued’. In North America, the current in-transit + post-transit mortality and non-ambulatory rates are around 0.15% and 0.40% respectively (Benjamin, 2005) representing in total around 11 pigs in every 2000 transported. It is therefore in the interests of the producer (and of course the pig) that the stress of transportation is minimized. In this chapter, we examine the welfare of pigs during the process of transportation and their welfare on reaching the slaughterhouse. We begin by breaking the transportation and slaughter process up into its constituent parts, namely loading, transport, unloading, lairage and slaughter, and, where information exists, we also examine how pigs at different stages of the production cycle respond to transport.

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10.2 Loading

When measuring stress parameters, the parts of transportation that appear to effect the greatest response are those of loading and unloading (Bradshaw et al., 1996a; Christensen and Barton Gade, 1996). When pigs are loaded, they may well be exposed to fearful situations such as handling and novelty. They may be mixed and they may undergo considerable physical exertion. This first part of the transport process can therefore be extremely stressful, but the amount of stress that individual pigs encounter during the process can be influenced by the housing environment in which they have been (Hunter et al., 1997), their previous exposure to handling (Abbott et al., 1997; Geverink et al., 1998a), the type of handling (Hemsworth et al., 2002) and the loading method used (Brown et al., 2005).

10.2.1 Housing Environment

Pigs that have been reared in enriched housing systems behave differently when exposed to novelty than pigs that were housed in barren environments. Generally, pigs from enriched housing tend to carry out more exploratory behavior and spend more time near novel objects (Bolhuis et al., 2004; Morrison et al., 2007). The consequence of this when it comes to handling, however, can be problematical. Although enriched housing system pigs may be less stressed by being released from their pen into the corridor, their propensity to investigate their surroundings may actually mean that they become harder to handle. Geverink et al. (1999) found that finishing pigs from a barren environment took significantly less time to load than pigs from an enriched environment. Beattie et al. (1995) also found that gilts housed in barren system were easier to drive than gilts housed in an enriched system. These results, however, contrast with the results of a postal survey that linked ease of handling at the abattoir with previous housing and handling experience (Hunter et al., 1997). This study found that pigs that were easy to handle at the abattoir were more likely to have access to daylight and straw than pigs that were hard to handle, although this was not a controlled experiment and other factors related to housing may well have impacted the results. Easily handled pigs had also been walked over longer distances when being moved between housing stages during the growth and finishing periods (Hunter et al., 1997).

10.2.2 Responses to Handling

During handling, pigs respond to the way the stockperson behaves and the stockperson responds to the way the pigs behave. If pigs are difficult to move, they can become subjected to more negative handling (Weeding et al., 1993) and the more negative handling they attract, the greater their stress response. Handling can induce increases in catecholamines, lactate, cortisol and heart rates (Ville et al., 1993; Neubert et al., 1996; Marchant-Forde et al., 2003). When handling becomes high intensity – e.g. by including the use of electric prods – then these increases are even higher (Hemsworth et al., 2002; Kuchenmeister et al., 2005) and the animal is at risk of metabolic acidosis (Hamilton et al., 2004) before it even gets onto the truck. For slaughter pigs, handling outside of the home pen occurs very rarely, perhaps only 2–4 times as they are moved between stages of the growing cycle. If animals are repeatedly subjected to handling and movement outside their home pen, they become habituated and more willing to exit the pen and easier to load at transport time. This has been reported in finishing pigs handled ten times (Geverink et al., 1998a) and three times (Abbott et al., 1997). However, the practicality of repeated handling on commercial farms has not been investigated. Willingness to exit may also be influenced by feed additives, such as ractopamine, which is a beta-adrenergic agonist widely used in both North and South America to increase lean muscle mass in slaughter pigs. It has been shown to affect pig behaviour, making pigs less willing to leave the home pen and harder to handle once outside the pen (Marchant-Forde et al., 2003). The number of pigs moved at one time should also be considered. Lewis & McGlone (2007) have recently shown that moving 5 or 6 pigs at a time was the optimum number and that loading 170 pigs onto a trailer took the same amount of time using groups of 5 or 6 pigs compared with groups of 10. Loading in groups of 10 resulted in elevated heart rates compared with groups of 5 or 6.

10.2.3 Loading Method

Once out of the home pen and down the corridor to the loading dock, the next challenge is to get the pigs onto the truck. Methods of loading may vary depending on the truck design, but most common is driving the pigs up a ramp. With a two-deck truck, the top deck may lower to enable loading, then be raised to enable loading of the bottom deck, or there may be an internal ramp to get pigs from the bottom deck to the top deck. Other potential loading methods employ either a tail-lift, or loading the pigs in self-contained units that are loaded onto the truck using a forklift.

With ramps, the main factor is the steepness of the ramp. Ideally, the ramp should be between 20 and 25°. As steepness increases, the physical effort required from the pigs increases and Van Putten and Elshoff (1978) have shown a direct correlation between HR during loading and ramp angle. Warriss et al. (1991) also examined the time taken to drive finishing pigs up different angled ramps, and found that between 0 and 20°, slope had little effect on time. However, above 20°, time taken to climb the ramp increased linearly with ramp angle. Phillips et al. (1988) looked at ramp angle preference in nursery-age pigs and showed that ramp use decreased with increasing angle. At 22°, only 2% of pigs refused to use the ramp. At 32°, 44% of pigs refused to use the ramp.

Driving pigs up a ramp using a solid board resulted in lower heart rates and lower body temperatures than loading pigs using an electric prod (Brundige et al., 1998). Ramps should also incorporate cleats to provide grip and prevent pigs from slipping, and the spacing of these cleats should be dependent on the age of the pig being transported. Cleats spaced for finishing pigs are too far apart for nursery age pigs and can result in dew claw injury (Grandin, 1987). With finishing pigs, cleat spacing can also interact with ramp steepness, with pigs taking longer to climb steep ramps with widely-spaced cleats than steep ramps with closer-spaced cleats (Warriss et al., 1991).

As alternatives to a loading ramp, hydraulically-operated mobile decks or tail-lifts are now available, meaning that animals can be loaded at floor level and then raised to the appropriate deck of the vehicle (see Fig. 10.1). More recently, a modular system has been developed in which pigs are loaded into a self-contained unit at floor level, which is then moved using a forklift onto the bed of a truck (Brown, et al., 2005). In a comparison of ramp, tail-lift and modular system, pigs appeared to be easiest to load using the modular system, with the pigs having lower heart rates, but cortisol levels were elevated for pigs in this system throughout the loading, resting (30 minutes resting on a stationary truck) and unloading procedures (Brown et al., 2005). The authors interpreted these results as indicating that the pigs appeared unable to fully settle in the module and perhaps suffered a small degree of stress. The resting period however was short and the results cannot be extrapolated to active transportation or a longer time period between loading and unloading.

Fig. 10.1 Pigs loaded onto tail-lift and ready to be raised to the upper deck

10.3 Transport

Once the pigs are on the truck, there are a number of different factors that impact their welfare during the journey. These include elements of vehicle design, which can impact climatic conditions during transport, stocking density within the truck, and the distance over which the pigs are transported. Even though loading and unloading appears to be a considerable stressor for pigs, the time that the pigs are on the truck has received the greater proportion of research effort.

10.3.1 Vehicle Design

As we have already seen above, the first critical element of vehicle design that impacts the pigs' welfare on the truck is the method and ease of loading. If the truck is poorly designed so that loading is difficult and very stressful, then the pigs will begin the journey in a stressed state. Key elements for safeguarding welfare on the truck are non-slip flooring, separation of pigs into relatively small groups by penning, ensuring adequate thermal environment and ensuring ride comfort. For flooring, many trucks use profiled metal flooring (see Fig. 10.2), to which may be added a light layer of bedding such as sawdust or wood shavings. These help to provide some thermal insulation and also reduce the amount of noise generated during loading and unloading. This type of flooring also makes hygiene relatively easy to maintain. There have been no specific studies investigating floor type on welfare during transport.

The ability to form pens within the truck (see Fig. 10.2) is important in maintaining pre-formed groups and minimizing mixing. Another practicality to consider is that smaller groups of pigs are also easier to handle than larger groups (Barton Gade et al., 1992; Lewis and McGlone, 2007). When pigs are mixed onto the truck, studies have shown that mixed pigs engage in more

Fig. 10.2 Internal view of livestock trailer showing flooring and metal gate to partition the deck into pens

fighting, have a general activity index score that is three times unmixed pigs and have higher cortisol levels (Bradshaw et al., 1996b). Mixed loads also present with more in-transit deaths and increased carcass damage (Gosalvez et al., 2006).

To ensure the thermal comfort of the pigs during transport, the vehicle needs adequate ventilation and insulation to prevent exposing the pigs to thermal extremes. In general, and in accordance with the pigs' behavioural and physiological capacities to thermoregulate, there is particular concern with the pigs' ability to cope with transport during summer months (June, July, August in the northern hemisphere). Some European epidemiological studies have found that in-transit mortality is highest during these months (Werner et al., 2005; Vecerek et al., 2006) when ambient temperature is highest, and a North American study has found that although temperature did not have a direct effect on mortality or fatigued pig incidence, humidity did affect fatigued pig incidence (Ritter et al., 2006). Keeping temperatures down during summer transportation is usually achieved by providing ventilation openings down the length of the trailer (see Fig. 10.3).

These openings are usually sufficient to keep the internal temperature at an acceptable level whilst the truck is moving, but when the truck is stationary for a long period of time, internal temperatures can increase quickly and the integration of both forced ventilation systems (Warriss et al., 2006) and/or misting systems (Christensen and Barton Gade, 1999) can be beneficial. Once temperatures do start to rise, the position within the truck can have a large effect on

Fig. 10.3 External view of livestock trailer showing ventilation openings

outcome. A number of studies have found that the most vulnerable position within the truck, in terms of mortality, is on the lower deck and in the front compartment (Sains, 1980; Riches et al., 1996; Christensen and Barton Gade, 1999). Warriss et al. (2006) also measured pigs' body temperatures after a 3 h journey plus 1 h wait before unloading and found that pigs carried at the front were hotter than those at the back but also that those pigs on the upper deck were hotter than pigs on the bottom deck. In this study, fan-assisted ventilation had no effect on pigs' internal temperature and no effect on mortality. However, external air temperatures were around 17°C and even the temperature of the air leaving via the fans was around 20°C. These temperatures in the U.K. are considerably lower than those faced by many pigs during summer transportation in hotter countries – for example Lewis and Berry (2006) reported average in-truck air temperatures of up to 30.3°C in summer transport in Canada – and in this situation, fan-assisted ventilation may have a real effect on pigs' body temperatures and overall comfort. Misting devices have also been used to aid cooling, but their effects have not been subject to research.

During the winter, most trucks are designed so that ventilation slots can be closed off, either to minimize or even to prevent air-flow (see Fig. 10.4) and maintain a comfortable internal temperature.

All pigs, other than neonates, are better-equipped to cope with cold stress than heat stress (Carroll, 2002). When exposed to low temperatures, pigs will adapt behaviorally, by huddling, and physiologically. This enables them to cope with temperatures encountered during winter transportation. The epidemiological

Fig. 10.4 External view of typical North American livestock trailer showing ventilation openings closed off using plastic strips for low temperature travel

studies on finishing pigs do not implicate winter temperatures in any measure of poor pig well-being (Werner et al., 2005; Ritter et al., 2006; Vecerek et al., 2006). However a recent study on early-weaned piglets, which are transported long distances in North America in all seasons, has shown that both summer and winter transportation appeared to induce post-transport fatigue, with increased post-transport resting (Lewis and Berry, 2006). In this study, the maximum above-piglet air temperature was 30.3°C in summer and the minimum was –2.8°C in winter.

The final element in vehicle design is that which affects ride comfort. One major finding of studies where behavioural observations have been taken directly by riding in the truck is that pigs are susceptible to travel-sickness (Bradshaw et al., 1996a; Randall and Bradshaw 1998; Bradshaw et al., 1998, 1999). In general, between 25–50% of pigs either vomited or showed behavioural symptoms of travel sickness on both short-duration and long-duration journeys, coinciding with increased levels of lysine vasopressin (Bradshaw et al., 1996a). Low frequency vibration (0.05–0.5 Hz) has been implicated as a major factor in travel sickness in humans and studies of real transport situations have shown that oscillations within this range are recorded at pig level (Randall and Bradshaw, 1998). The vibration characteristics of a given journey will depend on the type of vehicle suspension, the quality of the roads – both in terms of surface and 'straightness', the speed the vehicle is traveling, whether the truck is full, partly-laden or empty (all described in Randall et al., 1996) and on the quality/skill of the driver. Vibration delivered during simulated transport has been shown to increase heart rate, ectopic beats, cortisol and ACTH concentrations (Perremans et al., 1998, 2001). The smoothest ride is accomplished by using air ride suspension on all axles. Where driving style has been compared, 'wild' driving results in increased longitudinal and lateral accelerations, with pigs showing more standing and having changes in heart rate variability indicative of greater stress (Peeters et al., 2008).

10.3.2 Stocking Density

The provision of space per pig on the truck may be dependent on the length of the journey. If journey duration is short (<3 h) the pigs may stand for the entire duration (Barton Gade and Christensen, 1998), meaning that their space requirement is relatively low. However, if given enough space, pigs can also lie down, and choose to do so, during transport (Bradshaw et al., 1996a) and when journey durations increase, this means that relative space requirement is increased. Guise et al. (1998) compared stocking densities of 201 kg/m^2, 241 kg/m^2, 281 kg/m^{2}and 321 kg/m^2 over a 3 h journey and found no effect of stocking density on any of their measures of meat quality, but a corresponding study did find that creatine phosphokinase (CPK) levels increased with increasing stocking density, which was interpreted as the more densely-stocked pigs being unable to settle (Warriss et al., 1998a). At these higher levels, there is also evidence of increased skin damage and rectal prolapses (Guise and Warriss, 1989). Barton Gade and Christensen (1998) looked at four different stocking densities ranging from 200 kg/m^2 to 286 kg/m^2 and found only an effect on CPK, with levels decreasing as stocking density decreased over a 2.5 h journey. However, they also noted that the pigs did not lie down and that at lower density, the pigs were thrown about more in transit, resulting in higher levels of skin damage. This perhaps illustrates the interactive effect of stocking density with journey time. Lambooy and Engel (1991) investigated three stocking densities ranging between 186 kg/m^2 and 278 kg/m^2, transported over 25 h. At the highest stocking density, not all pigs could lie down at the same time and thus, this density resulted in pigs continually changing positions and being unable to rest. This led to poorer meat quality measures.

A large-scale study in the U.S.A. examined the transportation of over 12,000 pigs during an average 3 h journey (range 2.5–7 h) at three stocking densities – 269 kg/m^2, 286 kg/m^{2}and 330 kg/m^2 – primarily looking at losses during the transportation process (Ritter et al., 2006). The study reported that of the 12,511 pigs transported, 0.26% were non-ambulatory at the farm, 0.23% were dead on arrival and 0.85% were non-ambulatory at the plant. As stocking density was reduced, the percentage of total non-ambulatory pigs was reduced from 0.62% to 0.27% and the total losses (dead plus non-ambulatory pigs) at the plant was reduced from 0.88% to 0.36%. In summary, welfare and meat quality would appear to be improved if stocking density is kept below 250 kg/m^2 for finishing pigs.

For younger pigs, the studies that have investigated the effects of stocking density on welfare have not found any significant differences in various measurements. Riches and Guise (1997) and Riches (1998) investigated the transportation of 30 kg pigs at 200 kg/m^2, 167 kg/m^{2}and 131 kg/m^2 and found no effect on heart rate or salivary cortisol or posture over a range of 2–6 h journey times. In all cases fewer than half the pigs were sitting or lying during the journey and the pigs huddled together, thereby not utilizing all the available space, even though internal truck temperatures were moderate. Geers et al. (1994) studied 20 kg pigs transported at a very low stocking density of 73 kg/m^2 and found that pigs were recumbent for 90% of the time. For smaller pigs still, Riches (1998) transported at 125 kg/m^2, 95 kg/m^2 and 55 kg/m^2 and again found no effect on heart rate, although only around 30% of pigs lay down. This low number was thought to be a consequence of the journey being relatively rough.

Combined, these results suggest that stocking density is not an issue until it prevents all the pigs from being recumbent at the same time. However, there is still limited information on the potential interactive effects of stocking density, travel time and thermal environment.

10.3.3 Journey Time

In terms of legislation, this element of the transport process has perhaps attracted the most attention. Given that the most stressful parts of the process are loading and unloading, the duration of the journey is perhaps impacting the welfare of the pig to a lesser degree, although it will very much depend on some of the factors that have already been covered. It may well be harsher to travel a short distance – say 2 h – on a poorly designed vehicle, at a high stocking density, having been mixed with unfamiliar animals in the height of summer than traveling for 24 h on a well designed vehicle at low stocking density with pen-mates in spring. It is just these types of interactions that make determination of the 'optimal' journey time so difficult to achieve in isolation.

For finishing pigs, much of the work on journey times has focused on the effect on subsequent meat quality. Pérez et al. (2002) compared a 15 minute transport duration with a 3 h transport duration and found that pigs subjected to the short journey time showed a more intense stress response – increased cortisol and lactate levels – and lower muscle pH levels and higher fibre optic probe readings post-mortem. These results indicate that the pigs' welfare was more compromised by the 15 minute journey time, whereas those on the 3 h journey time were able to better adapt to the transport conditions (Pérez et al., 2002). Saco et al. (2003) investigated the effects of journey time on acute phase proteins by comparing a 1.25 h transport plus 2 h lairage with a 6 h transport plus 14 h lairage. They found that short duration transport did not affect acute phase proteins but did elevate cortisol. By contrast, the long duration transport increased both haptoglobin and pig major acute phase protein (PigMAP) in post-slaughter blood samples, whereas cortisol did not differ from pre-transport levels.

An epidemiological study conducted in Germany showed that, in terms of mortality, circulation problems and fractures, very short journeys (under 1 h) presented as many problems as journeys over 8 h in duration (Werner et al., 2005). Vecerek et al. (2006) also carried out large scale epidemiological study in the Czech Republic, examining records on over 4 million slaughter swine. From the records, journey time was not available, but distance traveled from the farm to the slaughter-house was, and these results showed an almost linear increase in farm-to-slaughter line mortality with increasing distance. The mortality in journeys under 50 km (which might be equated with a journey time of around 1 h) was 0.06%. With journeys over 300 km (around 6 h and above), mortality rate was six times higher at 0.34%.

Broadly similar results were found by Ritter et al. (2006) in their examination of a 240 km transport from farm to slaughter. Although the average travel duration was 3 h, the total transport time including loading, travel, waiting and unloading was just over 5 h. Also, the minimum–maximum range for the whole process was in fact just under 4 h to just over 9 h. This demonstrates that distance may not be a very reliable indicator of overall transport time, but it did enable Ritter et al. (2006) to investigate whether transport losses were influenced by journey time. They did find that total time from loading to unloading and unloading time by itself were quite highly correlated with total losses recorded at the plant ($r = 0.40$ and $r = 0.51$ respectively).

In terms of journey times over 8 h, there has been very little comparative research carried out, even though it is a major consideration in transportation legislation. There are some descriptive studies which have examined various parameters at the end of a long transport time. An early study by Lambooij et al. (1985) examined a transport duration of 44 h on slaughter pig welfare and meat quality, with half the pigs having access to water. The experimental design also included different stocking densities and a control group slaughtered 'right away' at a nearby slaughterhouse. Unfortunately these treatments are somewhat confounded by achieving stocking density by differing group sizes, which as pigs were mixed from two sources could have had a big impact on the amount of fighting that could have occurred on the truck. Also, the 44 h transported pigs had a holding delay of 45 minutes before unloading and slaughter, compared to the immediate unloading and slaughter of the 'control' group. The study was also non-replicated. However, these shortcomings notwithstanding, the authors found that transported pigs had higher levels of ketone bodies and higher hematocrit levels than control pigs and an 8 kg weight loss. With the highest stocking density, post-mortem muscle pH was also increased. In terms of behaviour, pigs in the two lowest stocking density treatments lay down within the first 2 h of the journey and remained lying. Pigs in the highest stocking density could not all lie simultaneously and thus were constantly changing posture. Having water available had little beneficial effect.

Lambooy and Engel (1991) carried out eleven journeys of 25 h duration with 60 pigs per journey. However, there was no control treatment against which to compare results and the actual journey was split up to: 4 h transport, 1 h rest, 8 h transport, 1 h rest, 4 h transport, 3 h rest and 4 h transport. The percentage of pigs lying down over the whole time period was around 60%, but there was a temporal pattern over the 25 h period. During the first 4 h segment, only around 30% of pigs lay down. During the rest, this increased to 95% but fell back to around 50% over the 8 h segment. During the next 1 h rest, 4 h transport and 3 h rest, about 80% of pigs were lying down – this corresponded to 1–9 a.m. During the last 4 h, in daylight, lying down was back around 50%. So, overall, there appeared to be a trend of increasing lying down as the journey progressed, apart from the last segment when the pigs were presumably beginning to get hungry and restless. Weight loss was 3.9 kg/pig (3.5%) over the whole journey.

Brown et al. (1999) carried out a comparative study looking at 8, 16 and 24 h of transport, coupled with either immediate slaughter or a 6 h lairage period. They did also include a non-transported treatment. For those pigs slaughtered immediately after transport, journeys of 8, 16 and 24 h led to weight losses of 2.2%, 2.0% and 4.3% respectively. Lactate and cortisol concentrations peaked with 16 h transportation, whereas total protein and albumin levels peaked with 24 h transport. With 6 h of lairage, these transportation effects had disappeared relative to controls. Ultimate pH in three muscles increased with increasing transport duration and this remained high in 2 of the muscles after 6 h lairage. Behaviourally, during the lairage period, all transported treatments spent more time drinking, eating and standing than non-transported pigs and the 24 h treatment spent the most time in these activities. The authors concluded that journey durations up to 16 h appeared to be acceptable in terms of pig welfare and that 6 h of lairage was beneficial in negating the adverse affects of the journey.

A similar study was carried out during the summer in Mexico by Mota-Rojas et al. (2006). Again, they compared 8, 16 and 24 h of transport, with all treatments undergoing an 8 h lairage period prior to slaughter. Immediately after unloading, weight loss over transport was 2.7%, 4.3% and 6.8%. After 8 h lairage, some weight was regained due to hydration. As transport duration increased, bruising skin blotchiness and the incidence of hind-limb tremors all increased. Rectal temperatures and incidence of hyperventilation were highest in the 16 h transported group, although this could be more due to the timing of arrival. They arrived at 4 pm and had just endured 5 h of very high ambient temperatures. There was an increase in dark, firm dry meat from pigs transported for 24 h. These authors also concluded that journey durations over 16 h appeared to be detrimental to pig welfare.

Pigs at other stages of their life cycle are also transported for considerable durations, but have been subject to relatively little research. For example, in North America in particular, it is not uncommon for weaned pigs and nursery-age pigs to travel for 24 h across country. Also breeding animals are frequently exposed to long-term transportation, which may also involve sea-crossings or air transportation. Lewis and Berry (2006) compared control (zero), 6 h, 12 h and 24 h transportation of 17-day-old piglets. They found that transported piglets rested more post-transport than control piglets and that during transport about 60% of piglets were resting at any one time during 0–12 h, but between 13 and 24 h, this increased considerably to 92% indicating increasing fatigue. Piglets transported over the longer 2 durations spent more time post-transport feeding and drinking. Overall, however, the piglets appeared able to adapt to and cope with long-duration transport.

Williams (2006) studied the effects of an 8 h mid-journey, off-load and re-load rest-stop on welfare of nursery age pigs during a 16 h total transport duration. She compared this strategy with a 16 h continual transport. Immediately post-transport, the continually transported pigs spent more time eating and drinking, whereas the rest-stop pigs had been able to satisfy water and feed requirements during the rest-stop. Continually-transported pigs also had altered immune function variables and shifts in microbial populations compared to rest-stop pigs, with Williams (2006) concluding that the addition of a mid-journey rest-stop was beneficial for the pigs.

Overall, evidence appears to suggest that pigs' welfare is compromised with journey times over 16 h. However, it is not a clear cut conclusion as the nature of a journey is impacted by other factors. Young pigs appear able to adapt and cope with extended transportation, provided conditions during transport are not too harsh. Slaughter pigs appear to have more problems with extended journeys, but because they are destined for slaughter, it is not known whether these problems are recoverable. Certainly if slaughter pigs are densely-loaded and transported in hot conditions over long periods of time, mortality increases. As this is an end-point measure of poor welfare, it would be safe to assume that if the journey results in the death of pigs, then the welfare of all pigs on that load may well be compromised. Further research is needed to investigate interactive effects of density, temperature and duration.

10.4 Unloading

Once at the destination, the pigs will require unloading. This part of the transport process has not received much research attention, and has mostly descriptive statements in the literature (e.g. SCAHAW, 2002) to suggest what should be done to maximize welfare. This E.U. document suggests that if ramps are used, steepness should not exceed 20° and that each deck should be unloaded compartment by compartment as small groups of pigs are easiest to move. With multiple decks, the height of the deck should ideally be adjustable so that the unloading crew can gain access relatively easily, but there is also likely to be a step between the deck and the ramp, which may make pigs hesitant to exit the trailer voluntarily.

Other factors that may make unloading more difficult include light changes, air flow and noise (Grandin, 2002). Anecdotal evidence suggests that pigs prefer to move from dark to light (Grandin, 1996) and so it is essential that lighting within the destination building is sufficiently bright to encourage pigs to move off the trailer. Reflected light off wet floors can also cause pigs to stop and these should be reduced by ensuring light placement is appropriate (Grandin, 1996). Pigs will also baulk if air is blowing into their face and thus air pressure within the building should be equalized with external air pressure to reduce air flow. Novel noises between 80 and 90 dB increase heart rate in pigs (Spensley et al., 1995) and induce behavioral responses, such as bunching (Geverink et al., 1998b). Intermittent noise is also more disturbing that continuous noise (Talling et al., 1998). Within the destination building, efforts should be made to reduce the acoustic environment, such as muffling air exhausts and preventing metal fittings from clanging. Handlers should work without shouting.

A major factor influencing welfare at destination is the wait time – i.e. the time between arrival and unloading. Once the vehicle stops moving, the temperature and humidity within the truck begins to rise (Craig, 2006). In hot external temperatures, additional increases in temperature can have a welfare impact on the pigs. Under hot conditions, Lewis (2006) shows an average internal temperature increase of 2.7°F (1.8°C) for every 15 minutes waiting. If external temperature is 90°F (32.2°C), by 1 h of waiting, internal temperature will be over 102°F (39.1°C). As mentioned earlier, Ritter et al. (2006) found that losses were at the slaughter plant were positively correlated with time taken to unload the trailer and waiting time. In their study, waiting times up to 3 h were experienced.

Grandin (undated) has the following example of what should be acceptable waiting times on arrival when auditing a slaughter facility:

Promptness of Truck Unloading

Excellent – start unloading within 15 minutes after arrival
Acceptable – start unloading within 15–30 minutes
Not acceptable – wait 30–60 minutes
Serious problem – wait over 60 minutes

The same document also states that it would be an acceptable measure to use electric prods on 2% or less of pigs during unloading.

In terms of recent advances in technology to assist unloading, Brown et al. (2005) compared a ramp versus a hydraulic tail-lift versus a modular system. They found that the tail-lift took longer to unload the pigs than the ramp which in turn took longer than the modular system. Similar trends were found in the mean and peak heart rate values of the pigs undergoing the unloading. However, pigs exposed to the modular system had elevated cortisol levels relative to the other treatments. Further work on this system is ongoing.

Another method already used in the U.S. by Premium Standard Farms (PSF) is the side unload method. Using specially designed trucks and docking stations at the slaughterhouse, pigs are able to exit the trailer at the same level of the deck, without having to move down a ramp (Hill, personal communication). Together with Iowa State University, PSF are also developing a specialized loading gantry (see Fig. 10.5) that is extendable and variable to fit different trailers without having any steps or gaps that may hinder pig movement (Messenger, 2006). An internal inverted stair design means that ramp angle to the bottom deck is only 6° to horizontal and to the top deck it is 17° – both less than the upper limit of 20°.

Fig. 10.5 Loading gantry designed and used by Premium Standard Farms in the U.S. (Source: Jeff Hill, Premium Standard Farms)

10.5 Lairage

On arrival at the slaughter plant, pigs are usually held in lairage for a period of time. This enables the pigs to have a recovery period after the stress of transportation and it also means that the slaughter line can be continuously supplied with pigs without gaps in production. It has been suggested that optimal lairage times are somewhere between 1 and 3 h (Warriss, 2003), but this is based on research within the U.K. and may not hold true for transport conditions elsewhere in the world – i.e. under longer average travel times and different thermal extremes. Although there may be an 'optimal' time that pigs should be held in lairage post-transport, the reality of the situation does often not allow for this optimal time to be accommodated.

Warriss and Bevis (1986) found that lairage times in U.K. abattoirs could vary from less than 1 h to over 20 h. Guise et al. (1995) reported a mean lairage time of 4.1 h, but with a range of 2.1–12.5 h. Elsewhere in Europe, researchers have reported 0–15 h in Spain (Gispert et al., 2000) and around 1–5 h in Belgium (Lammens et al., 2007). A recent pre-harvest food safety study carried out in Minnesota, U.S.A. between 1995–1997 reported minimum, maximum and average lairage times of 3 h, 32 h and 15 h (Bahnson et al., 2006). Combined, these studies show that there is a wide variety of lairage times in commercial slaughterhouse practice, and this variation may well impact pig welfare, meat quality and food safety.

10.5.1 Lairage Effects on Pig Welfare

The literature suggests that the length of lairage will have an impact on the pig's welfare. If lairage is too short, then it gives the pig insufficient time to recover from the stresses of the transportation. If lairage is too long, then physiologically the pig has time to recover, but it may then begin fighting with pen-mates, thereby compromising its welfare again. However, the optimal lairage time is difficult to state categorically because of the interaction with conditions during transportation. The stresses that pigs are subject to during transport are, as we have seen, multifactorial and expecting that a defined time in lairage will be optimal to meet all transport conditions is not realistic. Some studies have attempted to combine lairage duration with transport duration, but no-one has attempted to carry out a study to look at, say, transport duration × stocking density × season × lairage duration.

Studies that have compared very short lairage durations (0–1 h) with short lairage durations (2–3 h) have shown that pigs slaughtered after the very short lairage durations have increased cortisol levels (Warriss et al., 1992, 1998; Pérez et al., 2002; Hambrecht et al., 2005), increased lactate levels (Warriss et al., 1998), increased CPK levels (Warriss et al., 1998) and increased β-endorphin levels (Warriss et al., 1992). However, the 2–3 h lairage pigs have increased skin damage due to fighting (Geverink et al., 1996; Fraqueza et al., 1998; Warriss et al., 1998).

Other studies have compared short or very short (0–2 h) with longer lairage times (6–24 h). These types of comparisons show that the short lairage pigs have increased lactate (Brown et al., 1999; Salajpal et al., 2005), increased cortisol levels (Brown et al., 1999; Saco et al., 2003) and increased CPK levels (Brown et al., 1999) relative to longer lairage pigs. However, again, other indicators showed that welfare of long lairage pigs could be compromised, with increased acute phase proteins (Saco et al., 2003) and increased fighting and skin damage (Nanni Costa et al., 2002) compared with short lairage pigs.

The amount of aggression that occurs within lairage can be influenced by management, both within the lairage itself but also within the home farm environment. De Jong et al. (2000) demonstrated that slaughter pigs reared in a barren environment performed more walking behavior and fighting in lairage than pigs reared in an enriched environment. If pigs are provided with toys, such as plastic balls that can be filled with maize, during both transport and lairage, then this can reduce both physiological indicators of stress (cortisol and lactate levels) and shoulder lesions relative to pigs traveling without toys (Peeters and Geers, 2006). Finally, behavior within lairage can be greatly affected by post-transport treatment. Geverink et al. (1998c) compared three post-transport treatments whereby pigs were either: (1) vigorously handled down a 75 m passageway before moving into a holding pen with familiar pen-mates, (2) unloaded and mixed into a holding pen with unfamiliar pen-mates, and (3) handled and mixed. Pigs in the two treatments that involved mixing showed increased skin damage relative to unmixed pigs. Also, the handling plus mixing treatment resulted in the highest cortisol response to the experimental procedures, indicating an additive effect when the two stressors were combined.

10.5.2 Lairage Effects on Meat Quality

Another major factor that can affect the financial return for the producer, is the quality of the meat that is the ultimate end-product of the rearing cycle. In 1994, it was estimated that in the U.S. industry an average of $1.05 per slaughter pig produced was lost due to meat quality problems. This equated to around $70 million a year (Sonka et al., 1994). The main determinants of meat quality used in most studies are color (L* [brightness], a* [redness] and b* [yellowness] – the Commission Internationale de I'Eclairage – L*a*b* is the most popular standardized color system), ultimate muscle pH and rate of pH decline and drip loss. A fast drop in pH or low ultimate pH can result in pale, soft, exudative (PSE) meat, whereas a slow drop and high ultimate pH can result in dark, firm, dry (DFD) meat. Both of these types of meat are unpopular with consumers.

The time that pigs spend in lairage can have a direct effect on meat quality, although again, other factors such as transport conditions will influence the amount of effect that lairage has. Many studies comparing lairage durations have shown generally that short lairage (< 2 h) results in higher incidence of PSE meat compared to longer lairage (see Table 10.1), with corresponding lower ultimate pH levels, greater drip loss and L*, a* and b* scores that indicate paler meat. Fewer carcasses have meat of 'normal' quality. Conversely, however, where long (> 9 h) lairage durations are used, the incidence of DFD meat increases.

Table 10.1 Effect of lairage time on meat quality measures. The effect is described as the finding in carcasses of pigs exposed to short lairage duration relative to carcasses of pigs exposed to the longer duration. (For abbreviations, see above paragraph)

Article	Lairage durations	Measure (short compared to longer)
Aaslyng and Gade (2001)	0.3 h, 2.5 h	↑ drip loss, ↑ reflectance
DeSmet et al. (1996)	1 h, 2–3 h, 4–5 h	↑ drip loss, ↓ pH, ↑ L*,
Fabrega et al. (2002)	2 h, 12 h	↑ L*, a*, b* values
Fabrega et al. (2004)	2.5 h, 14.5 h	↑ conductivity, ↑ PSE %
Fortin (2002)	0.5 h, 3 h, 6 h	↑ PSE incidence
Fraqueza et al. (1998)	0.5 h, 3 h	↑ PSE %
Nanni Costa et al. (2002)	2 h, 22 h	↑ PSE %
Pérez et al. (2002)	0 h, 3 h, 9 h	↑ PSE % but ↓ DFD %
Salajpal et al. (2005)	2 h, 24 h	↑ drip loss, ↓ pH
Santos et al. (1997)	0.5 h, 2–3 h	↓ 'normal' quality carcass
Warriss et al. (1998)	1 h, 3 h, 24 h	↑ PSE % but ↓ DFD %

10.5.3 Lairage Effects on Bacterial Infection

Over the last few years, there has been increasing concern surrounding the safety of food. For pork, a major issue has been that of bacterial contamination, in particular salmonellosis. Early studies found that a lairage time greater than 12 h was associated with an increased incidence of salmonella infection in slaughter pigs (Craven and Hurst, 1982) and it was originally thought that these long lairage times were necessary for the infection to develop. However, more recent studies have found that salmonella infection can occur very rapidly in slaughter pigs subjected to lairage durations of 2, 3 and 6 h (Hurd et al., 2001) but not in slaughter pigs exposed to a contaminated lairage for only 1 h (Boughton et al., 2007). A 2 h lairage period is also sufficient to increase salmonella incidence in cull sows (Larsen et al., 2004).

The critical control point of contamination is the lairage pen and ordinarily abattoir holding pens and water sources may be highly contaminated (Rostagno et al., 2003). Even cleaning and disinfecting regimes imposed on abattoir holding pens may reduce environmental salmonella prevalence prior to housing pigs, but once pigs are introduced, cleaning may have little impact on the proportion of pigs that become infected (Schmidt et al., 2004). Resting pigs on the transport vehicle rather than a lairage pen has been shown to decrease salmonella levels at slaughter (Rostagno et al., 2005).

For pigs that are not going to slaughter, e.g. nursery age pigs, the transportation process can still offer some challenges in exposure to pathogens and consequences for animal health and welfare. Williams (2006) exposed nursery age pigs either to 16 h continuous transport and relocation to a new building, or to 8 h transport, 8 h resting in a new building, 8 h further transport and relocation to another new building. She found that pigs transported for 16 h continuously without a rest-stop did have diminished immune system responses to stress. These alterations encompassed peripheral immune cell populations and expression of cell surface recognition and adhesion molecules and an antimicrobial peptide in the gut, rendering these pigs potentially more susceptible to pathogens.

10.6 Slaughter

Ultimately, the end point of most transportation events is the slaughter of the pig. Once lairage time is complete, the pig is usually removed from the pen and driven towards the slaughter-hall manually. The pigs will enter a forcing pen and from here, they will enter the race, which may be double or single file until they enter the restraint system in single file. The restrainer will minimize body movements and make electrical stunning, in particular, easier to achieve. Stunning may be carried out automatically or manually by passing an electric current across the brain, or across brain and heart. Alternative stunning methods are CO_2 or argon gassing, which can be carried out with pigs kept as groups. Regardless of stunning method, the aim is to render the pig insensible and the pig is then exsanguinated by severing the carotid arteries and jugular veins, leading to death.

10.6.1 From Lairage to Stunning

Once lairage has been completed, the pigs within a pen need to be moved to the place of stunning. In many cases, this involves interaction with human handlers and manipulation of the group to single pigs. In some instances, movement may be achieved by automatic means and stunning may be carried out on groups rather than individuals. Automatic driving has been shown to improve meat quality but has not been subject to direct measures of welfare (Franck et al., 2003). The major advantage of automatic handling is that it removes the inconsistency associated with human handling. As soon as a human handler is involved, different pigs will get different amounts of positive and negative handling from the same individual, and also individuals will differ between each other in the way they handle the pigs, largely based on their own attitudes towards animals. For example, handlers with negative attitudes will use electric goads more to move the pigs (Coleman et al., 2003). There is plenty of evidence to suggest that excessive use of goads contributes to physiological responses indicative of stress and reduces meat quality (Faucitano et al., 1998; D'Souza et al., 1999; Stoier et al., 2001; Hemsworth et al., 2002).

Pigs have been found to be easier to drive towards the stunner if they are maintained in groups of 4 (Schaffer et al., 1997) and if the race to the stunner is relatively short (Floss et al., 1997). If pigs can be kept as a group for stunning, rather than forced to enter in single file, then this appears to be less stressful also (Hunter et al., 1994; Stoier et al., 2001). Over the last couple of decades, more attention has been paid to quantifying welfare within the slaughterhouse, and objective measures such as the percentage of pigs vocalizing, the percentage of pigs that fall down and the percentage of pigs that are electrically goaded have been proposed as robust for auditing purposes (Grandin, 2006). More subjective assessment of the stress levels experienced by the pig during pre-slaughter handling have been correlated with increased lactate and CPK levels and poorer meat quality (Warriss et al., 1994), illustrating the fact that exposing pigs to stress within these last few minutes of life can impact welfare and meat quality, thereby negating the pig's experience up to this final endpoint.

10.6.2 Stunning to Death

The first rudimentary stunner was the poleaxe or hammer, which was swung to hit the head of the pig and render it unconscious. Unsurprisingly, the use of a poleaxe is imprecise, both in terms of accuracy and force of application, resulting in a high proportion of animals not being rendered insensible prior to exsanguination. By the early 1920s in the U.K., the poleaxe was beginning to be replaced by the captive bolt. The poleaxe was banned from use by the Slaughter of Animals Act 1933, and a captive bolt or electrical stunner was recommended and later mandated. Nowadays, stunning is mostly carried out using electricity or gas, such as carbon dioxide, with electrical stunning still most prevalent.

Electrical stunning may be carried out using two methods. One is by the use of tongs which places electrodes either side of the head and passes a current horizontally through the brain. The alternative is a combination of head and body stunning which passes a current through the brain and also through the heart. The first method induces temporary insensibility and, without quick bleeding out, the pig will return to consciousness (see Fig. 10.6). Applied correctly, the second method also induces cardiac arrest as well as brain stunning in most pigs.

Stunning methods have been subject to an increasing amount of research over the last few decades as the topic has attracted increasing public scrutiny and technological advances in both stunning methodology and research

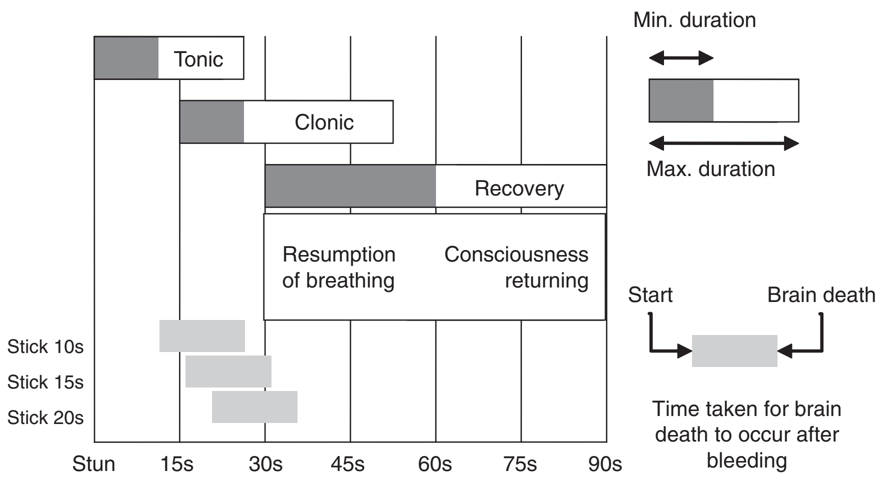

Fig. 10.6 Diagram of phases of stunning procedure and recovery relative to exsanguination after a 10-, 15- or 20-second gap
(Source: HSA 2006)

assessment capability have been made. For electrical stunning, a number of key factors have to be met for stunning to be effective. For head only stunning, it is imperative that the electrodes are positioned correctly so that the current spans the brain. Anil and McKinstry (1998) observed five different placement configurations during recording in commercial abattoirs including 2 which did not directly span the brain. One of these, snout placement, was significantly less effective at stunning the pigs, leading to welfare concerns regarding regaining consciousness before exsanguination. Sparrey and Wotton (1997) reviewed the design of head stunning equipment and highlighted deficiencies in the design of tongs to cope with the profile of the pig's head, small contact surface area of electrodes and rapid build-up of tarnish that may render them less effective.

Regular electrical frequency is 50 Hz, but there are some indications that stunning using this frequency can induce blood splashing or hemorrhages within the muscle. This has resulted in trial of higher electrical frequencies, ranging up to 3,000 Hz. Two commercially-available stunners operating at 1,600 Hz were compared with a 50 Hz stunner and found to produce epilepsy and unconsciousness adequately, but the duration of insensibility is reduced, meaning that exsanguination needed to be carried out very quickly after stunning (Anil and McKinstry, 1992). Troeger and Nitsch (1998) demonstrated that frequencies of 50, 500 and 800 Hz were all effective at stunning within 0.3 s, but higher frequencies (2–3 kHz) have been shown not to be effective in causing insensibility (Grandin, 2003).

As stated above, many slaughter plants use a head to body stun, to also induce cardiac arrest as well as brain stunning. Most pigs will go into cardiac

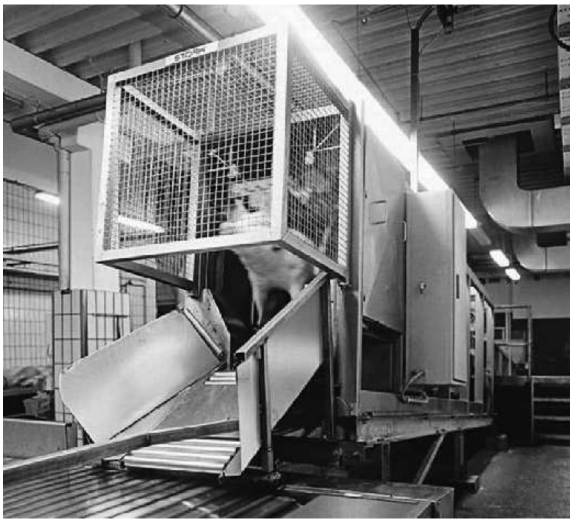

Fig. 10.7 Automatic electrical stunner – Stork MIDAS – shown with pig in stunning box awaiting electrode placement (Source: MPS, Lichtenvoorde, The Netherlands)

arrest with this type of electrode placement, but not all. Wotton et al. (1992) tried different electrode placements along the back and found no one single placement induced cardiac fibrillation in 100% of pigs tested. In modern abattoirs equipped with automatic stunning equipment such as the Stork MIDAS system (see Fig. 10.7), it has been shown that although automatic placement of the electrodes was incorrect on up to 14% of pigs, the presence of sensibility to pain post-stunning was 0.67% and no pigs showed a righting reflex (Verlade et al., 2000).

In all instances, exsanguination needs to be carried out ideally within 15 s of stunning, so that death is achieved before the animal enters the recovery period (see Fig. 10.6). However, a repeated application of electrical stun does achieve the same stun profiles in terms of insensibility as the original stun so can be used to render the pig insensible again if needed (McKinstry and Anil, 2004).

Gas stunning in commercial practice has increased greatly over the last decade following on from research and development that has been taking place over the last 30 years. The main gas used has been CO_2, but many studies have shown that this is not without welfare issues – the major one being aversiveness. Studies have shown that pigs exposed to high concentrations of CO_2 (80–90%) show signs of severe respiratory distress before losing consciousness (Raj and Gregory, 1995, 1996; Raj, 1999) and that this distress is also in evidence as CO_2 concentrations decrease (70–20% – Raj and Gregory, 1996). In commercial practice, many CO_2 stunners consist of a dip-lift, gondola type system, in which pigs are stunned in groups (see Fig. 10.8).

With CO_2 stunning it is imperative that the duration of exposure is sufficient to fully stun the animals and the appropriate time will depend on the concentration of the gas. At 80% CO_2, it has been recommended that duration of

Fig. 10.8 Pigs entering a CO_2 stunning system
(Source: MPS, Lichtenvoorde, The Netherlands)

exposure should be 100 s and that exsanguination should be started within 25–35 s (Nowak et al., 2007). Exposure at this concentration for only 70 s was not acceptable. With 90% CO_2, 100 s exposure was also recommended, but the gap between stunning and the start of exsanguinations could increase to 40–50 s and still be acceptable on welfare grounds (Nowak et al., 2007). Another study examined 80% and 90% CO_2 given for 73 s and found that this exposure time at the lower concentration was not sufficient to fully stun all pigs (Hartung et al., 2002).

In commercial practice, both the duration of exposure and stun-to-stick times may vary both between and within abattoirs (Verlade et al., 2000). In 2 Spanish slaughterhouses, using the same 83% CO_2 stunner, one abattoir (C) had an exposure time of 92 s and the other (D) an exposure time of 103 s. Both of these times should be sufficient to fully stun all animals, but the problem then lies with the stun-to-stick times. Abattoir C then also had stun-to-stick time of 58 s ($\pm$10 s) compared with 43 s ($\pm$5 s) for abattoir D. As a result of these two parameters, 33.3% of pigs from abattoir C showed a righting reflex and 42.8% showed presence of sensibility to pain. The values for abattoir D were 12.8% and 3.7% respectively. In both cases, these figures should be deemed unacceptable and they compare badly with pigs at two further abattoirs that were stunned electrically. In these abattoirs, no pigs showed a righting reflex and only 0.7% showed a presence of sensibility to pain (Verlade et al., 2000). Another study has also shown some disturbing issues at abattoirs using CO_2 stunning. Troeger et al. (2005) have recorded 1.1% of CO_2 stunned pigs showing signs of regaining consciousness 3 minutes after exsanguination has started. This is most likely due to inadequate bleeding rather than a consequence of stunning method.

An alternative to CO_2 is the use of argon to induce anoxia. Argon can be used in air or in combination with CO_2, and has generally been shown to be less aversive, with pigs showing minimal signs of respiratory distress (Raj and Gregory, 1995, 1996; Raj et al., 1997; Machold et al., 2003). However, the duration of convulsions and time to respiratory arrest are both longer in argon stunned pigs and therefore, exposure duration must be longer than for CO_2 for the pig to reach the same stunned state (Raj, 1999; Machold et al., 2003). This may have implications for facility design and line speed, which would make it difficult for abattoirs using CO_2 stunning to just switch over to argon stunning.

10.7 Euthanasia

Although the majority of pigs are slaughtered at an abattoir, some pigs will either die without intervention on farm or in transit and yet others will require humane euthanasia to prevent undue suffering. The timing and method of euthanasia is an area that farmers have long needed guidance. There has been some research carried out, but not a great deal, and indeed the U.S. National Pork Board (NPB) have had on-farm euthanasia as a research priority for a number of years. There is practical advice for farmers available, such as the joint publication of the NPB and the American Association of Swine Veterinarians (AASV) (NPB/AASV undated), but this is mainly drawn from practical experience rather than scientific research. The options given for the farmer are CO_2, gunshot, captive bolt, electrocution, anesthetic overdose and blunt trauma.

Carbon dioxide is recommended only for piglets up to 10 weeks of age and the design of the equipment should be such that the CO_2 inlet is at the top of the container to ensure that the heavier than air CO_2 completely fills the container above pig level. However, as we have seen earlier, CO_2 is aversive and this method of euthanasia on-farm will not be quick or without welfare concerns. Carbon dioxide has latterly also been proposed as viable for mass euthanasia of groups of pigs (including adult sows) in case of disease outbreak, such as foot and mouth disease (Meyer and Morrow, 2005).

Gunshot can be used for pigs of all ages over 10 weeks (NPB/AASV undated). Both free bullet (0.22 calibre and above) and shotgun can be used with either frontal or temporal placement of the shot. If using a shotgun, a 12-gauge variety is recommended loaded with 28 g of buckshot (Blackmore et al., 1995).

Captive bolt should be penetrating and again, can be used on pigs of all ages over 10 weeks. It should be used with frontal placement (NPB/AASV undated). A non-penetrating captive bolt has the danger of not causing much traumatic brain injury and only very mild axonal injury and should therefore be avoided (Finnie et al., 2003). Electrocution is recommended for pigs of all ages and should be carried out using commercial pig stunning equipment and a 2-step procedure should be practiced firstly across the brain to render the animal unconscious, and then across the heart to induce cardiac fibrillation and death (NPB/AASV undated).

Anesthetic overdose is also recommended for pigs of all ages, but it should be remembered that mature adult sows may be up to 300 kg bodyweight and thus will need a relatively large dose which might make delivery difficult, especially as it should be delivered intravenously (NPB/AASV undated). With piglets, it is also possible to deliver the drug by intracardiac injection and this results in very rapid unconsciousness and death (Baumans et al., 1998). Finally, blunt trauma is only recommended for piglets under 3 weeks of age and should consist of a sharp, firm blow to the top of the head over the brain (NPB/AASV undated).

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Chapter 11
Future Perspectives of the Welfare of Pigs

Don C. Lay, Jr. and Jeremy N. Marchant-Forde

11.1 Introduction

Over the next few years, it is estimated that the demand for pork and thus for raising pigs will increase between 6 and 14% over current levels, especially driven by increasing demand in South East Asia (EC, 2007). This is as a result of an increase in world population and, as *per capita* incomes rise in developing countries, there is likely to be a tendency toward higher intake of food of animal origin (Bellaver and Bellaver, 1999). As you have read in previous chapters, there are many concerns and issues that are being and need to be addressed in order to ensure that the welfare needs of pigs are met. The welfare of pigs in the future will be driven by many of the same things that creates their welfare status today: human virtue, social ethic, economics of production, scientific information, and the standards of an international community. Although the factors that determine pig welfare will stay the same, pig welfare will improve. The predominant driving forces of pig welfare that will change, are that countries will become more economically stable, science will discover new facts, and the international community will become more intertwined, perhaps resulting in global moves towards the highest common denominator, in welfare terms.

Something that will not change in the future is those characteristics that make us humans. Characteristics like empathy, concern, compassion, guilt, responsibility, are all part of being human. It is these characteristics that motivate us to be concerned about animal welfare in the first place. Human characteristics such as these form the basis from which we make decisions on how animals, and other humans, are treated, albeit entrained with differing cultural and perhaps religious influences. Although humans will have all of these same characteristics in the future, the circumstances in which we live will allow for a different expression of these characteristics and thus allow for a different level of swine welfare. For example, although a farmer in a less

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developed country may have great empathy for a sow that must be raised in an "inhumane" manner to save money, if he is faced with feeding his family or treating the sow in such a manner, he will choose to feed his family. When such economic restrictions are lifted, human nature can allow the farmer to act in a humane way by raising the sow such that her welfare is optimized.

In contrast to human virtues, the social ethics of a society are much more labile. Based on social norms, new facts, and heightened awareness, what is acceptable and not acceptable, changes over time. These changes can occur in an isolated community or they can change in the global community. Examples of such changes in social ethics are illustrated by our changed view of: slavery, women's right to vote, drinking and driving, etc. The social ethic of how we raise pigs has changed relatively recently in much of the European Union, and is starting to reach a heightened level of awareness elsewhere, such as in the U.S. This change in concern and feeling of responsibility is driven in part by our inherent compassion, empathy, and responsibility towards animals, and in part by an increase in the public's awareness of how swine are being raised, now that they are removed from first-hand experience of agricultural practices.

11.2 Historical Background to Welfare Awareness

In the early part of the 20th century, as many as 35% of the U.S. workforce was directly engaged in agriculture (Moore and Simon, 1999). By the end of the century, less than 3% of the U.S. population resided on or worked on a farm (Moore and Simon, 1999), and this percentage is likely to continue to decrease. However, the American idea of farming is still based on a life when most people farmed to feed themselves – i.e. the "family farm". The family farm had a few sows in a fenced paddock behind the barn, a milk cow, a plow horse to work the fields and chickens running free around the barnyard. Because the overall quality of human life in the U.S. has reached such a high level, citizens have been able to turn their attention away from simply making money to support themselves and to start paying attention to and acting on other concerns of interest. As more people turn their attention to issues outside of their immediate needs, they will come to the realization that pigs are no longer raised in the "family farm" fashion and this will cause an increasing amount of concern in terms of food safety, environmental protection and animal welfare (Blandford and Fulponi, 1999). With this heightened awareness, will come action. Thus, as countries become "more comfortable" our base human virtues allow for a change in social ethics, which, either directly or indirectly, will have a net effect of improving pig welfare.

The order of priority of these public concerns about food safety, environmental protection and animal welfare will vary from country to country; for example animal welfare retains high priority in Northern European countries, whereas food safety issues are higher in Japan and environmental concerns are perhaps higher in North America. However, regardless of the order of priority, it appears to be inevitable that pig production will be subject to a degree of "policing" via some form of assurance schemes, in order to ensure that the end product is produced to a given minimum standard and using a given set of guidelines. What may be more difficult to foresee is exactly where those guidelines are going to originate from, i.e. government, retailer or producer, and to what extent the various guidelines will be harmonized both within and between countries.

11.2.1 European Legislative Process

Within Europe, government-enacted legislation, both at an individual country level and across the European Union as a whole, has been passed in response to "public" concern about animal welfare specifically – that is, genuine concern from individual members of the public, but also welfare lobbying groups that "represent" public opinion. The influence of such groups should not be underestimated, as they have played a major role in the banning of sow stalls unilaterally in the United Kingdom and subsequently, the rest of the European Union. Historically, the industrialization and intensification of pig farming in the Western World began post-World War II, when farmers responded to public demand for cheaper, more plentiful products. Sows were no longer housed in small groups on "family farms". As more people moved into cities, farm size increased resulting in fewer numbers of people raising larger numbers of animals to produce pork. With an increase in herd size, sows had less space and mortality and competition for feed and space increased. As the ultimate economic and management development, sows were protected by housing in stalls (Marchant and Broom, 1996). Thus, intense confinement became the norm, and economic competition dictated that the majority of sows must be housed in stalls.

During the 1960s, through the publication of Animal Machines by Ruth Harrison (Harrison, 1964) and the subsequent establishment of the Brambell Committee (Brambell, 1965), the public in the U.K. became aware of how farm animals in general were being raised. In regard to stall housing of sows, however, it was not until about 20 years later that this awareness and concern was translated into legislation. In each session of Parliament, there is a ballot by which individual Members of Parliament are able to table a prospective piece of legislation known as a Private Member's Bill. In 1990, one of the Private Member's Bills to be debated concerned the banning of sow stalls, with a minimal lead-in time. This Bill had a great deal of popular support and was almost certainly going to be passed. The Governmental response was to pre-empt this Bill with its own legislation (Welfare of Pigs Regulations, 1991, SI1477), which banned stalls and tethers from January 1st 1999. Other E.U. countries also have unilateral legislation in place – Sweden banned tethers in the 1970s and stalls from 1994, Finland banned tethers from 1996 and stalls from

2006, the Netherlands banned tethers from 2002 and stalls from 2008. However, an E.U. Council Directive (2001/88/EC) passed in 2001 to harmonize sow housing in all current and future member countries, banned tethers from 2006 and stalls after 4 weeks from time of insemination, from January 1st 2013.

11.2.2 U.S. Legislative Process

Because the U.S. in many respects has followed the U.K. relative to animal welfare issues, it is likely that a similar chain of events will occur in the U.S. (Mench, 2003). The similarities in the process so far are illustrated in Fig. 11.1.

One exception might be that we may not see national level legislation in the U.S. to govern livestock production practices. The U.S. government was established on the principle that the people should govern the people, not to be governed by a higher body. Thus, upon separation from the U.K. and drafting of the U.S. Constitution, power was given to each state to govern itself, and power to make national law was split between three opposing bodies, the House of Representatives, the Senate, and the President. This three-way split of power, and the ability of each to prevent the passage of a law by the other, purposely made it almost impossible for a national law to be passed unless all parties agreed. To date, although there is one national law covering transportation and one national law covering slaughter, no national laws governing livestock production practices on the farm have been created in the U.S. (Wolfson, 1996). However, it is likely that, similar to events in the U.K., the U.S. public will gain an awareness of pig production practices and start to question their appropriateness. And, although national laws are difficult to pass, state laws are much easier. Recently, the above scenario of public awareness and passage of a law to govern sow housing, has occurred in Florida (November, 2002), Arizona (November, 2006), Oregon (June, 2007) and Colorado (May, 2008) which did pass state laws to prevent sows from being housed in stalls. California will also vote on the stall issue in November 2008. Thus, although national legislation is unlikely in the U.S., in the future we may see a progression of

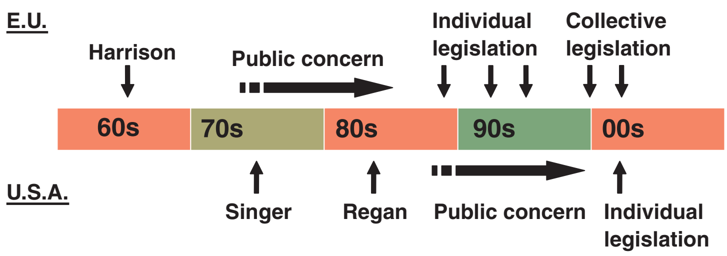

Fig. 11.1 Diagrammatic illustration of the timeline of animal welfare issues reaching public awareness and legislative processes

individual states passing legislation to govern how livestock animals are raised or to at least bring farm animal production under the umbrella protection of animal anti-cruelty legislation. At present, many states exempt farm animal production methods which are “Accepted,” “Common,” “Customary” or “Normal” Farming Practices (Wolfson, 1996).

11.3 Assurance Schemes and Welfare Change

Regardless of whether or not governmental legislation has been or will be enacted within a given country, recent years have seen a worldwide surge in the number of quality assurance schemes aimed at improving meat marketability (Wood et al., 1998). Whatever, the main driving force for the introduction of assurance schemes, they will impact pig welfare, either directly or indirectly. Currently, most schemes originating within industry and by retailers are not essentially welfare-led, but have more to do with aspects of traceability and food safety, with environmental and animal welfare issues somewhat secondary. However, there are exceptions and the RSPCA-led Freedom Food scheme established in the U.K. in 1994 has pioneered the introduction of schemes that are specifically welfare-led. Its success has resulted in mirror schemes starting up in other countries, such as the American Humane Association-led Free Farmed program and the ASPCA/Humane Society of the United States-led Certified Humane Raised & Handled program in the U.S.A. (HFAC, 2003). It has also potentially played a role in stimulating the retailer sector to initiate their own welfare-driven schemes, such as the Animal Welfare Guiding Principles of McDonald’s. In any measure, McDonald’s is a global company and they claim to be “the world’s leading food service retailer, with over 30,000 restaurants in 119 countries, serving 46 million customers a day”. In the U.S.A., McDonald’s corporation started auditing packing plants in 1999 to ensure that cattle were being humanely slaughtered. The corporation then progressed toward adopting humane standards similar to those proposed by the United Egg Producers (UEP, 2002), but with immediate compliance with increased space requirement and an end to feed-withdrawal induced molting, insisting that the producers from which they bought eggs adhere to these standards. Imposition of unannounced audits and adherence to these rules put a new level of attention on livestock welfare. In typical competitive fashion, other “fast” food chain restaurants followed suit, with Burger King, Wendy’s, Kentucky Fried Chicken and others also accepting and establishing animal welfare guidelines.

The motivations behind the establishment of assurance schemes, including those that retailers are keen to state are welfare-driven, are not always well defined, but the fact is that they are forcing changes in the way that animals are reared, transported and slaughtered and their importance in the future direction of animal agriculture, should not be understated or underestimated. There are currently calls that the plethora of schemes available within single countries should either show commonality or should go further and actually merge to give a single assurance scheme that could be effectively marketed to the consumer. This would remove the confusion that exists in the current market-place, where the consumer is positively bombarded with pork products that have various labels and which do not perhaps convey any real information about the way in which that product was reared. For example, meat labeled as "outdoor-reared" conjures up visions of happy, healthy pigs in fields, whereas the exact requirements to attain this label will be unknown to the vast majority of consumers and the welfare status of the animals themselves can indeed be very far from optimal. Within the U.S.A., the National Council of Chain Restaurants have joined forces with the Food Marketing Institute in order to try to establish common ground through their Animal Welfare Program. Some of the aims of this program are to bring consistency in assurance schemes across the U.S. retail sector, to implement practicable and attainable guidelines based on science and to implement a measurable audit process. Together, the NCCR and the FMI represent about 70% of the U.S. retail sector and thus, their potential influence on U.S. animal production is very great.

In a similar type of movement, the U.S. Government adopted standards for food that was to be produced organically (USDA, 2003). Because U.S. consumers sought to buy organically raised foods, yet no standard definition of organic existed, the Government adopted guidelines in 2002 and gave their seal to foods that met a set of minimum requirements. The movement towards assurance and quality standards by corporations and governments emphasizes a new social ethic in which people are becoming more concerned about where their food is derived and the conditions under which it was raised. Movements in such positive directions such as these cannot regress. Once considered a luxury, movements toward increase in "quality" or availability become accepted as being required. Similar to improvements like the telephone, electricity, and tomatoes in winter, which we now find unacceptable to live without; eating pork raised from sows that can turn around will likely be, not a novelty, but the expected standard in tomorrow's world.

It might also be argued that given the global trade of pork, the issue of commonality is one that should transcend national boundaries. There is little point for U.K. supermarkets to stock Danish and Dutch products that meet their own assurance standards but do not match those of the U.K. assurance standards. The European Union is likely to be one such body that can address this type of issue from a legislative point of view. However, commonality between such diverse entities as say, the E.U., U.S.A. and Australia could not foreseeably involve legislation, but would have to be voluntarily agreed by the industries themselves. This would be unlikely to happen, especially given the facts that even welfare scientists within these countries cannot yet agree on issues pertaining to the welfare of pigs. Within North America, the debate on the welfare of sows within confinement gestation systems continues unabated, whereas all confinement gestation systems will be banned within the E.U. as a whole from 2013, with the scientific evidence against them, perhaps influenced by public opinion, apparently clear-cut. Not surprisingly, national pig industries are protective of their methods of production and rally against any within-country opposition, with each stakeholder, such as animal rights groups, welfare groups and producer groups, seeing their own positions on the scientific evidence as balanced and reasoned. Opposition coming from the outside will usually be dismissed out of hand. Recently, the Office International des Epizooites (OIE) – an intergovernmental organization with 164 member countries – has established a permanent working group to provide specific recommendations on the nature and scope of OIEs animal welfare role (Bayvel, 2004) and this puts animal welfare firmly into the global marketing spotlight.

11.4 Global Production Outlook

11.4.1 Current Major Players

By far the world's biggest producer of pork in single country terms, is China, with a forecast production in 2008 of 44.7 million metric tons (FAS, 2008). The second largest single country producer is the U.S.A. with a 2008 forecast of 10.7 million tons (FAS, 2008). However, the European Union, recently expanded to 27 countries, will have a combined production forecast of approximately 22.5 million tons, in 2008. At present, somewhere between 5.2 and 5.5 million tons of pork are subject to import/export across national boundaries, with major importing countries being Japan, the Russian Federation, Korea and Mexico. The major exporting countries are the U.S.A., the E.U., Canada and Brazil. The diversity of production systems, cultural differences in attitudes to animal welfare and the importance of the global trade in pork in the countries included in these lists, perhaps highlights just how difficult it would be to introduce an element of commonality in welfare standards that transcends national boundaries. South-east Asia plays an important part in global pork trade, being an area of major production, consumption and importation. Latin and South America are also becoming increasingly important players in the market, as consumption and production increases. Clearly, there remain very big differences in the economic status of populations within the pork eating world and this has a large influence on the importance of animal welfare and environmental concerns relative to human welfare.

11.4.2 The Changing Picture

The rate of change within previously economically-depressed countries is much greater than in the developed Western world. Countries such as China, Korea, Brazil and Mexico are seeing rapid increases in consumption and in production capacity, as income per capita increases and pork production becomes industrialized using Western technology and investment. As touched on in Chapter 1, the industrialization of pork production is impacting the agrarian society. For example, small, backyard production still accounts for well over half of China's pork output, but this picture is changing rapidly as large intensive swine facilities are established. The high health status of industrialized production systems can impact local and backyard production units and the reduction in costs of production can put family-owned operations at a competitive disadvantage. With free trade and the globalization of the market, the extent of import or export between two given countries would be largely dependent on relative costs of production in those two countries. In reality, and independent of any protectionist tariffs imposed on trade, other factors such as societal issues relating to animal welfare or meat quality may come into play.

What has become apparent from the European experience is that the industries themselves ultimately lack the power to dictate the methods that they use. The real power-base lies with the retailer and the retailer to some extent is dictated to by what the consumers want or perhaps what they think the consumers want. Pig industries should therefore be aware of the need for flexibility in production methods or even the need for change. If a large cooperation that operated on the world market were to agree to purchase pork products that were only produced using certain housing systems, then it would be difficult for the swine industry not to adjust. For example, within North America in 2007, major purchasers McDonald's and Walmart have effectively forced some major pork producing companies (Smithfield Foods and Maple Leaf Foods) to introduce a voluntary ban on gestation stalls which will be phased in over 10 years. At the international level, we have already witnessed the buying policy of retailers in one country (U.K.), influence the housing of pigs in other countries (Denmark and the Netherlands), in response to perceived consumer preference. Pig industries elsewhere should expect that this could happen again. With these factors in mind, certain areas within the global pig industry will continue to come under scrutiny on the basis of welfare.

11.5 Current Welfare Concerns

11.5.1 Housing

Currently, the two biggest welfare issues that are open to direct consumer concern and thus, retailer pressure, are the issues of barren environments, such as intensive, indoor, non-bedded systems and close confinement, such as gestation and farrowing crates. Although there are many questions yet to answer on the degree of welfare that swine experience in the many production scenarios in which we place them, it appears that in some aspects the future is clear. The amount of space which is allocated to swine at every production stage will likely be increased. In situations in which swine are housed together, less allocation of space causes increased competition for resources such as food, water, and resting place. An increase in competition results in a decrease in the welfare of at least some individuals that are unable to successfully compete for the resource, as well as associated injuries and psychological stress associated with the act of competition (Marchant et al., 1995). Increasing space allowance can help address this issue; however, the quality of the space in which swine are housed and how this quality interacts with the amount of space provided is a critical component to optimizing welfare. Future research will need to more fully define this interaction. There is legislation within the E.U. to improve quality of space, in terms of including "access to manipulable material" (E.U. Council Directive 2001/88/EC), but this in practice, can mean placement of a chain in the pen. The extent to which this enriches the environment and meets the needs of the pigs and the spirit of the law is now in question, and we can expect to see further research on materials to enrich pig housing environments.

Currently the practice of single housing of gestating sows and farrowing sows has been accomplished in a very limited amount of space. These two similar systems have been implemented principally for economic reasons but are defended for two very different "welfare" reasons. The first is said to provide protection from overt aggression by herd mates while the latter is said to help prevent crushing of piglets by sows. Certainly close confinement can have a protective function but, regardless of the benefits, this amount of severe restriction presents a welfare concern and to the general public, the idea of sows in crates will always be regarded negatively. Increasing space alone will not automatically improve welfare; future research must resolve the disadvantages of providing increased space if a high level of welfare is to be provided to gestating and farrowing sows and their piglets.

11.5.2 Transportation

Some aspects of pig production that decrease welfare, such as transportation, appear to be unavoidable. Transportation places pigs in a novel environment which can be fearful and it is associated with handling and mixing which adds additional stressors. Improved methods of getting swine from the farm to the abattoir, including reduction of mixing of non-familiar animals and, increasing the ease of loading and unloading through enhanced facility design will all help to improve swine welfare. Future research will also need to address the optimal duration which is allowable for swine to be hauled. A complete understanding of the contribution of each factor contributing to distress from transportation, such as handling, mixing, duration of transportation, duration of feed and water deprivation, and housing methods upon arrival at the abattoir will need to be elucidated. Likely, future methods of transportation will implement shorter transportation durations, less mixing of unfamiliar individuals, and less stressful housing/handling upon arrival at the abattoir.

11.5.3 Genetics

In synchrony with these legislative and market driven changes in swine welfare production practices, will need to come a change in the swine themselves. Genetic selection during the past 50 years has created a line of pigs that do very well in the confinement systems that are currently being used. It can not be expected that these same animals can be moved into a new type of system and do equally as well. To date, selection criteria for swine has been concentrated in two areas, "maternal" traits, and growth traits. Maternal traits include consideration of milk production, number born, and number weaned. Growth traits include, gain to feed ratio, percent lean, and average daily gain. Emphasis has been placed on a sow that can produce a large litter and pigs that convert feed to muscle extremely well. Hidden in these selection criteria are characteristics that allow the pigs to live and reproduce in the system in which we keep them, otherwise they would be culled. If production systems are to move away from intensive confinement into more extensive type production systems, then pigs capable of living well in these systems will need to be selected. Characteristics that enable sows to live in single housing will not serve them well if they are to be kept in groups. For instance, a sow in a single stall need not compete for feed or protect herself from aggression. In a group housing system, these traits will likely be very important for her survival. To ensure optimum welfare of swine, further selection criteria will need to be addressed that specifically focus on welfare. Current issues of concern in swine herds are high mortality rates, high incidence of lameness, and a high rate of culling due to a lack of reproductive performance.

A mathematical and genetic difficulty presents itself as we pursue this goal because as we start to select for more than one trait at a time, our progress in selection slows dramatically. For example, if the estimated heritability for lean growth is 0.40 and reach (amount deviation from the average in the herd of selected individuals) is 60 pounds then selection for lean growth alone should show an improvement of 24 (0.4×60) pounds per year. And, if the estimated heritability for maternal care (defined here theoretically as time spent being vigilant) is 0.15 and the reach is 2 hours; then selection for maternal care alone would increase vigilance by 0.3 hours per year. However, selection for both variables at the same time would only allow an increase of 16.9 pounds and 0.2 hours in the same time period. These calculations are based on a one year generation interval, realistically generation interval would be 2 years at a minimum which would decrease these values by one-half, 8.45 pounds and 0.1 hour respectively. However, a more holistic approach for genetic selection, away from only traits that give an economic advantage and to the inclusion of traits that give both economic and welfare advantages, needs to be sought.

11.5.4 The Future

The generation of scientific information to address questions on animal welfare is steadily progressing as well. In accord the with the trend for greater attention in the E.U. on animal welfare and to a lesser extent in the U.S., a much greater amount of animal welfare research has been conducted in the E.U. as compared to the U.S. However, the number of animal welfare researchers in the U.S. is steadily increasing. In total, animal welfare research on a world basis has been relatively less than the amount of effort spent studying more "traditional" sciences such as nutrition, reproduction, and genetics. Because the study of animal welfare is relatively new, the information needed to answer many important questions is lacking. Research on basic questions such as: how painful are certain production practices?; how much space do livestock need?; what duration of transport is acceptable?; are currently being addressed. These important research questions represent a multitude of topics that require scientific information in order for us to optimize livestock welfare. However, even after all sorts of questions such as these are addressed, we still will need to move forward to understand how livestock think and feel. In the future, research aimed at understanding cognitive and emotive aspects of livestock will allow us to more fully understand if livestock are experiencing poor or good welfare. This is a difficult challenge but one that must be met if we are to correctly answer questions as to whether a livestock production system or practice adequately preserves the animals' welfare integrity.

11.6 Summary

In summary, future generations of swine will likely experience progressively increased welfare due to enhanced economic stability of world populations which will allow for more resources, intellectual and physical, to be directed toward optimizing welfare. The scientific field of animal welfare is steadily increasing and congruent with this increase will come a vast amount of knowledge allowing us to more fully understand those factors that contribute to welfare. Effectors of change will be the process of acceptable standards. Once "the bar is raised" on acceptable levels of swine welfare in our various production systems, it will be most difficult for future practices to allow swine welfare to slip below this level.

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