Principles of Taxonomy

Biol. 3063

Addis Ababa University, DPBBM

Ermias Lulekal (PhD)

Dr Ermias Lulekal_On line Note _for the course Principles of Taxonomy Prepared for classes interrupted due to Covid_19

Details

- **Semester: II**
- **Third Year,** Regular Program
- **Instructor**: Ermias Lulekal (PhD)
- **Consultation hours**: **Thursday 3:30-4:45PM**
- **Office:** The National Herbarium (ETH)
  No 105

Course description

- The course deals with the **historical development of taxonomy** as a science, **principles, procedures and rules of taxonomy**, rules of **botanical and zoological nomenclatures** and the **hierarchy of classification**, with examples from both plant and animal kingdoms.

- **Classification systems**, **taxonomic structures**, **taxonomic evidences**, **code of nomenclature** and **purpose of giving names** to organisms and **nomenclatural codes**, **taxonomic techniques** and the **application of taxonomic result** in different disciplines will be discussed in details.

Course Objectives

At the end of this course the student will be able to:

- Review **how the science of taxonomy grew** through time
- Discuss the **rules and procedures in taxonomic classification**
- Enumerate the **types and sources of characters** used in taxonomic classification
- Describe how species are **hierarchically arranged** into different taxonomic groups
- Explain various **species concepts**
- Employ **herbarium and museum techniques** in taxonomy

Course Contents

- **Introduction to Taxonomy (2 hrs)**
  - The meaning and scope of taxonomy
  - Definitions of important taxonomic terms
  - The objectives of taxonomy
  - The process of classification
  - General and special purpose classification
  - Alpha and omega taxonomy
  - Classification, identification and Nomenclature

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Course content contd...

- **The development of taxonomy (4 hrs)**
  - Inception of taxonomic thinking
  - Folk taxonomies
  - The practice by early Greek Philosophers
  - The herbalists
  - Early taxonomists
  - Linnaeus (and his students)
  - Post-Linnaean natural system
  - The impact of Darwin's book on the Origin of Species on taxonomy

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Course content contd...

- **Classification system (4 hrs)**
  - Artificial classification
  - Pre-Evolutionary Natural Systems
  - Natural classification (Adansonian)
  - Phyletic classification (Evolutionary)
  - Phenetics (Numerical/mathematical)
  - Cladistics (Phylogenetic)

Course content

- **The taxonomic Structure (6hrs)**
  - The hierarchy in classification (taxonomic hierarchy)
  - The categories of classification in different groups of organisms and standard endings in plants, animals and bacteria
  - Concepts of the Kingdom
  - The concept of species (the basic unit of taxonomy)

Course content

- **The concept of species (the basic unit of taxonomy)**
  - Morphological species concept
  - Biological species concept
  - Genetic species concept
  - Paleontological species concept
  - Evolutionary species concept
  - Cladistic species concept
  - Biosystematic species concept

Course content

Taxonomic characters (7hrs)

- Values of characters and character states
  Kinds of characters

Sources of taxonomic information

-Morphological and anatomical
- Reproductive and vegetative
- Chemical characters
- Chromosomal characters
- Other sources of taxonomic information

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Course content

- **Biological nomenclature (5 hrs)**
  - The scientific naming of organisms
    - Purpose of giving names to organisms
    - Necessary features of names
  - The codes of Nomenclature (bacteriological, zoological and botanical codes)
  - The purpose of Nomenclatural codes
  - Modification of the Code
    - Forms of Scientific names
    - Name of taxa above the rank of genus
    - Name of Genera
    - Name of taxa intermediate between genera and species
    - Name of Species
    - Name of taxa below the rank of species
    - Names, ranks and positions
  - Stability and Change
  - Advantages of the System
  - The conflict and its resolution
  - Operative principles of Nomenclature (publication, Typification, Priority, Synonymy))
  - Authorities and their citation

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Course content

Taxonomic techniques (2 hrs)

-Botanical techniques

- Zoological techniques

The application of taxonomic results (2 hrs)

-Dependency of taxonomy on other fields

-Disciplines that require service of taxonomy

References

1. Heywood, V. H. (1978). Modern Methods in Plant Taxonomy. Academic Press.London and New York.
2. Jeffrey, C. (1978). Biological Nomenclature (2nd ed.). Edward Arnold, London.
3. Simpson, g. G. (1961). Principles of Animal Taxonomy. Columbia University Press.New York & London.
4. Stace, C. A. (1980). Plant Taxonomy and Biosystematics: Contemporary Biology.
5. Edward Arnold, London.
6. Simpson, M. G. (2006). *Plant Systematic*. Elsevier Academic Press, UK.
7. Stuessy, T.F, (2009). Plant Taxonomy. (2^{nd} ed.) New York.
8. Singh , G. (2010). Plant systematic (3^{rd} ed). Science publishers, Enfield, NH, USA

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1. Introduction to Taxonomy

1.1. The meaning and scope of taxonomy

Q. What is taxonomy

- Taxonomy is a science which refers to the **description of the variation of organisms,** the **investigation of the causes and consequences of this variation**, and the **manipulation of the data obtained to produce a system of classification**.

Introduction contd....

- Taxonomy is the science of grouping biodiversity in to species, and classifying their diversity in to a higher level taxa that reflect evolutionary history

- Name derived from two Greek Words:

  Taxis---------- Arranged

  Nomos---------Law

- Taxonomy is the science of arranging, grouping, identifying and naming of organisms using standard laws

Introduction contd…

- The definition works also for the term **Systematics**
- **Taxonomy and Systematics** are used interchangeably
- **Taxonomy** strictly refers to **classification** though **Systematics** is **broader in that it focuses on theoretical and practical aspects of evolution, genetics, and speciation**

Introduction contd…

- Two approaches in taxonomy:
  1. **Experimental taxonomy** or **biosystematics**
  2. **Orthodox** or **classical taxonomy**.
- Experimental taxonomy focuses on study of organisms from the stand point of population and their evolutionary process occurring in the **population**, and it will not consider individuals

Introduction contd…

- Experimental taxonomy/ biosystematics emphasises on **genetic, cytological and ecological** information for classification and it involves studies **in the field, laboratory , experimental gardens or green houses**.

Introduction contd…

- **Orthodox taxonomic approach** basically relies on **morphological and anatomical** data
- **Orthodox taxonomic studies** could be addressed in **herbarium and in laboratories**.
- These two approaches are **not separate and opposing**, but they are closely interacting, they are **complementary approaches to taxonomy**, without either of which taxonomy is incomplete.

1.2. Definition of important taxonomic contd.

- **Taxon:** any **taxonomic grouping or** taxon is a group of organisms treated at a given rank
- **Description of a taxon**: a **statement of its characters**
- **Characters:** the **feature of a plant or an animal**
- **Character states:** the **value of a character**
- **Diagnosis:** a **shortened description** covering only those characters
- **Diagnostic characters:** are characters that **help to differentiate** a taxon from other related taxon
- **Taxonomy: study and description of the variation** of **organisms**, the investigation of the **causes and consequences** of this variation, and the manipulation of the data obtained to produce a system of classification

Definition of important taxonomic contd…

- **Flora:** a **book** or other work **describing the flora** of a given area
- **flora: plant life** of a given area
- **Symplesiomorphy:** is an **ancestral trait** shared by two or more taxa
- **Monophyletic:** a group **composed of an ancestor** and all **its descendents**
- **Phylogenetics:** The study of **evolutionary relationship** among organisms

1.3. The objectives of taxonomy

Q. What is the **importance of taxonomy**?

- to understand and communicate about the natural world
- taxonomy has two basic activities these are classification and naming
- both are ancient human methods of transferring information about the natural world which is important to human beings

Objectives contd…

- **Classification** of organisms is needed to group them into recognizable categories that one can sort out and understand the vast array of features among organisms

- Classification uses for the accurate recognition or identification of related species, predators, mates, foods, medicine, etc...

Objectives contd…

- Considering the number of living organisms known one can understand the real problem of classifying organisms
- So far many animals, plants and microbes are classified.
- Annually, for example, 2000 new species of plants are recorded.
- It is difficult for any biologist to know more than any tiny fraction of the total, number of organisms
- However, **if they are grouped into larger units one can ascertain** that an unknown organism belongs to an animal, plant or microbe.

Objectives cond....

- The objective of taxonomy goes **beyond** classification
- It is a **basis for more research and scientific studies** on organisms
- It has application in medicine, agriculture, pest management, fisheries and even **conservation** too

1.4. The Process of Classification

- The human species has a **compulsion for ordering** things
- This need probability derives from **a desire to deal with the environment** in a predictable way
- The **process of classifying** everything in our environment and the utilization of resultant product can be interpreted as **an attempt to lower the risk of uncertainty of living**

The Process of Classification contd…

- Human beings classify not only organisms but also objects and even ideas

- The importance of classification for humans comes from the **studies of primitive peoples of the world who classify objects and ideas in their environment** in much in the same basic fashion as do professional western taxonomists

The Process of Classification contd…

- There are various views by former scholars about the classification process, however, the **process of classification lies in the nature of the hierarchical system** developed earlier

- Most of the **classification we use currently** are **hierarchical,** but some are not, such as those done by **ordination in which variables are arranged in-two dimensional space** in relation to major axes of variation in the data set used

The Process of Classification contd…

- Hierarchical classification scheme has higher information content to human needs than the none hierarchical ones
- Hierarchical classification process is a particular scheme of grouping and ranking of a particular objects
- Grouping of species into one of several large units is not sufficiently precise in taxonomy
- A hierarchical system of classification combines **species into an ascending series** of **successively larger** and wider categories, ultimately **arriving at a single all-embracing group** covering all organisms

The Process of Classification contd…

- The hierarchical classification can be illustrated in two different ways:
  1. A **plan view or bird's eye view**: which is a box in box presentation
  2. **Elevation or side view**: present the hierarch using dendrogram
- Both illustrate and show how one or more taxa at each level are combined into a single taxon at the next higher level, and this higher level is defined by the sum of characters of all its subordinate taxa.

The Process of Classification contd…

- In the hierarchical system of classification, there is no limit to the number of levels contained in a hierarchy.
- The international Code of Nomenclature recognizes twelve main rank in the hierarchy (Kingdom, Division/Phylum, Class, Order, Family, Tribe, Genus, Section, Series, Species, Variety and Form)
- This number of ranks may double or even more by designating subcategories below or above each rank (subkingdom, subdivision/subphylum, subgenus, subspecies, etc).

The Process of Classification contd…

- The **names of these ranks** should be used in their strict senses.
- As an aid to indicate the ranks to which a taxon belongs, ranks between the level of division and subtribe are designated with **standardised endings**
- The **characteristic endings** are **not the same** to all groups of organisms for instance, endings used in plants vary from animals and fungus.
- How ever, bacteria's have similar kind of endings with that of plants.
- Adhering to the rules of using standardised endings will help as an aid to understand and know the different categories of organisms under study.

Hierarchy of taxonomic ranks

Taxonomic Rank	Botanical/algae	Bacteriological/fungi	Zoological
Kingdom	----------	----------	-------
Subkingdom	bionta	----------	-------
Division (Phylum)	phyta/…	…../mycota	…
Subdivision /sub Phylum	phytina/…	…../mycotina	…
Class	opsida/phyceae	**ia**/mycetes	…
Subclass	idae/phycidae	**idae**/mycetidae	…
Superorder	anae/anae	…/anae	…
Order	ales/ales	**ales**/ales	…

Hierarchical classification contd...

Taxonomic Rank	Botanical/algae	Bacteriological/fungi	Zoological
Suborder	ineae/ineae	ineae/ineae	…
Superfamily	--		**oidae**
Family	aceae/aceae	aceae/aceae	**Idae**
Subfamily	oideae/oideae	oideae/oideae	**Inae**
Tribe	eae/eae	eae/eae	**ini**
Subtribe	inae/inae	inae/inae	ina
Genus	Various	Various	Various
Species	Various	Various	Various

1.5. General and special purpose classification

- The utilization of a great number of characters with no a priori weighting follows logically from the observation that more natural or predictive classifications are based on more characters.

- When very few characters are used there is always a high degree of weighting, since most characters are automatically given zero-weighting.

General and special purpose contd…

Q. Are the best classifications those utilizing the most characters, and hence those which are more predictive?

Ans: yes.

- Such classification, are best for most purposes, and hence termed as general purpose classifications.
- GP classifications are best represented by the familiar sequences of families, genera and species, etc., which appear commonly in Flora and Fauna

General and special purpose contd…

- GP classifications have arisen over the past two centuries by a process of gradual improvement as more and more taxonomically valuable characters are discovered and incorporated.
- Theoretically, this process is never completed, but it obeys the law of diminishing returns, so that the broad outlines of the scheme adopted nowadays, at least that of higher plants, are not likely to be changed.

General and special purpose contd…

- There are situations, however, when a general purpose classification is not necessarily the best i.e. when predictivity is not the best criterion.
- In particular, many taxonomists wish to know something of the evolutionary history and relationships of a group of taxa; in other words they want the classification to reflect the phylogeny or the phylogenetic or evolutionary pathways of organisms.

General and special purpose contd…

- A classification which does this is known as a phylogenetic or phyletic classification, it differs from a phenetic classification which is based upon the overall present day resemblances and differences of organisms.
- General purpose classifications are therefore by definition phenetic, not phylogenetic,
- The adjective natural is more or less used as synonymo with phenetic

General and special purpose contd

- Phylogenetic classifications are at least theoretically not natural, because they aim particularly to reflect one feature of the organisms (they can be plants, animals or microorganisms), and in constructing such systems phylogenetic data are weighed against others

General and special purpose contd

- Therefore, except in the matter of evolutionary history, Phylogenetic classification systems are less predictive than phenetic classification,
- Phylgenetic classifications are thus one example of special purpose of classification.
- Special purpose classification, like artificial ones, are less predictive than general purpose classifications, in fact virtually all artificial systems may be considered special purpose classification.

General and special purpose contd

- If you look at the Linnaeus Sexual System is special purpose classification and at the time that it was most used it was the best one available, as it was easy to understand and brought order to a very confusing subject.
- Thus it may be seen that the merit of classification is not an absolute criterion, but must be judged according to its purpose.
- For general purposes predictivity is the criterion, but for special purpose the criteria may diverse from the particular interest and we need for the classification.
- Bear in your minds that data incorporated in the special purpose of classification may well be of value in constructing the general purpose of classification

1.7. Alpha and Omega Taxonomy

- Modern **phenetic classifications** are ideally based on a **very wide range of characters**, incorporation of which is a gradual, continuous process
- The naturalness or **predictivity** of a classification **depends on the extent to which the organisms** have been investigated

Alpha and Omega contd...

- Our level of knowledge of organisms varies in different ways.

- For example, we know far **more about the large fauna** and **vascular plant species of Ethiopia** than about **the invertebrates and lower plants and microorganisms of the country**, because we have fewer data for the later

Alpha and Omega contd...

- There are three stages/phases of taxonomy

1) **The exploratory phase**: involves collection and subsequent classification of organisms based on a **limited range of herbarium and museum specimens**;

2) The systematic phase: involves **extensive herbarium, museum and field studies** of a wide selection of material of each taxon

Alpha and Omega contd...

3) The **Biosystematic phase**: Involves detailed **genetic, cytological and even ecological studies** for classification.

- The first two phases of taxonomy (**exploratory and systematic**) are known as **Alpha taxonomy**.

Alpha and Omega contd...

- In **Alpha taxonomy,** taxonomic **classification is solely based on external morphological characters or feature.**

- Alpha taxonomy is considered as **classical taxonomy**

- Alpha taxonomy is the discipline of **detecting, describing and classifying new species**, as well as **revising the classification** of a **previously described** species

Alpha and Omega contd...

- Generally, Alpha taxonomy is based on exploratory and systematic phases where **either more or few studies are conducted on herbarium and museum species**
- In contrast, Omega taxonomy comprises of the biosystematic phase.
- **Omega taxonomy** refers to **taxonomic activities carried out based on data from ecology, phytochemistry, phytogeography, cytogenetics, physiology** and even coupled with **adequate computation**.

Alpha and omega contd....

- Some taxonomists consider **Beta and Gama taxonomies** between Alpha and Omega
- The **Beta taxonomy**, in addition to **morphological description**, refers to **classification which involves affinities and their inter-relationship** between separate groups of species
- The **Gama taxonomy** is concerned **with description, inter-relationship and evolution of one species from the other**
- Among all the Omega taxonomy is considered as **the modern taxonomy**

1.8. Classification, Identification and Nomenclature

- **Q. How do you define classification?**
- **Classification:** is the **ordering of organisms into groups** or sets on the basis of their **relationships** i.e of **their association, configurity, similarity or all of these**.

- It also refers to **arrangement of entities (organisms/taxa)** in to groups having **common characteristics** and **evolutionary relationships**

- Classification is the **production of a logical system of categories**, each containing any number of related organisms

Classification, Identification and Nomenclature contd.

Q. How do you understand nomenclature?

- **Nomenclature:** is **the study of the system and methods of naming of organisms**, and the construction, interpretation and **application of the regulations** governing this system.
- It is the **formal naming of taxa** based on standard international codes of Nomenclature
- These **formal names** are known as **scientific names**
- Classification **precedes naming**

Classification, Identification and Nomenclature contd.

Q. What is identification?

- **Identification:** is the process of **determining the group of an organism** by reference to **already existent classification** .

- It is a **process of placing individual organisms** into **classes that have been establised a priori**, the placement is based on specific features of an organism that belng to the group

- It also refers to **identifying organisms by recognition of crtain descriptive characters**

Classification, Identification and Nomenclature contd.

- **Identification** also refers to **the process of associating an unknown taxon with a known one,** usually with the help of an **identification key or taxonomic key**
- One can **identify an unknown taxon** by **first noting its characteristics,** that is, by describing it.
- Then, these **features are compared with those of other taxa** to see if they **conform**.
- Generally, it is **the practical use of classification criteria to distinguish certain organisms** from others

Classification, Identification and Nomenclature contd.

Q. What are the data sources we use for CIN?

- **Ans- Specimens from field, herbarium specimens, museum** specimens, **taxonomic literature, Flora, Fauna, monographs, revisions** different sources of taxonomic evidence, etc....
- A **monograph of a group of organism usually a genus or a family** is a comprehensive taxonomic treatise that synthesise **all information known about the group** and presents a classification based on this information
- **CIN** are the **basic components** of taxonomy

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Chapter 2

The Development of Taxonomy

Will be online very soon