# Hierarchy of Taxonomic Categories & Evolutionary relationship among taxa

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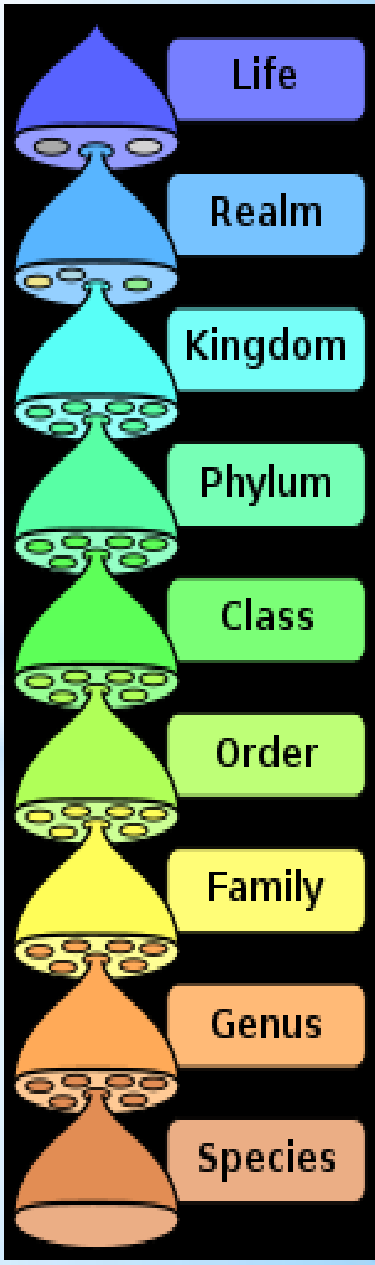
# INTRODUCTION

- Taxonomic hierarchy – An ordered group of taxonomic ranks used to classify organisms from general to specific.
- Hierarchy is the sequence of arrangement of taxonomic categories in descending order from higher to lower during classification of organisms. Hierarchy was first given by Linnaeus. There are seven categories. This includes kingdom, phylum, class, order, family, genus and species.
- In biological classification, taxonomic rank is the relative level of a group of organisms (a taxon) in a taxonomic hierarchy. Examples of taxonomic ranks are species, genus, family, order, class, phylum, kingdom, domain, etc.
- A given rank subsumes under it less general categories, that is, more specific descriptions of life forms. Above it, each rank is classified within more general categories of organisms and groups of organisms related to each other through inheritance of traits or features from common ancestors.
- The rank of any species and the description of its genus is basic; which means that to identify a particular organism, it is usually not necessary to specify ranks other than these first two.
- The International Code of Zoological Nomenclature defines rank as: "The level, for nomenclatural purposes, of a taxon in a taxonomic hierarchy (e.g. all families are for nomenclatural purposes at the same rank, which lies between superfamily and subfamily).“
- In his landmark publications, such as the ‘Systema Naturae’, Carl Linnaeus used a ranking scale limited to: kingdom, class, order, genus, species, and one rank below species. Today, nomenclature is regulated by the nomenclature codes. There are seven main taxonomic ranks: kingdom, phylum or division, class, order, family, genus, species. In addition, domain (proposed by Carl Woese) is now widely used as a fundamental rank, although it is not mentioned in any of the nomenclature codes, and is a synonym for dominion (lat. dominium), introduced by Moore in 1974.
- Binomial nomenclature – A two-part system of naming species; species are referred to by their genus name followed by their species name.

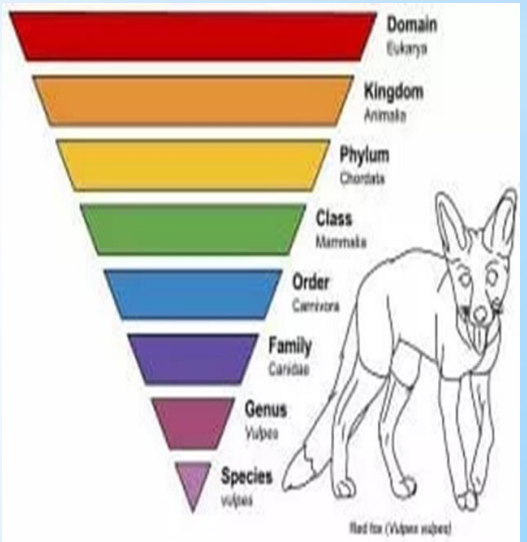


# INTRODUCTION : CONTD..

- A taxon is usually assigned a rank when it is given its formal name. The basic ranks are species and genus. When an organism is given a species name it is assigned to a genus, and the genus name is part of the species name.
- The species name is also called a binomial, that is, a two-term name. For example, the zoological name for the human species is Homo sapiens. This is usually italicized in print and underlined when italics are not available. In this case, Homo is the generic name and it is capitalized; sapiens indicates the species and it is not capitali
- A higher taxon is an aggregate of related species separated from others by a dis continuity but this definition fails to give any help in determining the rank of the taxon because it is equally valid for higher taxa of all levels from genus and family up to the phylum.
- most well defined higher taxa particularly at the genus and family level occupy a well defined niche or adaptive zone. They owe their origin to the invasion of the zone by a founder species and to a subsequent active and adaptive radiation which usually follow a successful adaptive shift (Simpson,1953,1959b,1961).
- A taxon is in fact a group of relatives and whether or not they have the same characters in common' is irrelevant. Many taxa are based on a combination of characters and frequently not a single one of these characteristics present in all members of the taxon, yet such a taxon is defined on the basis of "polythetic basis".
- Animals occur in nature as distinct species. The individuals of a species show similar features and recognisably distinct from other species. Species, which share most of the features are placed into large and more inclusive taxa called the genera. Genera are similarly included into families and so on. This sort of arrangement of taxa into ascending series of ever increasing exclusiveness is called as"hierarchic system of classification".

**Main taxonomic ranks**

| Latin | English |
|---|---|
| vitae | life |
| regio | domain |
| regnum | kingdom |
| phylum | phylum(in zoology) |
| classis | class |
| ordo | order |
| familia | family |
| genus | genus |
| species | species |



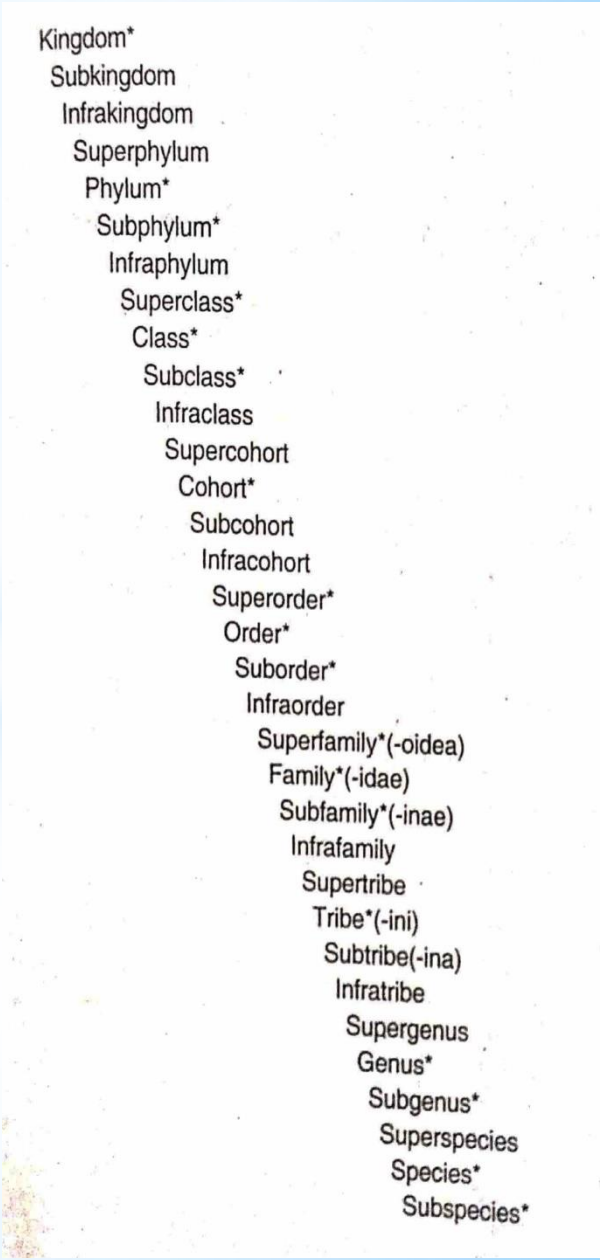
# Significance of Taxonomic Hierarchy

- Taxon is a taxonomic group which is sufficiently distinct to be worthy of being distinguished by the name and to be ranked in a definitive category (Mayr, 1969) or a group of real organism recognized as a formal unit at any level of hierarchical classification (Simpson,1961)
- It was firstly proposed by Meyer, 1969 but formally adopted by the 14$^{th}$ International Congress of Zoology held in Copenhagen in 1953.
- A hierarchy is thus a systematic framework for zoological classification, within a sequence of classes (or sets) at different levels in which, each class except the lowest includes one or more subordinate classes(Simpson, 1961). This disjoint classes at each level are called taxa and the ordinal levels are called as ranks. The taxa of a given rank constitute a category.
- The taxonomic category is a class, the members of which are all taxa assigned to a given rank (Mayr,1969). The species and subspecies are the lower categories, while the rest above the species are called higher categories.
- The systemic categories permit a semblance of order for the bewildering array of natural entities composing the animal kingdom. The main role of these categories has been to permit grouping of these natural entities in a form indicating their natural relationship in the best possible manner.
- The classical taxonomist prefers to delimit them on the basis of distinctive morphological characters, while the experimental taxonomist does this thinking of natural interbreeding populations primarily on the basis of presence or absence of barriers to gene exchange and ecological adaptation.
- The arrangement of taxa into a taxonomic hierarchy not only serves as an aid to memory, but also has a true biological basis, as the different levels in the hierarchy can be regarded to throw light on different degrees of evolutionary divergence.

# THE LINNEAN HIERARCHY OF CATAGORIES

## THE LINNEAN HIERARCHY:

- Linnaeus, the first taxonomist to establish a definite hierarchy of the taxonomic categories recognized within an animal kingdom only five – *classis*, (class) , *ordo* (order), *genus*, *species* and *varietas*. Later two additional categories were added – the *family* (between genus and order, Butschli,1790) and the *phylum* (between class and kingdom, Haekel,1886).
- The *varietas* , used by Linnaeus as an optional category for various types of intraspecific variants was eventually discarded and replaced by sub species.
- The basic five categories (genus, family, order , class and phylum) permits the placing of a species of animals with a fair degree of accuracy. However, as the number of known species increased and with our knowledge of the degree of relationship of these species, the need arose a more precise indication of the taxonomic position of species. This was accomplished by splitting of seven basic categories and inserting additional ones among them. Most of these are formed by combining the original category names with the prefix super or sub. Thus there are the inclusion of super orders , sub orders , super families and subfamilies.
- Besides the term *tribe* has been inserted for a category between genus and family. Vertebrate paleontologists have further added category *cohort* between order and class. some authors have also used additional sub divisions like-*cladus*, *legio* and *sectio* , *infra class* (below the sub class) and *infra orde*r (below the sub order).
- In this way in Linnaeus hirarchial system there are altogether 33 categories, of these only 18 (marked by asterisk) are generally followed. The standardized endings are shown in the parenthesis for the names of *tribes*, *sub families*, *families* and *super families*. However standardized endings for the categories above the family groups have not been adopted in the zoology..



# * THE LINNEAN HIERARCHY OF CATAGORIES : CONTD..

**Merits of Linnaeus hierarchy of taxonomic categories**:

- The Linnaean hierarchical system was criticized by few taxonomists, who called it as unscientific classification system and introduced numerical scheme. However the numerical schemes were discarded because of two basic reasons-

  1. Assigning definite numerical values to taxa demands afar greater knowledge of the relationship of taxa that can be inferred from the available evidence,

  2. An assignment of such values would freeze the system into finality which would preclude any further improvements.

- In the midst of these problems, the Linnaean hierarchy gives flexibility, required by the incompleteness of our knowledge of relationship.

- It permits the proposal of alternate models of relationship and gives different authors an opportunity to test which particular balance between splitting and lumping, permits the presentation of a maximal amount of information.

# EVOLUTIONARY RELATIONSHIP AMONG TAXA

- A higher category is a class into which are placed all the taxa that rank in the same level in a hierarchic classification.
- The category species is self operationally defined by the testing of isolating mechanism in nature, while non arbitrary definition for the supra specific categories are not available.
- The species category signifies singularity, distinctness and difference while higher categories have the function of grouping and ordering not by emphasizing differences between species rather by emphasizing affinities among group of species.
- Higher taxa are often , if not usually, well delimited and separated from other taxa of the same rank by a pronounced gap. The comparative data furnish the evidence used for the delimitation of higher taxa and their breaking into the categories, while interbreeding is the criteria used for ranking at the species level, because the species is a relational concept (Mayr,1957b) and the higher categories are not.
- Pre-evolutionary taxonomists like Linnaeus used higher categories , but they were unable to denote their significance in the frame work of Aristotelianism, as was particularly evident from the categories above the genus level. They tried to explain the origin of the categories by deriving the lower ones from the higher through splitting, a remnant of Thomistic thinking.
- It was Darwin , who supplied the scientific interpretation (1859):" the natural system is genealogical in its arrangement like a pedigree; but the degree of modification, which the different groups have undergone have to be expressed by ranking them under different so called genera, sub- families, families, section , orders, classes."
- The descendants of an aberrant species may evolve into a different genus, the genus in the course of geological history into a different family and so forth.
- The origin of higher categories is thus exactly opposite from that envisioned by the scholastic philosophers. Higher categorical ranks evolves through evolution not lower rank through sub division of higher categories.
- No yardstick has yet been found for the non arbitrary ranking of taxa. There is hardly a higher taxon, that is not ranked higher by some and lower by other specialist. It is in the arbitrariness of the definition that all higher categories differ from the species category.

# * HIERARCHY OF TAXONOMIC CATAGORIES : THE SPECIES

What is a species ?

- According to Cuvier (1829)-"The species is the assemblage descended from one another or from common parents and of those, who resemble each other".
- Thompson defined species as "The group of individuals distinguished by an inducible set of constant properties and connected by descent and genetic relationship".
- According to Dobszhansky (1937a)"there is a single systematic category, which in contrast to others , withstood all the changes in the nomenclature with an amazing tenacity and that is the category of Species".
- According to Huxley (1942) the species can be regarded as "a geographical definable group, whose numbers actually interbreed or are potentially capable of interbreeding in nature, which normally in nature does not inter breed freely or with full fertility with related groups and is distinguished from them by constant morphological differences".
- Species is the most specific major taxonomic rank; species are sometimes divided into subspecies, but not all species have multiple forms that are different enough to be called subspecies.
- There are an estimated 8.7 million different species of organisms on Earth, but the vast majority have yet to be discovered and categorized.
- While each genus name is unique, the same species names can be used for different organisms. For example, *Ursus americanus* is the American black bear, while *Bufo americanus* is the American toad.
- The species name is always italicized, but never capitalized. It is the only taxonomic rank that is not capitalized.
- In scientific articles where the species name is used many times, it is abbreviated after the first full use by using just the first letter of the genus name along with the full species name. Homo sapiens is abbreviated

# * HIERARCHY OF TAXONOMIC CATAGORIES : THE GENUS

What is a Genus ?

- The genus is the lowest higher category and the lowest of all categories established strictly by the cooperative data. (Cain, 1956).

**The pragmatic definition of the genus** :

A genus is a taxonomic category containing a single species or a monophyletic group of species, which is separated from the other taxa of the same rank (Other genera) by a decided gap.

- For the practical reason it is recommended that the size of the gap be in the inverse ratio to the size of the taxon.
- In other words, more species in a species group, the smaller the gap needed to recognize it as a separate taxon, and the smaller the species group the larger the gap needed to recognize it.
- An equivalent nearly, identical pragmatic definition is available to the categories above the genus-family, order and class.
- In order to qualify for a given rank a taxon must satisfy a number of condition-
  - It must be sufficiently different from other taxa of the same rank:
  - It must be separated by a discontinuity it should occupy a distinctiv3enicheor adaptive zone;
  - In the absence of a marked discontinuity it should not display too great an internal diversity (heterogeneity).
  - Finally, it should if possible satisfy certain practical requirements, in consequence of which the recognition of a higher taxon is often a balanced compromise between the stated qualification.
- Only an ideal genus is well separated by a gap, is of the proper size, is internally homogenous and fills a distinctive adaptive zones .

# * HIERARCHY OF TAXONOMIC CATAGORIES : THE GENUS -Contd..

**Generic characters**:

- The species included in the genus usually have many features in common , thus facilitating its delimitation. Recognition of higher taxon is usually based on the occurrence of correlated characters complexes. These may include some rather minute and inconspicuous characters.
- Some genera are clearly natural groups yet cannot be diagnosed unequivocally by a single character. This occurs because every character, even though diagnostic of the majority of the species, is modified or absent in at least one or the other species of the genus.
- A genus taxon is a phylogenetic unit, which means that the included species are descended from a common ancestor. Almost invariably it is also true that the genus is an ecological unit consisting of species adapted for a particular mode of life.
- the genus niche is obviously broader than the species niche, but both kinds of niche exists.
- Lack(19470 has convincingly shown the adaptive significance of genera for the Galapagos finches (which can be visualized in the subsequent page).

# HIERARCHY OF TAXONOMIC CATAGORIES : THE GENUS- CONTD..



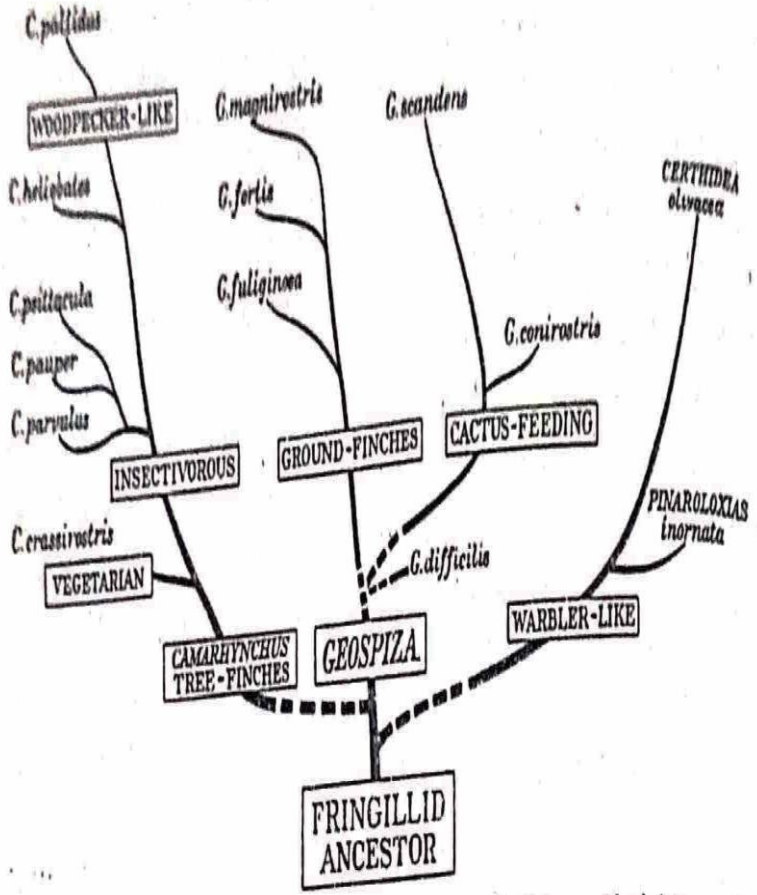



Fig. 5-1. Adaptive radiation of Darwin's finches (Geospizinae) on the Galapagos Islands into a number of different niches (*from Lack*, 1947).

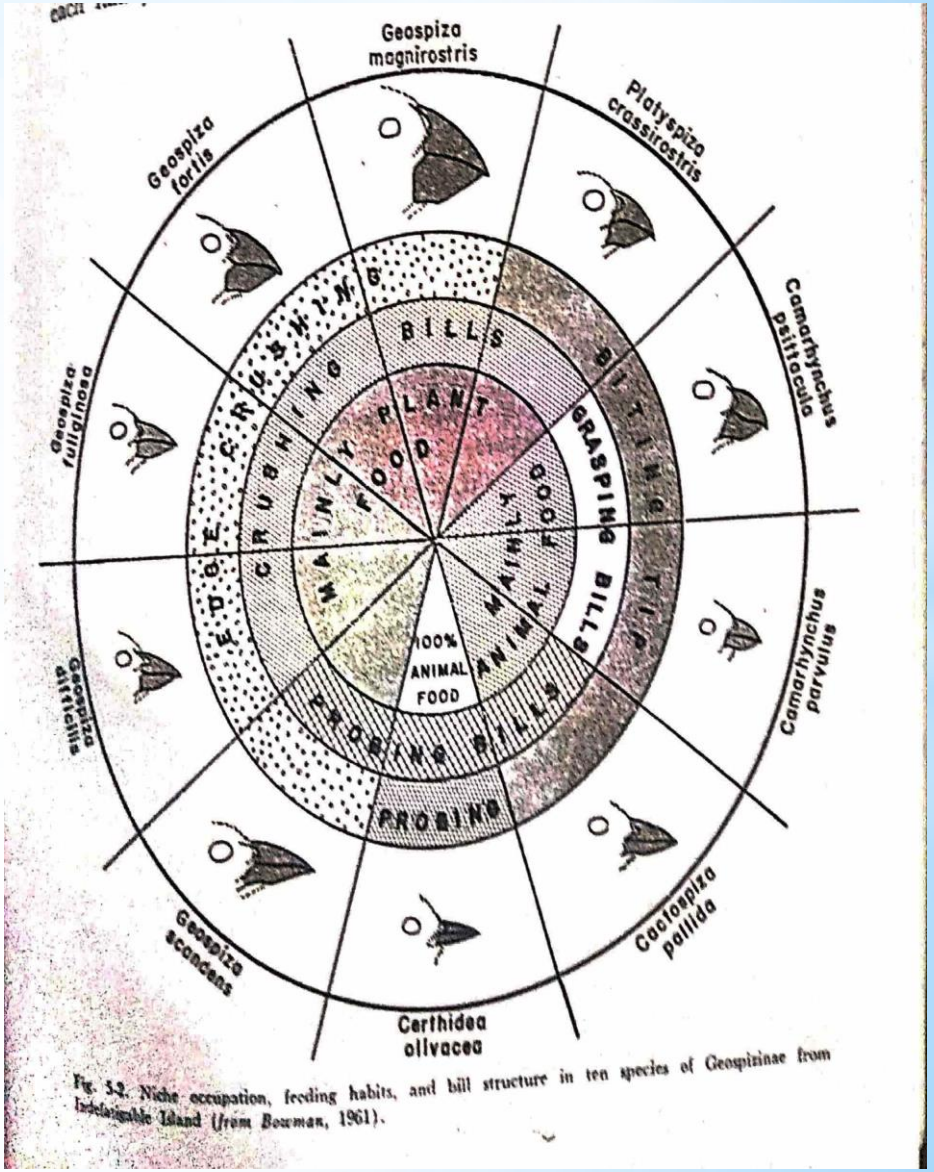



Fig. 5-2. Niche occupation, feeding habits, and bill structure in ten species of Geospizinae from Indefatigable Island (*from Bowman*, 1961).

# * HIERARCHY OF TAXONOMIC CATAGORIES : THE FAMILY

- It is not possible to give the non arbitrary definition of the family category. A family is even more specific than the order. A family is taxonomic category containing a single genus or a monophyletic group of genera, which is separated from other families by a decided gap.

- It is recommended, as in the case of genus, that then size of the gap be in inverse ratio to the size of the family. Like the genus , but perhaps to an even greater degree, the family is usually distinguished by certain adaptive characters which fit it to a particular niche or adaptive zone e.g., the woodpeckers of the family *Picidae*, the leaf beetles of family *Chrysomelidae* etc.

- In most cases families, obviously are older than the genera and have more often a world wide distribution. An entomologist who knows the 422 families of British insects can go to Africa or even Australia and recognise nearly all the same families occupying similar niche in their particular community.

- Linnaeus did not recognise the family as a category, but it is significant that most of his genera have since been elevated to the rank of families. From this, we may infer that his generic concept was not incompatible with our modern family concept, the difference between the genus and the family being merely one of degree. With only 312 genera of animals in 1758 Linnaeus had no need for an intermediate category between genus and order,. However the number of newly discovered animal types increased so rapidly that the early $19^{th}$ century naturalists gradually evolved and universally applied the family concept to designate an intermediate level between genus and order .

# HIERARCHY OF TAXONOMIC CATAGORIES : THE ORDERS AND CLASSES

The higher taxa above the family level are on the whole very well defined in the recent fauna, and much less often connected by intermediates than families or genera.
The taxa ranked in higher category represent the main branches of the phylogenetic tree. They are characterized by a basic structural pattern laid down early in evolution, the special adaptive significance of which can now be perceived only dimly, if at all.. Superimposed on it are seemingly endless adaptive modifications resulting from series of adaptive radiations that have taken places in class and phyla.
In general, then, taxa in the higher categories are definable in terms of a basic structural pattern, but except for certain highly specialized groups such as the order *Siphonoptera* (fleas), the order *Chiroptera* (bats),the order *Impennes* (penguins) etc., the higher taxa are not primarily or even pre-dominantly distinguished by *ad hoc* adaptation. The taxa contained in the higher categories are in most cases widely distributed in space and time.

## Order:

**Order** is more specific than class. Some of Linnaeus' orders are still used today, such as Lepidoptera (the order of butterflies and moths). There are between 19-26 orders of Mammalia, depending on how organisms are classified—sources differ. Some orders of Mammalia are *Primates*, Cetaceans (whales, dolphins, and porpoises), *Carnivora* (large carnivores/omnivores), and *Chiroptera* (bats).

## Class:

Class was the most general rank proposed by Linnaeus; phyla were not introduced until the 19th Century. There are 108 different classes in the kingdom Animalia, including Mammalia (mammals), Aves (birds), and Reptilia (reptiles), among many others. The classes of Animalia that Linnaeus proposed are similar to the ones used today, but Linnaeus' classes of plants were based on attributes like the arrangement of flowers rather than relatedness. Today's classes of plants are different than the ones Linnaeus used, and classes are not frequently used in botany.
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# * HIERARCHY OF TAXONOMIC CATAGORIES : THE PHYLUM, KINGDOM AND DOMAIN

## Phylum

- Phylum (plural:phyla) is the next rank after kingdom.
- It is more specific than kingdom, but less specific than class.
- There are 35 phyla in the kingdom Animalia, including *Chordata* (all organisms with a dorsal nerve cord), *Porifer*a (sponges), and *Arthropoda* (arthropods).

## Kingdom

- Before domains were introduced, kingdom was the highest taxonomic rank. In the past, the different kingdoms were *Animalia*, *Plantae*, *Fungi*, *Protista*, *Archaea*, and *Bacteria* (Archaea and Bacteria were sometimes grouped into one kingdom, *Monera*). However, some of these groupings, such as *Protista*, are not very accurate.
- Protista includes all eukaryotic organisms that are not animals, plants, or fungi, but some of these organisms are not very closely related to one another.
- There is no set agreement on the kingdom classification, and some researchers have abandoned it altogether. Currently, it continues to be revised; in 2015 researchers suggested splitting Protista into two new kingdoms, *Protozoa* and *Chromista*.

## Domain

- A domain is the highest (most general) rank of organisms.
- Linnaeus did invent some of the taxonomic ranks, but he did not invent the domain rank, which is relatively new.
- The term domain wasn't used until 1990, over 250 years after Linnaeus developed his classification system in 1735.
- The three domains of life are *Bacteri*a, *Archaea*, and *Eukaryota*. *Archae*a are single-celled organisms similar to bacteria; some archaea live in extreme environments, but others live in mild ones. *Eukaryota*, or every living thing on earth that is not a bacterium or *archaeon*, is more closely related to the domain *Archae*a than to Bacteria.

Taxonomic ranks are always capitalized, except for species. This allows people to differentiate between bacteria (the organisms; could refer to all bacteria or just two specific bacteria) and Bacteria (the domain, which includes all bacteria).

# * OUTLINE CLASSIFICATION OF ANIMAL KINGDOM: AT A GLANCE

## Eight Major Taxonomic Ranks (Hierarchy of Biological Classification)

- Life
- Domain
- Kingdom
- Phylum
- Class
- Order
- Family
- Genus
- Species

## Eukarya Domain (Protista Kingdom)

## Protista Kingdom (Three Main Groups)

**Animal Like** — also called Protozoans
- Pseudopods
- Cilia
- Flagella
- Sporozoans

**Plantlike**
- One celled Algae
- Multi-celled Algae

**Fungus-like**
- Slime Mold
- Water Mold

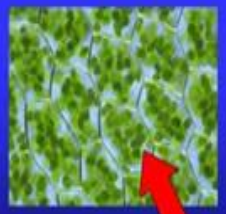
## Eukarya Domain (Fungi Kingdom)

- Mold
- Mushroom
- Lichen

Most fungi use spores to reproduce and need moist, warm places to grow.

## Eukarya Domain (Plantae Kingdom)

Plants produce their food through photosynthesis.



Plant cells with visible chloroplasts.

## Plantae Kingdom (Three Main Groups)

Ferns

**Vascular**

Seedless and Seed Producing

- Gymnosperms
- Angiosperms

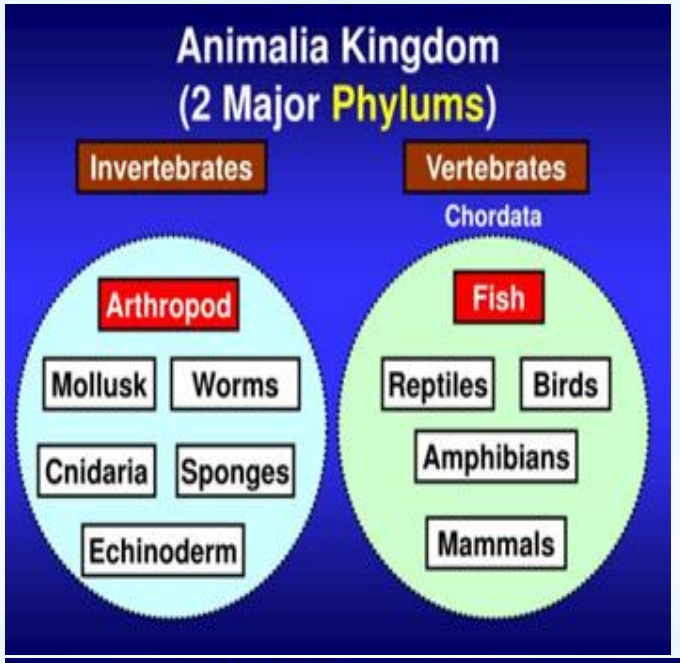
**Green Algae**

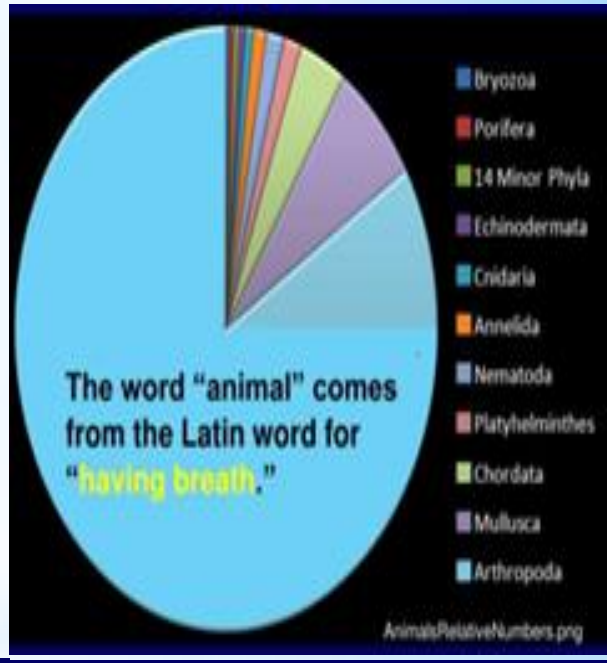
Most species are single-celled

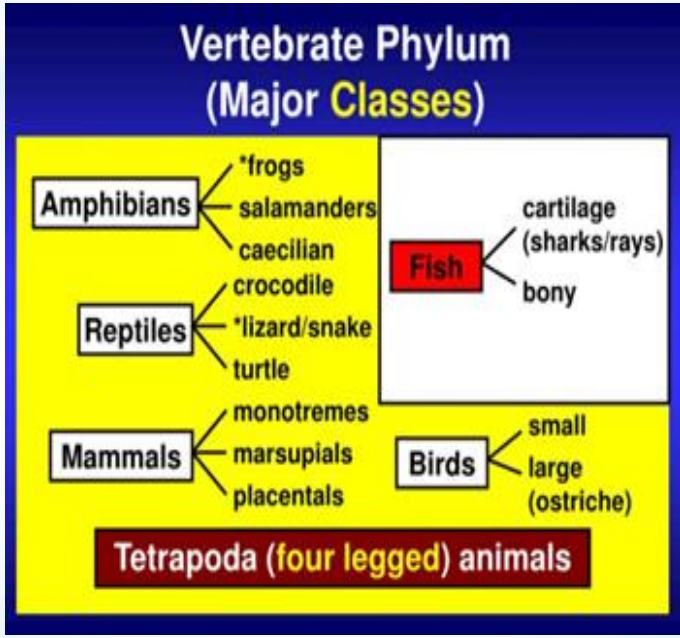
**Non-Vascular**

Mosses

# * OUTLINE CLASSIFICATION OF ANIMAL KINGDOM: AT A GLANCE





# * OUTLINE CLASSIFICATION OF ANIMAL KINGDOM : AT A GLANCE

## Mammal Class (Three Main Groups or Subclasses)

- **Monotremes** — Lay eggs
- **Marsupials** — Pouched
- **Placentals** — Placenta developed from fetus

Every young mammal is fed with milk produced in its mother's body.

## Mammal Class (Placental Subclass)

- **Primate** — prosimian, simian
- **Carnivora** — Feliformia, Caniformia
- **Cetacea** — whales, dolphins, porpoises
- **Ungulates** — even-toed, odd-toed

**Rodent** **Bats** **Shrews** — largest orders

## Placental Subclass (Primate Order)

- **Lemurs**
- **Galagos**
- **Tarsiers**

- **Monkeys**
- **Apes**
- **Gibbons**
- **Human**

**Prosimian** **Simian**

## Mammal Class (Placental Subclass)

Placenta is an organ in pregnant female mammals that helps to feed the offspring during gestation, before birth.

## Hominidae Family (Homo sapien Species)

- Homosapien means "wise man" or "knowing man."
- Have highly developed brains capable of abstract reasoning, language, introspection, and problem solving.
- Adept at self-expression, exchange ideas, and organization.
- Create complex social structures with variety of values, social norms, and rituals.

## Hominidae Family (Homo sapien Species) (cont)

- Only species known to build fires, cook their food, clothe themselves, and use numerous other technologies.
- Capable of full bipedal location.
- Human brain is more intelligent than any other species.

# * CONCLUSION

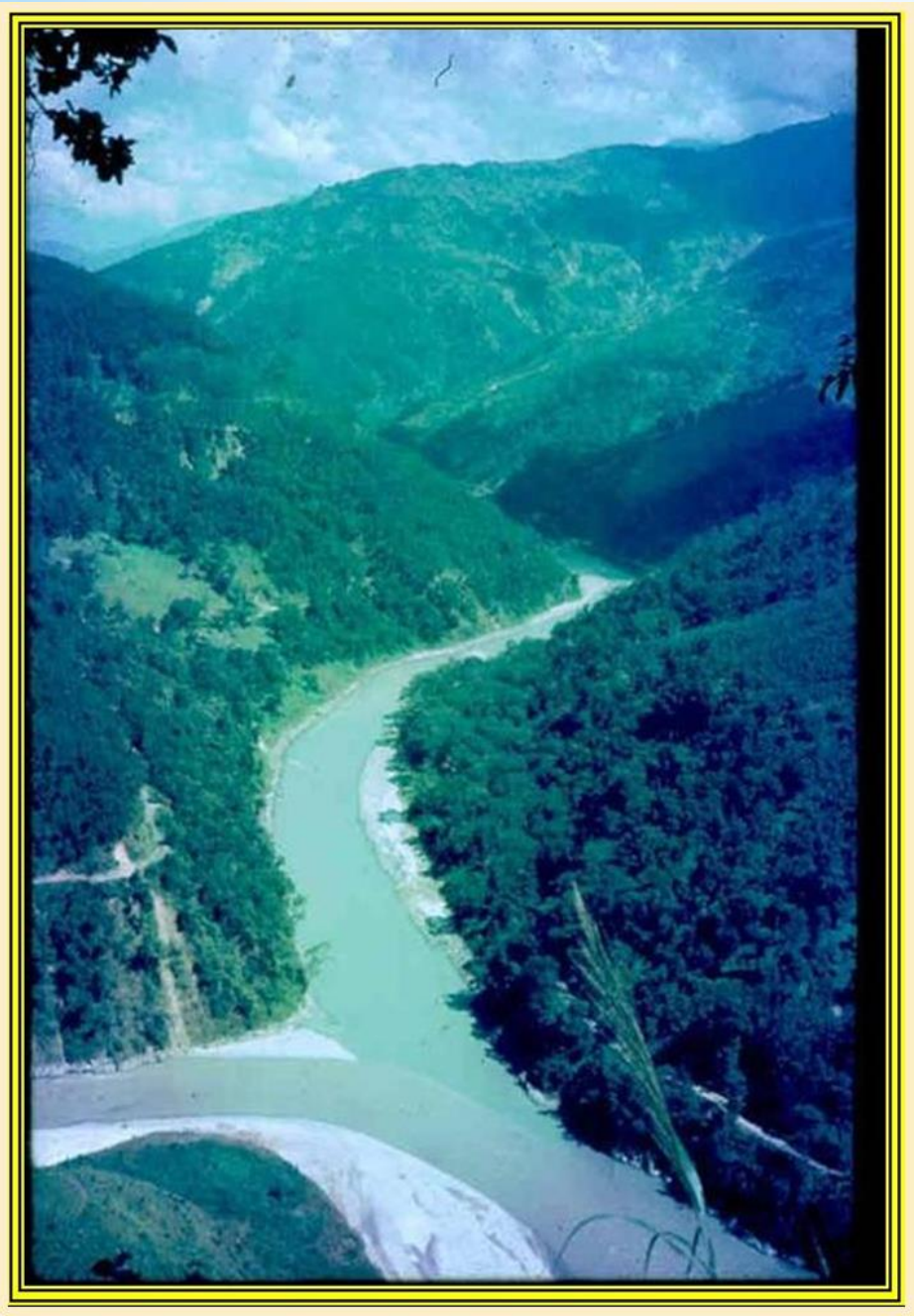
- Biological classification is based on the fact that evolution produces groups of more nearly or more distantly related species.

- Evolution, thus sets severe limit to the number of possible classification. Nevertheless, even where there is complete consensus about the phylogeny of a group of organism, it is nearly always possible to translate this knowledge into a number of alternate classification. The reasons for this is that the three operations of taxonomists cannot be carried out without an element of arbitrariness :

    1. The delimitation of groups , which we formally recognize as taxa (their 'size')
    2. The rank in the hierarchy, which we assign to a given taxon (e.g. *tribe*, *sub family*, family) and
    3. The position in the sequence in the taxa.

- A taxonomists will be more successful in his classification the more clearly he realizes that it is the major function of a classification to be useful.

- A classification is a communication system, and the best one is that which combines greatest information content with greatest ease of information retrieval.



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