History and fundamentals of classification

Taxonomy is the science of classifying living things (biodiversity).

It has 2 branches:

i. **Nomenclature** – This is the naming of organisms

ii. **Systematics** – This is the placing organisms into groups according to their similarities and differences.

In taxonomy, organism are identified, named and grouped according to their characteristics and evolutionary history. Organisms with certain basic features in common are grouped together.

1.1 History of classification

Classification begun with the early natural historians. Early natural historians sought a means to organize biological diversity. Initially, they started with plants due to their medicinal value. With time classification was extended to animals and other organisms. The contributions of natural historians are as follows:

Early ages

285 -370 BC – Theophrastus (Plato & Aristotles's student) classified plants into 4 groups: herbs, sub shrubs, shrubs and trees. He distinguished between flowering and non- flowering plants. He suggested that corolla and calyx are modified leaves. He described about 500 plants in details and some names are applicable to date. Eg. Asparagus, Daucas

23 – 79 AD – Caius Plinius Secundus described the biological, medicinal and agricultural aspects of the plants known to the world then. He introduced the word' stamen'

62 – 128 AD – Pedanios Dioscorides described the botany of 600 species of medicinal

plants.

This was compiled as Medical Materail(Materia Medica) which is used to-date. He suggested names such as Aloe, Anemone, Phaseolus.

Middle ages

1200 – 1280AD – Albertus Magnus introduced a scheme of classification of plants that recognized monocots and dicots, and separated vascular from non-vascular.

16th century

1500AD onwards- Many people motivated to publish their own botanical medical books. The books were called **herbals** and the authors were called **herbalists**. 16th century known as the "time of great herbalists", most of whom were based in Germany.

17th century

1560 – 1624 – Gaspar Bauhin (Swiss botanist) compiled a register of all the different plants known to science then. He introduced systematic botany and initiated the use of binomial nomenclature though it was inconsistent. He distinguished the concept of genus and species.

1686 – John Ray (English) suggested a scheme of classification of plants

1656 – 1708 – Joseph Pitton de Tournefort arranged over 9000 kinds of plants in about 700 genera and grouped them into classes.

18th century

1707 – 1778 – Carolus Linnaeus used the binomial system of nomenclature consistently. In 1753 Linnaeus proposed a system that gave each organism two names,

Denoting genus and species (eg *Homo sapiens*). He then grouped genera into families, families into orders, orders into classes, classes into phyla, and phyla into kingdoms. He identified two kingdoms: Animalia (animals) and Plantae (plants). However, several unrelated organisms were classified together.

Animal kingdom contained motile organisms that feed heterotrophically while the plant kingdom contained mainly static organisms which feed autotrophically by photosynthesis. Unicellular heterotrophs (protozoa) were put in the animal kingdom while unicellular autotrophs (protophyta) were put in the plant kingdom.

Challenges with 2 kingdom system:

i. Unicellular flagellates such as Euglena are put with protozoa in the animal kingdom yet they contain chlorophyll and feed autotrophically.

ii. Fungi had been classified with plants yet they lack chlorophyll and feed heterotrophically. Also there cell structure is different from that of plants in several ways.

iii. Bacteria and blue-green algae are similar to each other(prokaryotes) and are very different from all other organisms that are eukaryotic

The challenges were addressed by classifying the organisms in 5 kingdoms

In 1969 - Thomas Whittaker proposed a "five kingdom" system in which three kingdoms, that is Monera (bacteria), Protista, and Fungi were added to the animals and plants. Whittaker defined the kingdoms by a number of special characteristics. First, he specified whether the organisms possessed a true nucleus (eukaryotic) or not (prokaryotic). Monera are prokaryotic and all are unicellular. The other 4 kingdoms are Eukaryotic. Eukaryotic unicellular organisms were placed into the kingdom Protista. The five kingdoms system captured the diversity of life much

better than the 2 kingdom system.

Importatnce of Classification

classification is bringing into order organisms among the many existing organisms in the world by organizing and categorizing them.

Classification aims at:

i. To help clarify relationships among organisms

ii. To help us remember organisms and their traits

iii. To enable us to communicate clearly the identity of organisms being studied

iv. To improve our predictive powers

v. To provide stable names for organisms

Importance of classification systems:

- improve our ability to explain relationships among things enhancing easy reconstruction of the evolutionary pathways that have produced the diversity of organisms living today.
- Make it easier to remember organisms by grouping them into categories, whose members share many characteristics.
- provide relatively stable, unique, and unequivocal names for organisms. If those names are changed, the systems provide means of tracing the changes.
- greatly improves our predictive powers such that if the general characteristics of a group of organisms are known, a prediction can be made for a newly discovered organism that has most of the traits even if some may be non-functional.

Taxonomic Hierarchy

This is the system of grouping organisms into hierarchical categories. It is based on Carolus Linnaeus classification using morphology of organisms.

These categories in descending order are :

1.Kingdom

2.Phyla/ Division

3.Class

4.Order

5.Family

6.Genus

7.Species

The 7 levels are called taxonomic categories (ranks) and collectively make up the **taxonomic hierarchy.** The kingdom is the largest category . As one goes down the taxonomic hierarchy from kingdom to species, the number of organisms in each group decreases and similarities between them increase. Species is the smallest grouping and it contains a single organism type. If the members of the same species show significant variation then subsets called sub-species are formed. The subsets are sub-species(animals) or varieties(plants)

1.4 Binomial Nomenclature (Two-Part Naming System)

This is the system of scientific naming organisms using two-part names.

Rules of Binomial nomenclature

1.The first part of the name is the genus and the second part of the name is the species (species identifier).

2.The generic name begins with a capital letter while the specific name starts with a small letter. Both names must be written in italics or underlined.

3. The genius name and species name should be underlined as different words when handwritten or italicized when typed

4. The scientific words must be italicized for uniformity. This enables scientists around the world to identify organisms by the same name.

LIMITATIONS OF BINOMIAL NOMENCLATURE

1. Binomial nomenclature is majorly concerned with a two part naming system using a genius and species name whereas not all organisms have a two part naming system soecially where there is variation in species;sub-species or varieties that is some of the organisms end up having a three part name; genius name' species name' and sub-species/variety parts example . East box turtle ; *Terrapene carolina tringui.*

2. Some organisms may end up sharing common name especially generical name because of different international codes of naming organisms which are independent of each other. Organisms from different taxonomic groups may end up being assigned a common generical name even if they are different greatly.

3. If two or more names are actually in use in compliance with the priority rule, the appropriate name will be used first and other names will end up being synonyms because authenticity is synonymous with the senior. This must be stressed ensuring consistency in the naming and classification of species hence tiresome.

4. As binomial nomenclature is based on giving organisms scientific names, the Latin names are difficult to memorize hence less people get to learn them making organizations and government agencies to create a list of official names based on the country`s native language or official language. This is expensive and time consuming.

5. Some botanical names refer to groups that are very stable such s magnoliaceae whie other names need a careful and special check to see which circumscription is being used example scrophulariaceae which requires specialized personnel thus making it tiresome and labor intensive.

6. The scientific names are long and hard to learn compared to common names hence less people have interest in learning them.

7. Moat scientific names are unfamiliar to ordinary people and being in Latin. They seem to be meaningless ton the people thus rendering the names void.

8. Names used prior to these included within the " systema Naturae" by Linnaeus are not recognized or acknowledged thus the historical background of naming of the organism may be forgotten or lost.

9. Sometimes , taxonomic groups are not fixed in size since a taxon may have a varying circumscription thus the usefulness of botanical names is limited.

10. The group of a particular botanical name refers to can be quite small according to some people and quite big according to others. This will depend on taxonomic view point or taxonomic system.

11. Not all organisms have been assigned or given scientific name especially those without distinct characteristics of features and the newly identified ones thus lack of unity of the organism name globally.

Example of classification hierarchy of organisms:

TAXONOMIC GROUP	EG. PLANT	EG. ANIMAL
Kingdom	plantae	Animalia
Division /Pyllum	Angiospermatophyta	Mammalia
Class	Magnoliopsida	Chordata
Order	Ranales	Carnivora
Family	Ranunculaceae	Felidae
Genus	Ranunculus	Panthera
Species	Acris	Leo
Scientific name	Ranunculus acris	
Common name	Meadow buttercup	Lion

Importance of scientific names

a) In agriculture for the purposes of plant breeding, biological control and chemical control of pests.

b)In medicine the names are useful in developing drugs such as antibiotics because it is important to know the particular pathogenic organisms they are intended to destroy.

Identification of Organisms

Organisms are identified using the observable characteristics. These are readily observable morphological features such as shape, colour, number of appendages, segments etc. The feature may be used either in a manner that is either qualitative or quantitative. Qualitative use of features includes shape and colour of abdomen while quantitative features include number of hairs, number of appendages and length of stem. The chosen characteristic must be constant for that species and not subject to variation due to environmental

influences. Qualities of a good characteristic are : it is constant, easily observable, exist in two or more forms, external and be able to be used either qualitatively or quantitatively.

There are many types of identification (diagnostic) keys but the simplest and most common is the dichotomous key.

A dichotomous key is a system of identifying organisms whereby the organisms are split into 2 successive groups of equal size based on a certain clearly distinguishable feature. The feature must exist in two or more states. There are 2 types of dichotomous keys, spider key and linear key. In a spider key, the organisms are split into 2 successive pairs of groups of approximately equal size on the basis of the specific distinguishable feature. This gives a spider key from which each specimen can be identified.

The same information can be rearranged in the form of a linear key. A statement is made based on a specific feature and there is a number referring to the next lead to be considered if the specimen matches the feature. The number of steps in a linear key should be one step fewer than the number of organisms being identified. A linear key is more convenient than a spider key since it takes up less space.

Characteristics used in identification

i. External structure

External features visible to the naked eye permit quick identification of organisms.eg shape of leaves, presence of petiole, presence or number of antennae, number of appendages, number of wings, shape of abdomen etc. Such features are useful for identification at higher level such as families and genera. Distinguishing between specie requires smaller features to be used necessitating the use of hand lens or microscope.

ii. Cell structure

Cell structure is used to make basic split in the classification of living things into prokaryotes and eukaryotes. The number of chromosomes in the cell of an organism is used to distinguish between organisms in the same species.

iii. Chemical constitution

Similar organisms can be distinguished by comparing the chemical substances which they contain. Techniques such as chromatography and electrophoresis are used to compare the amino acids in the proteins of different organisms. The sequence of amino acids in a particular

protein or DNA can also be determined. This analysis is useful in determining phylogenetic relationships. Chemical composition is particularly useful when identifying bacteria which may all look alike and have an identical cell structure. Other characteristics used in identification are immunological reactions, types of symbionts that organisms associate with and the behavior of the organisms such as the way they respond to stimuli or the way they build their nests.

Process of identification

1. Decide on type of sample. Eg plants or animals. Plants- leaves, flowers or fruits. Animal-insects etc
2. Sample collection and organization
3. Determine and list down the characteristics to be used in identification
4. The presence or absence of the different characteristics is presented on a data matrix

Eg. Data matrix showing the presence or absence of a series of 5 different characteristics in 10 hypothetical organisms; A J

Organisms	**Characteristics**				
	1	**2**	**3**	**4**	**5**
A	√	X	√	√	√
B	X	√	X	X	X
C	√	X	√	√	X
D	X	√	√	X	X
E	X	X	X	√	√
F	√	√	X	√	X
G	√	√	√	X	X
H	X	X	√	X	√
I	X	√	X	√	X
J	√	X	√	X	X

5. These characteristics are then used to identify the different types of organisms that have been collected and /or to split them into groups.

The use of various characteristics to split organisms into groups is the basis of taxonomy.

Types of Classification

There are 2 main categories of classification: Artificial classification and Natural classification

Artificial classification is based on one or few easily observable characteristics. Eg Linnaeus classification of all worm-like organisms as vermes etc. This put snakes and worms in the same group.

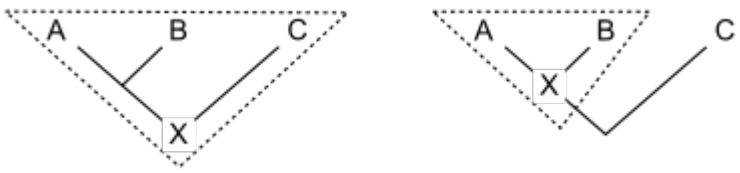
Natural classification uses the natural relationship between organisms. It is based on characteristics such as anatomy (physical structures visible to the naked eye), Physiology, Cell structure, Biochemistry (chemical constitution & reactions).

Types of natural classification:

1. **Phylogenetic classification (cladistics /evolutionary)**

Based on evolutionary relationship and ancestry alone. It shows the degree to which different groups are connected in evolution. The organisms are classified into groups according to the presence or absence of certain basic characteristics. It ignores their degree of morphological similarity or difference. A cladist looks for features which different organisms have in common based on their ancestry and constructs a branched diagram called a cladogram (phylogenetic tree). A group with shared features is a clade. A clade contains one ancestor (which can be an organism, a population, or a species) and all its descendants. The closeness of organisms on a cladogram indicates the presumed time since they diverged from their most recent common ancestor. The clades are the taxa. Each clade (taxon) is a single lineage that includes all-and only-the descendants of a single ancestor.

Example:



In first illustration : A , B and C are all descendants of X, hence form a clade.

In second illustration: A , B and C are all descendats of X. A , B and X form a clade. C is not part of the clade, C diverted from the ancestor X and forms a diferent evolutionary path. This can be caused by a mutation in organism C that gave rise unique characteristics to C , thus making C very different from the rest of the descendants of ancestor X.

2. **Numerical (phenetic) classification**

Based on numerous characteristics. The closeness between different groups is determined by the total number of individual characteristics which they have in common. Usually 10 100 characteristics are selected and they all carry equal weight. The greater the number of characteristics, the more valid the classification is presumed to be. Any observable characteristic may be chosen:

- Morphological
- Physiological
- Anatomical
- Biochemical
- Behavioural etc

It is called phenetic because it is not based on any preconceived ideas.

Phenetic classification can be applied to any taxa from species to phyla.

EXAMPLE

To classify 10 different groups of organisms A J

a) Draw a list of the observable characteristics

b) Construct a data matrix whereby you record whether or not each characteristic is present in each group.

c) Each group is compared with each of the other groups with respect to all characteristics and the degree of similarity is estimated as follows:

Number of characteristics common to the two groups x 100
Total number of characteristics being considered

If the 2 groups share 21 out of 50 characteristics, then the similarity between them is;

$$\frac{21}{50} \times 100 = 42\%$$

Degree of similarity is 100 % if the 2 groups are identical and 0% if the 2 groups are completely different.

d) Display the percentages on a similarity matrix

	A	B	C	D	E	F	G	H	I	J
A	100	54	80	63	62	81	50	83	50	61
B	54	100	55	57	57	55	86	56	87	56
C	80	55	100	62	64	85	51	86	50	62
D	63	57	62	100	74	63	56	65	56	96
E	62	57	64	74	100	64	56	67	56	72
F	81	55	85	63	64	100	54	67	52	65
G	50	86	51	56	56	54	100	87	85	55
H	83	56	86	65	67	87	54	100	54	67
I	50	87	50	56	56	52	85	54	100	55
J	61	56	62	90	72	65	55	67	55	100

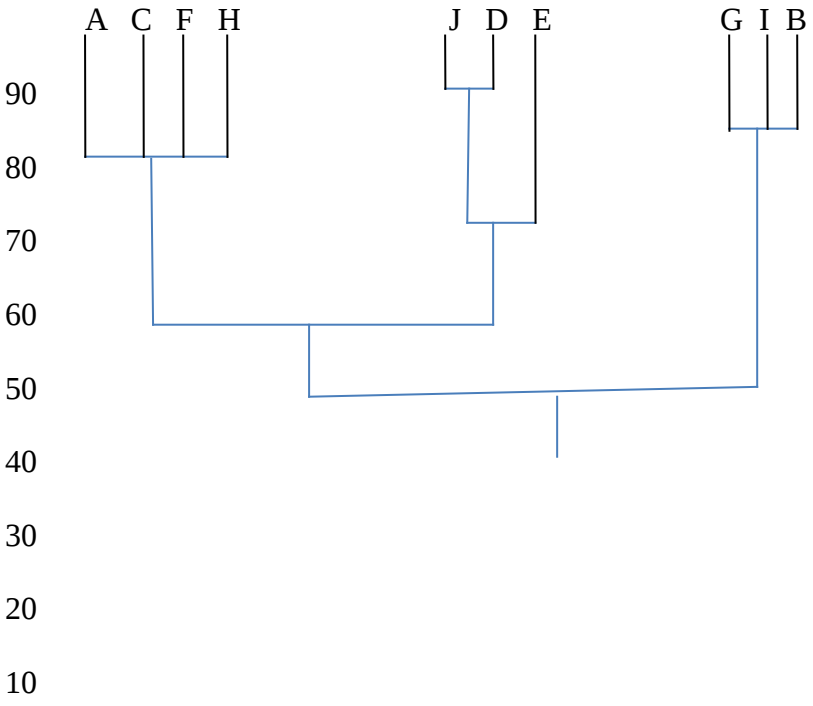
e) Rearrange the similarity matrix so that groups which show the closest similarity are clustered together. This is done by looking at the figures. If the groups are too many then a computer is used.

	A	C	F	H	J	D	E	G	I	B
A	100									
C	80	100								
F	81	85	100							
H	83	86	87	100						
J	61	62	65	67	**100**					
D	63	62	63	65	**90**	**100**				
E	62	64	64	67	**72**	**74**	**100**			
G	50	51	54	54	55	56	56	100		
I	50	50	52	54	55	56	56	85	100	
B	54	55	55	56	56	57	57	86	87	100

There should be no value after the 100 figure

f) Link the various groups together according to the degree of similarities between them to form a tree-like diagram called a **dendogram**. Classification is then constructed from the dendogram

Dendogram



3. Orthodox classification

This is a combination of numerical (phenetic) and phylogenetic (cladistics). It uses both evolutionary relationships and other characteristics to classify organisms.

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