

Principles of Systematics

Module# 1

Principles of Systematics

Basic Terminologies

Basic Terminologies

Taxonomy

Theory and practice of classification of organisms

- Taxonomy is derived from Greek words “Taxis” which means arrangements and “Nomos” means laws /methods

Basic Terminologies

Taxonomy



Carolus Linnaeus (1707-1778)

- Carolus Linnaeus, the Swedish botanist, Zoologist and Physician
- Regarded as the father of modern taxonomy.

Basic Terminologies

Contribution of Carolus Linnaeus

His two important contributions to taxonomy were:

- A hierarchical classification system
- The system of binomial nomenclature

Basic Terminologies

Carolus Linnaeus

He proposed that there are three broad groups called **Kingdoms** into which whole nature could fit.

These kingdoms were:

- Animals
- Plants and
- Minerals

Basic Terminologies

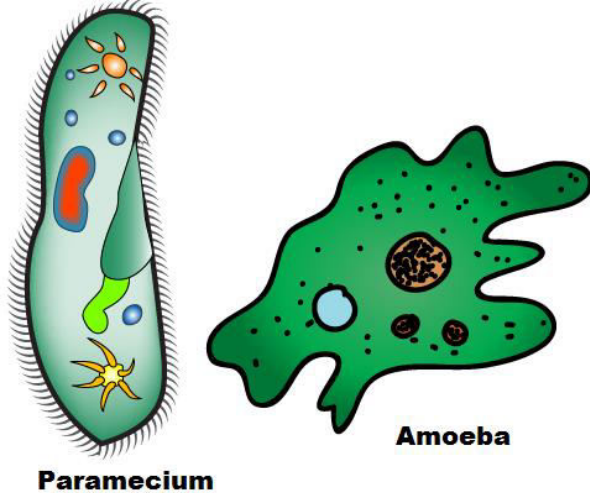
Classification

- It is a systematic method of arranging organisms into different groups and subgroups, based on their similarities and their differences.
- It makes the study of organisms very easy and convenient.

Basic Terminologies

Classification

- Organisms can be classified on the **basis** of several different factors:
- Cell nature –Are cells Prokaryotic or Eukaryotic?
- Cells – Do they occur Singly or in Clusters?
- Mode of Nutrition
- Level of Body Organization



Basic Terminologies



Aristotle
Greek Philosopher
384-322 BC

Aristotle-Father of Biological Classification

- To understand anything, one must classify it according to its parts
- He established numerous collective categories or genera using differentiating characteristics

Basic Terminologies



Aristotle
Greek Philosopher
384-322 BC

Aristotle-Father of Biological Classification

- Blooded and bloodless
- Two-footed vs four footed
- Hairy vs feathered
- With or without an outer shell
- **Note:** He failed to provide orderly and fully consistent classification of animals.

Principles of Systematics

Module# 2

Principles of Systematics

Basic Terminologies

Basic Terminologies



Simpson
(1902-1984)

Systematics

According to Simpson (1961)

- Scientific study of kinds and diversity of organisms and of any or all relationship among them
- Broad term which include Taxonomy, Nomenclature and Classification etc.
- Professor of Biology at San Diego State University, Colombia

Basic Terminologies

Aims of systematics

- Invent worlds kinds of organisms
(flora and fauna)
- Provide method for identification
and communication
- To produce coherent and
universal system of classification
and
- Demonstrate evolutionary
implications of biodiversity

Basic Terminologies

Component fields of systematics

- Component fields of systematics are:
 - Biodiversity
 - Taxonomy
 - Classification
 - Nomenclature
 - Biogeography
 - Evolutionary biology

Basic Terminologies

Taxon

- According to Simpson (1961)
taxon is a group of real organisms
recognized as formal unit at any
level of hierarchic classification
- Blue birds, song birds, vertebrate
refer to groups of organisms.

Basic Terminologies

Taxon

- Taxon always refer to concrete Zoological object
- Species of Robins is not a taxon but category
- Robin is a Taxon

END

Principles of Systematics

Module# 3

Principles of Systematics

Contribution of Systematics in Biology

Contribution of Systematics in Biology

Systematics contribution

The contribution of systematic to biology can be studied under two heads:-

- Theoretical Biology
- Applied Biology

Contribution of Systematics in Biology

Theoretical Biology

- Evolution
- Ecology
- Molecular Biology
- Evolutionary Biology

Contribution of Systematics in Biology

Evolution

- Evolution is a process by which plants and animals that exist today have been evolved from plants and animal of past.
- Before the rise of genetics, the study of evolution was carried out entirely by taxonomists.
- Virtually all major evolutionary problems were first pointed out and often solved by systematics.

Contribution of Systematics in Biology

Evolution

- Taxonomists helps us categorize organisms so we can more easily communicate biological information.
- No other branch of biology has made greater contribution to our understanding than systematics.

Contribution of Systematics in Biology

Ecology

- No thorough ecological surveys can be conducted without the identification of all species that are of ecological significance.
- Elton (1947) acknowledged the progress in ecology depends upon accurate identifications of species.

Contribution of Systematics in Biology

Molecular Biology

- Molecular biologist use genetic data for establishing relationships among different organisms.
- However, they need assistance of traditional taxonomist for accurate results.
- **Examples:** DNA barcoding and taxonomist

END

Principles of Systematics

Module# 4

Principles of Systematics

Contribution of Systematics in Biology

Contribution of Systematics in Biology

Applied Biology

- Agriculture and forestry
- Biological control
- Public health
- Quarantine
- Wild life management

Contribution of Systematics in Biology

Applied Biology

- Mineral prospecting
- National defense
- Environmental problem
- Soil fertility
- In commerce

Contribution of Systematics in Biology

Agriculture and Forestry

- In order to control and minimize pest attack on crops and diseases caused by vector
- It is necessary to know about correct names of pests
- Taxonomists give us correct identification of pests
- Identification is vital for control

Contribution of Systematics in Biology



Biological Control

- Involved in designing biological control programs of pests
- Determination of exact country of origin and their parasite and parasitoids is compulsory.

Contribution of Systematics in Biology



Asian Citrus psyllid



Tamarixia radiata

(Hoddle & Pandey, 2014)

- Asian citrus psyllid is serious pest of citrus orchards
- Its origin is Asia
- *Tamarixia radiata*, a parasitic wasp was introduced from Pakistan to California to control this pest.
- Best example of classical biological control.

Contribution of Systematics in Biology

Public Health

- Number of diseases are spread by Arthropods which are controlled by targeting specific species.
- For example: All *Anopheles maculipennis* are not responsible for transmitting malaria.
- Out six siblings some are involved in transmission of malaria.

Contribution of Systematics in Biology

Public Health

- Although the species are virtually indistinguishable morphologically, they are isolated reproductively, in part because they breed in different habitats.
- Taxonomists help to identify this particular sibling species for effective control at minimum cost.

END

Principles of Systematics

Module# 5

Principles of Systematics

Contribution of Systematics in Biology

Contribution of Systematics in Biology

Quarantine

- Many diseases are spread from one country to other via transportation.
- Respective Governments established quarantine labs at aerodromes and ports etc
- Taxonomists help in prompt identification of these diseases

Contribution of Systematics in Biology

Wild Life management

- The indiscriminate killing and felling of trees create disturbance in natural environment.
- It help environmental protectors by identifying economically and ecologically important wild life.
- It is important for preservation and protection of biodiversity.

Contribution of Systematics in Biology

Mineral Prospecting

- The identification of fauna and flora by paleontologists in sedimentary rocks show the sequence of geological events
- Which help in search for fuels and mineral deposits.
- Example: It attain great success in American industrialization

Contribution of Systematics in Biology



National Defense

- During World War II (On November 3, 1944), **Japan** released **balloon bombs**, into the Pacific jet stream
- Created havoc in the forest of north east America.
- Balloons covered with sand contained a large number of shells of micro-organisms.
- Bombing of this beach area destroyed the balloon launching site.

Contribution of Systematics in Biology

Detection of Environmental Problems

- Phytoplankton and zooplankton are sensitive to changes in water quality.
- They are good indicators for changes in water quality as they respond quickly to changes in nutrient input.
- Taxonomists help to detect such problem by identifying specific species.

Contribution of Systematics in Biology



Soil Fertility

- Taxonomist help to detect organisms that enhance soil fertility
- For example bacteria, earthworms etc.

Contribution of Systematics in Biology

In commerce

- Systematics play role in increasing and improving the qualities of commercially used animal products such as:
 - Honey
 - Silk
 - Lac
 - Dyes etc

END

Principles of Systematics

Module# 6

Principles of Systematics

Binomial Nomenclature

Binomial Nomenclature

- Scientific names of species is a combination of two names:
 - Generic name
 - Species name

Binomial Nomenclature



- Spider *Oxyopes javanus* is found in agro-ecosystems.
- The first part of a scientific name, *Oxyopes*, is called the genus.
- The second part of a scientific name, *javanus* is in this example, is the species name

Binomial Nomenclature



- *Hottentotta tamulus*, the Indian red scorpion also known as the eastern Indian scorpion, is a species of scorpion of the family Buthidae.
- It occurs in most of India, eastern Pakistan and the eastern lowlands of Nepal, and recently from Sri Lanka.

Binomial Nomenclature



https://en.wikipedia.org/wiki/Hoplobatrachus_tigerinus#/media/File:HoplobatrachusTigerinus.jpg

- *Rana tagrina* is an amphibian which is solitary and nocturnal in nature.
- They inhabit holes and bushes near water source.
- They do not stay in water for longer time.
- They belong to order anura.

Principles of Systematics

Module# 7

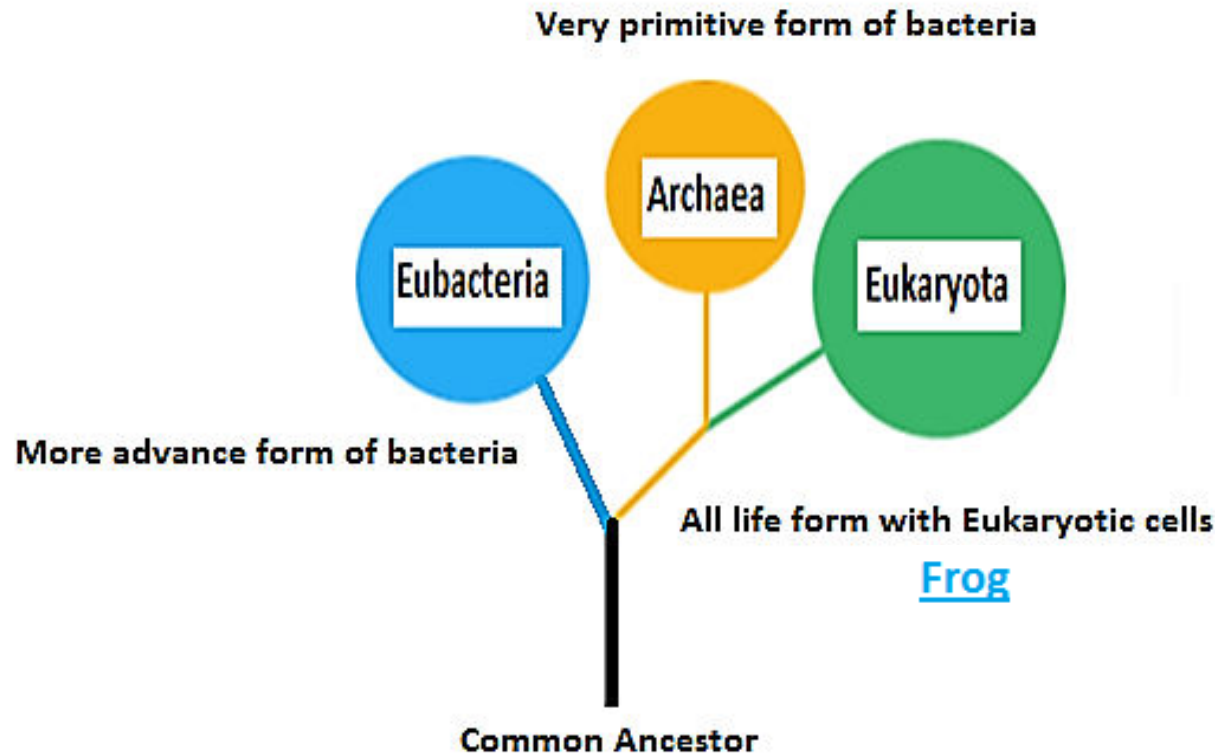
Three Domain system

Archaea

Eubacteria

Eukaryota

Three Domain system



- A domain is a broadest taxonomic category.
- All organism belong to one of the three domains, depending upon their characteristics.
- A single domain can contain one or more kingdoms.
- Introduced by **Charl Woese et al.** In 1990.

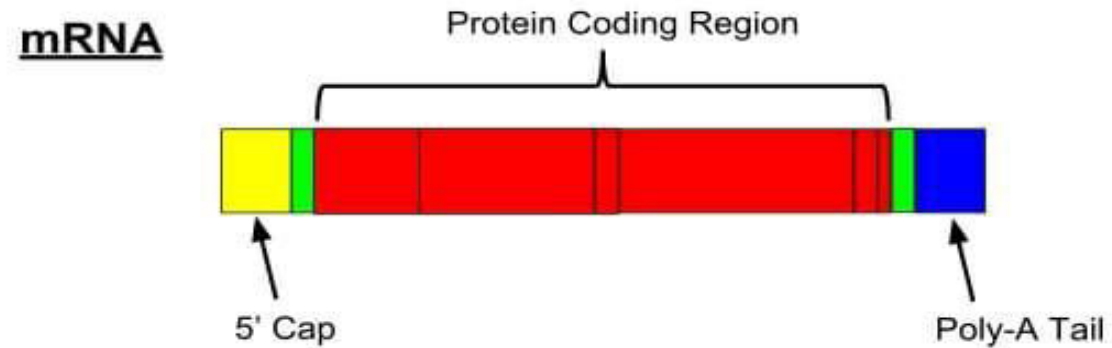
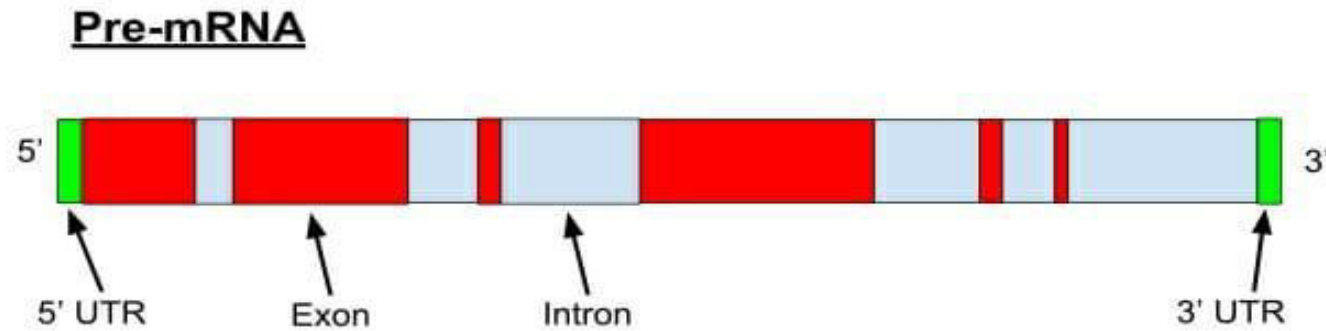
Three Domain system

Domain of Viruses

- Viruses are DNA and RNA shielded by protein coat called capsid.
 - Viruses do not have a domain
- 

Three Domain system

Three Domain system



<https://biologydictionary.net/intron/>

Principles of Systematics

Module# 8

Principles of Systematics

Five Kingdom Classification

Five Kingdom Classification

Two Kingdom classification

- Plants (Autotrophs)
- Animals (Heterotrophs)

Problem

- Euglena

Solution by Ernst Haeckel (1866)

- Protista

Five Kingdom Classification

- E- Chatton in 1937 introduced the term “Procariotique” to describe bacteria and “Eucariotique” to describe animals and plant cells.
- Five kingdom classification was proposed by Robert Whittaker in 1967.

Five Kingdom Classification

- Morgulis and Schwatz in 1988 modified R. Whittaker classification.
- They considered genetics along with cellular organization and mode of nutrition in classification.

Five Kingdom Classification

- Five kingdoms proposed by Robert Whittaker include:
 - Monera
 - Protista
 - Fungi
 - Plantae
 - Animalia

Principles of Systematics

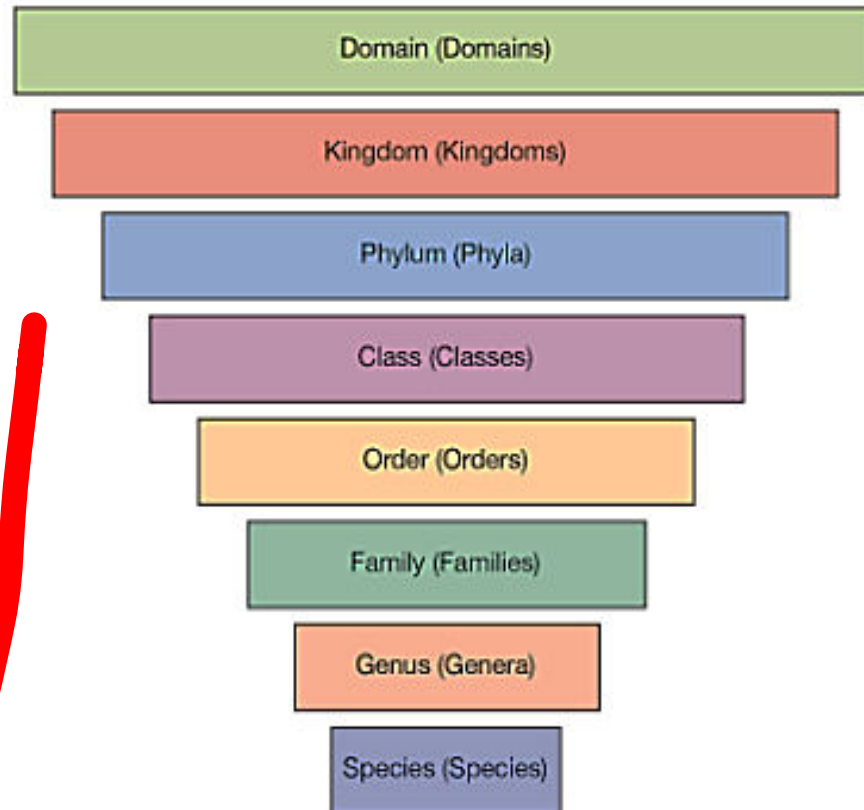
Module# 9

Principles of Systematics

History of Taxonomy

History of Taxonomy

How animals are classified



<https://Britannica.com/science/taxonomy>

- Taxonomy is as old as the language skill of mankind.
- Taxonomy is the science of naming, describing and classifying organisms including all plants, animals and microorganisms of the world.
- Taxonomy identifies and enumerates the components of biological diversity.

History of Taxonomy

- Native tribes used to call the species on the basis of their morphological characters
- **Development of scientific theory of classification**a remarkably recent phenomenon

History of Taxonomy



George Gaylord Simpson (1902-1984)

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- Simpson in 1961 gives a valuable survey of History of Taxonomy.
- Simpson was the most influential paleontologists of the twentieth century.
- He published extensively on the taxonomy of fossil and extinct mammals.

History of Taxonomy



Frederick Smith 1805-1879

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- **Frederick Smith** worked in the zoology department of British Museum from 1849.
- He published from 1851 to 1870 on ant taxonomy.
- During the 28 years of his activity he describe 25 genera, 702 species and subspecies of which hare.

History of Taxonomy



Thomas E. Mittler (1928-2012)

https://www.google.com/search?q=thomas+E.Mittler+pic+pic+taxonomy&tbm=isch&ved=2ahUKEwiSPCJiuLuAhUP_BoKHfOBCwsQ2cCegQIABAA&oq=frederick+smith+pic+pic+taxonomy&gs_lcp=CgNpbWcQA1CQEFj1KWCxLWgAcAB4AIABjQOIAegXkgEFMi0xLjiYACgAQGqAQtnD3Mtd2l6LWltZ8ABAQ&scient=img&ei=BkQlYJLdHo_4a_ODrlg&bih=625&biw=1366#imgrc=k331uXCLcv1IsM

- **Thomas E. Mittler** was an Austrian entomologist.
- He worked on history of higher taxonomy and also on the classification of insects

History of Taxonomy



Ernst Mayr (1904- 2005)

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- **Mayr in 1982** provided a details of various periods of History of Taxonomy
- His work contributed to the conceptual revolution that led to modern evolutionary synthesis of taxonomy and systematics

Principles of Systematics

Module# 10

Principles of Systematics

History of Taxonomy

History of Taxonomy

- **Mayr** described the History of Taxonomy into four periods:

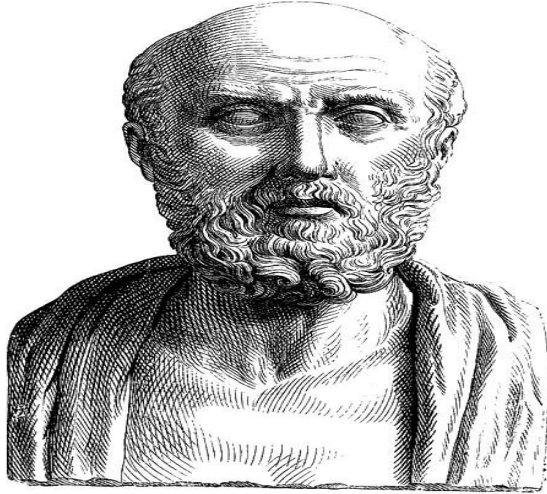
- ❖ 1st Period

- ❖ 2nd Period

- ❖ 3rd Period

- ❖ 4th Period

History of Taxonomy



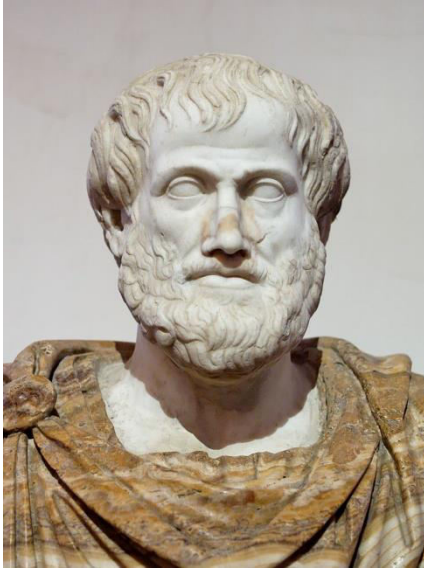
Hippocrates (460-377 B.C.)

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1st Period (Study of local fauna)

- Several early Greek scholars notably **Hippocrates** enumerated the types of animals But he did not classify.

History of Taxonomy



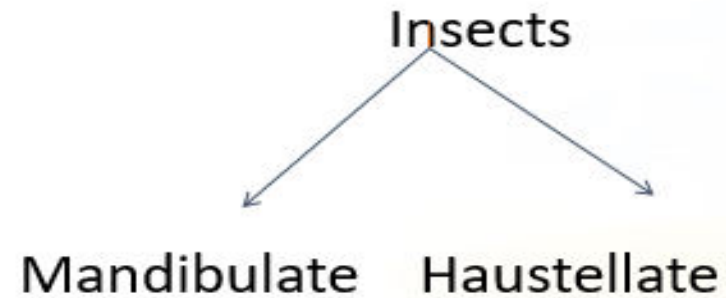
Aristotle (384-322 B.C.)

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- 1st Period (Study of local fauna)
- **Aristotle** known as father of biological classification, referred to the major groups of animals.

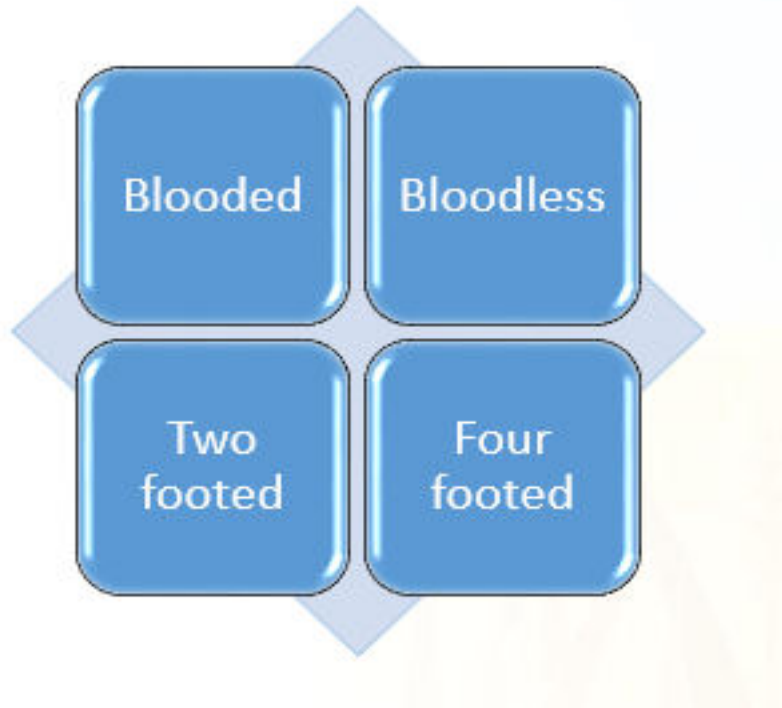


History of Taxonomy



- Aristotle also made distinction in insects
- He first used the following terms: Coleoptera and Diptera

History of Taxonomy



- He established numerous collective categories, or genera using differentiating characters

History of Taxonomy

- Aristotle made further categories of animals
- His thinking dominated for next two thousand years
- After his death no system of classification were recognized

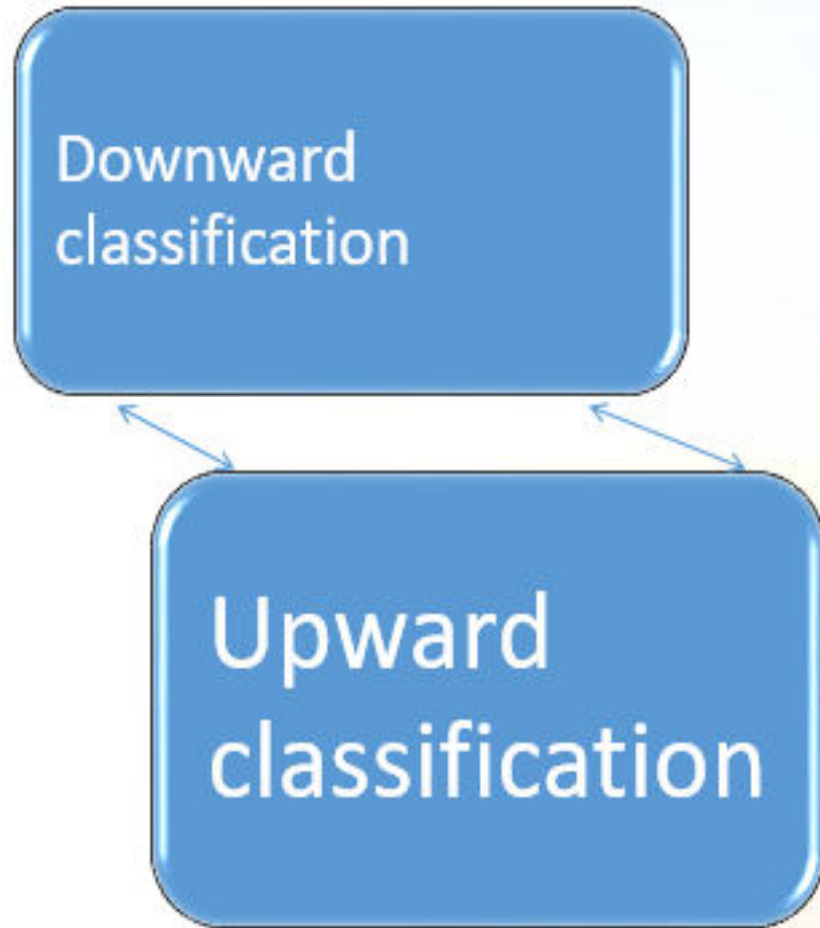
Principles of Systematics

Module# 11

Principles of Systematics

History of Taxonomy

History of Taxonomy



- From 1551 rapid progress started in knowledge about animals.
- There are two major forms of classification in first period

History of Taxonomy

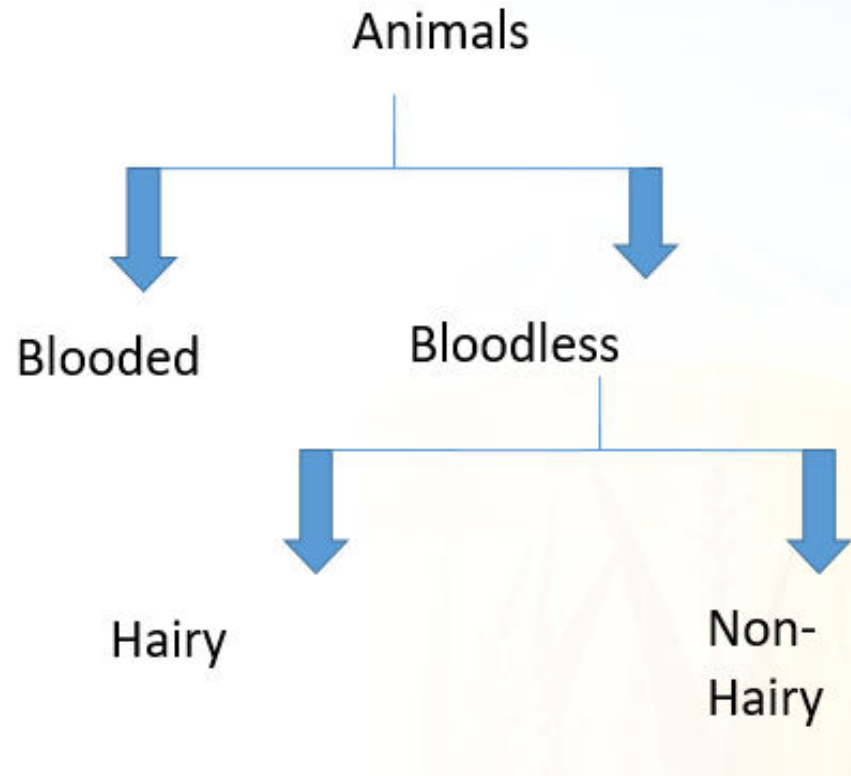


Carl Linnaeus (1707-1778)

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- Taxonomy based on local fauna reached its peak by the work of Linnaeus (1707-1778)

History of Taxonomy



- Downward classification are the principles of logical division which consist of dividing the larger groups based on dichotomy into smaller groups. e.g,

Animals

History of Taxonomy

- Linnaeus adopted the principle of downward classification in 15th edition of his book (Systema naturae)
- He for the first time applied **binomial nomenclature** to animal kingdom.

History of Taxonomy

- Linnaeus's idea was largely acceptable for the classification of insects.
- Not acceptable for the classification of birds, amphibians, and lower vertebrates (Vermes)

History of Taxonomy



Comte de Buffon (1707-1778)

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- Buffon prepared the way for the biological species concept, by using sterility barriers instead of degree of morphological differences as the species criterion

Principles of Systematics

Module# 12

Principles of Systematics

History of Taxonomy

History of Taxonomy

- By the mid of 18th century shortcomings of downward classification system were recognized.
- Gradually replaced by upward classification system

History of Taxonomy

- It consists of assembling species by inspection into groups of similar and related species and forming hierarchy by again grouping of similar taxa of next lower rank.

History of Taxonomy



Comte de Buffon (1707-1778)

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- Buffon in 1749 supported this system.
- He said that the only way to design a method is to group together the things that resemble each other and separate the things that differ from each other

History of Taxonomy



James Anderson (1738– 1809)

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- Anderson 1763 (Botanist) applied this design for the classification of plants

History of Taxonomy

- Cuvier recognized five phyla



Georges Cuvier (1769-1832)

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History of Taxonomy

- **Van Baer, Owen** divided all species into limited no. of groups each representing a distinct type



Karl Ernst von Baer (1792-1876)



Richard Owen (1804-1892)

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History of Taxonomy

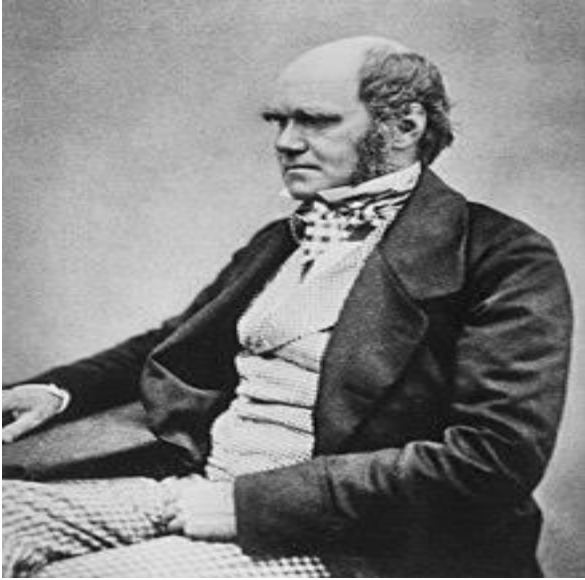
Developments during Linnaeus and Darwin Period

1. Specialization became more pronounced. Many authors identified birds, beetles, or butterflies
2. Classification became more hierarchical and soon the categories family and phylum were added
3. Philosophical guidelines were rejected
4. Search for a natural system was intensified

History of Taxonomy

- This thought was applied by a botanist in 1873 and later by nearly all zoologists.
- This shift from downward classification to upward classification was a philosophical change

History of Taxonomy

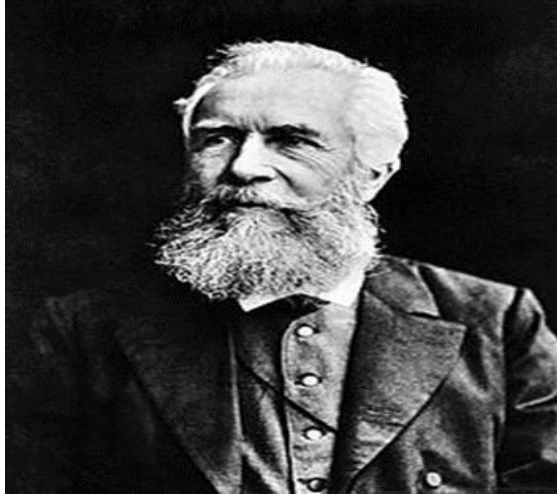


Charles Darwin (1809-1882)

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- Evolutionary thought was widespread in 18th century
- Darwin believed in fixity of species but after observing natural fauna in Galapagos island, he begin to believe in the plasticity of species

History of Taxonomy



Ernest Haeckel (1834-1919)

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- Empirical taxonomists were greatly influenced by Darwin's idea.
- The phylogenetic tree of **Ernest Haeckel** also stimulated the empirical workers.
- Large number of new species were discovered and described.

History of Taxonomy

- The greatest development of modern taxonomy started around 1930, when the workers realized that the Linnaeus species based on one or two specimens are not as perfect as those which are based on population

History of Taxonomy

- Due to this **Mayr** in 1942 considered species as a group of interbreeding natural population.
- This idea of population taxonomy was useful in developing the polytypic concepts.
- New terms like new systematics and biosystematics were added to extend the taxonomic theory.

History of Taxonomy

- The publication of the book 'new systematics'
 - Become a landmark in the History of Taxonomy.
 - Thus taxonomy got a new label of biological taxonomy
 - By 1955 taxonomy reach such a status that it was called taxonomic explosion
- 

History of Taxonomy

- New systematic deal exclusively with the species level.
- The present day taxonomic work include all available differences and similarities.

History of Taxonomy

- Instead of morphology as an original base, phylogenetic adaptations, embryological patterns, biochemical variations, genetic variabilities and similarities, behavioral characteristics are all applicable to taxonomic study

END

Principles of Systematics

Module# 13

Principles of Systematics

Basic Definitions

Basic Definitions

Sibling Species

- Two or more than two closely related species which are morphologically alike but behaviorally or reproductively isolated from each other.
- Examples are *Drosophila persimilis* and *D. pseudoobscura*.

Basic Definitions

Sibling Species

- The mosquito *Anopheles maculipennis* complex consists of several subspecies, of which a few are vector of malaria and the rest are harmless.

Basic Definitions

Monotypic Species

- species with a single subspecies, called monotypic species
- *Example: Bardala labarda*

Polytypic Species

- A species contains two or more subspecies
- Examples are tiger, *Panthera tigris* which has several subspecies

Basic Definitions

Endemic species

- The species which are found in a particular region, called endemic species.

Example

- The Darwinian finches are the endemic species of Galapagos Islands
- Indus dolphin in Pakistan

END

Principles of Systematics

Module# 14

Principles of Systematics

Basic Definitions

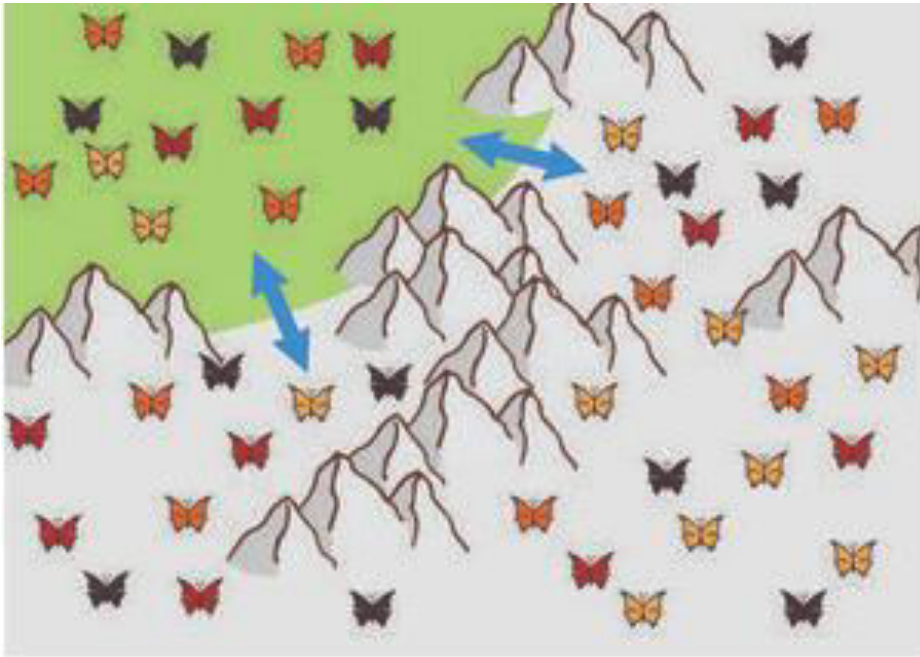
Basic Definitions

Deme

- A deme is a sub-population (a smaller group within the population) that can freely interbreed.
- A population is usually made of several demes (groups) that are partially isolated from each other.

Basic Definitions

Deme



<https://www.pathwayz.org>

- Often a geographical barrier limits gene flow between demes, but not sufficiently to result in speciation.
- Enough gene flow occurs between demes ensuring that all of its members remain the same species.

Basic Definitions



<https://www.pathwayz.org>

Cline

- A cline is the gradual change in the phenotypes and genotypes of a species across a geographical gradient
- Allele frequencies and traits might vary slightly across the geographical gradient because of different selection pressures.

Basic Definitions

Types of cline

- Smooth cline
- Step cline

<https://www.pathwayz.org>

Basic Definitions



- A clade is a group of organisms that evolved from a common ancestor
- Eutheria is one mammalian clade and the other is Metatheria, which includes marsupials.
- Another example of a clade could be **birds**: they all also descended from a common ancestor.

Principles of Systematics

Module# 15

Principles of Systematics

Concept of Speciation and Causes

Concept of Speciation and Causes

Speciation

Speciation refers to the creation a new species.

Through this process, the earliest groups of similar organisms were able branch out and populate the world with millions of different varieties of life

Basic Definitions

Types of speciation

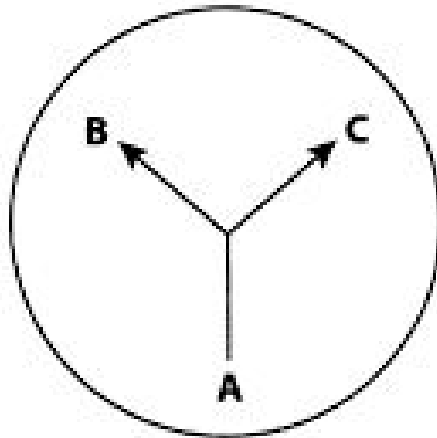
Anagenesis

- A single species may change over time into a new form that is different enough to be considered a new species.
- One species replaces other
- No net change in number of species

Basic Definitions

Types of speciation

Cladogenesis



Cladogenesis

- A species may become split into two groups that no longer share the same gene pool.
- Net increase in number of species
- Increase in diversity

Concept of Speciation and Causes

Causes of speciation



- Geographical Isolation
- Behavioural isolation
- Reproductive isolation

END

Principles of Systematics

Module# 16

Concept of Speciation and Causes

Types of speciation

Concept of Speciation and Causes

Types of speciation



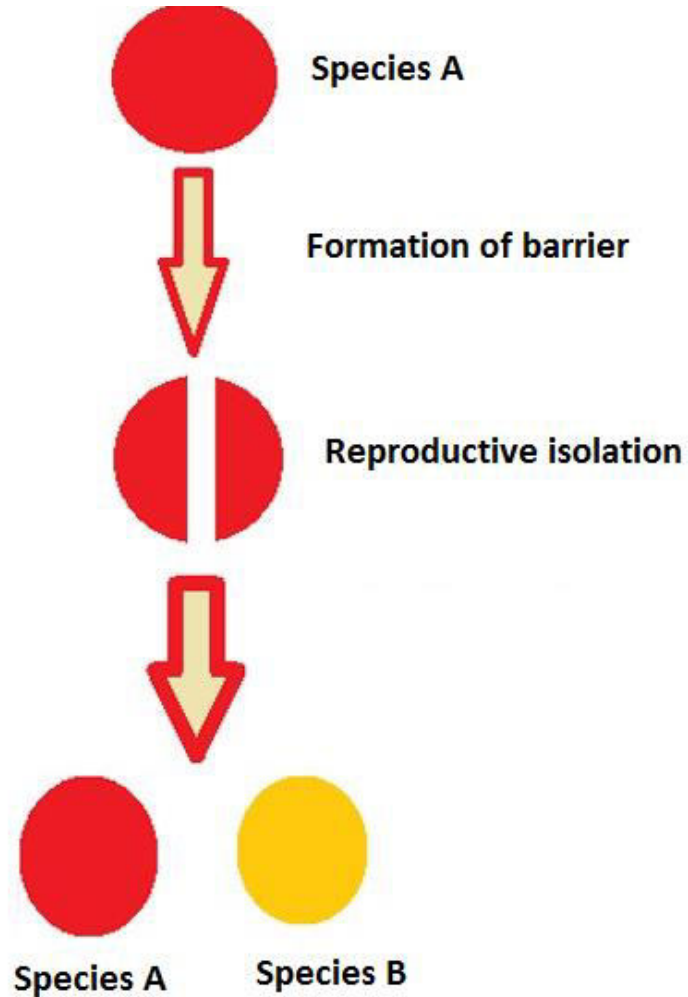
- Allopatric speciation
- Peripatric speciation
- Sympatric speciation
- Parapatric speciation

Concept of Speciation and Causes

Allopatric Speciation

- The most common form of speciation
- Occurs when populations of a species become geographically isolated.

Concept of Speciation and Causes



Allopatric Speciation

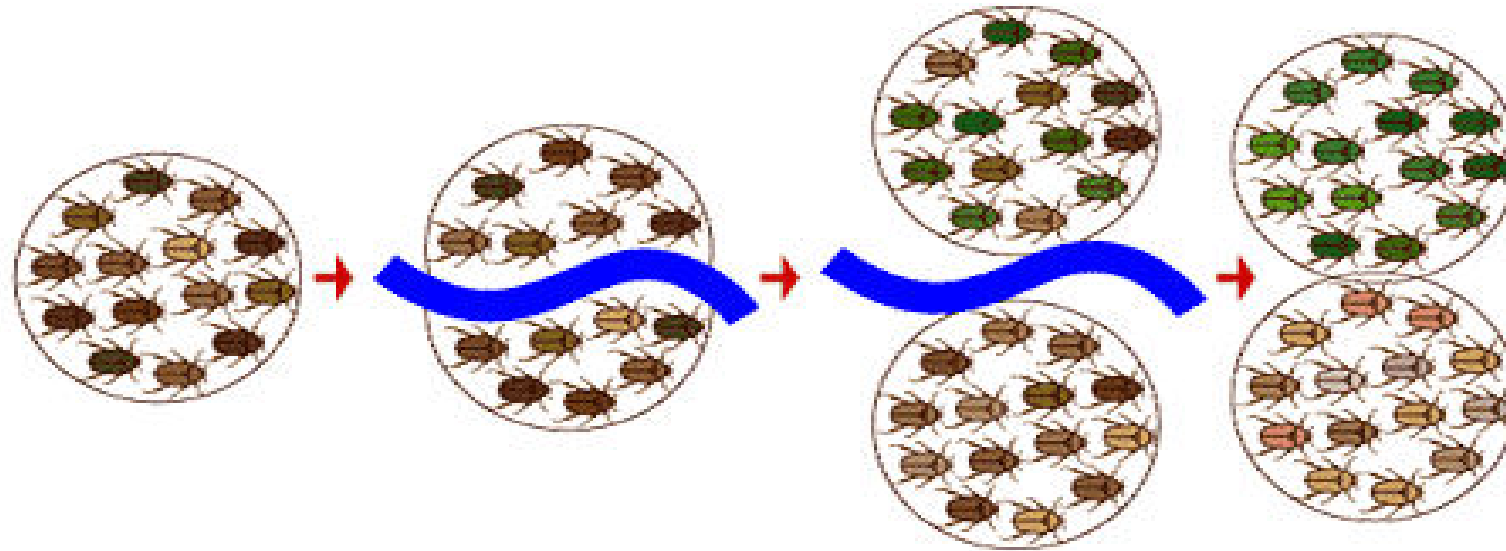
- When populations become separated, gene flow between them ceases.
- Over time, the populations may become genetically different

Concept of Speciation and Causes

Examples

- Speciation is the Galápagos finch
- Different species of these birds live on different islands.
- The finches are isolated from one another by the ocean.
- Over millions of years, each species of finch developed a unique beak that is especially adapted to the kinds of food it eats.

Concept of Speciation and Causes



<https://evolution.berkeley.edu>

Principles of Systematics

Module# 17

Principles of Systematics

Sympatric Speciation

Sympatric Speciation

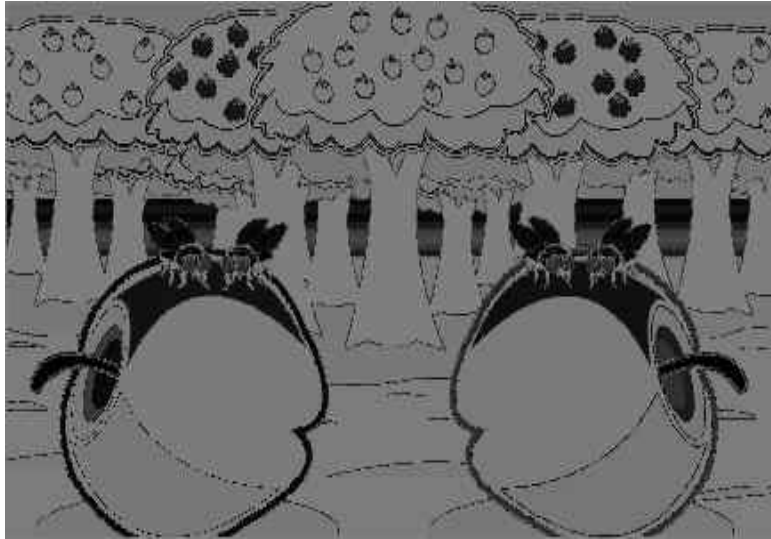
- A speciation in which a species is evolved from a single common ancestral species while inhabiting the same geographical range.
- Share the same habitat but become reproductively isolated from each other.
- More common in plants

Sympatric Speciation

Polyploidy in plants

- Plants produce offspring that are polyploid. Hence, the offspring live in the same environment as their parents but are reproductively isolated.

Sympatric Speciation



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Example

- 200 year ago ancestor of maggot flies were used to lay eggs on hawthorn.
- Now they lay eggs on hawthorn (native to America) and domestic apples (introduced)
- Host shift/genetic differences (Coyne, 2007)

Principles of Systematics

Module# 18