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HIGHLIGHTED HANDOUT

ZOO511T

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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:

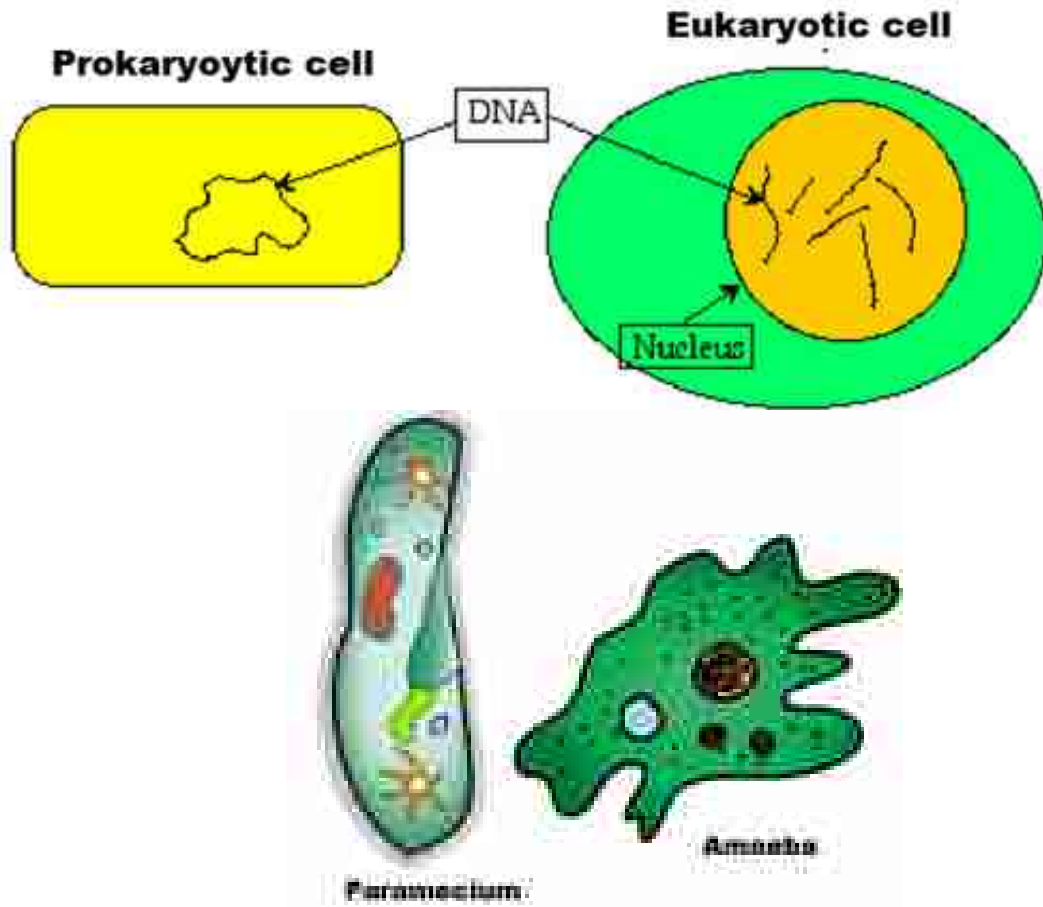
- Animals
- Plants and
- Minerals

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.

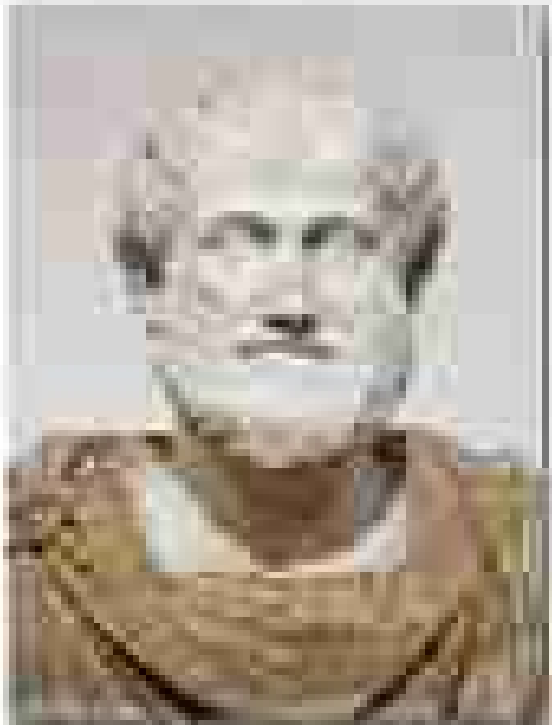
Basic Terminologies



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

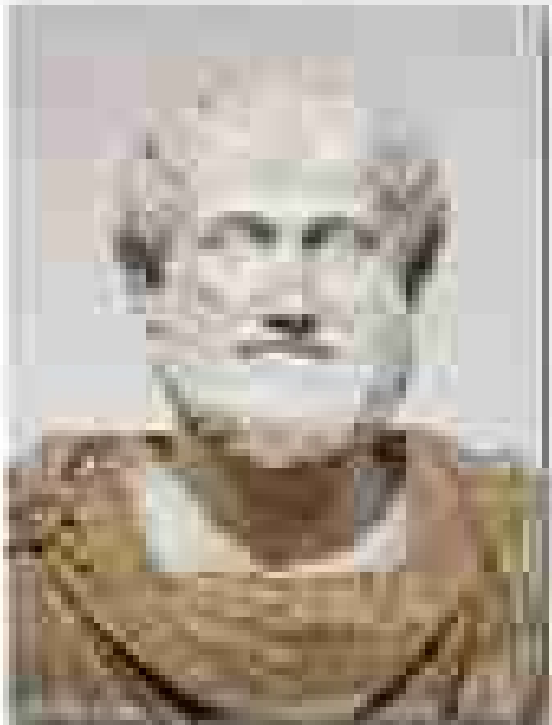


Aristotle
Greek Philosopher
384-322 BC

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

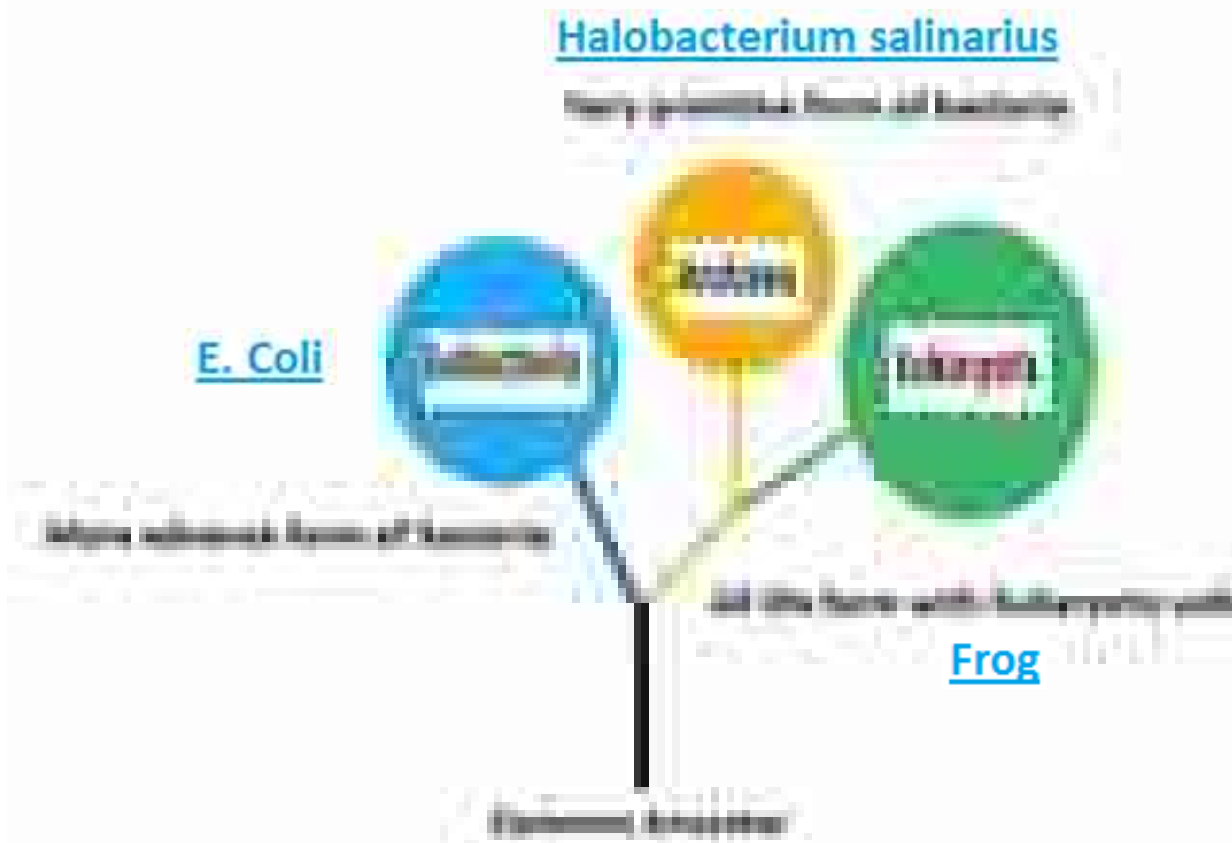
Three Domain system

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

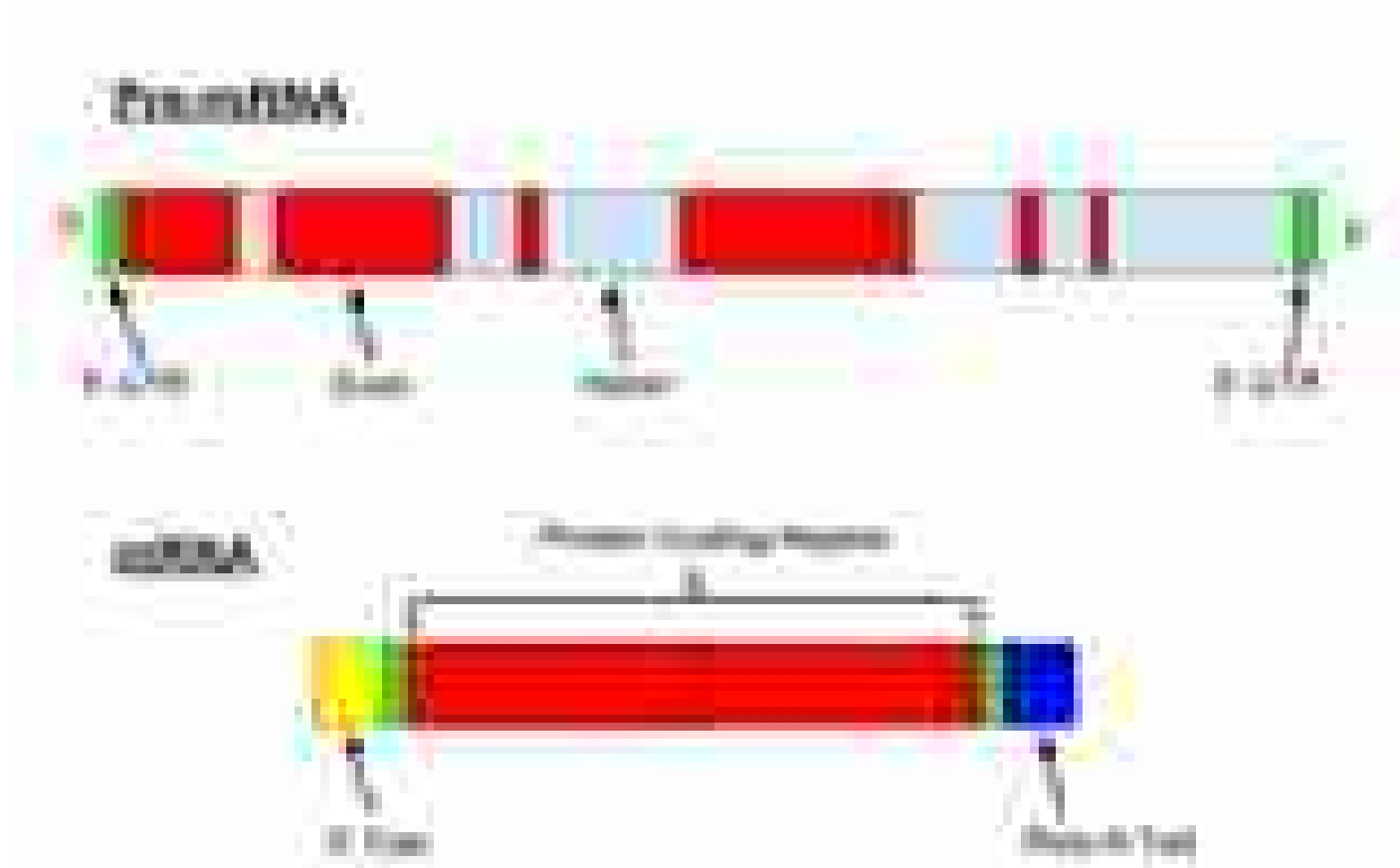
- Viruses are DNA and RNA shielded by protein coat called capsid.
 - Viruses do not have a domain
- 

Three Domain system

Similarities and differences of Eubacteria and Archaea

Characteristics	Eubacteria	Archaea
Cell type	Prokaryotic	Prokaryotic
Cell wall	Contain peptidoglycan	Carbohydrates, proteins or No cell wall
Interons	No interons	Interons present
Ribosomal proteins	No ribosomal proteins	Ribosomal proteins present
Diseases	Can be parasitic and cause diseases	None are parasitic
Gene resemblance	No resemblance	Eukaryotes

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

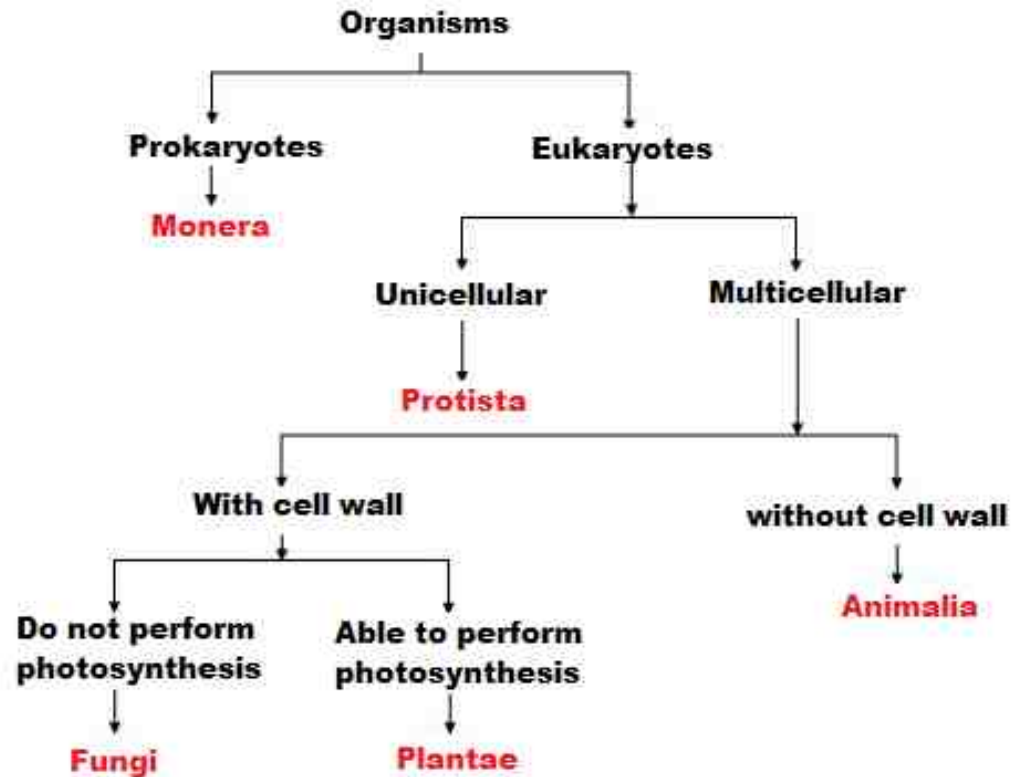
Five Kingdom Classification

- 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

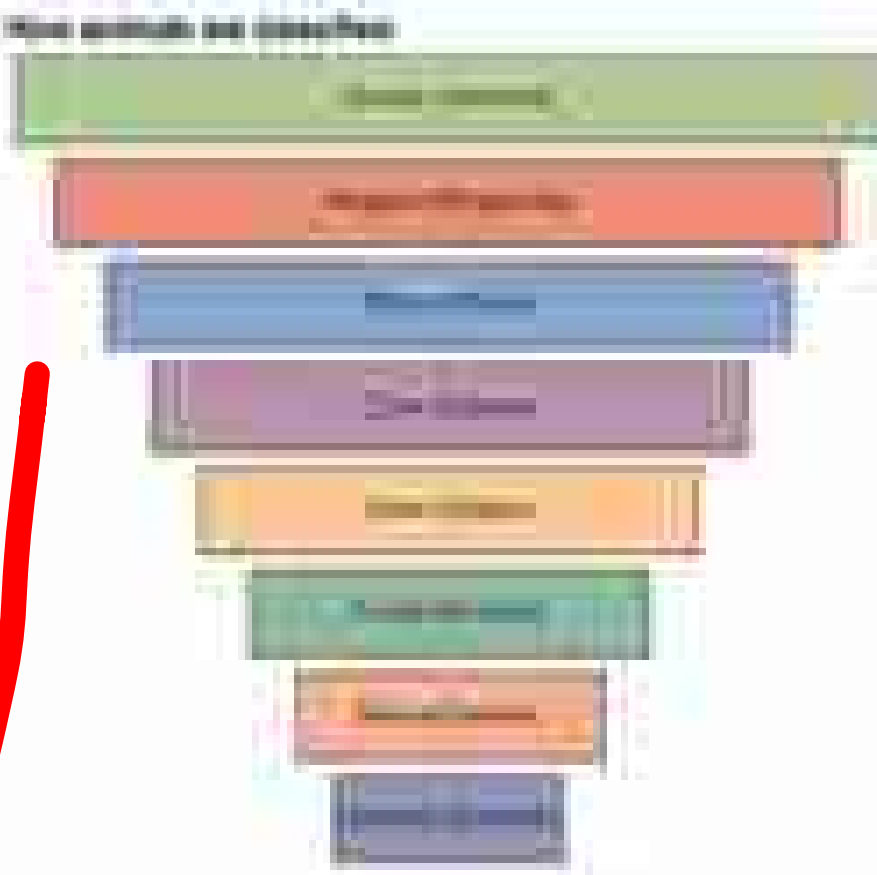
Principles of Systematics

Module# 9

Principles of Systematics

History of Taxonomy

History of Taxonomy



<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)

https://www.google.com/search?q=george+gaylord+simpson+pic&sxsrf=ALeKk016UQ5865EIGFEM0Awryp5IHsxm-Q:1613054410489&source=lnms&tbm=isch&sa=X&ved=2ahUKEwilsI_5hLuAhUJnlkKH5DkgQ_AUoAXoECA8QAw&biw=1366&bih=625#imgrc=siNionRQ1ItxWM

- 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

https://www.google.com/search?q=frederick+smith+pic+pic+taxonomy&tbm=isch&ved=2ahUKEwiSPCJiuLuAhUP_BoKHfOBCwsQ2cCegQIABAA&oq=frederick+smith+pic+pic+taxonomy&gs_lcp=CgNpbWcQA1CQEFj1KWCxLWgAcAB4AIABjQOIAegXkgEFMi0xLjiYACgAQGqAQtnD3MtD2l6LWltZ8ABAQ&sclient=img&ei=BkQIYJLdHo_4a_ODrlg&bih=625&biw=1366#imgsrc=k331uXCLcv1IsM

- **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)

https://www.google.com/search?q=ernst+mayr+pic+taxonomy+&tbm=isch&ved=2ahUKEwjs6e2JjuLuAhXBwIUKHfhfAU0Q2cCegQIABAA&oeq=ernst+mayr+pic+taxonomy+&gs_lcp=CgNpbWcQA1D6lIibLmD8MmgAcAB4AIAbjgSIACgXkgEHMy0zLjMuMZgBAKABAaoBC2d3cy13aXotaW1nwAEB&scclient=img&ei=OEglYOztC8GBIwT4v4XoBA&bih=625&biw=1366#imgrc=PdnA5xdNdrOdwm//

- **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:

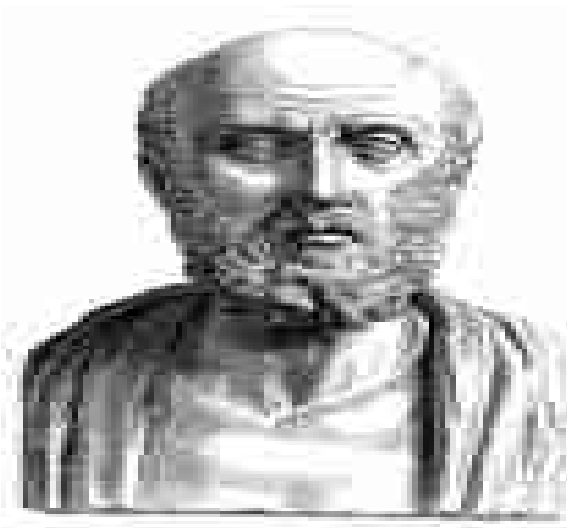
- ❖ 1st Period

- ❖ 2nd Period

- ❖ 3rd Period

- ❖ 4th Period

History of Taxonomy

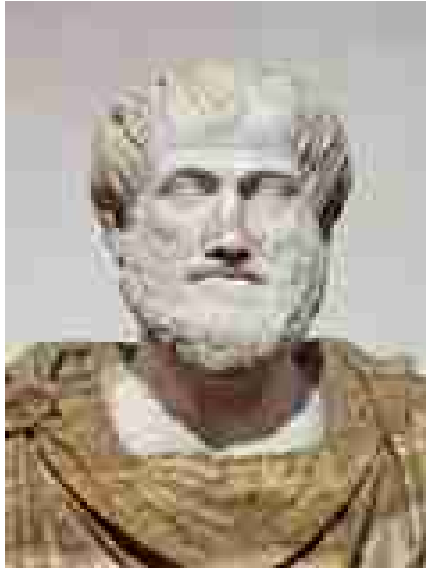


Hippocrates (460-377 B.C.)

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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.)

https://www.google.com/search?q=aristotle+taxonomy&tbm=isch&ved=2ahUKEwi19KNjuLuAhUEPhoKHY92BQQQ2cCegQIABAA&oq=hippocratespic+taxonomy&gs_lcp=CgNpbWcQAzoGCAAQCBAeUM_LJliV9CZgy_cmaABwAHgCgAGHBYgBvTySAQczLTYuNy40mAEAoAEBqgELZ3dzLXdpei1pbWfAAQE&sclient=img&ei=QEglYLXbCIT8al_tISA&bih=625&biw=1366#imgrc=77dKLgexqooJoM

- 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

Downward
classification

Upward
classification

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

History of Taxonomy

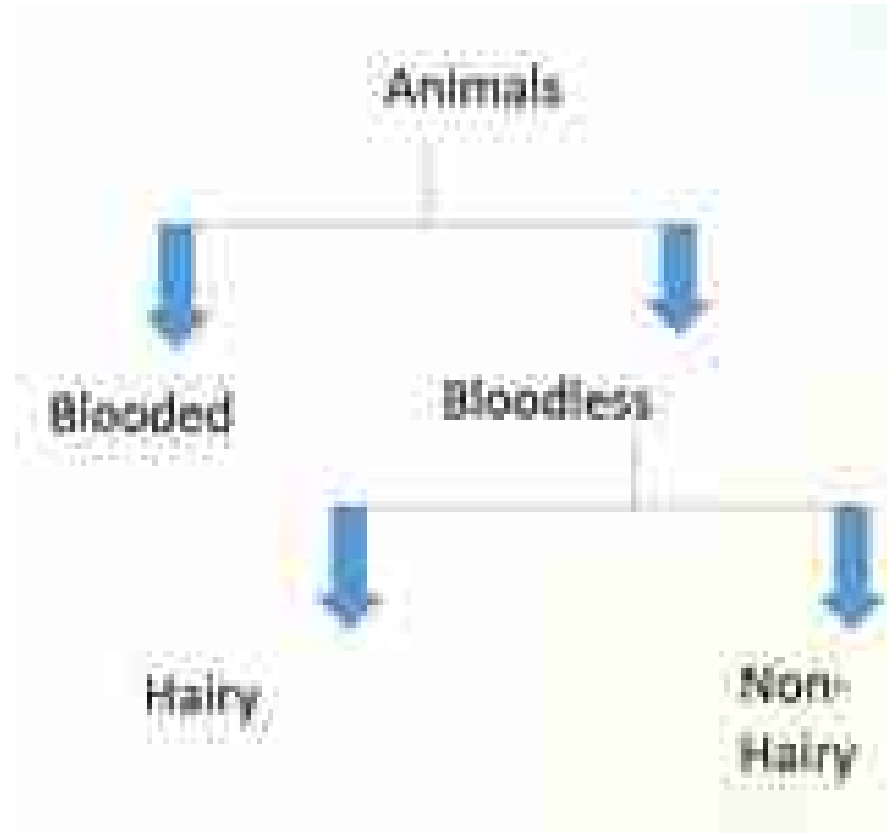


Carl Linnaeus (1707-1778)

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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)

https://www.google.com/search?q=comte+deBuffon+taxonomy&tbm=isch&ved=2ahUKEwi19KNjuLuAhUEPhoKHY92BQQQ2cCegQIABAA&oq=hippocratespic+taxonomy&gs_lcp=CgNpbWcQAzoGCAAQCBAeUM_LJliV9CZgy_cmaABwAHgCgAGHBYgBvTySAQczLTYuNy40mAEAoAEBqgELZ3dzLXdpei1pbWfAAQE&sclient=img&ei=QEglYlXbCIT8aI_tISA&bih=625&biw=1366#imgsrc=77dKLgexqooJoM

- 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



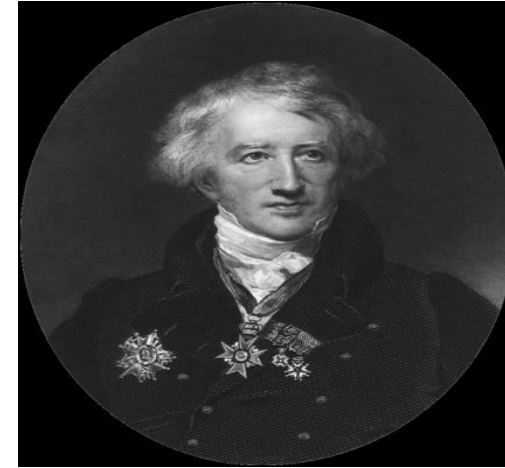
James Anderson (1738– 1809)

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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 (1801-1876)



Richard Owen (1804-1892)

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History of Taxonomy

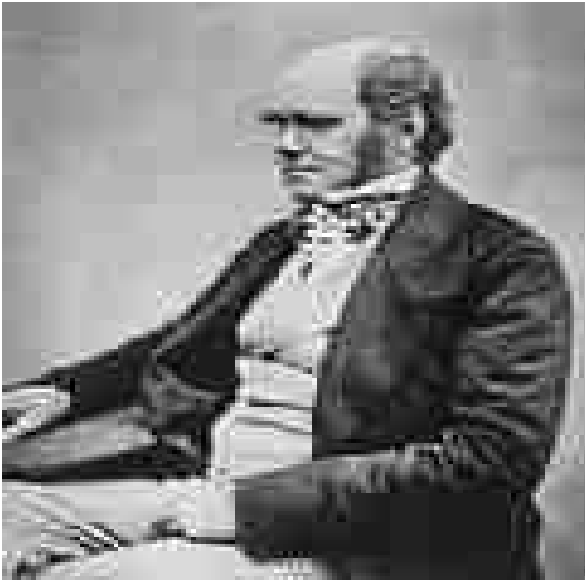
Developments during Linnaeus and Darwin Period

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

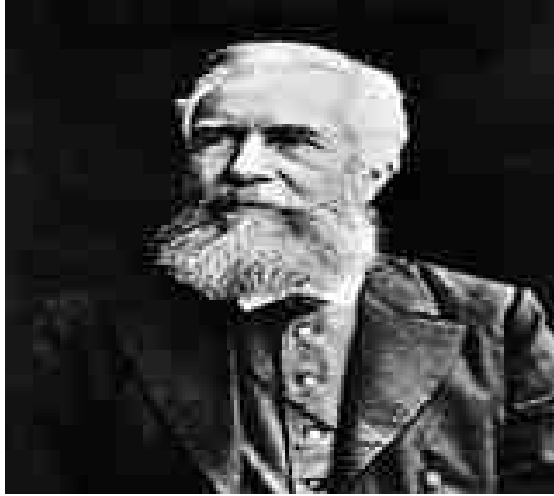


Charles Darwin (1809-1882)

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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)

https://https://www.google.com/search?q=ernst+hackel&tbm=isch&ved=2ahUKEwiH3uDFn-LuAhUt5IUkHQxDDdoQ2-cCegQIABAA&oq=ernst+hackel&gs_lcp=CgNpbWcQAzICCAAyBggAEAoQGDIGCAAQChAYMgYIABAKEBgyBggAEAoQGDIGCAAQChAYMgYIABAKEBg6BAGjECc6BAGAEEM6BwgjEOoCECc6BQgAELEDOgQIABAEogQIABAYULWsDFjy5wxgpu0MaAFwAHgAgAGCBogBrUWSAQkzLTguMy42LjKYAQCgAQGqAQtn3Mtd2l6LWltZ7ABCsABAQ&sclient=img&ei=iVolYMf1DK3IlwSMhrXQDQ&bih=625&biw=1366#imgsrc=clElbdaRJgSkeM

- 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.difference.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

Cline



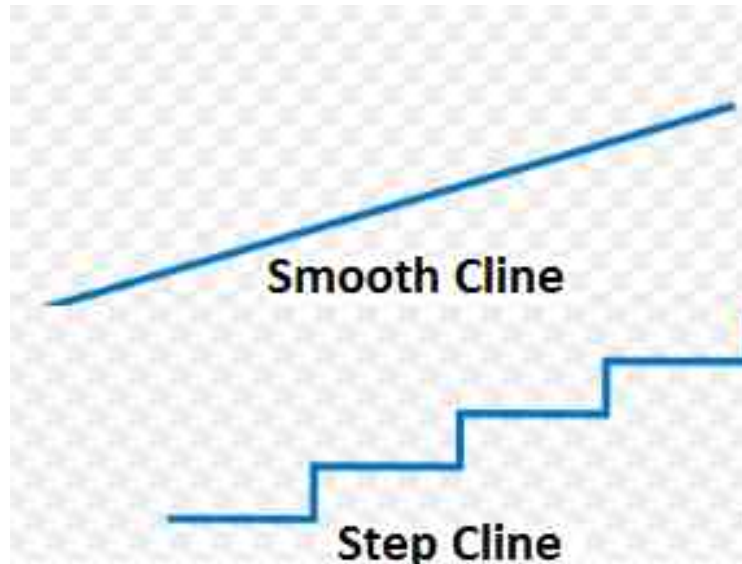
<https://www.pathwayz.org>

- 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

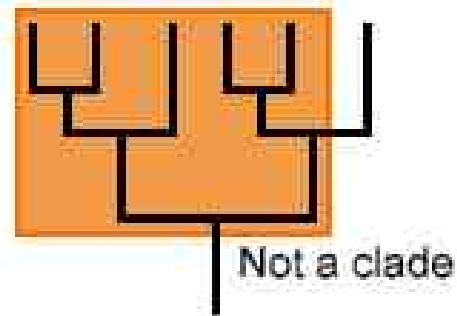
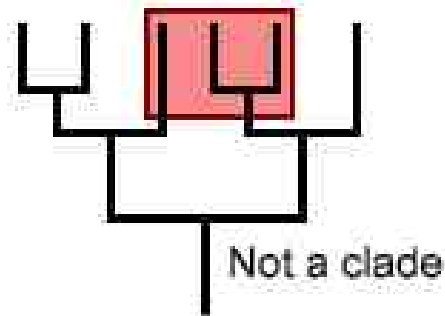
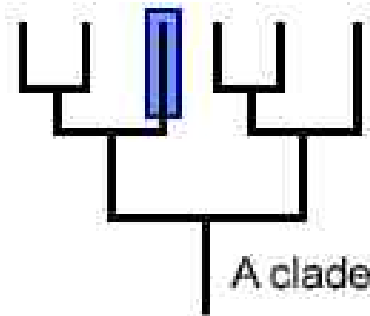
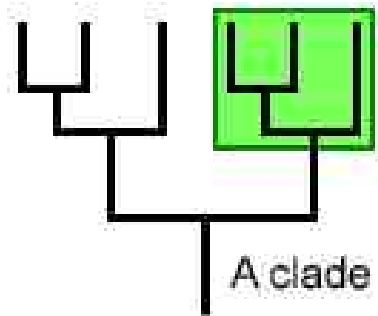
- Smooth cline
- Step cline



<https://www.pathwayz.org>

Basic Definitions

Clade



<http://www.evolution.berkeley.edu>

- 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

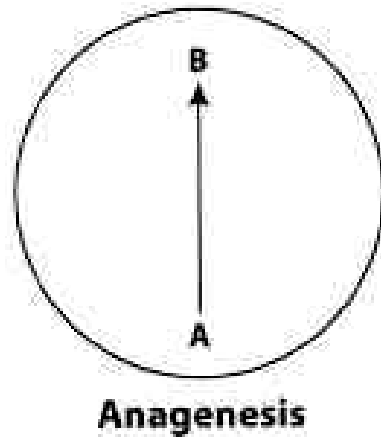
Speciation refers to the creation a new species.

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

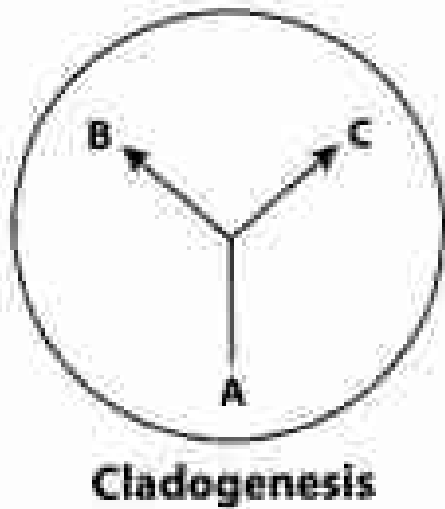


- A single species may change over time into a new form that is different enough to be considered a new species.
- One species replaces other
- No net change in number of species

Basic Definitions

Types of speciation

Cladogenesis



- 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



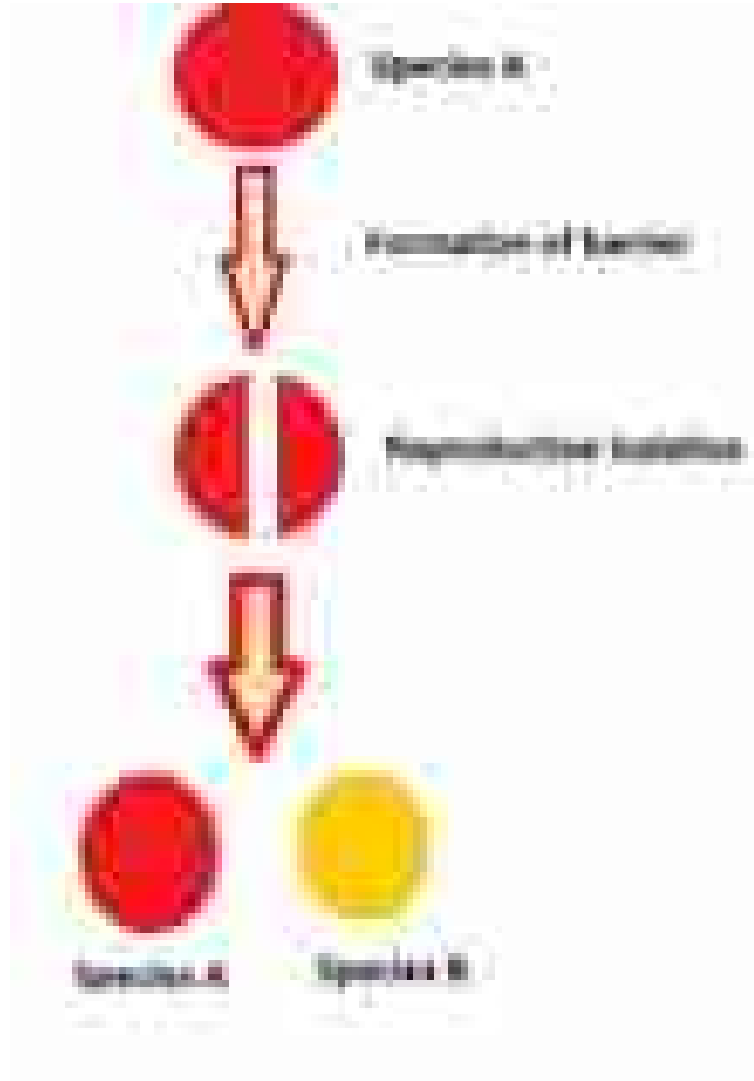
- Allopatric speciation
- Peripatric speciation
- Sympatric speciation
- Parapatric speciation

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

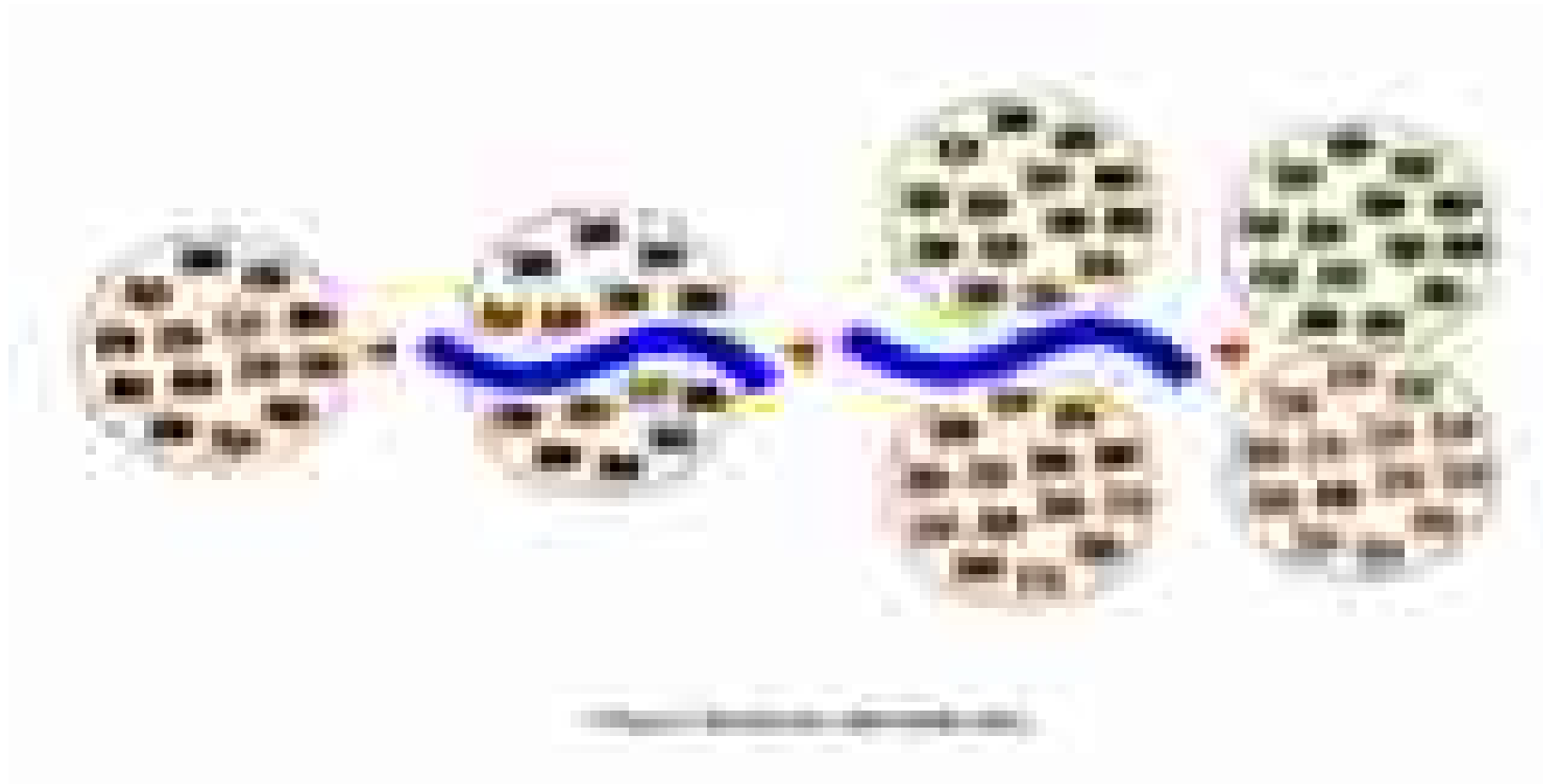
- When populations become separated, gene flow between them ceases.
- Over time, the populations may become genetically different

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



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



<https://images.app.goo.gl/5Q15k3p4fVkJcktA7>

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)

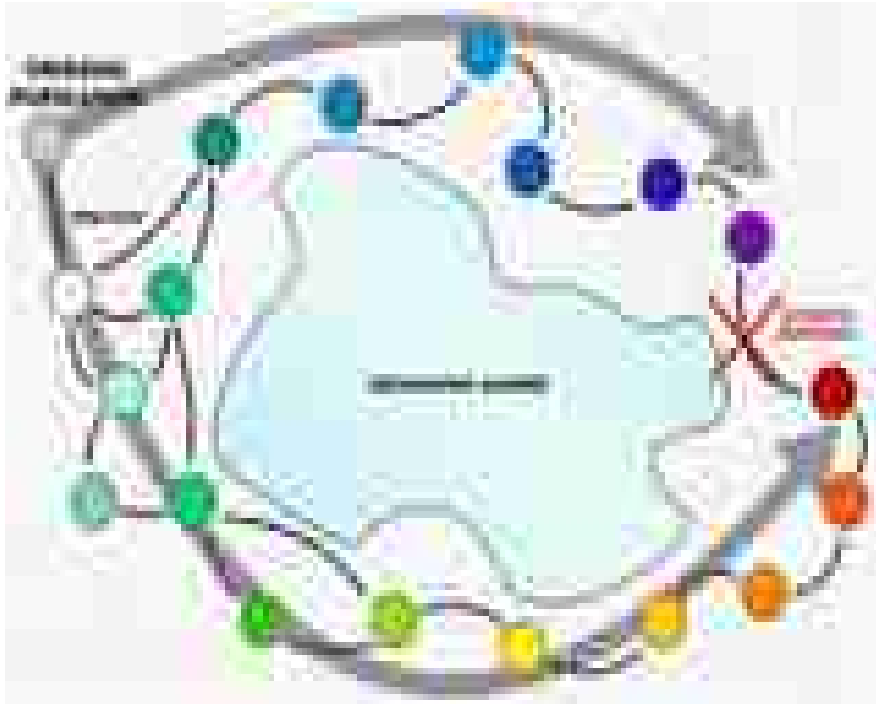
Principles of Systematics

Module# 18

Principles of Systematics

Parapatric Speciation

Parapatric Speciation



[https://en.wikipedia.org/wiki/Parapatric_speciation#/media/File:Ring_Species_\(gene_flow_around_a_barrier\).png](https://en.wikipedia.org/wiki/Parapatric_speciation#/media/File:Ring_Species_(gene_flow_around_a_barrier).png)

Parapatric speciation

- It occurs when populations are separated not by a geographical barrier, such as a body of water, but by an extreme change in habitat.
- Populations in these area may interbreed.
- Charles Darwin was the first to propose this mode of speciation.

Parapatric Speciation

Parapatric speciation

- Although interbreed but reduced gene flow.
- They often develop distinct characteristics and lifestyles.
- Reproductive isolation is rather temporal or behavioral.
- It is extremely rare.

Parapatric Speciation

Example



<https://images.app.goo.gl/iMY6DE1PcER2Dx1k7>

- Population of grass plant is present near mining area
- Soil near mining area is infused with metals due to which plants grow slowly than those that grows away from mines.
- As a result, two populations of grasses arise having different flowering time.

Parapatric Speciation

Example



<https://www.google.com/search?q=cave+snails&tbm>

- A study of tropical cave snails (*Georissa saulae*) found that cave-dwelling population descended from the above-ground population, likely speciating in parapatry

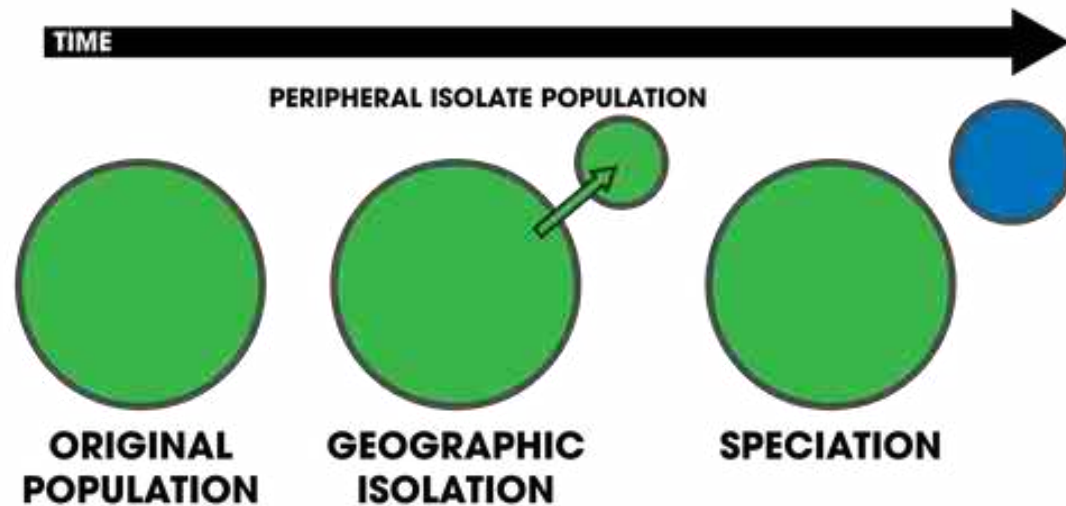
Principles of Systematics

Module# 19

Principles of Systematics

Paripatric Speciation

Paripatric Speciation



https://en.wikipedia.org/wiki/Peripatric_speciation#/media/File:Peripatric_Speciation_Schematic.svg

Paripatric speciation

- Peripatric speciation is a mode of speciation in which a new species is formed from an isolated peripheral population.
- Resemble allopatric speciation/barriers
- Isolating population is small

Paripatric Speciation



<https://www.youtube.com/watch?v=7TNN-WGYWks>

Paripatric speciation

- Peripatric speciation is a mode of speciation in which a new species is formed from an isolated peripheral population.
- Resemble allopatric speciation/barriers
- Isolating population is small

Paripatric Speciation



<https://www.google.com/search?q=london+underground+mosquito&hl>

Example

- An **example** of this is the London Underground mosquito, a variant of the mosquito *Culex pipiens*, which entered in the London Underground in 19th century.
- It is found in the London Underground railway system

Paripatric Speciation

Example

- Evidence for its **speciation** includes genetic divergence, behavioral differences, and difficulty in mating.

END

Principles of Systematics

Module# 20

Principles of Systematics

Typological Species Concept

Typological Species Concept

- Species is the basic unit of classification according to the International Commission of Zoological Nomenclature.
- Survey of taxonomic literature shows that there are more than 20 species concepts.

Typological Species Concept

Typological species concept

- This concept was proposed by Aristotle and Plato

According to this concept

“A certain pattern of features is found in each species of organisms and all members of species show maximum equality in this format”

Example: certain pattern in dogs

Typological Species Concept

Typological species concept

- Monotypic species
- Polytypic species

Typological Species Concept

Postulates of Typological species concept

- Species consist of similar individuals sharing the same essence.
- Each species is separated from all others by sharp discontinuity.
- Each species is completely constant through time.
- There are strict possible limits to variations within any one species.

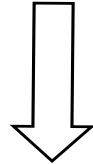
Typological Species Concept



Ara ararauna



Ara macao



sterile hybrid
Catalina macaw

Example

- Two macaw species, blue-and-yellow macaw *Ara ararauna* and the scarlet macaw *Ara macao* are considered different species due to different coloration.
- In nature, their habitats overlap but they not produce hybrids except in captivity.

Typological Species Concept

Strengths

- Applicable to living or extinct species.
- Doesn't depend on complex genetic analysis.
- Morphology can be readily observed, without harming the organisms.



Anchura substriata

<https://www.google.com/search?q=macaw&tbm=isch&ved=2ahUKEwiQyL>

Typological Species Concept

Problems with Typological species concept

- Polymorphism within populations.
- Sibling or cryptic species.
- Geographical variations among populations

END

Principles of Systematics

Module# 21

Principles of Systematics

Biological Species Concept

Biological Species Concept

- According to Biological species concept:
- Species are groups of actually or potentially interbreeding natural populations, which are reproductively isolated from other such groups.” Ernst Mayr(1942,1963)

Biological Species Concept

- Can successfully interbreed and produce fertile offspring.
- A species' integrity is maintained by interbreeding within a species.

Biological Species Concept

Why members of species resemble

- This concept explains why members of species resemble and differ from other species.
- When organisms breed they shuffle their gene pool which gives the species its identity.
- Genes are not shared with other species so they look different.

Biological Species Concept

Biological species concept

Members of species constitute:

- Ecological unit
- Reproductive unit
- Genetic unit

END

Principles of Systematics

Module# 22

Principles of Systematics

Biological Species Concept

Biological Species Concept

Biological species concept

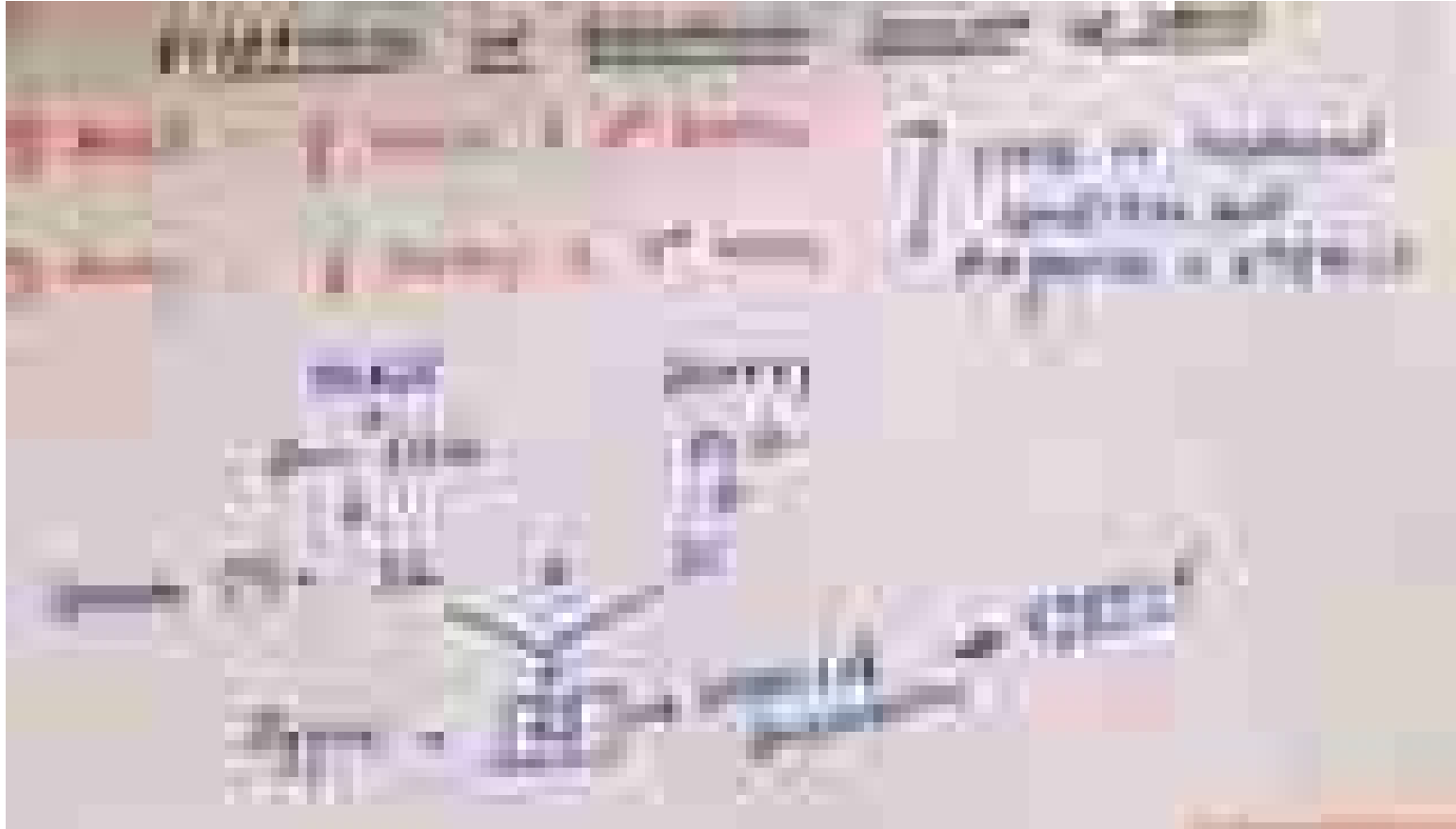
- Ecological unit
- Reproductive unit
- Genetic unit
- .” Ernst Mayr (1942, Darwin of 20th century)

Biological Species Concept

Biological species concept

- Most widely accepted species concept.
- Dobzhansky (1951) and Hanson (1981) accepted the definition of biological Species concept because of two reasons:
 - Gene pool
 - Reproductive isolation

Biological Species Concept

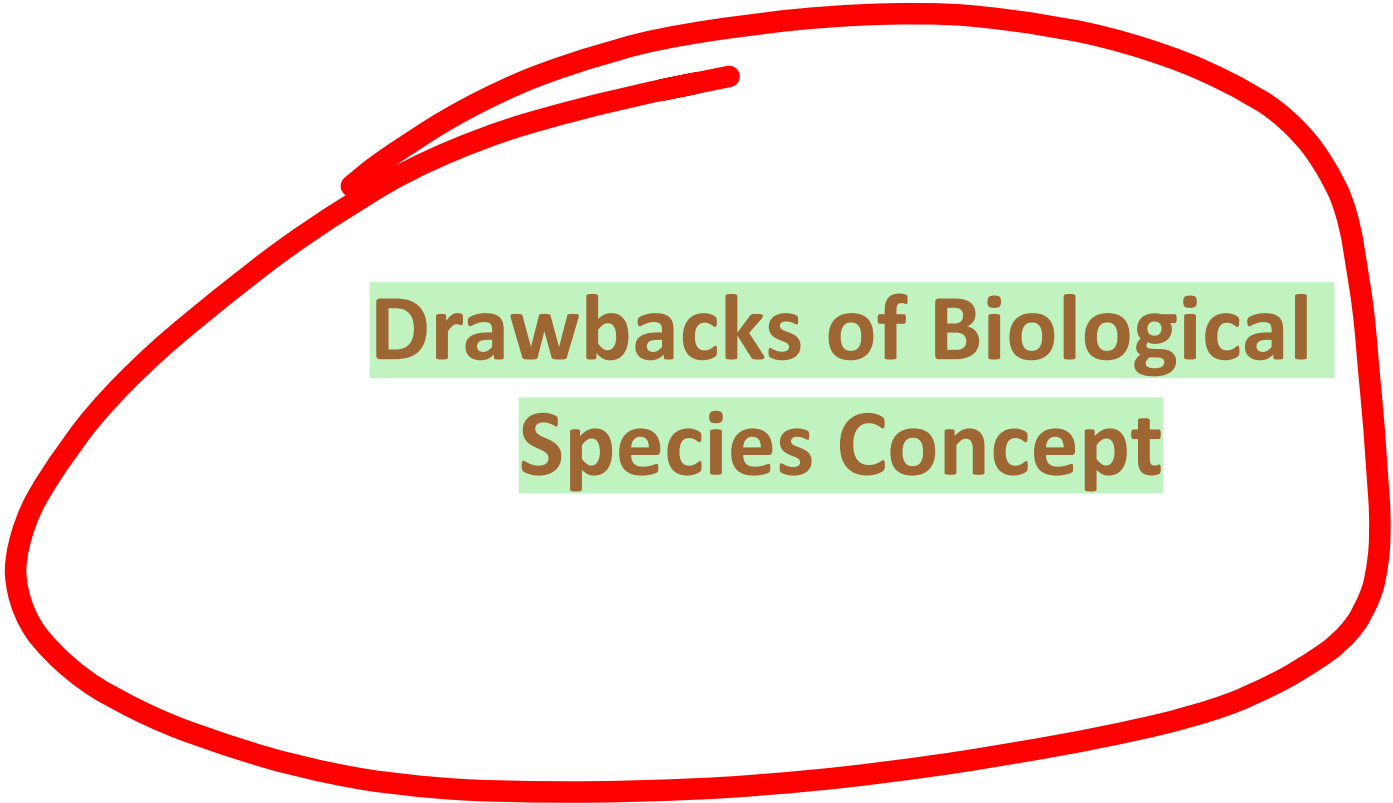


<https://www.youtube.com/watch?v=3Chz-XJHvNE>

Principles of Systematics

Module# 23

Principles of Systematics



Drawbacks of Biological Species Concept

Drawbacks of Biological Species Concept

Drawbacks

- Asexual reproducing organisms.
- Fossils
- Sibling or cryptic species
- Distinguishing between species on the basis of reproductive separation is problematic because reproductive isolation is often incomplete .

Drawbacks of Biological Species Concept

Asexual reproduction/Uniparental reproduction

- Not applicable on apomictic species
- Do not fulfill interbreeding criterion (Most important in BSC) 
- Apomictic groups (parthenogenesis, apomixis, budding etc)

Drawbacks of Biological Species Concept

Asexual reproduction/Uniparental reproduction

- Uniparental reproduction is Common in lower invertebrates and lower vertebrate
- Decedents are called agamospecies, binoms or paraspecies
- According to Mayr (1988a) these are not species

Drawbacks of Biological Species Concept

Sibling species/Cryptic species

- As they are morphological similar but reproductively isolated

Incompleteness of Speciation/fossil record

- Evolution is gradual and continuous process. However, fossil record is not complete

END

Principles of Systematics

Module# 24

Principles of Systematics

Drawbacks of Biological Species Concept

Drawbacks of Biological Species Concept

Interbreeding between two different species

- According to BSC two different species can not breed and produce fertile offsprings
- However, there are exceptions

Drawbacks of Biological Species Concept



<https://www.youtube.com/watch?v=3Chz-XJHvNE>

Principles of Systematics

Module# 25

Principles of Systematics

Evolutionary Species Concept

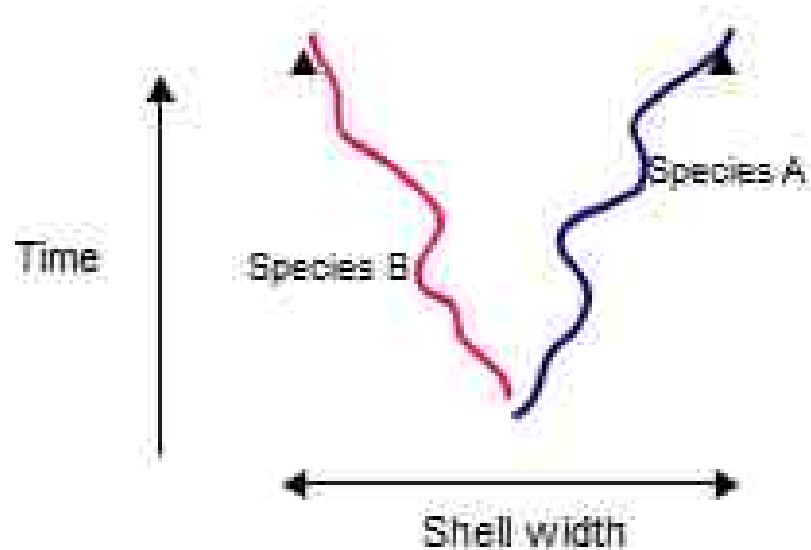
Evolutionary Species Concept

Evolutionary species concept

- Simpson (1940s)
- An **evolutionary species** “is a single lineage of ancestor-descendant populations of organisms which maintains its:
 - Identity from other such lineages [in space and time]
 - Own **evolutionary** tendencies
 - historical fate” (Wiley, 1981)

Evolutionary Species Concept

Evolutionary species concept



- Initially developed to define fossil species.
- Applicable to both sexually and asexually reproducing species and emphasizes common descent.

Evolutionary Species Concept

Drawbacks

- Arbitrary: how to define independent roles and tendencies.
- Does not provide mechanism.

END

Principles of Systematics

Module# 26

Principles of Systematics

Taxonomic Characters

Taxonomic Characters

Character

- It is any attribute of member of taxon by which it may differ from member of other taxon.
- A heritable trait possessed by an organism
- Characters are usually described in terms of **character states**.

Taxonomic Characters

Character state

- One of the variant conditions of a trait.
- **Binary states:** For example: "hair present" vs. "hair absent," where "hair" is the **character**, and "present" and "absent" are its **states**
- **Multistate characters:** Yellow, white or pink flowers or AGCT for nucleotide sequence data.

Taxonomic Characters

Qualities of key characters

- Apply to all member of taxon
- Fairly stable and durable
- Qualitative and absolute
- Detectable without special equipment's, dissection or histological preparations

Taxonomic Characters

Taxonomic Characters are illustrated as:

- Morphological character
- Physiological character
- Behavioral character
- Ecological character
- Geographic character
- Molecular and biochemistry character
- Ontogenetic character

END

Principles of Systematics

Module# 27

Principles of Systematics

Morphological Characters

Morphological Characters

Morphological Characters

Morphology describe the structural features. Morphological characters include:

- External morphology
- Genetelic structure
- Internal morphology
- Embryology
- Karyology and other cytological differences

Morphological Characters



https://tse2.mm.bing.net/th?id=OIP.k_dPDFg2fl7OVNpR7Y72-gHaDa&pid=Api&P=0&w=

General external morphology

The apparent features are easy to detect and observe.

e.g. Plumage of birds, scales of fish and reptiles, pelage of mammals, phylogenetically significant sutures and sclerites of arthropod body etc.

Morphological Characters



https://www.researchgate.net/profile/Aidas_Saldaitis/publication/321343778/figure/fig2/AS:568147356336130@1512468293710/Male-genitalia-and-leg-structures-of-the-C-katsumii-holotype_Q320.jpg

Genetalic structures

- The genital structure of each specie are different to depict the reproductive isolation.
- Used to delimit species
- Key and Lock model
- Highly effective insects
- Genetalic structures appear to be among the first to change in the course of speciation.

Morphological Characters

Coloration

- Color pattern and other aspects of coloration are convenient characters in certain group of animals.
- Bird and coloration except few genera with sibling species.
- Same is true or certain reef fishes and butterflies
- Many subspecies are indentified on the basis of colour

END

Principles of Systematics

Module# 28

Principles of Systematics

Morphological Characters

Morphological Characters

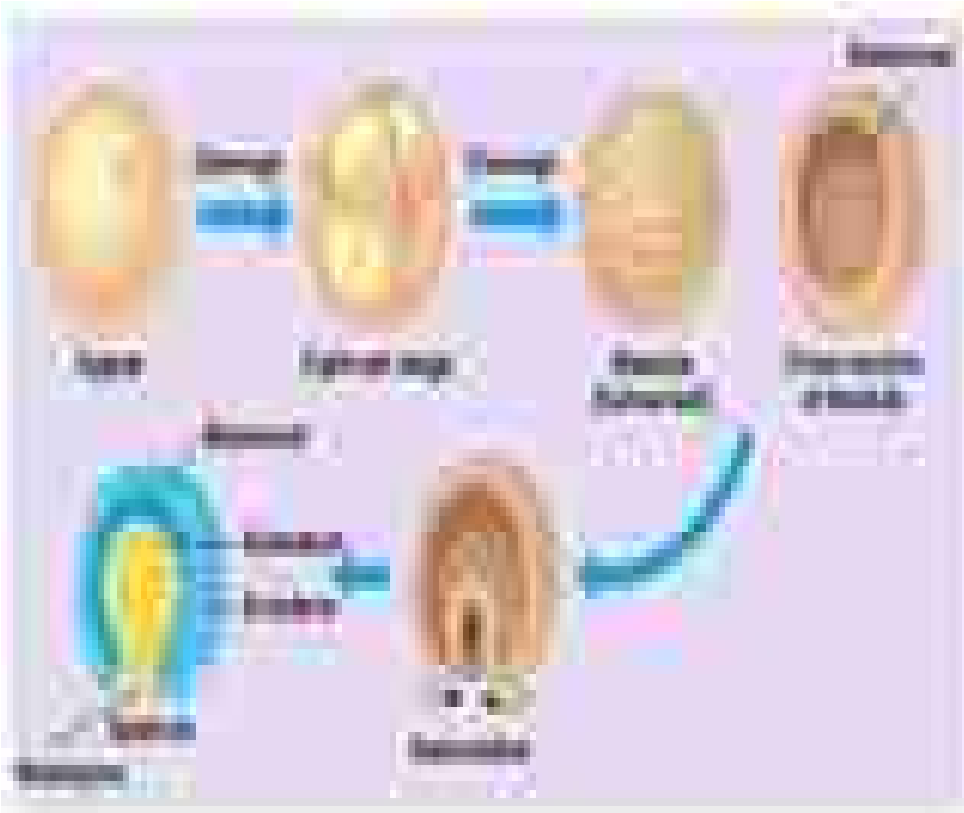
Internal morphology

- Internal anatomy provides Taxonomic Characters for all groups of higher animals.
- The extent to use vary from group to group.
- The skull is routinely used in classification of higher mammals.
- Teeth and bones of fossils and other hard parts.



<https://www.google.com/search?q=evolution+in+skulls+of+vertebrates>

Morphological Characters



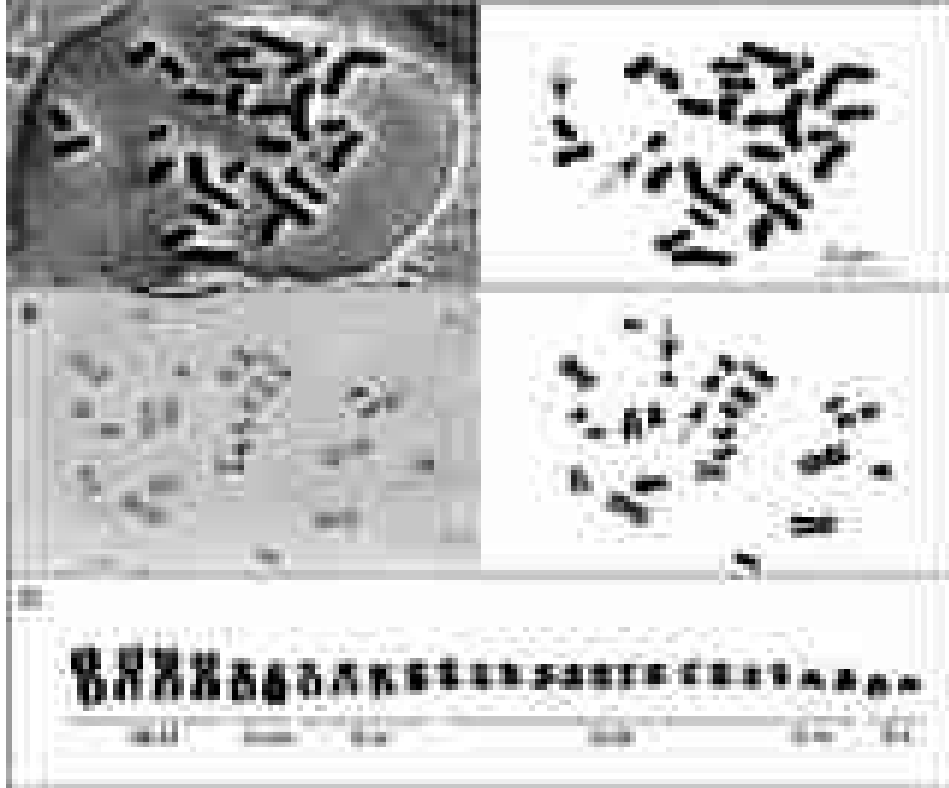
<https://i1.wp.com/orbitbiotech.com/wp-content/uploads/2018/04/embryonic-development-Orbit-Biotech-Training.jpg?ssl=1>

Embryology

Various larval stages, embryology and even eggs may provide taxonomic information.

- Sibling species of *Anopheles maculipennis*-----Egg structure
- Identification of white flies are based on pupae
- Comparative embryological stages like cleavage, blastulation, gastrulation etc are helpful

Morphological Characters



<https://www.liberaldictionary.com/wp-content/uploads/2019/02/karyology-4570.jpg>

Karyology and other cytological factors

- Karyology is description of size, shape and number of chromosomes
- The simplest cytological character is chromosomal number (species specific)
- Comparison of closely related species (sibling species)
- Establishing phyletic lineage

Principles of Systematics

Module# 29

Principles of Systematics

Physiological Characters

Physiological Characters

Physiological Characters

Physiological characters are low weight characters and are variable:

- All structures are product of physiological process and are thus physiological characters.
- This character can not be studied in preserved animals.

Physiological Characters

Physiological Characters

- Metabolic activities
- Body secretion
- Serological protein and other biochemical differences
- Genic sterility factor

Physiological Characters

Metabolic Factors

- Metabolic factors/enzymes help to find the relations in the closely related species

e.g. Gram +ive and Gram –ive bacteria

Physiological Characters



<https://thecotyledon.files.wordpress.com/2010/10/scale-honey.jpg>

Body secretion

Body secretions also have the consistent pattern

- Links can be created by finding the number
- Size and
- Structure of the glands

e.g. waxy secretion of scale insects

Principles of Systematics

Module# 30

Principles of Systematics

Physiological Characters

Physiological Characters

Serological protein and other biochemical differences

- Serology is concerned with the nature and interaction of antigens and antibodies.
- Antigens are the substances capable for inducing the formation of antibodies when introduced into the blood stream of animals.

Physiological Characters

- According to antibodies produced in response to the introduction of foreign antigen **Bovden** (1943)
- Protein antigens are conservative hereditary trait.
- Proteins of one organism react more strongly with the antibodies of closely related organism than more distantly related.

Physiological Characters

- Good precipitin technique are reveal the relative degree of biochemical similarity of protein antigens among organisms.

Physiological Characters

Genic sterility factors

- Reproductively incompatible species cannot reproduce new young one
- Only closely related species can hybridize successfully.
- As a result give genetically sterile species.
- Cross fertility in Dobkey and Hourse- Mule
- Cross fertility in ducts (species and genera)

END

Principles of Systematics

Module# 31

Principles of Systematics

Behavioral Characters

Behavioral Characters

Behavioral characters

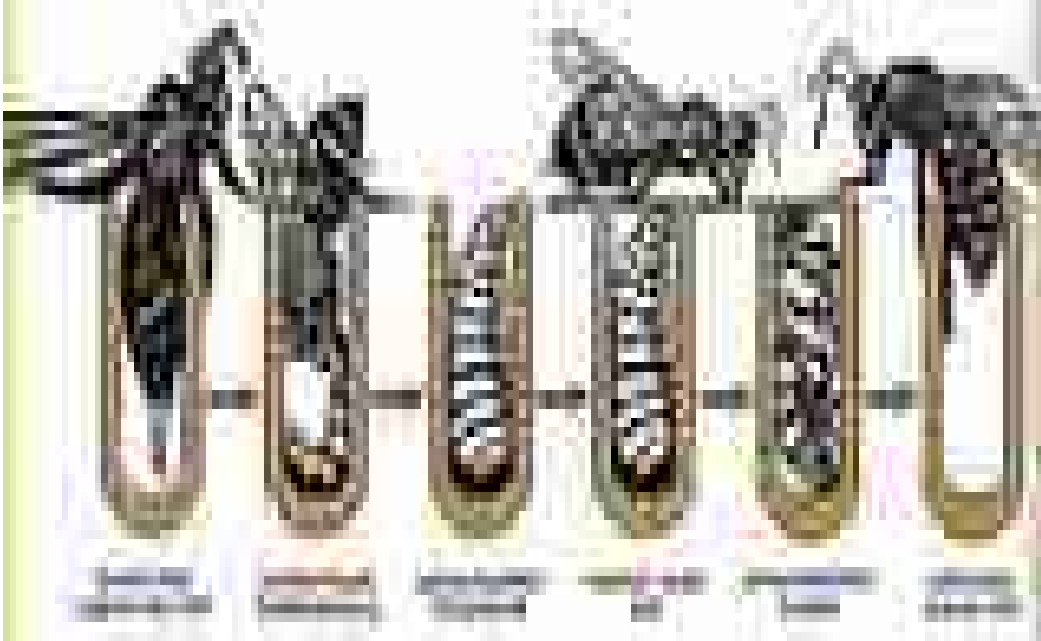
- Behaviour is one of the most important source of Taxonomic Characters.
- They are more superior than morphological characters in the study of closely related species.
- Especially in sibling species
- Mating behaviour, egg laying, nesting behaviour, drinking habit of birds etc.

Behavioral Characters

Behavioral characters

- Mating calls of frogs, toads and crickets are used in species delimitation.
- Webs pattern in spiders can be at various level in classification.

Behavioral Characters



<https://tse3.mm.bing.net/th?id=OIP.eubyf9OPir29CdF7wsFukQHaDO&pid=Api&P=0&w=392&h=171>

Reproduction

Mating and reproduction behavior of species help in taxonomic classification and also help in determining reproductive isolation and speciation.

E.g. slugs

Behavioral Characters



<https://media.buzzle.com/media/images-en/photos/birds/peacocks/1200-77866817-peacock-drinking-water.jpg>

Other behavior pattern

The living, eating and nesting behavior of the animals also depicts the taxonomic character

e.g. drinking habit of pigeon and sand grouse, use of mud in nest building

Behavioral Characters

Drawbacks

- Can not be studied in preserved material
- It is intermittent even in living animal.
- Some behaviours are seasonal
- Change within 24 hours

Principles of Systematics

Module# 32

Principles of Systematics

Ecological Character

Ecological Character

Ecological characters

- Each species has specific niche
- Types of niches
- Habitats and hosts environment
- Food sources
- Seasonal variation
- Parasite and host interaction reaction

Ecological Character

Habitats and host environment

- Habitat of the organisms is not same
- Species cannot coexist at same place or in same environment or partitioned their resource to avoid competition.

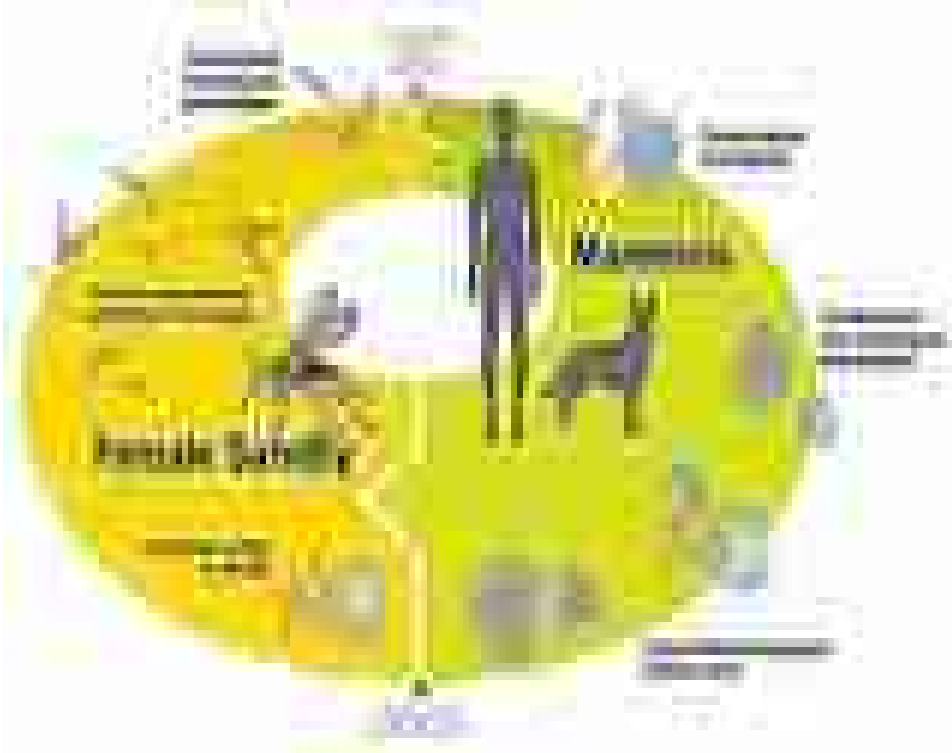
Ecological Character

Food and seasonal variation

- Food sources also varies like in parasites and many others.
- Characteristics of organism also vary depending on season

e.g. plumage of birds and breeding coloration

Ecological Character



<https://tse4.mm.bing.net/th?id=OIP.CDWG77aR8le8a2HGocriegHaEV&pid=Api&P=0&w=341&h=201>

Parasite and host interaction reaction

- Structural changes can occur in host after parasitic attack
- Various responses of body like distortion, swelling etc.

Principles of Systematics

Module# 33

Principles of Systematics

Ecological Character

Ecological Character

Ecological Character

- Every species has its own ecological niche in nature differing from its close relatives in (spider example)
- Food preference
- Breeding season
- Tolerance to physical factors
- Resistance to predators
- Compotators and pathogens

Ecological Character

Ecological Character

- Larvae of both *Drosophila mulleri* and *Drosophila aldriachi* live simultaneously in decaying pulp of the fruits of cactus *Opuntia lindheimeri*.
- Both species are specialized in using certain types of yeast and bacteria.

Ecological Character

Ecological Character

- Similarly tapeworms of man and rodents and *Ascaris* of man and pigs are host specific.
- Each species of Galapagos finch is also specialized according its habitat/ environments

END

Principles of Systematics

Module# 34

Principles of Systematics

Geographical Characters

Geographical Character

Geographical Character

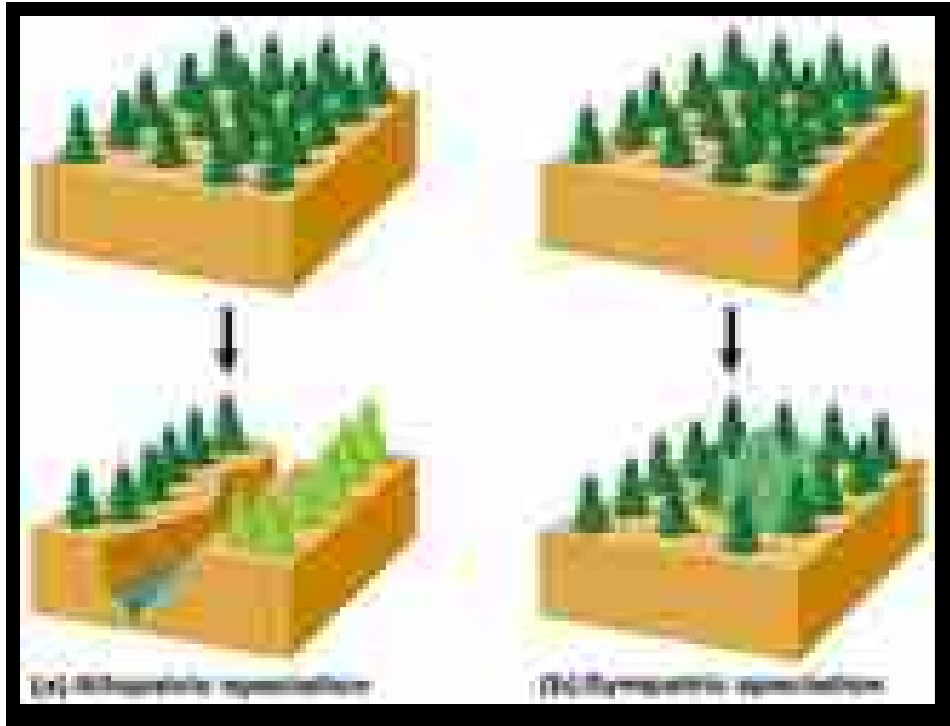
- Each taxon has a geographical range
- Range changes as the taxon evolve
- Distribution of taxa provide past history
- Geographic characters are important at two levels
- Microtaxonomy
- Macrotaxonomy

Geographical Character

Geographical Character

- Taxonomists are important in two types of geographical characters:
- General biogeographical patterns, which are especially useful in arrangement of higher Taxa
- Allopatric-sympatric relationship, which is helpful in determining whether or not two species are conspecific.

Geographical Character



Sympatric-allopatric relationship of population

These isolation pattern that occur in the population also determine the links in population

<https://s-media-cache-ak0.pinimg.com/736x/18/49/1c/18491ced4bf91ceac2f85a3fdee59a5f.jpg>

Principles of Systematics

Module# 35

Principles of Systematics

**Molecular and
biochemistry character**

Molecular and Biochemistry Character

Molecular and biochemistry character

This character as taxonomic character is also an approach for the evolutionary links and relations determines if classical taxonomy is defined.

Molecular and Biochemistry Character

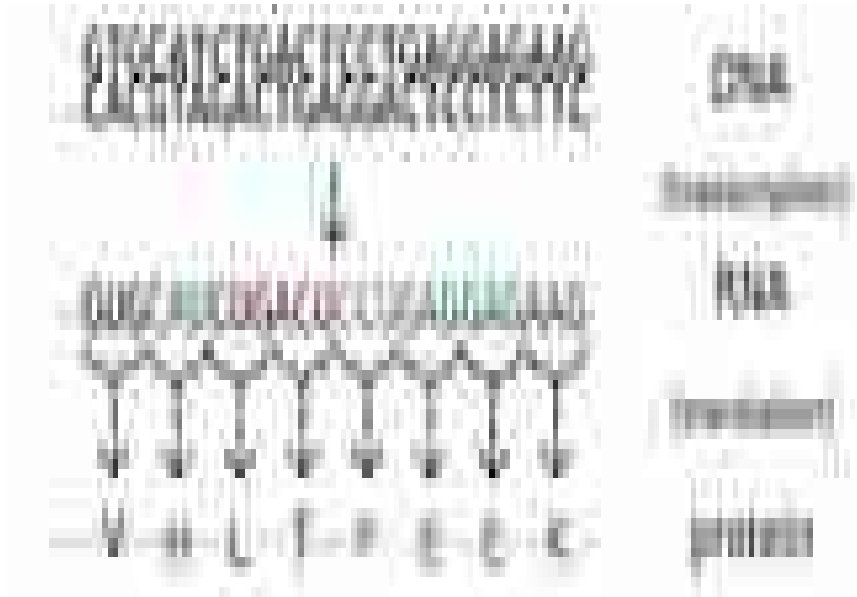
Molecular and biochemistry character

- Immunological distances
- Electrophoretic differences
- Amino acid sequence of protein
- DNA hybridization
- DNA and RNA sequence

Molecular and Biochemistry Character

Amino acid sequences

- Amino acid sequences help to determine the links.
- This approach as a taxonomic character is more absolute.



<https://tse2.mm.bing.net/th?id=OIP.Uo3B4dsPEz-PEzHf3uJ4OwHaCz&pid=Api&P=0&w=517&h=197>

DNA and RNA sequences

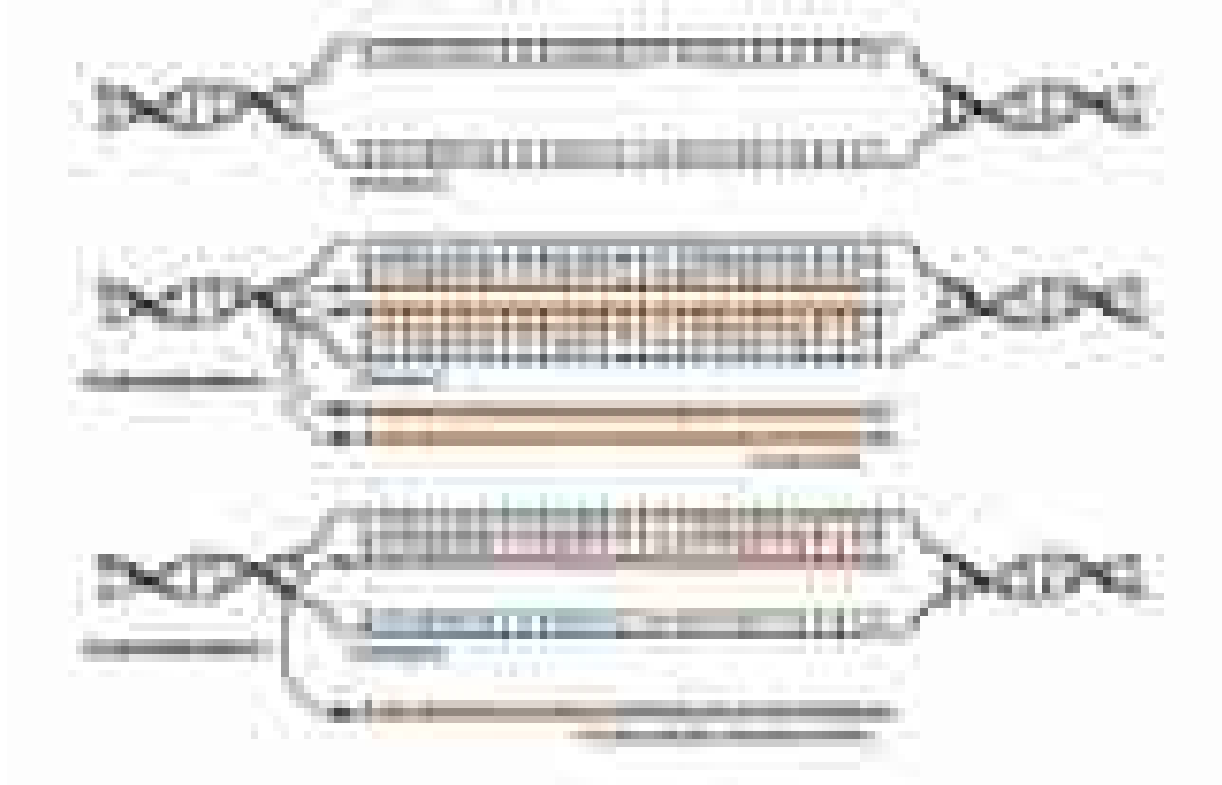
- These sequences help to determine the direct links on the basis of sequences
- But these sequences can also undergo some changes under the evolutionary pressure

Molecular and Biochemistry Character

Electrophoretic differences

- This method determine the difference in the isozyme and allozyme.
- Can help to determine share character among taxa.

Molecular and Biochemistry Character



<https://www.genome.gov/sites/default/files/tg/en/illustration/hybridization.jpg>

DNA hybridization

- This method is used to determine the genetic distance between two organisms
- Mainly measure the genetic similarity

Principles of Systematics

Module# 36

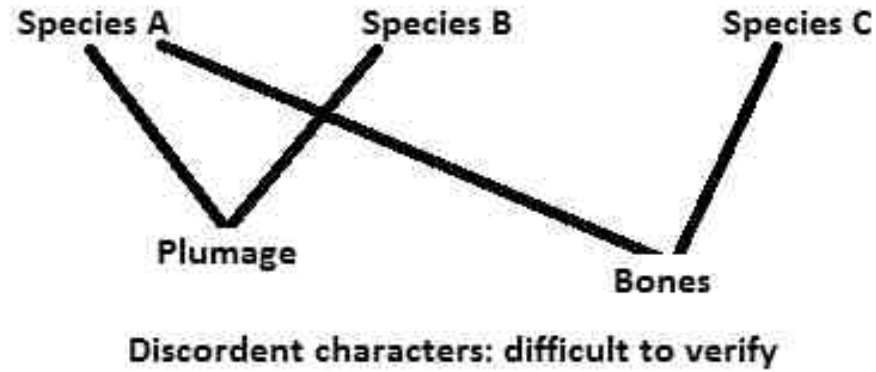
Principles of Systematics

Weighing of Characters

Weighing of Characters

- Any attribute by which member of a taxon differ
- Raw material of classification
- Amount of phyletic information contents in a given character
- More phyletic information----high weigh
- Low phyletic information---low weight

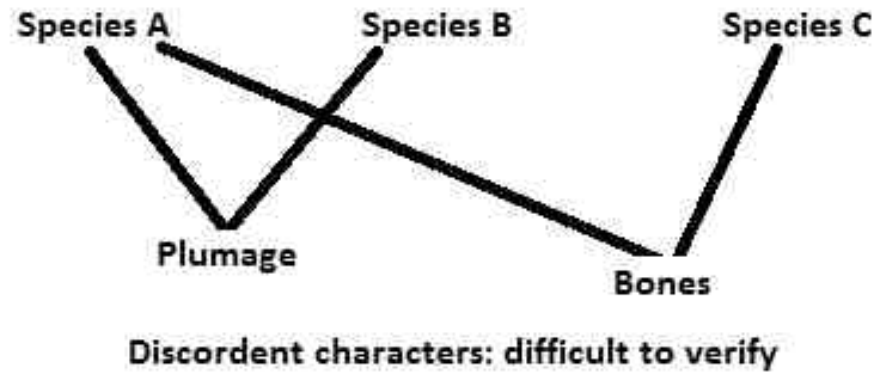
Weighing of Characters



- Animal character may of high weight ----mostly used by taxonomist
- Low weight---rarely used
- Also characters of intermediate weight
- Challenge for taxonomists which discordant character should be trusted?

Weighing of Characters

- Process to determine that which character is more reliable is called *weighting*.



Weighing of Characters

1. Priori (before/without phyletic information)

- Proposed by Aristototele

2. Posteriori

- Proposed by Adenson (after phyletic information collection)
- All classification is based on this model.

END

Principles of Systematics

Module# 37

Principles of Systematics

Correlated Characters

Correlated Characters

- Characters which are functionally correlated have very low weight
- They have low phylogenetic content
- Do not deserve to be treated as separate character
- Analogues organs birds wings, bats and insects (analogus)/convergent evolution
- Redundant

Correlated Characters

- Phyletic correlation
- High weight
- Higher genetic contents
- Diagnostic characters of
Deuterostomes and Chordates
(concordance)----phyletic
correlation—evolutionary related

END

Principles of Systematics

Module# 38

Principles of Systematics

High Weight Characters

High Weight Characters

High weight characters

- Complexity
- Constancy
- Consistency
- Not affected by ecological shift
- Apomorphy
- Not a specific adaptation
- e.g. Morphological and behavioral character

High Weight Characters

Complexity

- Complexity-Genitalia
- Deep genetic character
- Higher complexity-higher weight age

Constancy

- Character which is constant in a large group of species than variable character (Darwin 1859)
- According to Farris (1969) Low phenotypic variability be given high weight

High Weight Characters

Consistency

- A character which is consistently present in one group and consistently absent in related groups should have high weight

High Weight Characters

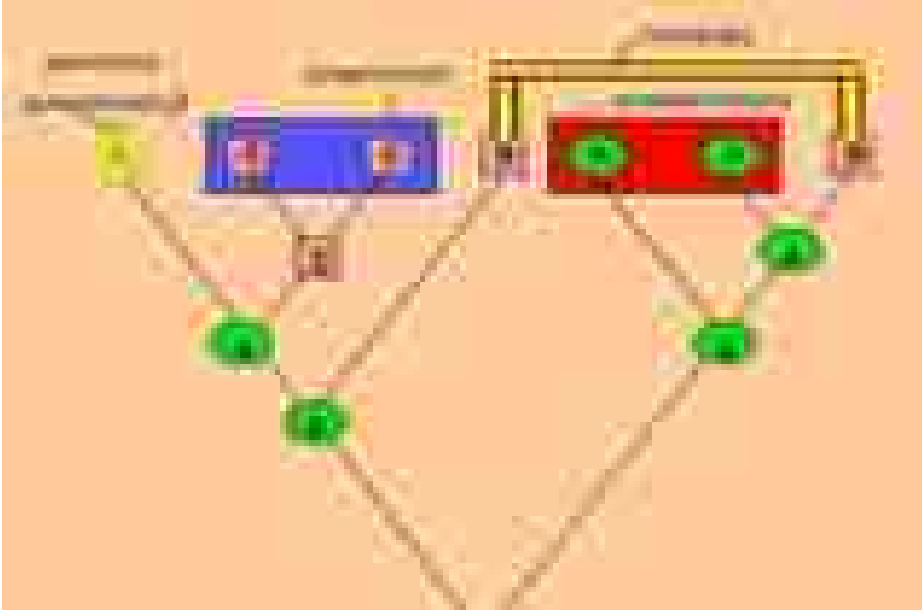


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Not affected by ecological shift

- A character that no change with ecology
- A bird feeding on fish in one habitat continue to feed on fish in another habitat
- An example is adaptation of mergansers (Mergus) for fish eating

High Weight Characters



https://www.google.com/search?q=apomorphy&sxsrf=ALeKk03Y_tzp73qJK0Em_Bfingu_YHOxiw:1603614144234&source=lnms&tbm=isch&sa=X&ved=2ahUKEwjbjLGbqM_sAhWzShUIHdkiB1oQ_AUoAXoECCAQAaw&biw=1360&bih=600#imgrc=GcYTyU7VcBY0LM

Apomorphy

- A novel evolutionary trait that is unique to a particular species and all its descendants and which can be used as a defining character for a species or group in phylogenetic terms.
- Hence, the possession of feathers is unique to birds and defines all members of the class Aves.

Principles of Systematics

Module# 39

Principles of Systematics

Low Weight Characters

Low Weight Characters

- Characters having less taxonomic importance
- Less phylogenetic content
- Not reliable
- Poor indicators of relationships

Low Weight Characters

- Highly variable Characters (hairs, branching pattern of arteries)
- Monogenic and oligogenic characters (albinism) varies independently of other characters

Low Weight Characters

- Regressive characters (loss of eyes, loss of wings, wing veins in insects, loss of teeth in mammals, loss of segments in segmented animals are unnatural.
- Loss may be due to environmental conditions (eye loss in cave, loss of digestive systems in parasitic tapeworms)
- Narrow specialization
e.g. Physiological character

Low Weight Characters

- Not constant
- Not consistent
- Change with ecology
- Less complex
e.g. Physiological character

END

Principles of Systematics

Module# 40

Principles of Systematics

Non-Genetic Variations

Non-Genetic Variations

Types of Non-Genetic variations

- Individual variations in Time
- Social Variations
- Ecological Variations
- Traumatic variation
- Post-mortem variations

Non-Genetic Variations

Individual variations in Time

- Age variations
- Seasonal variations of individuals
- Seasonal variations of generations

Non-Genetic Variations



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Age Variations

- Animals pass through large numbers of juvenile or larvae which are quite different from adult.
- Immature stage of eel (*Anguilla anguilla*) were originally described as *Leptocephalus brevirosteris* in 1856
- Larval stages different from adult (Caterpillar and butterfly)

Non-Genetic Variations

Seasonal Variations of individuals

- Same animal may have different appearance in different parts of the year
- In arctic and sub-arctic birds there may be change from white winter dress to normal colour summer dress.

Non-Genetic Variations



https://www.google.com/search?q=ptarmigan&sxsrf=ALeKk015nxwTbGZOdxCyoPYsK-TETw_DOA:1603517715139&source=lnms&tbn=isch&sa=X&ved=2ahUKEwjH3bT-wMzsAhVoQEEAHabtBjEQ_AUoAXoECCcQAw&biw=1360&bih=600#imgrc=sK318okbBMjJi

Rock ptarmigans (*Lagopus muta*)

- Gray and brown upper parts in summer
- White plumage in winter

Principles of Systematics

Module# 41

Principles of Systematics

Individual Variations

Individual Variations



https://www.google.com/search?q=european+starling+in+october&hl=en&sxsrf=ALeKk00IEQwoUE0nvDEAwcEeS_aFlcXkJg:1603518950740&source=lnms&tbm=isch&sa=X&ved=2ahUKEwil7MvLxczsAhV4UhUIHTdZA0QQ_AUoAXoECBYQAw&biw=1360&bih=600#imgrc=nUnihAZz9S-NkM

European Starling (seasonal variation)

- Freshly molted bird of October is covered with white spots and all feathers show whitish margins
- In winter edges of feathers wear off

Individual Variations

European Starling



- In spring (beginning of breeding season) whole bird is glossy black without the mold of single feather

<https://www.google.com/search?q=european+starling+in+spring%2C+glossy+black&tbm=isch&ved=2ahUKEwi6xauzsAhVC-4UKHZh3BakQ2-cCegQIABAA&oq=european+starling+in>

Individual Variations



https://www.google.com/search?q=bicycles+anyana+in+wet+season&tbm=isch&ved=2ahUKEwjQsK3DxszsAhULcxoKHfjYAKMQ2-cCegQIABAA&oq=bicycles+anyana+in+wet+season&gs_lcp=CgNpbWcQAzoECCMQJzoHCAAQsQMqqzoECAAQzoFCAAQsQM6AggAOgYIABAIEB5QyY0uWN6XL2CLmi9oAHAAeACAAegDiAGKRJIBCDItMjEuOC4xmAEAoAEBqgELZ3dzLXdpei1pbWfAAQE&sclient=img&ei=4cKTX5C8Novmafixg5gK&bih=600&biw=1360&hl=en#imgrc=zxMXuCnjPwLPSM

Seasonal variations of consecutive generations

- Seasonal plasticity
- These variations are called polyhenism.
- African butterfly *Bicyclus anyana*
- Eyespots on margins (ventral side)---- in wet season
- Very small or No eyespot ---Dry season

Principles of Systematics

Module# 42

Principles of Systematics

Social Variations

Social Variations

- In social insects there are definite groups of individuals in a colony.
- Each type of individual in a colony perform specific function.
- For examples in a colony of Honey bee:
- Queen, males (drones) and workers, soldiers

Social Variations

Social variations

- **workers:** All workers are females, product of fertilized eggs.
- They are in majority in the colony.
- May be from 10000 to 50,000 per colony.
- development.
- Projection of colony, food collection, feeding of queen, take care of young ones, cleaning of hive etc

END

Principles of Systematics

Module# 43

Principles of Systematics

Social Variations

Social Variations

Social variation in ants

- Ants live in complex social colonies.
- **Queen:** founder and leader of the colony.
- Primary goal is to populate colony .
- Lay thousands of eggs
- Queen chambers are deep within the colony for protection.
- Long life in some species upto 30 years.

Social Variations

Social variation in ants

- **Drones:** Only function is to fertilize female
- Die after fertilization
- Rarely encountered outside the colony
- **Workers:** Foraging and protection
- Sometime: queen lay eggs, winged male and females-**Alates or reproductive.**

Social Variations

Social variation in ants

- After maturation leave the colony in swarms.
- Establish new colony

END

Principles of Systematics

Module# 44

Principles of Systematics

Ecological Variations

Ecological Variations

- A. Habitat Variation
- B. Variations induced by climatic conditions
- C. Host determined variations
- D. Density dependent variations
- E. Allometric variations
- F. Neurogenic color variations

Ecological Variations

A. Habitat variation

- Populations of single species in different habitat are visibly different.

Oyster in still water

- Round or broader

Oyster in strong currents

- Narrow, elongated and usually straight

Ecological Variations

A. Habitat variation

Oyster in clean water on pebble

- Lower valve is deep and more or less sharply ribbed to acquire strength
- Not needed attachment is with perfectly flat surface

Oyster in muddy area

- Valves are less commonly ribbed

END

Principles of Systematics

Module# 45

Principles of Systematics

Ecological Variations

Ecological Variations

B. Variations induced by climatic conditions

- Animals with phenotypic plasticity
- Variations with temperature, draught, cold etc.

Ecological Variations



https://www.google.com/search?q=apanteles+flaviconchae&tbm=isch&ved=2ahUKEwjkg7Ob_czsAhUD8IUkHQs4BLsQ2-

C. Host determined variations

- Braconid wasp, *Apanteles flaviconchae* spin white cocoons if reared from blue green caterpillars of *Choliase philodice*
- Golden cocoons if reared from yellow green caterpillars of same species.

Principles of Systematics

Module# 46

Principles of Systematics

Ecological Variations

Ecological Variations

D. Density-Dependent variations

- When newly hatched nymphs of locust are reared under crowded conditions----**Gregarious phase**
- Less crowded condition---**Transitional phase**
- Separate rearing---**Solitary phase**
- These phase differ in anatomy, colour and behavioral characteristics----**distinct species**

Ecological Variations

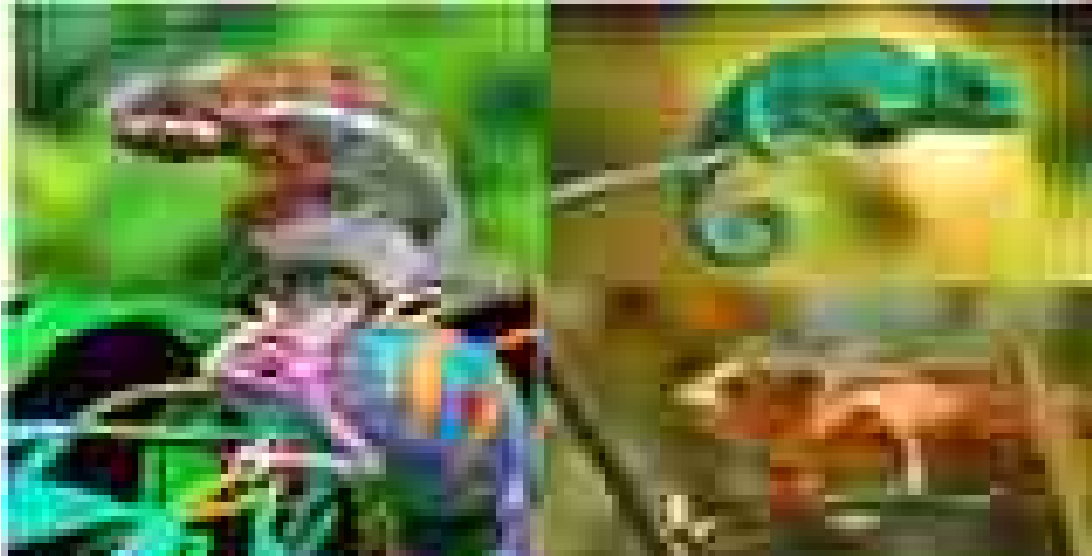


<https://www.google.com/search?q=allometric+variations&tbm=isch&ved=2ahUKEwjirbyKg83sAhXC4YUKHRKVBOwQ2-cCegQIABAA&oq=allometric+variations&gs>

E. Allometric variation

- Allometry results in misappropriate size of some structure in relation to rest of the body.
- This results in animals of different sizes----Allometric variability

Ecological Variations

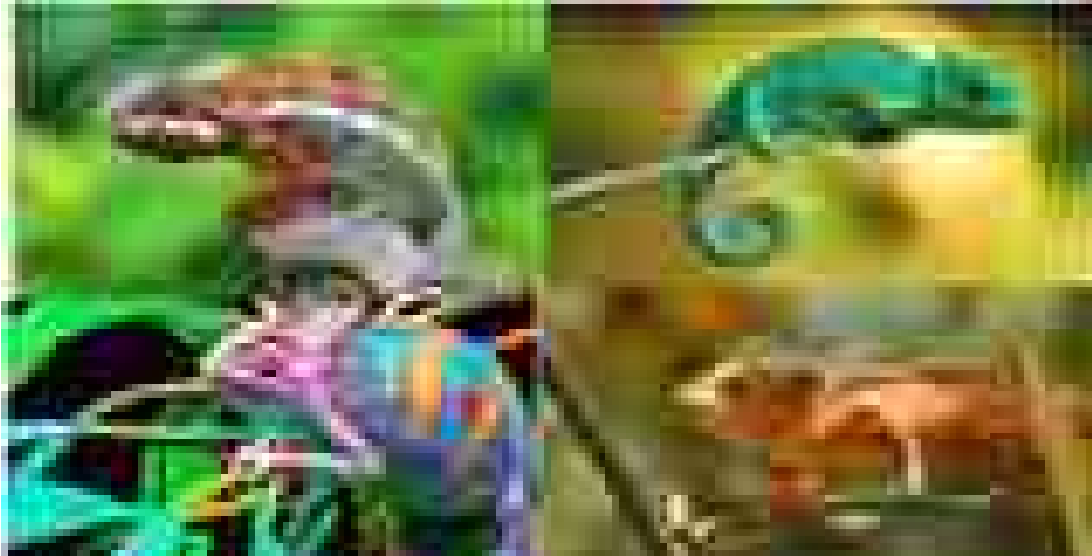


<https://www.google.com/search?q=chameleon&sxsrf=ALeKk03w9hngHVfxaApti0b4bszoZ9g->

F. Neurogenic variation

- It is colour change in response to environment.
- Chameleons have Chromatophores in three layers below their transparent skin.
- Xanthophores (Yellow) and erythrophores (red) in upper layer
- Iridophores or guanophores (blue or white) 2nd layer
- Melanophores (dark colour) in deep layer

Ecological Variations



<https://www.google.com/search?q=chameleon&sxsrf=ALeKk03w9hngHVfxaApti0b4bszoZ9g->

F. Neurogenic variation

- Chameleons change their colours in response to temperature and to camouflage.

Principles of Systematics

Module# 47

Principles of Systematics

Traumatic Variations

Traumatic Variations

- **Teratology** is the study of abnormalities of physical development.
- **Taratogen** are the toxic substances which cause abnormal development.
- Mercury, alcohol, lead, thalidomide
- Teratological variations are common in animals.

Traumatic Variations

- In those forms which undergo metamorphosis injury to an earlier stage may produce abnormalities which are not easily recognized.
- Important if abnormality is in characters of taxonomic importance.
- Modification in wing pattern

END

Principles of Systematics

Module# 48

Principles of Systematics

Post-Mortem Variations

Post-Mortem Variations



<https://www.google.com/search?q=twelve+wire+bird+of+paradise&sxsrf=ALeKk00Z6PMYPqESiQ3ZTFbrIC6T6hsR6Q:1603611950298&tbm=isch&source>

- It is impossible to prevent post-mortem changes in some animals.
- Deep yellow plumage of twelve wire bird of paradise----white

Post-Mortem Variations



<https://www.google.com/search?q=Chinese+jay+bird%2C+green&tbm=isch&ved=2ahUKEwiMgpaQocsAhUCYBoKHRVPDI0Q2->

- Chinese jay plumage changes from green to blue in collection
- Wasps over-expressed to cyanide turn bright red
- Insects
- Spiders

Principles of Systematics

Module# 49

Principles of Systematics

Genetic Variation

Genetic Variations

- Difference in the individual members of a population
- Genetic variations are important for survival and adaptation of species
- Evolution
- Natural selection

Causes of evolution

- Mutations
- Genetic recombination
- Genetic drift
- Migration

Genetic Variations

- Population s with small variation
- Population with large variability among individual
- Variability in characters
- Variability biological fitness

Major causes variability

- Mutations
- Genetic recombination
- Mutations are not always bad (Sickle cell disease—present Malaria) END

END

Principles of Systematics

Module# 50

Principles of Systematics

Types of Genetic Variation

Type of Genetic Variation

Sexual Dimorphism

Many of the variants in a population are sex-associated.

- They may be sex limited (express themselves in one sex only) or otherwise associated with one sex or the others
- Primary Sex differences (PSD)
Difference in primary sex organs such as gonads genitalia etc.)
- When two sexes are similar morphologically—PSD helpful

Type of Genetic Variation

Sexual Dimorphism

- Secondly Sex differences (SSD)
- Striking differences in male in females e.g bird of paradise, humming bird and ducks
- Due to differences different sexes were considered different species until painstaking works by naturalist established their relationship.
- Celebrated case of King parrot, *Eclectus roratus* (Muller)

Type of Genetic Variation



https://www.google.com/search?q=King+parrot+Eclectus+roratus+,+male+female&sxsrf=ALeKk02h0vVHJDTAOjHTEAE5PQB iERJ9_Q:1604040706059&source=lnms&tbm=isch&sa=X&ved=2ahUKEwirmfWj3dvsAhXBDGMBHZgZCBEQ_AUoAXoECBkQAw&biw=1360&bih=657#imgrc=kLDkWlLeXUZ6cM

King parrot *Eclectus roratus*

(Muller) of Papuan region

- Male is green with orange bill
- Female is red and blue with black bill.
- Described in 1776, two considered different for nearly 100 years
- Until naturalist proved conclusively in 1873 that they belonged together.

Principles of Systematics

Module# 51

Principles of Systematics

Types of Genetic Variation

Type of Genetic Variation



https://www.google.com/search?q=African+Ant+Dorylus+male+females&tbm=isch&ved=2ahUKEwiajc-y39vsAhUU_RoKHbZ2CW0Q2-cCegQIABAA&oq=African+Ant+Dorylus+male+females&gs_lcp=CgNpbWcQA1DywQFY1egBYJ_qAWgAcAB4AIAB_QOIAfQa kgELMC4xLjkuMi4wLjGYAQCgAQGqAQtn3Mtd2l6LWltZ8AB AQ&scient=img&ei=ObqbX9qMLpT6a7btpegG&bih=657&biw=1360#imgsrc=-C_HA25vlwfHRM&imgdii=kDy2tGctcC0wiM

Sexual Dimorphism

Striking sexual dimorphism in Hymenoptera.

- Males of African Ant *Dorylus* are so unlike others ants that they were not recognized as ants and considered belong to different family.
- In certain families of wasps small wingless females and large winged males are so different that some taxonomists use different nomenclature for both.

Type of Genetic Variation

Sexual Dimorphism

Some time males and females are so different that it is very difficult to decide which male belong to which female:

- Field study by ecologist
- Which male is attracted to which female

END

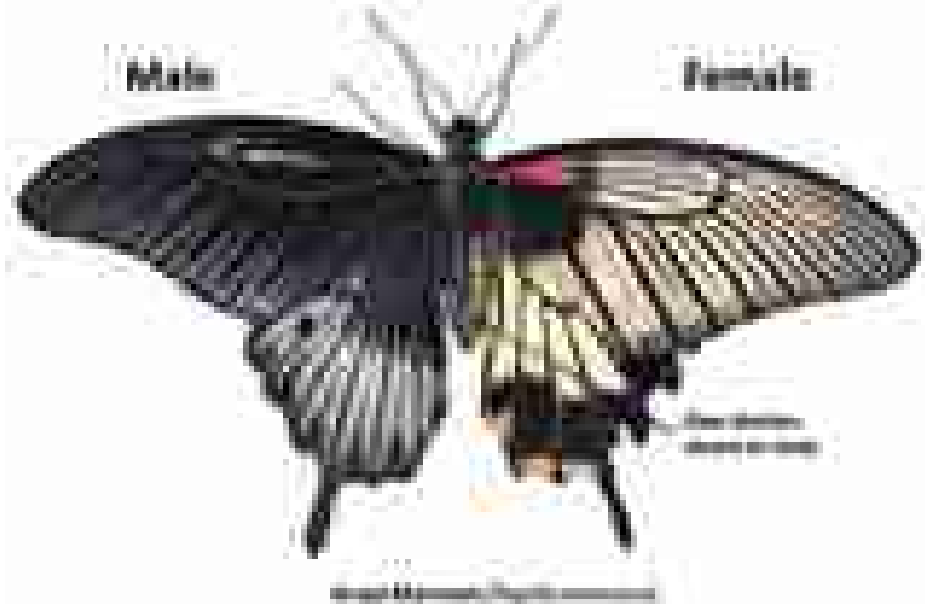
Principles of Systematics

Module# 52

Principles of Systematics

Types of Genetic Variation

Type of Genetic Variation



Gynandromorphs and intersexes

Individuals that show male characters in one part and female characters in other parts of body.

- Two halves of the body may be of opposite sexes.
- The division may be transverse or the sex characters may be scattered in mosaic.
- In later case symmetrical variants may be produced.
- Produced due to unequal distribution of chromosomes/SC

https://www.google.com/search?q=gynandromorph+of+papilio+adardanus&tbm=isch&ved=2ahUKEwiGuK-l5tvsAhWO0YUKHdbFCn4Q2-cCegQIABAA&oeq=gynandromorph+of+papilio+adardanus&gs_lcp=CgNpbWcQAzoECAAQZoCCABQoa0BWImWAmC8mQJoAHAAeAGAAYYJiAGNPpIBEDAuMi4xMS4yLjAuMS4yLjKYAQCgAQGqAQtnnd3Mtd2l6LWltZ8ABAQ&sclient=img&ei=dcGbX8apAY6jlwTWi6vwBw&bih=657&biw=1360#imgsrc=sCA1PSyDaBTaiM

Type of Genetic Variation



https://www.google.com/search?q=intersexes,+Example:+Lymantria&hl=en&sxsrf=ALeKk01diF3YZHp0xEbXUCJVibS92jJ0-w:1604043782080&source=lnms&tbm=isch&sa=X&ved=2ahUKEwi_udbe6NvsAhXiA2MBHQRuCRYQ_AUoAXoECAsQAw&biw=1360&bih=657#imgrc=_xPgprPy1k57CM&imgdii=Uia9hvBTpb27TM

Intersexes

Blending of male female characters.
body. Intersexes are produced due to:

- Upset in balance between male-tendency and female-tendency genes
- May result from irregularities in fertilization or mitosis
- Physiological disturbances associated with parasitism.
- Example: Gipsy moth, Lymantria

Principles of Systematics

Module# 53

Principles of Systematics

Types of Genetic Variation

Type of Genetic Variation



https://www.google.com/search?q=agemic+generation+gall+wasp&hl=en&sxsrf=ALeKk02oVJis8aalDyE2Y0wVwXJoadWcQ:1604054434479&source=lnms&tbm=isch&sa=X&ved=2ahUKEwiTu5G2kNzsAhXVh1wKHZ_ZBjoQ_AUoAXoECBkQAw&biw=1360&bih=657#imgrc=SO7OXhMqVG7A9M

Reproductively different generations

- In many insects there is an alternation of generations that is very confusing to the taxonomist.
- In cynips (gall wasp) agemic generation is different from bisexual one.
- In aphids parthenogenetic wingless females are different from winged females of sexual generation.

Type of Genetic Variation



https://www.google.com/search?q=Slugs,+Arion&hl=en&sxsrf=AleKk02zw1UrLr9HBnEK7giReGZMJt64pA:1604055019292&source=lnms&tbm=isch&sa=X&ved=2ahUKEwiOuv_MktzsAhWjnVwKHTUaB1MQ_AUoAXoECCUQAw&biw=1360&bih=657#imgrc=AKvOHe8xqdKJVM

Sexual and uniparental strains

- In some species of slugs (Arion) several strains are found which differ in their sexuality.
- Sexually reproducing strains are highly polymorphic in their enzymes
- While self fertilizing hermaphroditic strains are highly homozygous.

Type of Genetic Variation

Discontinuous variation (Polymorphism)

- Certain members of population have certain conspicuous characters.
- Such discontinuous individual variations is called polymorphism.
- Frequently controlled by single gene.
- Follow simple Mendelian inheritance.

Type of Genetic Variation



https://www.google.com/search?q=laddy+beeles%2C+spotted&tbm=isch&ved=2ahUKEwi0gs_PktzsAhVRlxoKHdwxAYwQ2-

- Spotting in lady beetles
- Industrial melanism in moths
- Understanding of polymorphism is helpful to taxonomists.
- More than 100 birds species names were given to morphs.

Principles of Systematics

Module# 54

Principles of Systematics

Types of Genetic Variation

Type of Genetic Variation

Continuous variations

- Most common type of individual variations is due to slight genetic differences among individuals.
- No two individuals (except monozygotic twins) in a population of sexually reproducing animals are exactly alike
- Morphologically or genetically
- Small difference/special techniques.

Type of Genetic Variation

Continuous variations

- Each characters may show a different degree of variability within a single population.
- Different degree of variability among related species.
- Why one species is highly variable while another is NOT?
- Answer this question required lot of background knowledge and research.

Type of Genetic Variation

Continuous variations

- Some early taxonomists vastly underrated individual variations in many genera of animals.
- Species of the snail genus *Melania* (fresh water and brackish water) have been described largely on the basis of shell characters as presence or absence of spines and diagonal versus spiral ribs.
- Revision showed 114 species were just because of individual variation.

Principles of Systematics

Module# 55

Principles of Systematics

Systematic Collection

Systematic Collection

Systematic collection

Systematic collection is a method of collecting valuable biological specimens and preserving them along with specimen documentations such as labels and notations. It possess various attributes:

- Raw material of classification
- Document earth's biodiversity
- Initially additional specimens of species—duplicates-exchange purpose

Systematic Collection

Systematic collection

- As there is variability in members of species
- Adequate sample of every population should be collected and preserved.

What is adequate?

- More material is needed in s species with strong individual and geographical variation than in uniform species.

Systematic Collection

Objective of study?

Simple study or genetic variability

- When population analysis is attempted dealing with size, proportions, coloration, or polymorphism large samples from numerous locations are needed.
- For example in fishes where each population of a species may vary in some metric characters (fin ray, vertebrae), a single specimen per locality would tell us little.

Systematic Collection

- Facilitate the process of researching relationships among and within different groups of organisms biodiversity
- We can use systematics to find out how insects are related to the rest of the invertebrates.

Systematic Collection

Preservation of collection samples

The collected samples are preserved by;

- Wet method and
- Dry method

Systematic Collection

Wet method

- Wet method of preservation involves the use of liquid preservatives to prevent deterioration.
- Chemicals like alcohols, formalin etc. are commonly used for specimen preservation. Animals belonging to phylum porifera, annelida, nematoda are mostly preserved by wet method.

Systematic Collection

Dry method

- In this method, specimens are preserved in dry state is a traditional method to place several kinds of insects in a box for an indefinite period allowing them to become dry.
- Not advisable for soft bodied insects.
- The process of pinning insect specimens is a dry method to preserve and display collections.

END

Principles of Systematics

Module# 56

Principles of Systematics

Systematic Collection

Systematic Collection

Importance of systematic collection

- Safe storage of historical material such as fossils
- Rarely found specimens
- Specimens of geographically inaccessible areas
- Extinct species specimens to place in museums for documentation
- Provide permanent record of faunas and floras from natural catastrophes

Systematic Collection

Importance of systematic collection

- Help in the verification of original data or for renewed study from new knowledge and technique
- The systematic method assumes the size of the population is available
- Aid in identification of organisms through comparison
- Teaching/Public Outreach:
stimulate interest in earth's

Systematic Collection

- Facilitate the process of researching relationships among and within different groups of organisms biodiversity
- We can use systematics to find out how insects are related to the rest of the invertebrates.

END

Principles of Systematics

Module# 57

Principles of Systematics

Collection Methods

Collection Methods

Collection methods

There are various collection methods to collect specimens

- Black light trap
- Sweep net
- Suction device
- De-Vac
- Pit fall method
- Aspirator
- Beating sheet
- Trawling
- Dipper
- Hand picking

Collection Methods



<http://mississippientomologicalmuseum.org.msstate.edu/images/traps/blacklight.sheet>.

Black light trap

- Entomologists often collect night flying insects using a black light and sheet.
- The black light is suspended in front of a white sheet.
- Insects attracted to ultraviolet light fly toward the light, and alight on the sheet.

Collection Methods



Black light trap

- **A:** Tying the rope between two trees
- **B:** Sheet and light are hung
- **C:** A quiet night of collecting

<https://mississippientomologicalmuseum.org.msstate.edu/collecting.preparation.methods/Blacklight.traps.htm>



Collection Methods



<https://ffs.ipm-info.org/wp-content/uploads/2015/05/Collecting-insects-with-a-sweep-net>.

Sweep Net

- Sweep nets are used to collect arthropods from long grass and other types of vegetation.
- This net is with round mouth and canvas bag fixed with a long rod.
- Its advantages lie in its simplicity and speed, and its ability to collect relatively dispersed insect species on top of the vegetation.
- It cannot be used on very short vegetation.

Collection Methods



Suction device/De-Vac

- Used for collection of arthropods from vegetation, long grasses, forest, orchards etc.
- Engine operated.
- Large scale insect collection.

https://www.google.com/search?q=suction+device+for+insect+collection%2F+devac&tbm=isch&ved=2ahUKEwikjtP_hN7sAhUKahoKHTraDt0Q2

Principles of Systematics

Module# 58

Principles of Systematics

Collection Methods

Collection Methods

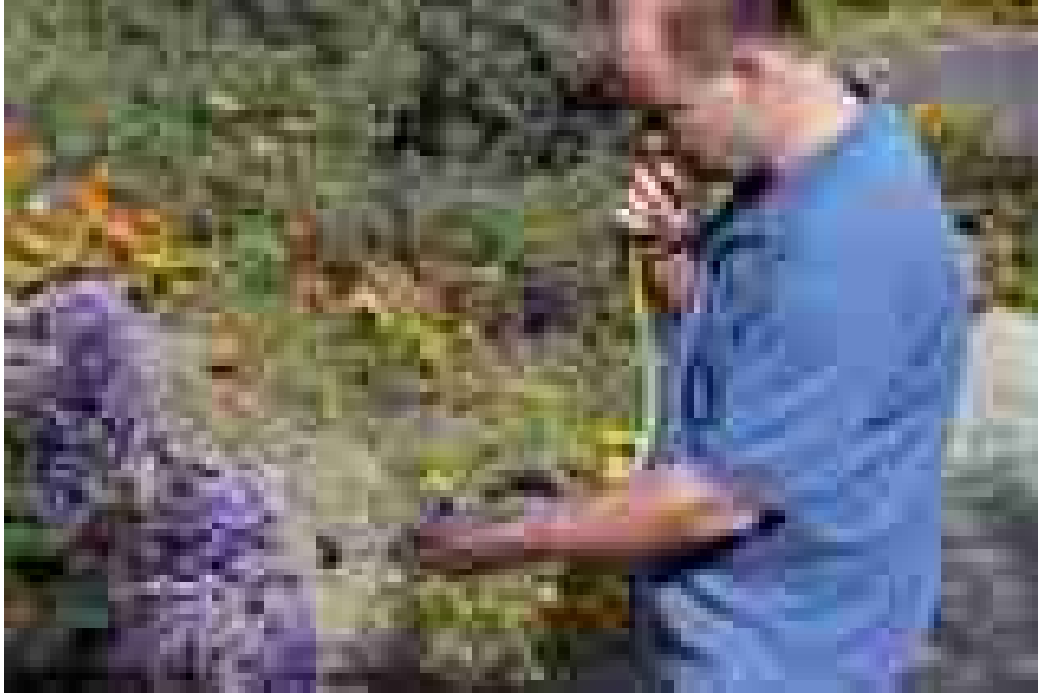


https://upload.wikimedia.org/wikipedia/commons/b/b2/Barber_pitfall_trap

Pit Fall Method

- In this method, the insect falls into a pit, a container that is buried in the soil.
- The pitfall trap catches ground-dwelling insects.
- Glass jar is buried in soil with its rims at the level of ground.
- Filled with formalin/alcohol
- Detergent drops to break surface tension
- May be covered

Collection Methods

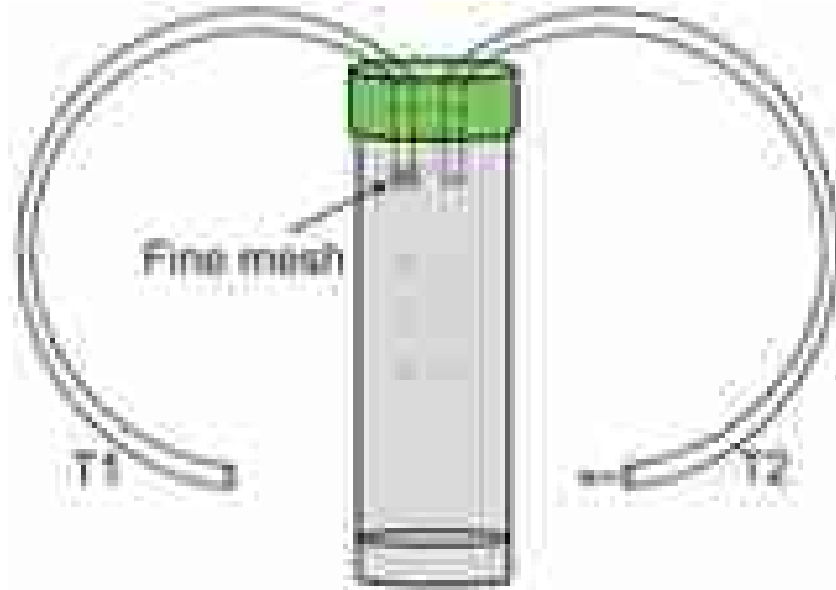


Aspirator

- Small insects or insects in hard to reach places, can be collected using an aspirator.
- The aspirator is a vial with two pieces of tubing, one with a fine screen material over it.
- By sucking on one tube, you draw the insect into the vial through the other.

<https://bioquipinc.com/wp-content/uploads/2017/05/%C3%92Pooter%C3%93-Style-Aspirator-4>

Collection Methods



Aspirator

- The screen/fine mesh prevents the insect or anything else unpleasant from getting drawn into your mouth.

<https://www.google.com/search?q=aspirator%2C+i nsect+colection&tbm=isch&ved=2ahUKEwiNwOKFi N7sAhUI7xoKHS47DLQQ2- cCegQIABAA#imgrc=7omrJPNCN0eAqM>

Principles of Systematics

Module# 59

Principles of Systematics

Collection Methods

Collection Methods



<http://www.nzffa.org.nz/images/design/beatingbig.jpg>

Beating Sheet

- To study insects that live on branches and leaves, like caterpillars, a beating sheet is a tool to use.
- Stretch a white or light-colored sheet below the tree branches. With a pole or stick, beat the branches above.
- Insects feeding on the foliage and twigs will fall down onto the sheet, where they can be collected.

Collection Methods



<https://bharatabharati.files.wordpress.com/2015/03/bottom-trawling.jpg?w=460&h=260>

Trawling

- Trawling is a method of fishing that involves pulling a fishing net through the water behind one or more boats.
- The boats that are used for trawling are called trawlers or draggers
- In Trawling baited fishing lines are drawn through the water.
- Trawling is commonly used as a scientific sampling, or survey method for marine specimens.

Collection Methods



<https://www.researchgate.net/profile/Richard-Nisbett/publication/265226839/figure/download/fig15/AS:669421387382787@1536613904116/Dipper-for-the-collection-of-mosquito-larvae-41.jpg>

Dipper

- The most commonly used larval collection method is the "standard dipper."
- Estimates of larval density can be carried out by counting the number of mosquito larvae per dip, using a standard 1-pint dipper.
- A minimum of three to five dips should be completed at each site.

E.g. collection of mosquito larvae

Principles of Systematics

Module# 60

Principles of Systematics

Curation of Collection

Curation of Collection

- A **curator** is a person who manages, administers or organizes a collection for exhibition.
- A museum curator is custodian of collection of museum and is responsible for their management.
- **Curation** is process of identification and organization animal collection.

Curation of Collection

- All types of museums have at least one curator.
- A large museum may employee several curators
- Each have specialization in particular fields.
- American Museum of Natural History (AMNH), New York
- Housing of collection in fire free buildings that are dust proof
- Air-conditioned Building

Curation of Collection

Cataloging

- Museum number
- Original field number
- Scientific Name (at least generic name)
- Exact locality
- Date of collection
- Name of Collector
- Remarks
- Card systems/electronic data processing
- Exchange of materials

END

Principles of Systematics

Module# 61

Principles of Systematics

Important Properties of Taxa Names

Important Properties of Texa Names

Three important properties

- Uniqueness
- Universality
- Stability

Important Properties of Texa Names

Uniqueness

- Names of an animal gives immediate access to all known information about that taxon.
- Every names has to be unique
- If several names---clear cut method should be there to determine valid name.
- Principle of priority usually decides in case of conflict.

Important Properties of Texa Names

Universality

- Scientific communication would be very difficult if there were only vernacular names for animals.
- Specialist would have to learn the name of texa in different languages in order to communicate with each other.
- Zoologist use single language

Important Properties of Texa Names

Stability

- A name should be stable
- Any change of a well-established name is likely to produce confusion and impede information retrieval.
- Even a principle of priority can be set aside by International Commission on Zoological Nomenclature in cases where stability is threatened.

END

Principles of Systematics

Module# 62

Principles of Systematics

Type Specimen

Type Specimen

- A type is a specimen (or a group of specimens) which serves to illustrate the defining characters of a species or genus.
- A type is a specimen serve as a reference which can be used by later scholars to verify the identity of species being described.

Type Specimen

- Precise collecting locality and other relevant data on the labels of specimen.
- Sex
- Developmental stage or form to which the type is referable
- In the case of parasites, the name of host species

Type Specimen

- Name of collector
- Specimens numbered
- Altitude of the type locality or depth in meters below sea level at which the holotype was taken
- In the case of fossils species, geological horizon

Type Specimen

- Type designation or fixation should always be completed before publication
- Type designation should be clear and unambiguous
- The deposition and museum number of the type always be recorded

END

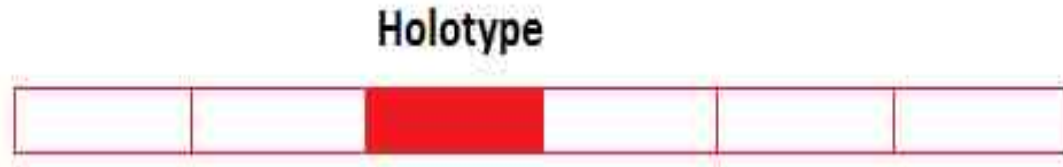
Principles of Systematics

Module# 63

Principles of Systematics

Kinds of Type Specimen

Kind of Type Specimens



Holotype

- A single specimen designated or indicated as the type by the original author at the time of publication of the original description of a species”
- If no specimen designated or indicated as the type by the original author but it is clear that only one specimen was used for description then it will be considered as Holotype.

Kind of Type Specimens

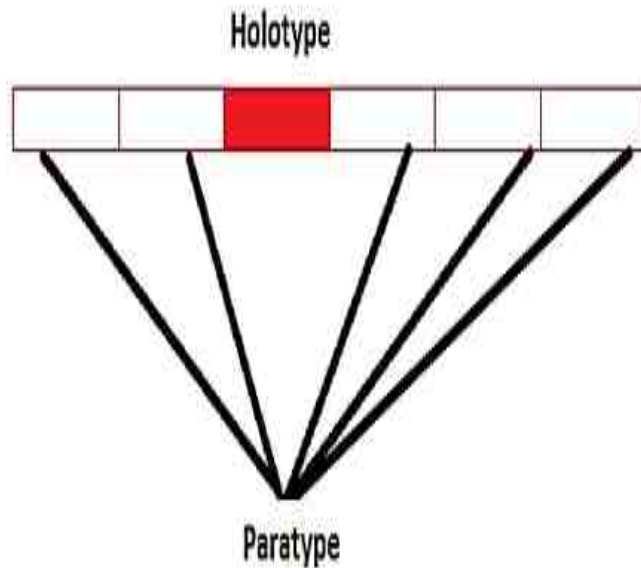
Holotype

- For a species described after 1999, holotype must be designated.

Holotype



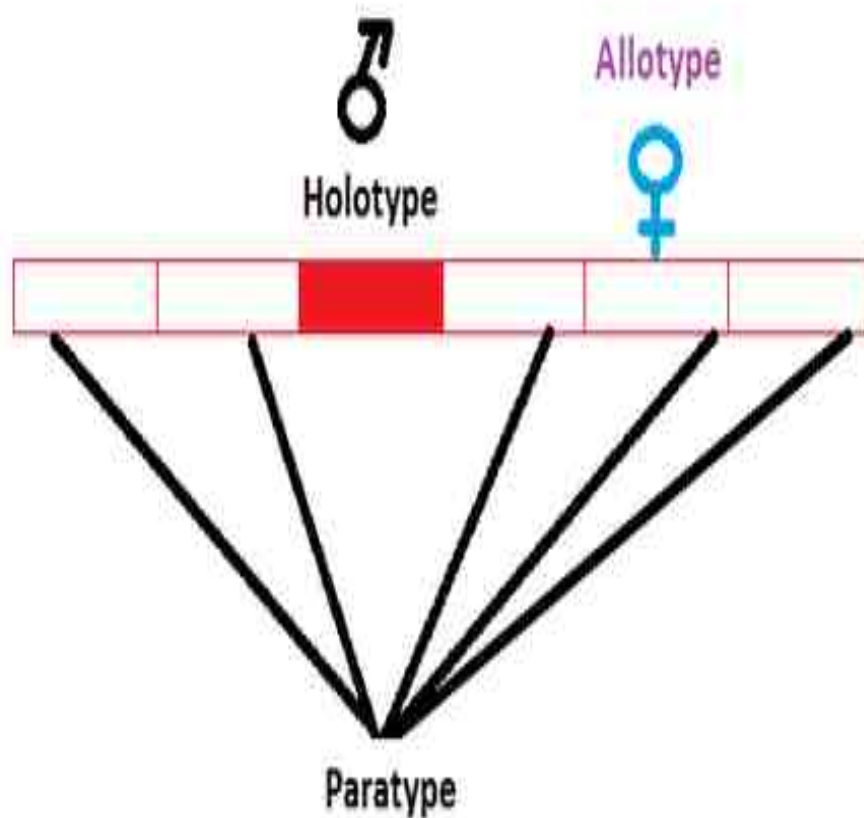
Kind of Type Specimens



Paratype

- The specimen other than the holotype, which has been used in the description.

Kind of Type Specimens



Allotype

- A specimen of opposite sex as the holotype, which has been used in the description.
- It is often used to describe a morphological character not shown in the Holotype

Principles of Systematics

Module# 64

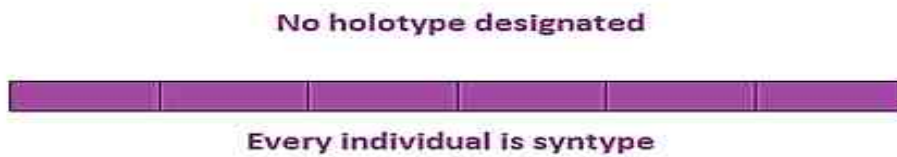
Principles of Systematics

Kinds of Type Specimen

Kind of Type Specimens

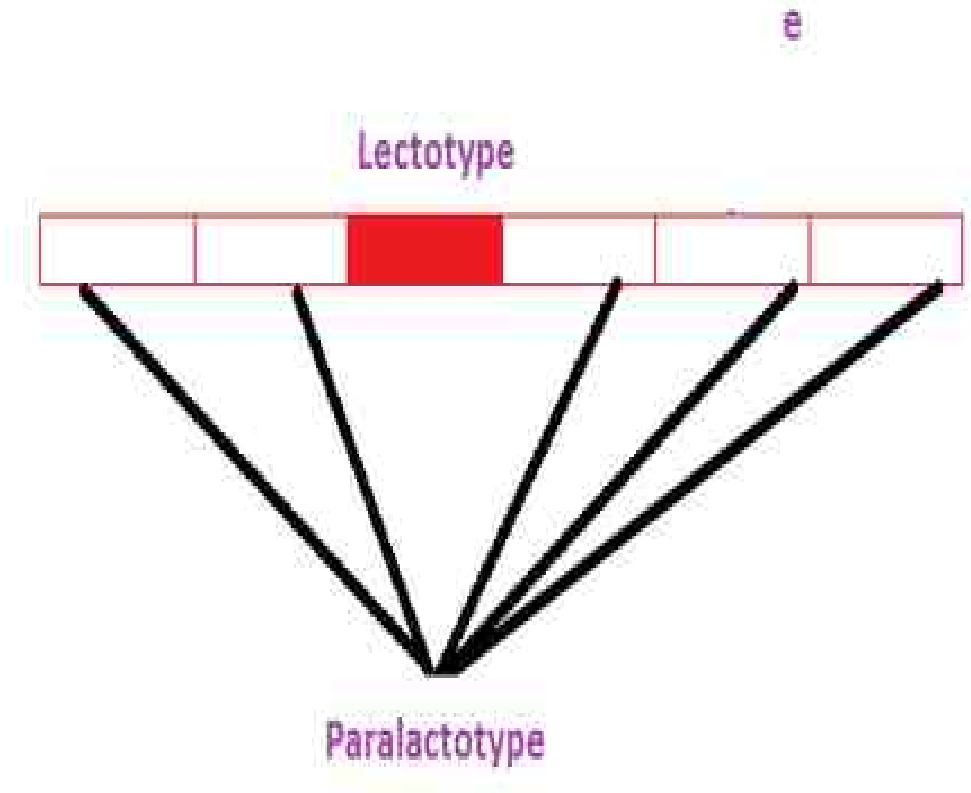
Syntype

- When description is based on two or more specimens, no holotype was designated, every specimen in a type series will be syntype



Kind of Type Specimens

Lectotype/Paralectotype



Kind of Type Specimens

Neotype

- A specimen selected as a type subsequent to the original description in the cases where the original types are known to have been destroyed or suppressed by commission

Kind of Type Specimens

Isotype

- A specimen that is a duplicate of holotype or very similar to the type specimen collected at the same time but not from same place as holotypes, paratype or syntype and not included in any of these.
- Can be used as a reference specimen if the type specimen is lost.

Kind of Type Specimens

Monotype

- When holotype of the species is the only specimen known to science, it is known as monotype.

END

Principles of Systematics

Module# 65

Principles of Systematics

Type Locality

Type Locality

- Place of collection of Holotype and lectotype.
- Paratype can be from different locality to holotype.
- Specimens collected at type locality are called **Topotypes**.
- Population that occur at type locality is called **Topotypical population**.

Type Locality

- In the case of parasites, the term type host is used to indicate the host organism from which the type specimen was obtained.
- Importance of type locality

END

Principles of Systematics

Module# 66