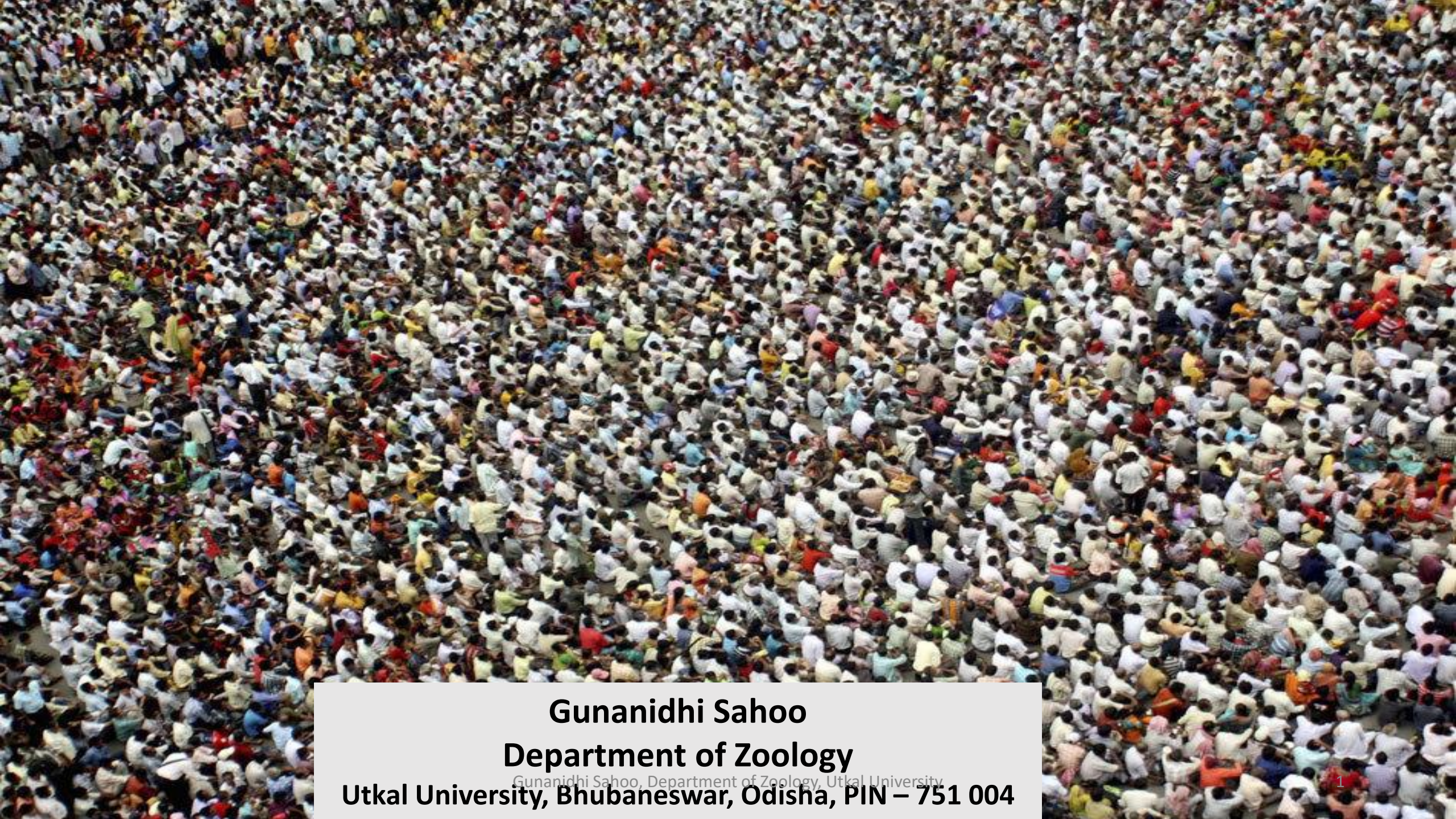

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SPECIES CONCEPT

1. **Individual organisms can usually be recognized, but the larger units we use to describe the diversity of life, such as populations, subspecies, or species, are not so easily identifiable.**

2. **The justification for these group terms is utility, rather than intrinsic naturalness.**

3. **Total No. of species (expected) on earth: 3-10 million.**

   Total No. of species described till date: 1.7 million.

4. **Most recent authors suggest that species are more objectively identifiable, and thus more "real" than, say, populations or genera.**

WHAT IS A SPECIES?




1. Species = Latin for “kind” or “appearance”.
2. Linnaeus described species in terms of their morphology.
3. Modern taxonomists also consider genetic makeup and functional and behavioural differences when describing species.

The species Problem, Ernst Mayr (Editor); American Association for the Advancement of Science, Publ. No. 50, 1957. 395 p.

- **Confusion:** Species is man's creation OR Species is a product of evolution
- **Cuvier (1829):** The assemblage descended from one another or from common parents, and of those who resemble each other.
- **Darwin (1859):** Could not define species properly.
- **Thompson (1937):** The group of individuals distinguished by an irreducible set of constant properties and connected by descent and genetic relationship.
- **Dobszhansky (1937):** That stage of evolutionary process at which the once actually or potentially interbreeding array of forms becomes **segregated** in to two or more separate arrays which are physiologically incapable of interbreeding.
- **Borgmeier (1963):** Species is a natural phenomenon and biological unit based on objective facts.
- **Wilmoth (1967):** A well defined autonomous and persistent organic unit, living in a free state of nature, not grading freely into any other unit, and generally of less perfect fecundity outside than inside its limits.

Mayr (1957) reviewed the species problem and concluded that all these definitions given so far can broadly fall into 3 main concepts –

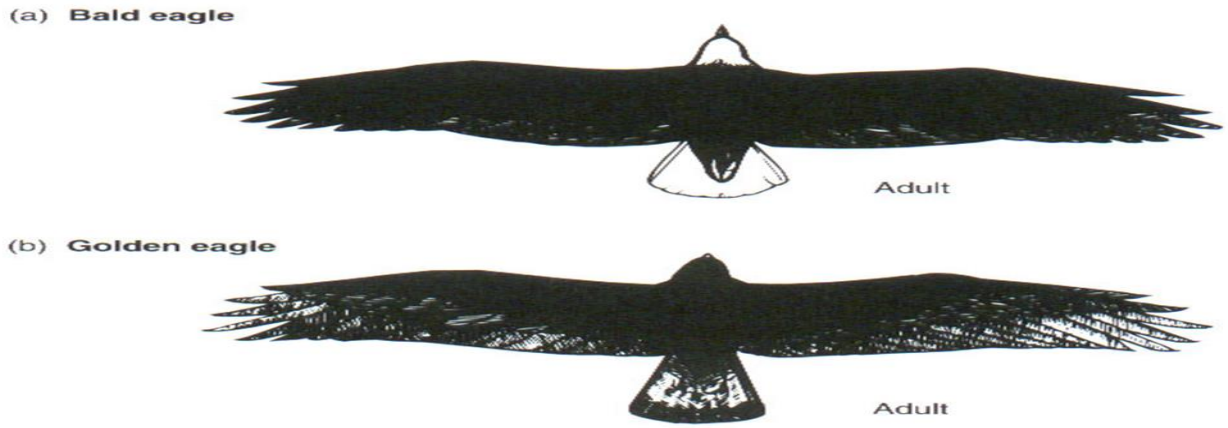
- **Typological or essentialist species concept**
- **Nominalistic species concept**
- **Biological species concept**

Godfray & Marks (1991): Species is a fundamental unit of biology

SPECIES IN THEORY AND PRACTICE

1. Biologists have not been able to agree on exactly what a species is, or how species should be abstractly defined - the controversy is theoretical, not practical.
2. Under most circumstances, there are no practical problems when defining species.

(a)Adult bald eagle (*Heliaeetus leucocephalus*) and (b) the golden eagle *(Aquila chrysaetos)* seen from underneath. The species can be distinguished by their pattern of white coloration.



3. Practical problems do arise when

i. Species are recognized and identified based on phenotypic characters.

ii. Variation poses most of the practical problems of species recognition using phenotypic characters.

iii. Geographic variation creates difficulties.

CRITERIA FOR SPECIES CONCEPT

1. Universality (generality)

A single way exists to divide the living world into kinds which are organised by a single hierarchy of laws.

2. Applicability (operability)

Species must be defined by taking into account the sort of data available.

3. Theoretical significance (explanation)

Species and the characters on which they are based provide evidence to arrive at a theoretical explanation.

SPECIES CONCEPTS

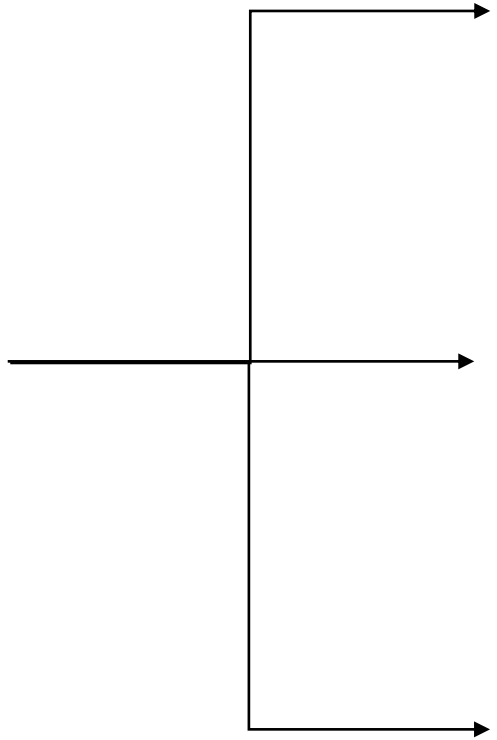
1. Much of conservation, biodiversity studies, ecology, and legislation concerns this taxonomic level. It may therefore seem rather surprising that biologists have failed to agree on a single species concept.

2. The pre-Darwinian species concept (of Linnaeus) was **essentialistic**.

3. Number of species concepts in use today.
   (a) Mayden (1997) identified no less than **24 species concepts**.
   (b) Many of these concepts dwell on the **same ideas**.

1. Agamospecies Concept;
2. Biological Species Concept
3. Cladistic Species Concept
4. Cohesion Species Concept
5. Composite Species Concept
6. Ecological Species Concept
7. Evolutionary Significant Unit
8. Evolutionary Species Concept
9. GenealogicalConcordance Concept
10. Genetic Species Concept
11. Genotypic Cluster Concept
12. Hennigian Species Concept
13. Internodal Species Concept
14. Morphological Species Concept
15. Non-dimensional Species Concept
16. Phenetic Species Concept
17. Phylogenetic Species Concept (Diagnosable version)
18. Phylogenetic species concept (Monophyly version)
19. Phylogenetic Species Concept (Diagnosable and monophyly version)
20. Polythetic Species Concept
21. Recognition Species Concept
22. Reproductive Competion Concept
23. Succesional Species Concept
24. Taxonomic Species Concept

Three main breeds of species concepts



Similarity Concepts

Overall similarity and/or gaps in character distributions (MorphSC, PhenotSC, TaxSC,...)

Evolutionary Concepts

Theoretical commitment to evolutionary theory (BioSC, EcolSC, EvolSC, RecogSC, CohSC,...)

Phylogenetic Concepts

Commitment to phylogenetics (CladSC,PhyloSC,...)

Typological or Morphological species concept

***"Species are the smallest groups that are consistently and persistently distinct, and distinguishable by ordinary means"* (Cronquist, 1978).**

1. **Species traditionally have been described and identified on the basis of morphological criteria, a classification system referred to as the morphological or typological species concept.**

2. The smallest natural populations permanently separated from each other by a **distinct discontinuity in heritable characteristics** (e.g. morphology, behavior, biochemistry).

Species are distinct, unchanging entities defined by unique, morphological features.

The species can be recognized by their essential natures or essential characters, and these are expressed in their morphology.

This concept advocates that

- The species is **completely constant through time,**
- It is separated from other species by a **sharp discontinuity,**
- There are strict limits to the possible variation within any one species,
- The species consists of **similar individuals sharing the same fundamental nature.**

According to this concept, the observed diversity of the universe reflects the existence of a limited number of underlying ‘universals’ or ‘types’. Individuals do not have any special relation to each other as they are merely expression of the same type.

(a)P. cornutum

(b)P. coronatum

(c)P. douglassi

(d)P. m'calli

(e)P. modestum

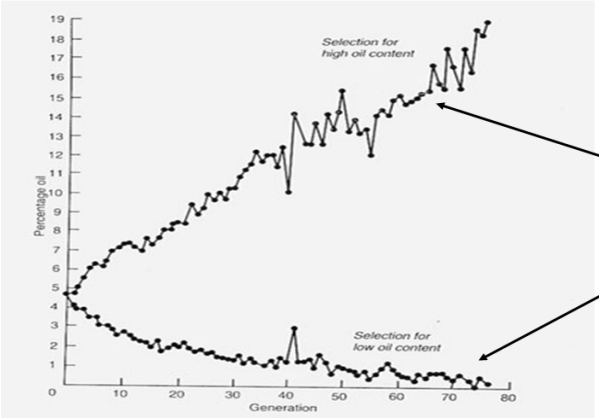
(f)P. platyrhinos

(g)P. solare

An example of species distinguished by morphological characters.

The 7 species of horned lizards (*Phrynosoma*) from Western North America can be distinguished by differences in the number, size and arrangement of horns and scales as well as body size and proportion, color pattern and habitat (Stebbins, 1954).

It ignores evolution: species are not "unchanging entities"



1. Artificial selection: artificial selection for oil content in corn

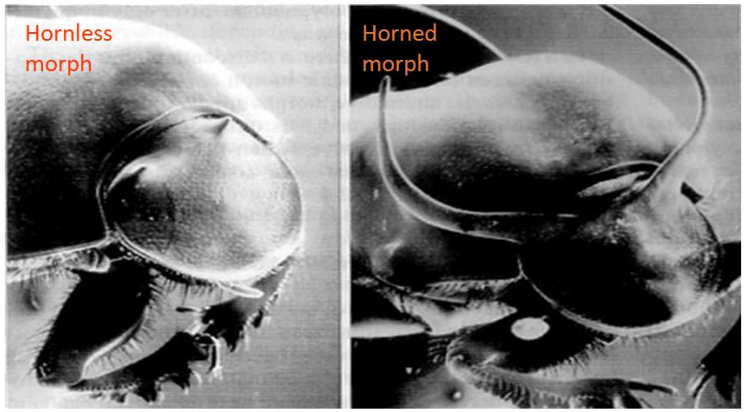
High oil

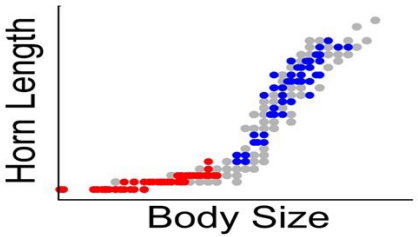
Low oil

Sexual Dimorphism: the sexes differ morphologically

Sailfin molly

Alternative morphs:





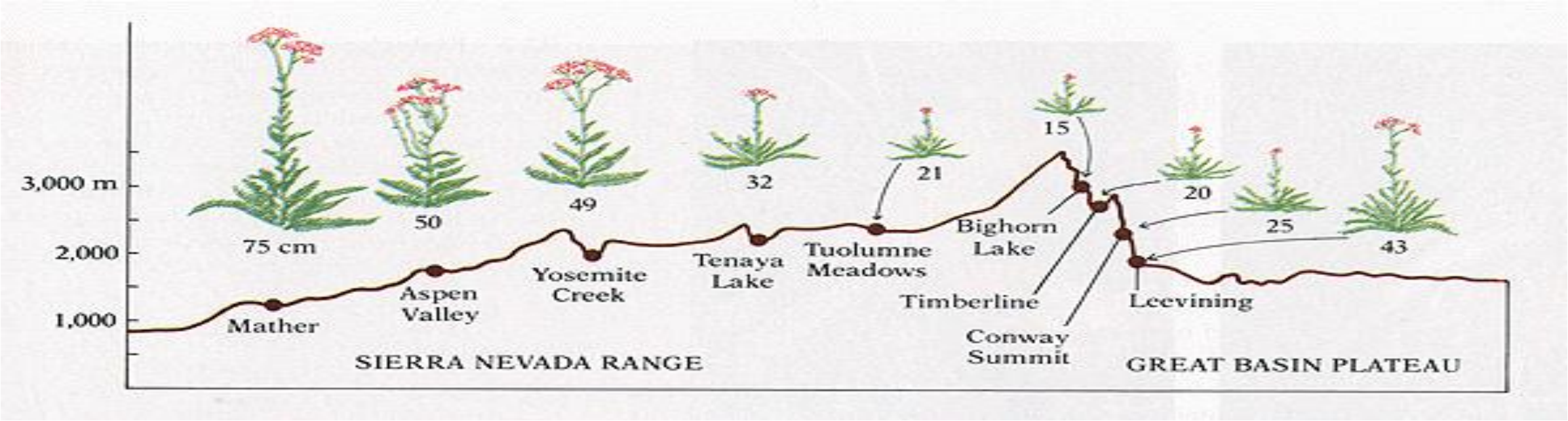
e.g. horn polymorphisms in beetles

Cryptic species: some species are similar morphologically but differ in other important ways

Western meadowlark

Eastern meadowlark

Cline: a change in morphology along an environmental gradient



CONCERNS REGARDING MORPHOLOGICAL SPECIES CONCEPTS

A distinct morphological species at the local level is merely one in a series of morphologically intergrading populations on a broader geographic scale.

1. Individuals are frequently found in nature that are clearly **conspecific** with other individuals in spite of striking morphological differences which are due to

   (a) Sexual dimorphism

   (b) Age differences

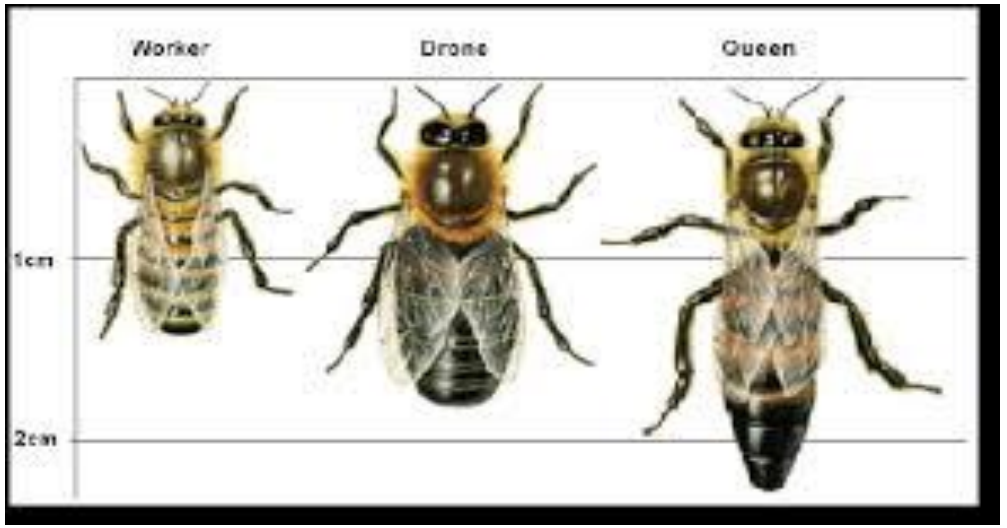
   (c) Polymorphisms and other forms of individual variation

1. Sibling species.

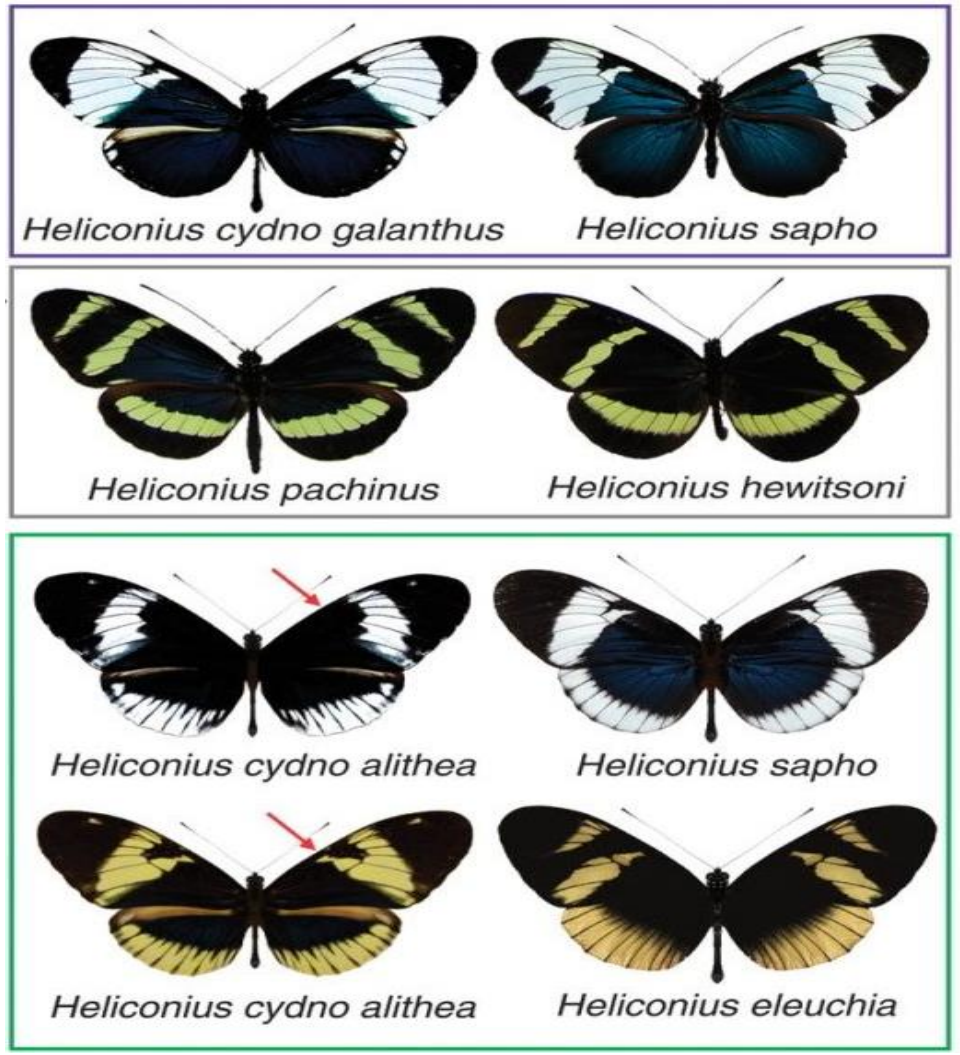
   Any of two or more related species that are morphologically nearly identical but are incapable of producing fertile hybrids.

   Sibling species can only be identified by genetic, biochemical, behavioral, or ecological factors, and are thought to have become divergent very recently.

(a)



(b)



Sibling species.

(a)California king snake & (b) ant showing genetics polymorphism

Is the Morphological Species concept still Applicable?

Jackson and Cheetman (1994) addressed whether the fossil morpho-species they had identified were consistent with genetically distinct living bryozoans.

1. **Determined that the morphological features used to distinguish bryozoans had a genetic basis.**

2. **Found unique allozymes in each of the distinguished morphospecies.**

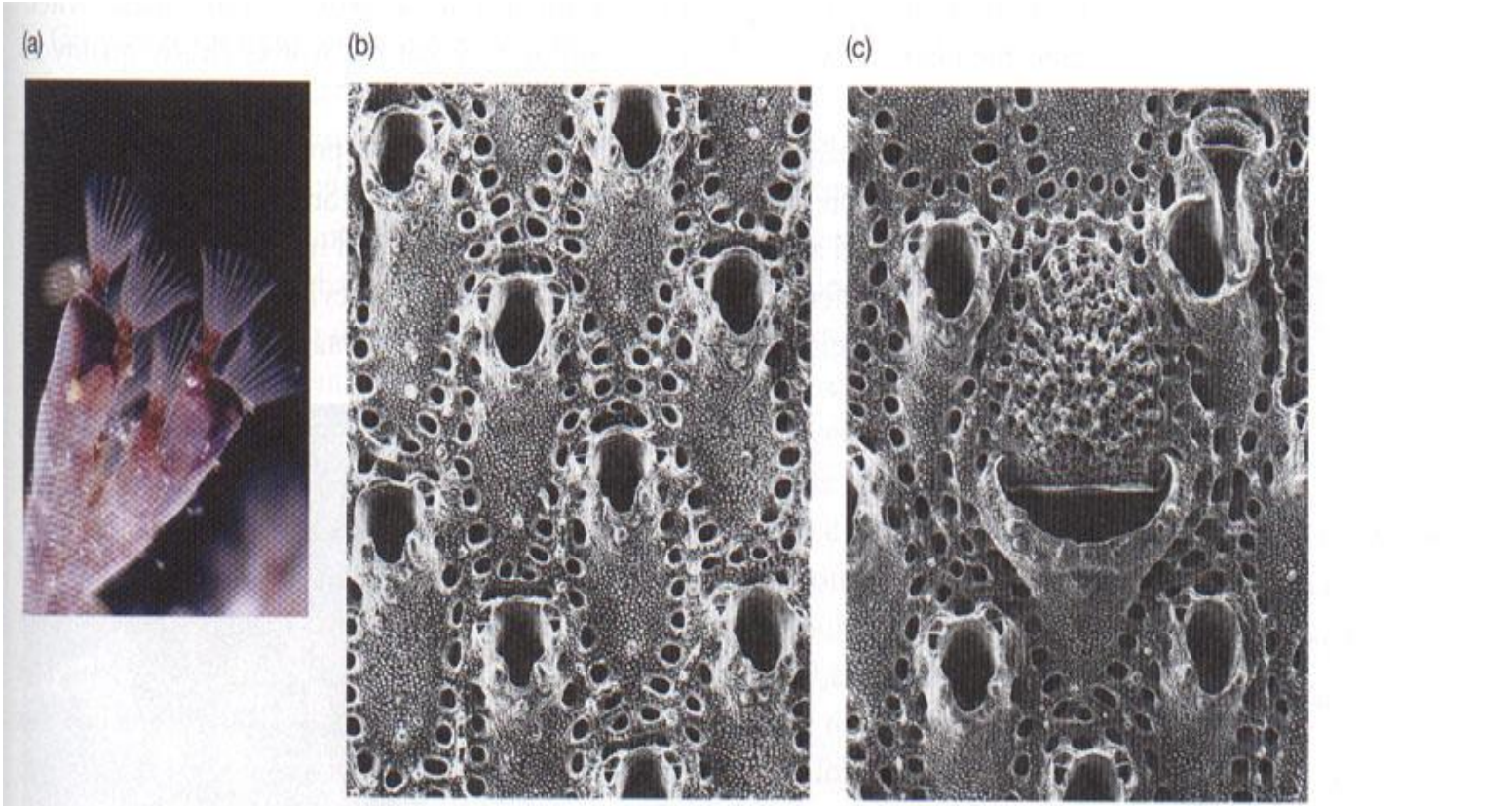


FIGURE 12.3 **Morphological characters used to distinguish morphospecies in cheilostome Bryozoa** Living colony members are shown in photo (a). (Kjell B. Sandved/Butterfly Alphabet, Inc.) The enlarged photos show the skeletons of *Stylopoma spongites* (b) and *Metrarabdotos tenue* (c). Each colony member occupies one of the long chambers that have an orifice near the top. To distinguish morphospecies in these genera, Jackson and Cheetham (1994) measured traits like orifice length and width and the number of pores present per 0.2mm square. (b, c: Smithsonian Institution Photo Services)

Nominalistic species concept

- **Proposed by Occam and was popular in France in the 18th century.**
- **Individuals exist, species are man's own creation. Nature produces individuals and nothing more, species have no actual existence in nature.**
- **Bessey (1908): They are mental concept and invented in order so that we may refer to great numbers of individuals collectively.**

- **Species are products of evolution.**

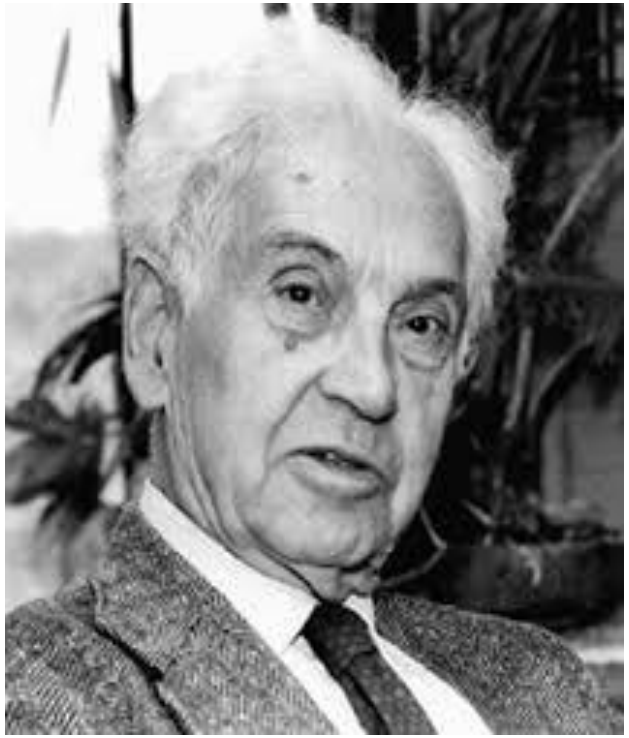
- **Misinterpretation of the causal relation between similarity and relationship. Members of a species taxon are similar to each other because of common heritage. It is not true that they belong to this taxon because they are similar.**

Examples: Twins are so not because they are extraordinarily similar, but because they are both derived from a single zygote.

Biological species concept

1. **Ernst Mayr, in 1942, proposed the biological species concept.**

2. **A biological species is defined as a population or group of populations whose members have the potential to interbreed and produce viable, fertile offspring but cannot do so with members of other species , hence are reproductively isolated.**



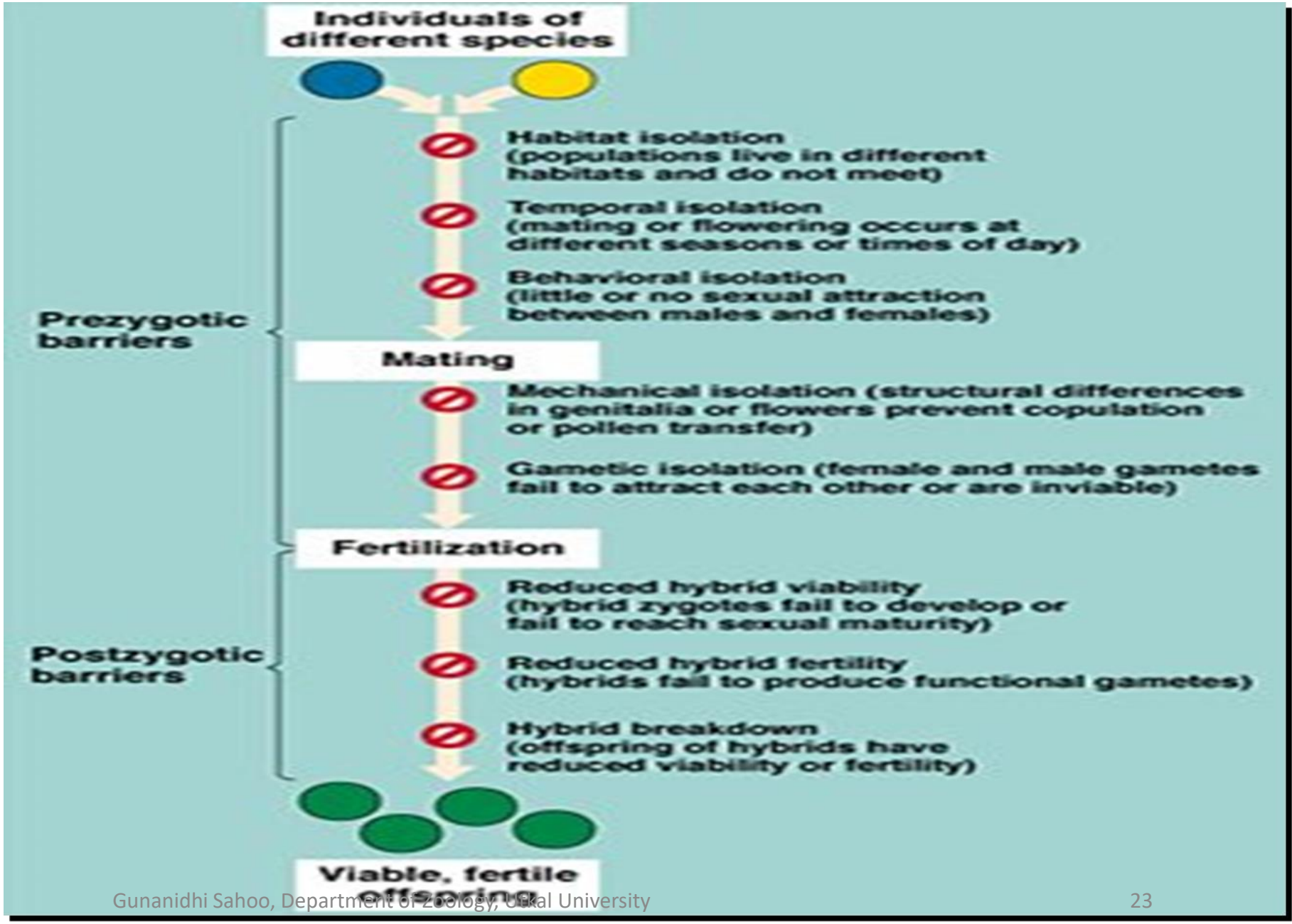
Ernst Mayr

- **The species is the largest unit of population in which gene flow is possible.**

- **It is defined by reproductive isolation from other species in natural environments (hybrids may be possible in the lab or in zoos).**

REPRODUCTIVE ISOLATION

It means any of the several biological barriers that greatly reduce gene exchange between two species, even though they are not separated geographically.



Thus, **a species has three separate functions**.

A. Reproductive unit

1. The individuals of a species looks upon each other as **actual and potential mates and seek each other for reproduction.**

B. Genetic unit

1. The individual of a species has **same number of chromosomes and similar genes**.

2. They consist of a **large intercommunicating gene pool**, whereas the individual is merely a temporary vessel holding a small portion of the contents of the gene pool for a short period.

C. Ecological unit

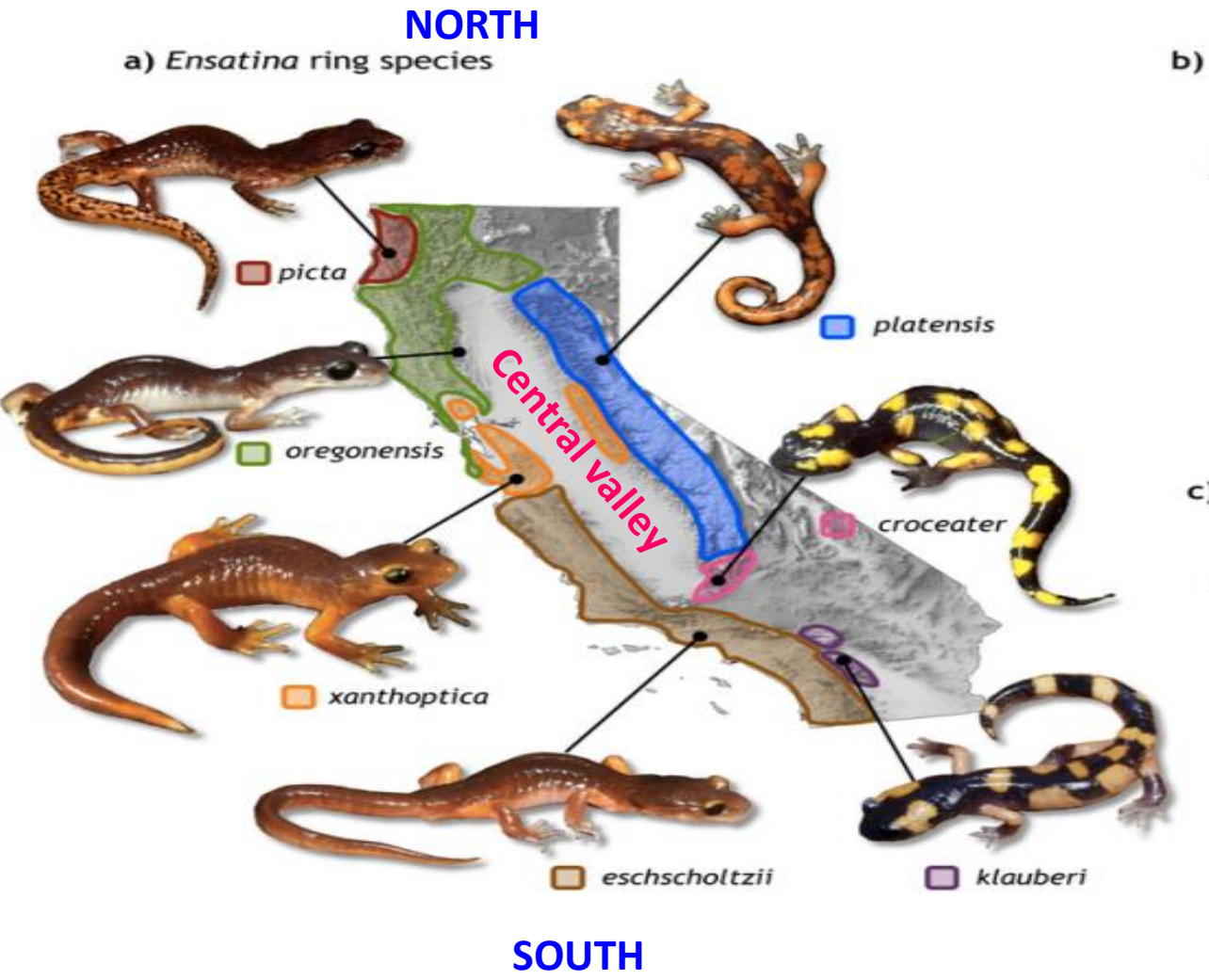
1. They share a **common niche** and regardless of the individuals composed, it interacts as a unit with other species with which it shares the environment.

Drawbacks of biological species concepts

1. **Asexual groups**: **Parthenogenesis** (a degeneration process of sexual mode of reproduction).

2. **Sibling/cryptic species**: Feebly or not at all separated morphologically.

3. **Gradual speciation**: All stages of differentiation between the individual variant and the well characterised distinct species. Many species pass through intermediate stages like **biotypes, races, subspecies, ecotypes or semispecies.**
4. **Fossil forms**
5. **Ring of race**
6. **Hybrids**



b) C

- Yellow Blotched *Ensatina* — *E. e. croceater* (Cope, 1868)
- Monterey *Ensatina* — *E. e. eschscholtzii* Gray, 1850
- Large Blotched *Ensatina* — *E. e. klauberi* Dunn, 1929
- Oregon *Ensatina* — *E. e. oregonensis* (Girard, 1856)

c)

- Painted *Ensatina* — *E. e. picta* Wood, 1940
- Sierra Nevada *Ensatina* — *E. e. platensis* (Jiménez de la Espada, 1875)
- Yellow Eyed *Ensatina* — *E. e. xanthoptica* Stebbins, 1949

A ring species is a situation in which two populations which do not interbreed are living in the same region and connected by a geographic ring of populations that can interbreed. Famous examples of ring species are the herring and lesser black-backed gulls in northern Europe and the *Ensatina* salamanders of California.

Hypothesis proposed by Robert's Stebbins in 1947

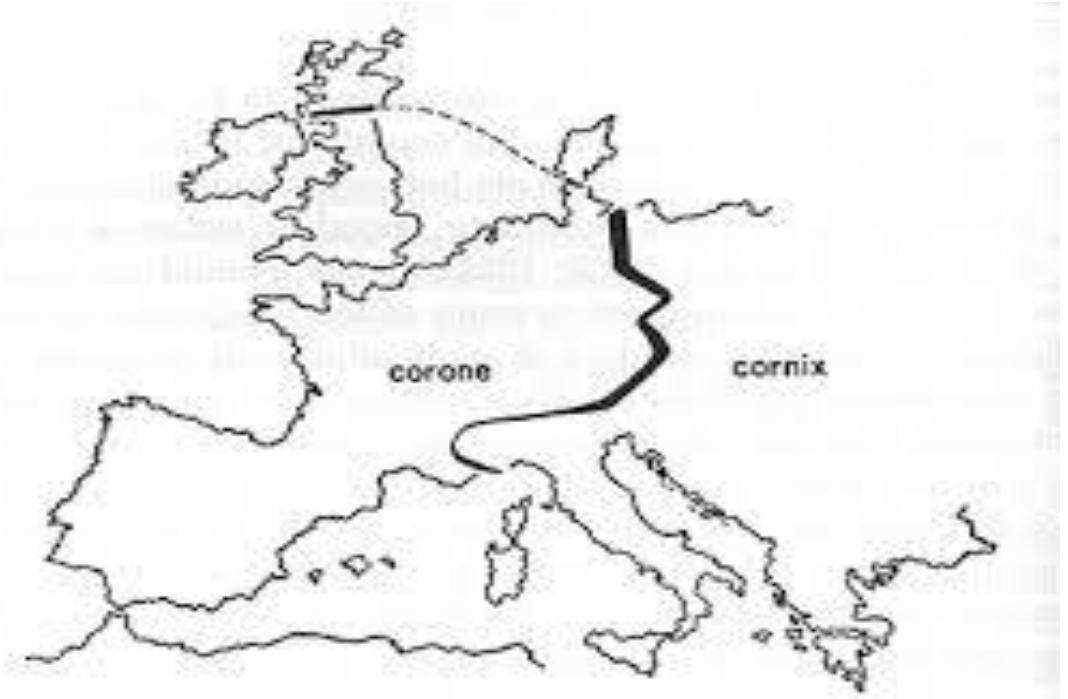
Based on the ring-like distribution of the different forms of *Ensatina* (a Plethodontid or lungless salamander), Robert had proposed that the species started off in Northern California and Oregon and then spread south along both sides of the Central Valley, which was too dry and hot for salamanders.

As the pioneering populations moved south, they evolved into several subspecies with new color patterns and adaptations for living in different environments.

By the time they met again in Southern California as the subspecies *eschscholtzii* and *klauberi* they had each evolved so much that they no longer interbred — even though the subspecies blended into one another around the rest of the ring.

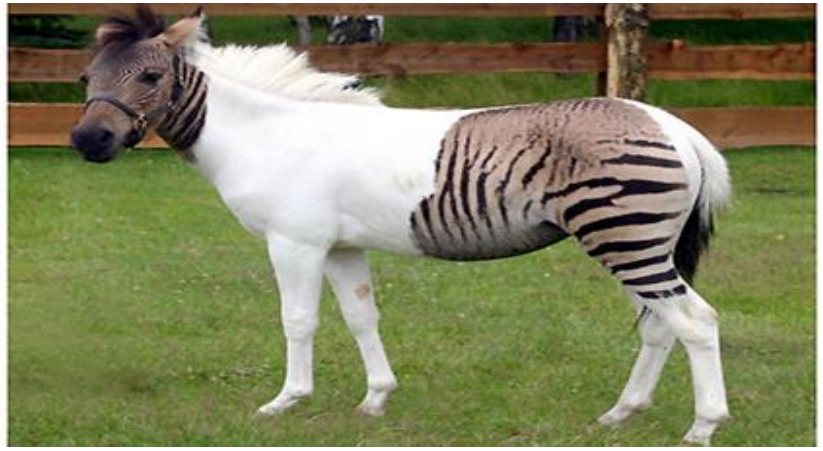
Since species are often defined by their inability to interbreed with other species, *Ensatina* seemed to represent the whole process of speciation — all the gradual changes that accumulate in two lineages and that wind up making them incompatible with one another.

(a)



(b)

Two species that can hybridise- (a)Indigo bunting and lazuli bunting, (b)carrion crow and hooded crow.



Zebrose

Liger

Mules

Wholphin

Lostly (1925) called hybrids as syngameon.

Recognition species concept

1. **According to Patterson (1985), species have a specific mate recognition system (SMRS).**

   A species is "that most inclusive population of individual biparental organisms which share a common fertilization system".

2. **Species can be defined as a set of organisms with a common method of recognizing mates. The organisms recognise each other as mates [active (as in courtship rituals and responses) or passive (as in mechanisms of gamete fusion) recognition)].**

Ecological species concepts

1. The **ecological species concept** defines a species as a **set of organisms exploiting a particular set of resources**, called a **niche** (adaptive zone).

2. The ESC supposes that ecological niches in nature occupy **discrete zones**, with gaps between them.

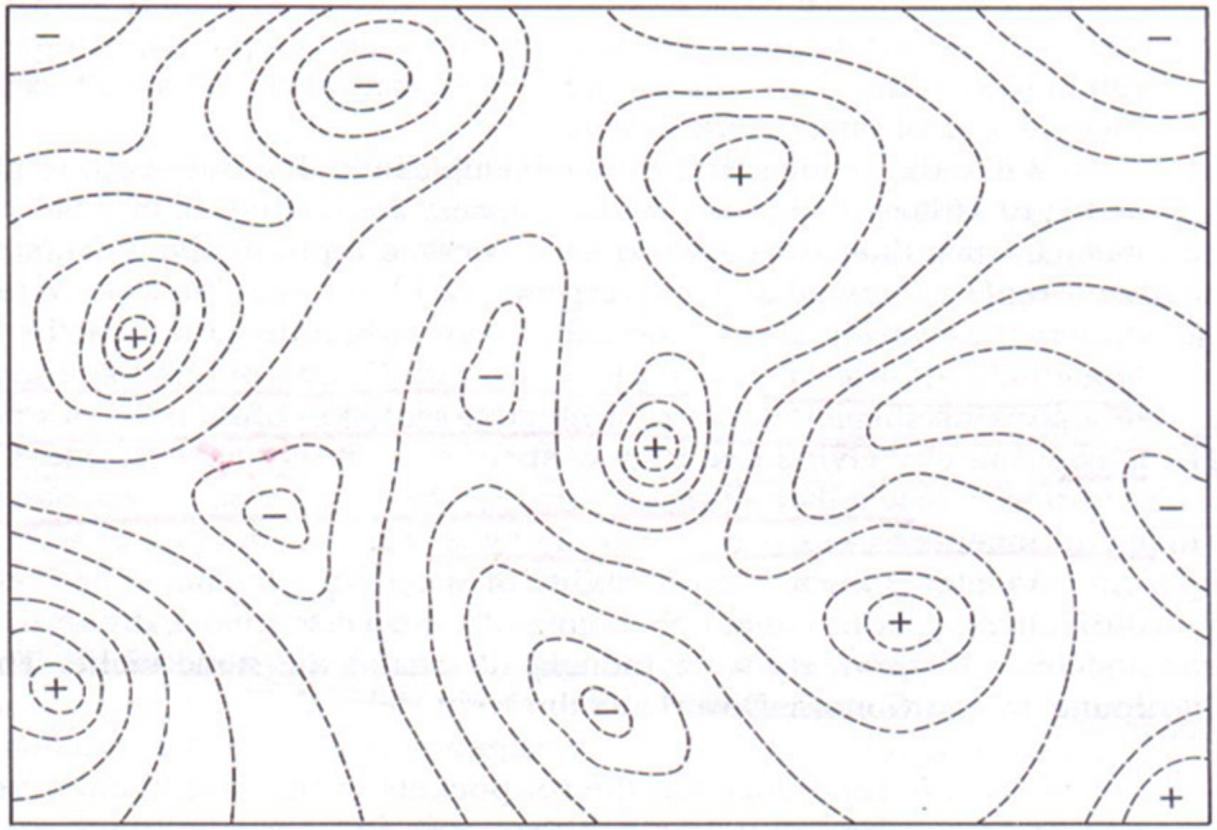
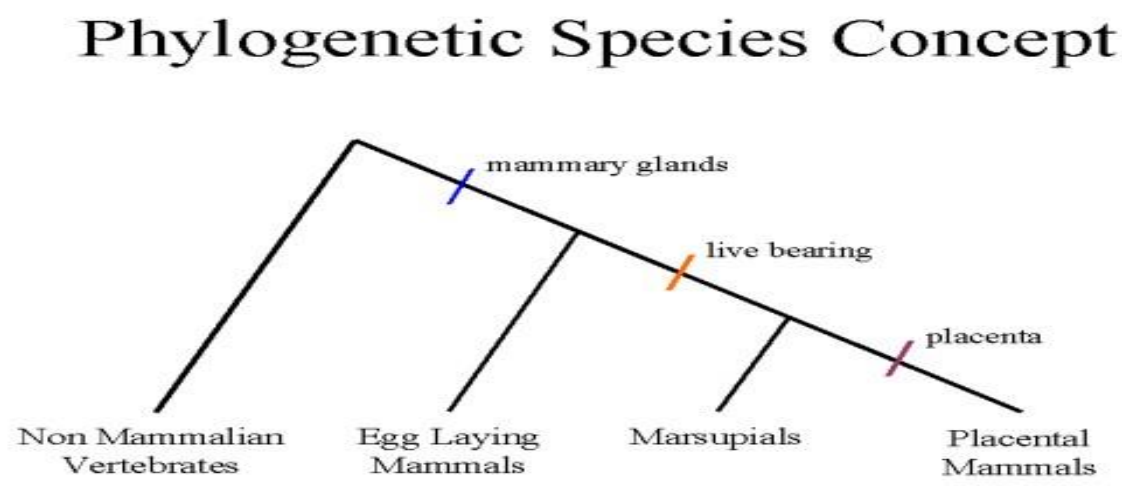


Figure 10.1 Adaptive field: *a* hypothetical two-dimensional representation of the relative fitnesses of various genotypes as determined by the environment. Peaks represent well-adapted genotypes and valleys represent poorly adapted ones. Contours depict genotypes of equal fitness. Note that peaks are not all of equal height. [From S. Wright. "The roles of mutation, inbreeding, crossbreeding, and selection in evolution," *Proceedings of the 11th International Congress of Genetics* 1:356–366 (1932).]

Phylogenetic species concept

1. **The smallest group of organisms that is diagnostically distinct from other such clusters and within which there is parental pattern of ancestry and descent.**
2. **It distinguishes traits (variable features within a group) from characters (invariant features within a group).**
3. **Each phylogenetic species is defined by a unique character or unique combination of characters.**
4. **Classifies organisms according to their evolutionary predecessors and how closely related they are, using DNA profiling and sequencing methods.**



Phylogeny of mammals

Evolutionary species concept

1. A single lineage of ancestor-descendant populations which is distinct from other such lineages and which has its own evolutionary tendencies and historical fate.

2. **Simpson (1961):** A lineage (an ancestral-descendant sequence of populations) evolving separately from others and with its own unitary evolutionary role and tendencies.

3. Supported by **Grant (1971)** and it is applicable to apomictic populations and fossil lineages.

4. **Wiley (1978)** recosidered and concluded that ‘a species is a single lineage of ancestral descendant population of organisms which maintains its own evolutionary tendencies and historical fate’.

Sl. No.	Species Concepts	Practical Application	Weakness
1.	Morphological species concept	Common	Morphological criteria may not reflect actual links that hold organisms together into a natural unit; only possibility for paleontologists; but what with cryptic species?
2.	Biological Species concept	Difficult	Popular, explains why the members of a species resemble one another and differ from other species (shared gene pool + reproductive isolation). Irrelevant to fossils, asexual organisms, complicated by natural hybridization, polyploidy, etc.
3.	Recognition species concept	Difficult	Determining if a feature is used to recognise potential mates is difficult or impossible in many populations.
4.	Phylogenetic species concept	Increasing	Will give rise to recognition of many more species than more traditional concepts; but from what point onwards do we conceive differences to be 'statistically significant'?
5.	Ecological species concept	Difficult	It is common for the different life stages of an organism to have utterly different ecologies. Adaptive zones are difficult to identify.
6.	Evolutionary species concept	Difficult	Slow process and difficult to observe.

Biological evidences of species concept

Species concepts	Biological evidences
Morphological species concept	Morphologically distinct
Biological species concept	Reproductively isolated
Recognition species concept	Usually prefer to mates with their own species
Ecological species concept	Different habitat
Phylogenetic species concept	Monophyletic DNA
Evolutionary species concept	Intermediate species

SPECIES CONCEPTS DO MATTER…

Species concepts affect:

1. **the specific status of diagnosable populations;**
2. **estimates of species diversity;**
3. **the historical analysis of these units;**
4. **an understanding of patterns of gene flow within and among these units;**
5. **delineation of areas of endemism;**
6. **the demographic characterization of such units;**
7. **decisions on captive breeding**
8. **which units to receive protection under local, national, or international legal instruments.**

Other kinds of species

- Sibling species
- Cryptic species
- Morphospecies
- Agamospecies
- Umbrella species
- Keystone species
- Indicator species
- Flagship species
- Sympatric species
- Allopatric species
- Parapatric species
- Continental species
- Insular species
- Cosmopolitan species
- Panmictic species
- Apomictic spcies

Cryptic species

- Cannot be reliably distinguished based on their morphology. Serving to conceal, as the form or colouring of some animals. Cryptic species camouflage with other non-palatable ones (belonging to altogether different family or order) to protect themselves from their potential enemies (two or more species hidden under one species name, sister species).

Sibling species

- Mayr: Any of two or more related species that are morphologically nearly identical but are incapable of producing fertile hybrids. Sibling species can only be identified by genetic, biochemical, behavioral, or ecological factors and are thought to have become divergent very recently (two cryptic species that are each other's closest relative).

Morphospecies

Animals from the same species show strong morphological differences across due to sexual dimorphism. Includes features that come from convergent evolution, e.g., many species of butterfly appear similar due to morphological similarities, irrespective of other attributes.

Agamospecies

Species in which sexual reproduction is absent, fertilization of male & female gametes not required to produce offspring (agamic, apomiktic, asexual). Uniparental origin. Looks morphologically so similar that classified as a single species. Ex.: many bacteria, some plants and fungi.

Umbrella species

- The term was first used by Wilcox (1984).
- Species selected for making conservation-related decisions, typically because protecting these species indirectly protects many other species that make up the ecological community of its habitat.
- Two commonly used definitions:
- A: "A wide-ranging species whose requirements include those of many other species".
- B: A species with large area requirements for which protection of the species offers protection to other species that share the same habitat.
- Ex: Spotted owl and old growth trees, relatively large-bodied and wide-ranging species of higher vertebrates.

Keystone species

- A species that has a disproportionately large effect on its environment relative to its abundance. Play critical roles in maintaining the structure of an ecological community, affecting many other organisms in an ecosystem and helping to determine the types and numbers of various other species in the community.
- A species whose addition to or loss from an ecosystem leads to major changes in abundance or occurrence of at least one other species (Tiger).

Indicator species

- **An indicator species is any biological species that defines a trait or characteristic of the environment.**

  Example: a species may delineate an ecoregion or indicate an environmental condition such as a disease outbreak, pollution, species competition or climate change. Indicator species can be among the most sensitive species in a region, and sometimes act as an early warning to monitoring biologists.

- **Examples:**
- **Stone flies: indicate high oxygen water.**
- **Grease wood: indicates saline soil. In high saline areas, grease wood grows in nearly pure sands.**
- **Lichens: some species indicate low air pollution.**
- **Fungi: high conservation value, old-growth forests. Their diversity correlates well with insect diversity, and indicates continuum of dead wood at the stand or landscape level.**
- **Mollusca: numerous bivalve molluscs indicate water pollution status.**
- **Their population status or structure, physiology, behaviour or their content of certain elements or compounds can reveal the contamination status of any aquatic ecosystem. They are extremely useful as they are sessile - which means they are close representatives of the environment.**
- **Tubifex worms: indicate non-potable, stagnant, oxygen-poor water.**
- ***Agave lechuguilla*: an important indicator species in the Chihuahuan Desert.**

Flagship species

- **A species selected to act as an ambassador, icon or symbol for a defined habitat, issue, campaign or environmental cause. Concept developed during mid 80s.**
- ***species that have the ability to capture the imagination of the public and induce people to support conservation action and/or to donate funds***
- ***popular, charismatic species that serve as symbols and rallying points to stimulate conservation awareness and action***
- The term flagship is linked to the metaphor of representation. In its popular usage, flagships are viewed as ambassadors or icons for a conservation project or movement.
- The concept of **flagship species** has its genesis in the field of conservation biology. The flagship species concept holds that by raising the profile of a particular species, it can successfully leverage more support for biodiversity conservation at large in a particular context.
- Examples:

  The Bengal tiger (*Panthera tigris*), the giant panda (*Ailuropoda melanoleuca*), the Golden lion tamarin (*Leontopithecus rosalia*), the African elephant (*Loxodonta sp.*), Asian elephant (*Elephas maximus*) and Olive ridley turtle.

Sympatric species

- Two or more related species have the same or overlapping geographical distributions, regardless of whether or not they occupy the same macrohabitat.
- The two groups of **Orca** in the northeast Pacific occur in the same habitat but avoid each other and they do not interbreed. They have different diets, vocal behaviour, and social structures. **More common in plants.**

Allopatric species

Two or more related species which have separate geographic distribution i.e., inhabit completely different geographical areas. Example: **Darwins' finches.**

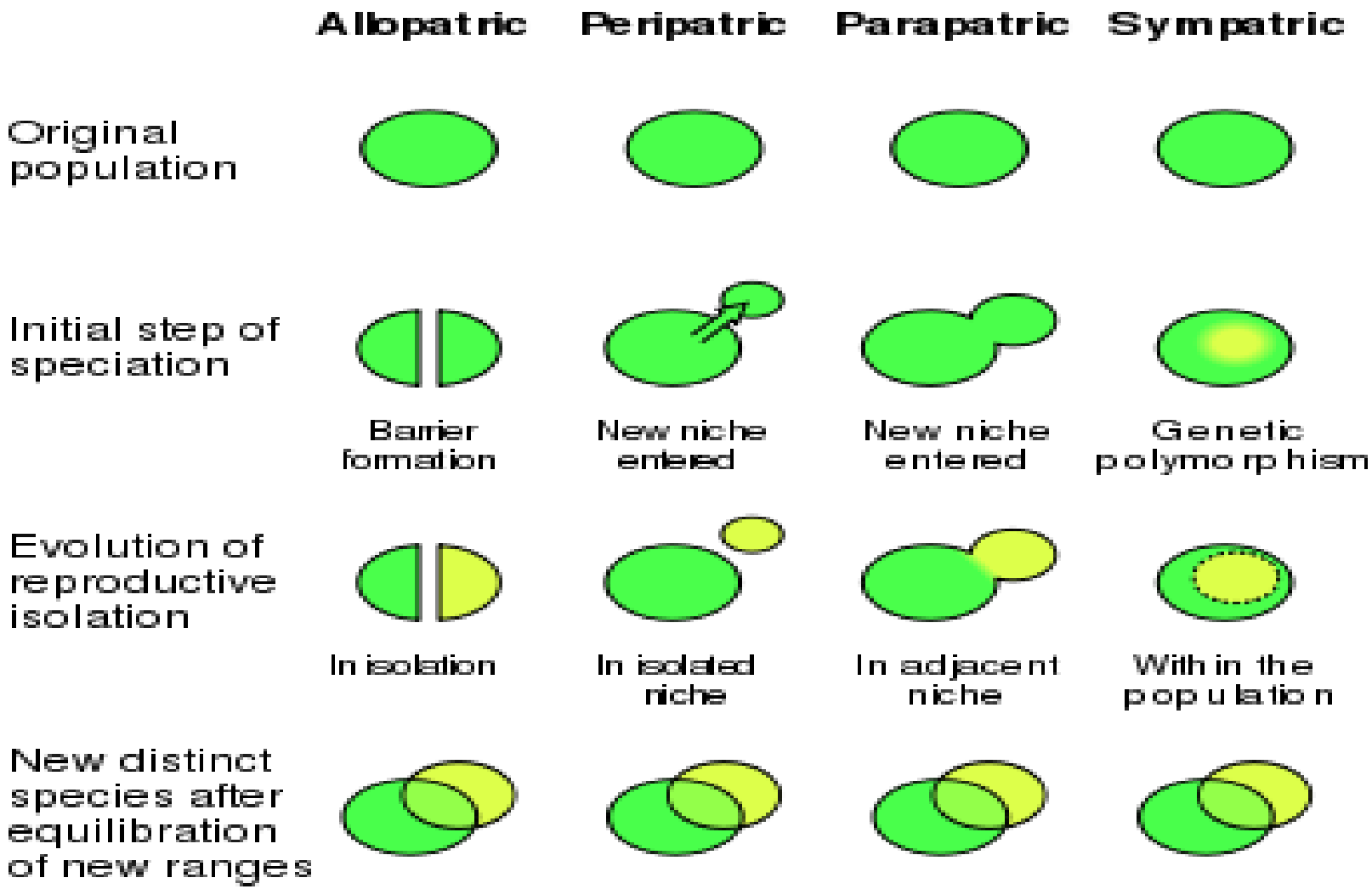
Parapatric species

Parapatry is the relationship between organisms whose ranges do not significantly overlap but are immediately adjacent to each other; they do not occur together except in a narrow contact zone. Parapatry is a geographical distribution opposed to sympatry (same area) and allopatry or peripatry (two cases of distinct areas).

Peripatric species

A new species is formed from an isolated peripheral population. Difficult to distinguish from allopatric.

Comparison of allopatric, peripatric, parapatric and sympatric speciation



Continental species

- **Animals those living on the large land masses, as distinct from insular species.**

Insular species

- **Animals those living on isolated islands which owe their fauna to dispersal methods other than overland migration.**

Cosmopolitan species

- **Widely distributed species over the earth, in all majority zoogeographical regions.**

Montane species

- **Species which occur at high elevations on mountain ranges.**

Subspecies

- Ornithologist H. Schlegel in 1844 introduced the term, giving rise to trinomial nomenclature.
- Term applied to geographically isolated population or groups of populations that are genetically different, but are not sufficiently different to be reproductively isolated.
- A geographically separate aggregate of local population of the species.

Geographical subspecies: separated geographically during the mating times.

Temporal subspecies: Temporarily isolated during mating season

Seasonal subspecies: Two distinct sympatric populations or aggregation of populations within a given species mature at different times during the same calender year (one in spring other in fall) with no period of time during which reproductive forms of both the demes coexist.

Annual subspecies: A population of a species mature only during different years from those of another population of the same species.

Geological subspecies: Populations which function during different geological times, hence no chances of becoming synchronic.

Ecological subspecies: Populations isolated microgeographically, but whose members would cross-breed freely and normally if the populations were to become microgeographically sympatric under natural conditions. These occur in different niches, biotypes or populations of biotypes.

Other Intraspecific Groups

DEME

- **Term proposed by Gilmore and Gregor (1939). Mayr (1953) called them Phena; Camp & Gill described them as Phenon.**
- **Group of individual animals of one species or subspecies so localized that they are in easy and more or less frequent contact with each other.**
- **A small locally interbreeding group of individuals within a larger population. Demes are isolated reproductively from other members of their species. The isolation may only be partial and is not necessarily permanent.**
- **Deme and phenon has no nomenclatural status.**

VARIETY

- **Proposed by Linnaeus, in common use for many years, the most controversial and abused term in zoological taxonomy.**
- **Typologically, each species had a fixed pattern and anything that did not fit under this pattern was named a variety.**
- **The term no more in use after 1960.**

- **MORPHOTYPE**
- **Aggregate of particular variations within populations rather than to all varying organisms forming a population.**
- **Edward (1955): Distinguishable sympatric or synchronic interbreeding populations of a single species.**

- **CLINE**
- **Term used by Huxley in 1938. Represents variation within a species.**
- **Defined as a gradation in measurable characters. Not a taxonomic category.**
- **Formed by a series of continuous populations in which a given character (may be morphological, physiological, ecological, etc. and also of the % frequencies of polymorphic characters)) changes gradually.**
- **Geocline, ecocline and chronocline are for geographic, ecological and successional clines, respectively.**

- **RACE**
- **Mayr (1969): Race is a subspecies and is an aggregate of phenotypically similar populations of a species, inhabiting a geographic subdivision of the range of a species. It differs taxonomically from other populations of the species.**
- **Dobzhansky (1970): races are genetically distinct Mendelian populations.**

Superspecies

- **Mayr (1931) introduced the term.**
- **A monophylectic group of closely related and largely or entirely allopatric species.**
- **Represents groups of populations that seem to have passed beyond the point of potential interbreeding and have acquired separate evolutionary role.**
- **These are nascent species that will, if survive, collectively form subgenera or eventually a genus but have hardly reached the degree of divergence and expansion.**
- **Not given any special name.**

Semi-species

- **A group of organisms that are taxonomically intermediate between a race and a species, with reduced outbreeding and gene flow, i.e. with incomplete reproductive isolating mechanisms. Semi-species are thought to represent advanced stages of speciation.**

CONCLUSION

Species is one of the basic unit of biological classification and a taxonomic rank. Concepts like classification, taxonomy, systematics, molecular taxonomy and integrative taxonomy (most recent) revolve around it.