

Speciation

Speciation is the evolution of more than one species (or, at least, a single different species) where previously there was only one.

=> species are the unit of evolution

But what is a species?????

- Scientists have been arguing about this for decades and still don't agree on the exact definition of a species. This is a very hotly debated issue.
- They have rather come up with whole range (about 15) of species concepts
- In this lecture I will talk about 7 of them.

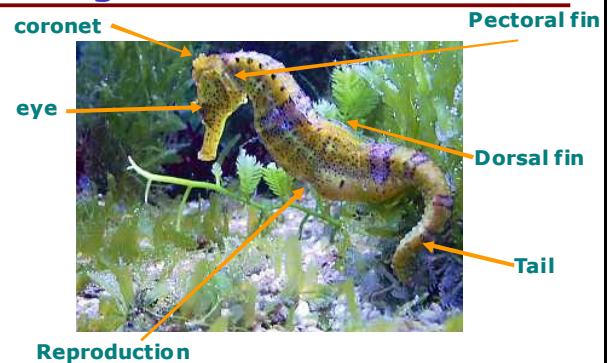
Species Concepts

1. Morphological Species concept

Linnaeus: A species is the smallest group of individuals that are distinct and distinguishable from all others

- Morphology refers to the form and structure of an organism or any of its parts.

E.g. Parts of a seahorse



Strengths:

- Is in fact the way we recognise species differences.
- Works well for sexual and asexual organisms
- Applies well to past species (fossils can be related to extant species)
e.g **Coelacanth** was previously only known from fossils

Weaknesses:

- Does not connect with genetics. Morphological differences can be present without significant genetic divergence!

- Polymorphism, sibling species, *sexual dimorphism*, *mimicry complexes*

Polymorphism



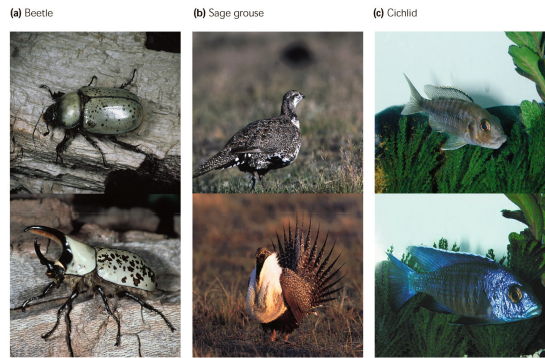
Light-morph jaguar (typical) Dark-morph jaguar (rare)

Sibling species



Argyrosomus japonicus (RSA) *Argyrosomus coronus* (Angola)
Reproductively isolated, yet very similar morphology

- Differences between sexes



(a) Beetle
During the breeding season, males of the beetle *Dinastes granti* use their elongated mandibles to fight over females.

(b) Sage grouse
Each male sage grouse has a display territory. Males vie among themselves for the best territory. Females choose the male giving the best display as the father of their offspring.

(c) Cichlid
In this species and many other cichlids from the Rift Lakes of Africa, males are brightly colored and perform courtship displays.

Mimicry



Saddled Puffer
Canthigaster valentini

1 dorsal fin



Mimic Leatherjacket
Paraluteres prionurus

2 dorsal fins!

2 pairs of spines on the caudal peduncle

2. Biological Species Concept (BSC) - Ernst Mayr, 1942:

- Most dominant concept in ecology studies

"A species is a group of interbreeding natural populations that are reproductively isolated from other such groups."

As long as gene flow continues individuals will remain members of a species even though they may be geographically distant.

This concept assumes that Genetic divergence is key to speciation

Genetic divergence is when local units of a population become reproductively isolated from other units. The driving forces of evolution (genetic drift, natural selection and mutation) may operate in each isolated population and thus lead to changes in gene frequencies.

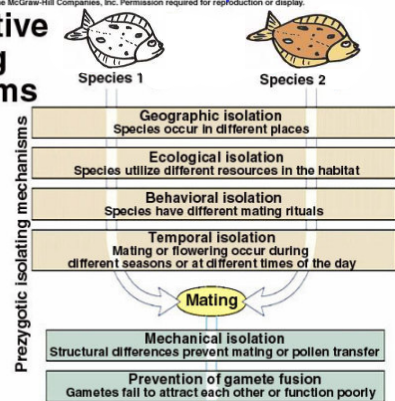
Biological Speciation is the process by which species form when two genetically diverging species remain isolated from each other.

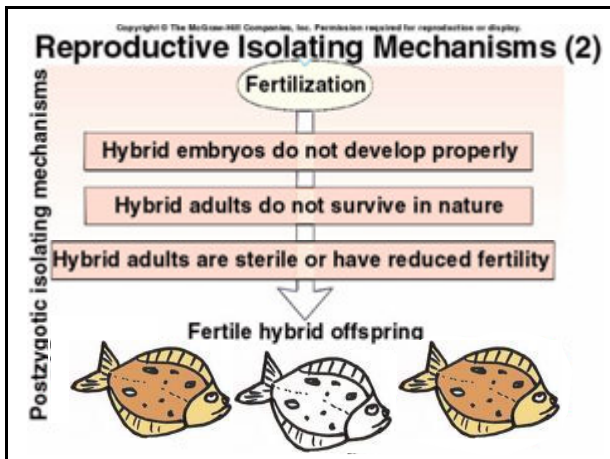
Because genetic divergence is a gradual process, it is impossible to say precisely when species form.

Reproductive isolation is key to the BSC:

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Reproductive Isolating Mechanisms (1)





2. Biological Species Concept

Strengths

- Criterion of reproductive isolation can be tested, observed, and / or inferred
- Includes genetic information

Weaknesses

- Ignores hybridization
- Does not work well for asexual organisms
- Dependent on geographic isolation to achieve sp. status
 - Reproductive isolation evolves gradually
- Can not be used for paleo species (extinct or fossils)!

3. Evolutionary Species Concept

Or Genealogical species concept

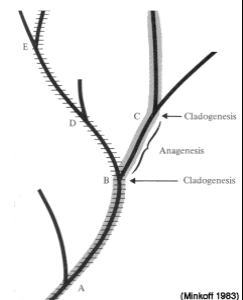
An evolutionary species is a **lineage** (an ancestral-descendant sequence of populations) which maintains its **identity** evolving separately from others and with its own **unitary evolutionary role and tendencies**"

- **Identity**: biologically distinct

Includes concepts associated with BSC e.g. Species Recognition Mechanisms

- **Tendencies and historical fate**:

- Species have an origin
- Undergo evolution
- May disappear by extinction.



3. Evolutionary Species Concept:

- Recognizes more than just genetic and morphological differences

• However:

- Change within lineages does not create a new sp.
- difficult to determine "evolutionary fate"
- how much diversity is allowed within a common evolutionary fate?
- The study of speciation is key, not the study of microevolution

4. Phylogenetic Species Concept:

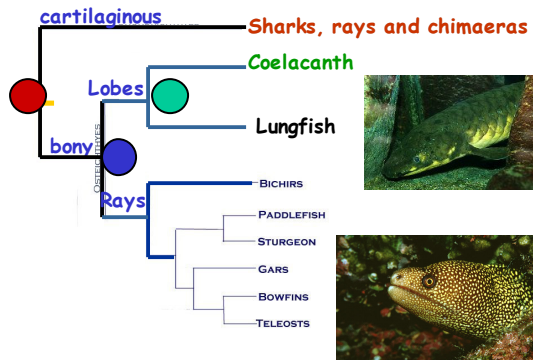
A species is a cluster of organisms that is diagnostically distinguishable from other such clusters, and within which there is a parental pattern of ancestry and descent."

- It rates traits as ancestral or derived and then looks for groupings based on similarities.

Avoids all reference to reproductive isolation and focuses instead on phylogenetic histories of populations.

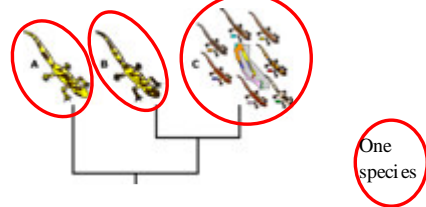
Lineage: ancestor descendant

members of a species have a **common ancestor**



4. Phylogenetic Species Concept:

a species is a "tip" on a phylogeny, that is, the smallest set of organisms that share an ancestor and can be distinguished from other such sets. Under this definition, a ring species is a single species that encompasses a lot of phenotypic variation.



Problems

- (1) confuses histories of traits with histories of organisms, may divide species into groups based on characteristics that do not have any clear biological relevance
- (2) classifications change with more data
- (3) creates taxonomic inflation (new species names without the discovery of new species)

5. Recognition species concept:

"A species is the most inclusive population of biparental organisms that share a common fertilization system" (Paterson, 1985).

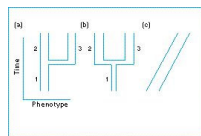
Comment: Similar to BSC in viewing conspecific populations as a field for recombination, but focuses on reproduction facilitating mechanisms within species rather than on reproductive barriers.

disadvantage

Like BSC can only be applied to contemporaries, sexual, and geographically contiguous populations, hence to a minority of natural populations

6. Cladistic species concept

A species is a set of organisms (an evolutionary lineage) between two branch points or between one branch point and an extinction event or a modern population (Ridley 1993).



Problem:

- Teleosts
- Adaptive radiation
- Phylogenetic status of species changes over time

- 3 species using this definition, but 1 and 2 phenotypically identical
- 3 species, and all are phenotypically different
- 1 species, but with significant phenotypic change over time

Other concepts...

7. Cohesive Species concept

A species is the most inclusive group of organisms having the potential for genetic and/or demographic exchangeability. (Templeton, 1989)

Attempts to incorporate strengths of BSC, ESC, and RSC.

Cohesion mechanisms are genetic exchangeability (factors that define gene flow) and demographic exchangeability (factors that define and spread new genetic variants through genetic drift and natural selection).

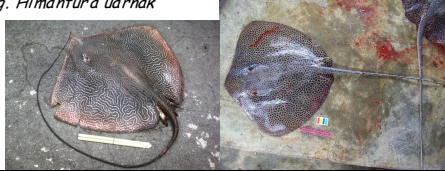
Difficult to use based on the fact that different scientists may choose to emphasize different cohesive mechanisms

Problems in defining species

1. Polymorphisms

variation within a population. Different individuals in the population have distinctly different structures, colors, biochemistry, etc. but clearly belong to the same population since they reproduce with one another.

e.g. *Himantura uarnak*



2. Geographic variation

Refers to variation over geography

populations in different areas look different from each other.

One common pattern of geographic variation is **clinal variation**. **Clinal variation** refers to a gradual change in some feature across geography.



3. Hybrid zones

Geographic areas where two distinctly different forms of organism contact each other and interbreed.

Outside this zone, the two forms retain distinct differences from one another but within the zone intermediate forms between the two occur as a result of interbreeding.

e.g. *O. niloticus* in southern Africa

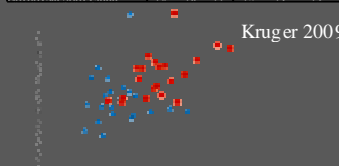
GRELBEN – Is the Angolan popn a New species?

As a consequence of the 2 million year isolation, there is a high level of genetic divergence (4.5% COI gene) between the *A. aequidens* populations.



	ANGOLA (n=52)			South Africa (n=33)		
	Mode	Min	Max	Mode	Min	Max
1st Dorsal Fin Spine Count	10	10	10	10	10	10
2nd Dorsal Fin Spine Count	1	1	1	1	1	1
2nd Dorsal Fin Ray Count	27	24	28	27	26	29
Anal Fin Spine Count	1	1	1	1	1	1
Anal Fin Ray Count	9	9	9	9	9	9
Pectoral Fin Ray Count	18	16	19	17	16	18
External Line Scale Count	73	70	77	75	71	79

Kruger 2009



• Genetic Divergence of *A. aequidens* Populations

• Population Genetic Structure of *A. aequidens* Populations (Kruger 2009)



• Genetic Divergence of *A. aequidens* Populations

• Population Genetic Structure of *A. aequidens* Populations (Kruger 2009)

	South Africa	
	Angola (1)	(2)
Max. Size (Fork Length)	960 mm	1300 mm
Max. Weight	6.8 Kg	25 Kg
Length at Maturity (Fork Length)	430 mm	900 mm

• Population Genetic Structure of *A. aequidens* Populations (Kruger 2009)

• Genetic Divergence of *A. aequidens* Populations

- Morphological species concept **X**
- Biological species concept **✓**
- Evolutionary species concept **X**
- Phylogenetic species concept **✓**
- Recognition species concept **can't test**
- Cladistic species concept **✓** 3 species
- Cohesive species concept **X**

Angola



RSA



Species Concepts

- Value of each concept depends on its use. Various authors have argued that a combination is the best method.
 - morphological, physiological, behavioral
 - geographic
 - life history & development
 - habitat & feeding ecology
 - phylogenetics
 - evolutionary fate
 - And **Genetics** etc. barcoding
- **Note:**
 1. There is uncertainty of the species rank
 2. The term "species" can mean different things in different taxonomic groups