Lesson 2: Species Concept and Speciation

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Lesson 2 — Species Concepts and Speciation

What is a Species?

- During Linnaeus' time, species were groups of organisms that could be distinguished from each other.
- This idea is not widely accepted today because members of the same species can look very different.
  - Example: sexual dimorphism — males and females of the same species have different physical features.
- Because of this, scientists developed different species concepts to define what a species is from different perspectives.

Species Concepts

1. Typological Species Concept

Species = a group of organisms that share a common, idealized physical form.

- Also called the **Morphological Species Concept**.
- Species are identified mainly through their **morphological features** (physical characteristics).

Four Postulates:

1. Species consist of similar individuals sharing the same **essence**.
2. Each species has a **sharp difference** separating it from other species.
3. Each species remains **constant through time**.
4. There are strict limits to how much individuals within one species can vary.

Why it was rejected:

- Members of the same species can have very different appearances because of:
  - **Sexual dimorphism**
  - **Polymorphism** — different forms within the same species
  - **Age differences**
- It does not work well for **cryptic species** because they look almost identical but are genetically different species.

2. Nominalistic Species Concept

Species = categories created by humans.

- Only **individual organisms** are considered real.
- Species are human-made **names or labels** used to classify organisms.
- Popular in **France during the 18th century**.
- Still used by some botanists.

3. Biological Species Concept

Species = a reproductive community whose members can interbreed and share a common gene pool.

- **History**
  - **Karl Jordan** — first formulated in **1905**

- **Dobzhansky** — supported it in **1937**
- **Ernst Mayr** — developed/described it in **1940**

- **Important idea**
  - Organisms can:
    - **Look alike but be different species**
    - **Look different but belong to the same species**

Three Properties:

1. **Reproductive Community**

- Members recognize each other as possible **mates**.

2. **Ecological Unit**

- Members may differ in some characteristics but function together as a unit.
- They interact with other species as a unit in their environment.

3. **Genetical Unit**

- Members can **freely interbreed**.
- They share an **intercommunicating gene pool**.
- An individual carries only a small part of the species' gene pool.

Problems:

- Does not work well for **asexual organisms** because they do not interbreed.
- **Reproductive isolation can be incomplete**.
  - Hybridization occurs in some waterfowl, plants, and freshwater fish.
- Does not work well for **extinct species** because fossils provide limited information about reproduction.

4. Evolutionary Species Concept

Species = a lineage of ancestor-descendant populations that has its own evolutionary direction and historical fate.

- Developed partly because of problems with the Biological Species Concept.
- Especially useful for studying **fossil species**.
- Associated with **G.G. Simpson** and **E.O. Wiley**.

Easy idea: Follow a species through time and look at its unique evolutionary history.

5. Ecological Species Concept

Species = organisms adapted to a particular set of resources, or a particular ecological niche.

- A **niche** is the role and resources an organism uses in its environment.
- Differences between species can result from adaptations to different available resources.

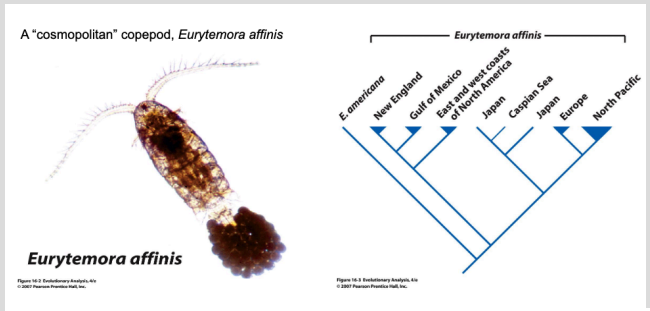
Easy idea: If organisms are adapted to different ways of using their environment, they may represent different species.

6. Phylogenetic Species Concept

Species = the smallest diagnosable monophyletic group of populations with a shared pattern of ancestry and descent.

- **J. Cracraft** is associated with this concept.
- Less restrictive than the Biological Species Concept.
- Breeding between different species is not necessarily a problem.
- Can recognize species that evolved continuously from one ancestral line.

Easy idea: Identify the smallest group that has its own clear evolutionary history.



How Many Species Currently Exist?

- Estimated total: **about 8.7 million species**
  - **6.5 million** on land
  - **2.2 million** in oceans
- This is only an estimate because:
  - Many groups are poorly studied, especially **microorganisms and parasites**.
  - Many environments have not been sampled well.
  - Only about **3% of the ocean** has been explored.
  - Molecular/genetic methods are discovering more **cryptic species**.

Cryptic Species

- Species that are **morphologically indistinguishable** from another species.
- They look the same but can be distinguished **genetically**.

Types of Species

Some examples include:

- **Chronospecies**
- **Subspecies**
- **Cosmopolitan species**
- **Superspecies**
- **Cryptic species**
- **Vicariant species**
- **Endemic species**
- **Sister species**
- **Fugitive species**
- **Sibling species**
- **Polytypic species**
- **Semispecies**
- **Relic species**
- **Ring species**
- **Lazarus species**

The Species Problem

- Scientists still do not completely agree on **how species should be defined and identified**.
- Darwin (1859) pointed out that the distinction between **species and varieties** can be vague.
- Therefore, there is **no single species concept that works perfectly for every organism**.

Which Species Concept is Best?

- It depends on the organism being studied.

Infraspecific Ranks

Infraspecific = ranks below the species level.

- A scientific name can use a **trinomial**:
  - **Genus + specific epithet + infraspecific rank**
- Used when a group has **small differences** from its closest related group.
- Deciding whether something should be a species or an infraspecific group is partly **subjective**.
- A taxonomist can propose a **revision**, such as:
  - Raising a subspecies to species level
  - Lowering a species to an infraspecific rank

In Plants, Algae, and Fungi

Under **ICN**:

- **Subspecies**
- **Variety**
- Infraspecific ranks are generally encouraged.

In Animals

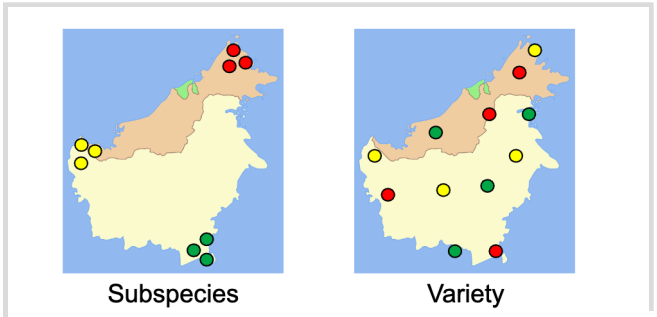
Under **ICZN**:

- Infraspecific ranks are not always encouraged.
- Usually, only **subspecies** is used.

In Prokaryotes

Under **ICNP**:

- Similar approach to animals; **subspecies** is usually recognized.



Speciation

Speciation = the process where one lineage splits into two or more separate species.

- **Gene flow stops** between populations.
- For speciation to happen:
  1. Populations become **isolated**.
  2. They become **genetically different**.
  3. Eventually, they become separate species.

What can stop gene flow?

- **Geographical barriers**
- **Biological barriers**

Mechanisms of Speciation

Geographical Models

- **Allopatric**
- **Peripatric**
- **Sympatric**
- **Parapatric**

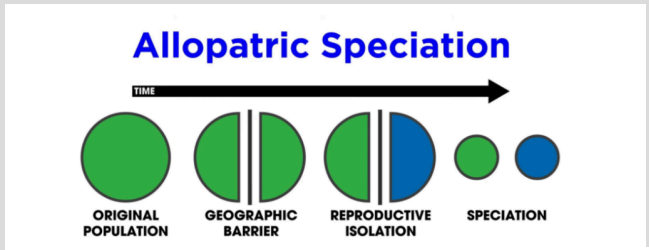
Genetic Models

- **Natural selection**
- **Genetic drift**
- **Mutation**

For two species to maintain their identity, **mating between them must eventually stop or become limited**.

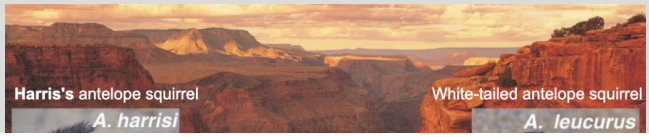
1. Allopatric Speciation

- **Speciation caused by geographical separation.**
- Gene flow is interrupted by a **geographical barrier**.



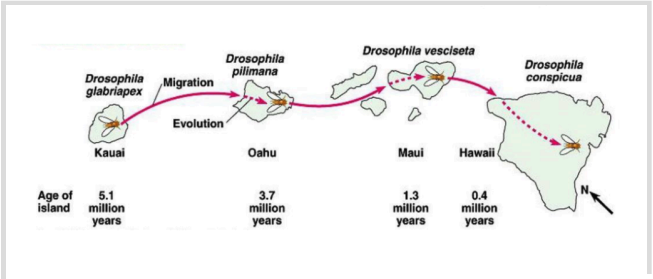
Allopatric via Vicariance

- A population is separated by a **physical barrier**.
- Example: a mountain, river, or other barrier divides a population.



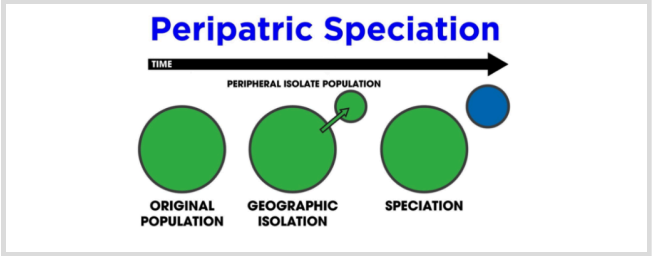
Allopatric via Founder Effect

- At least one **fertilized female** enters a new geographical area or habitat.
- The small new population can eventually become genetically different.



2. Peripatric Speciation

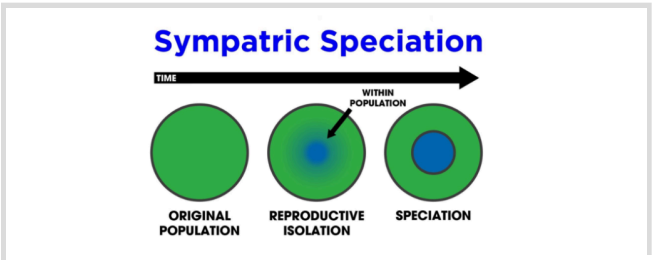
- **A small group breaks away from a larger population and forms a new species.**
- Usually involves **physical/geographical isolation**.
- The smaller population may experience strong **genetic drift**



Easy idea: Big population → small group gets separated → small group changes → new species.

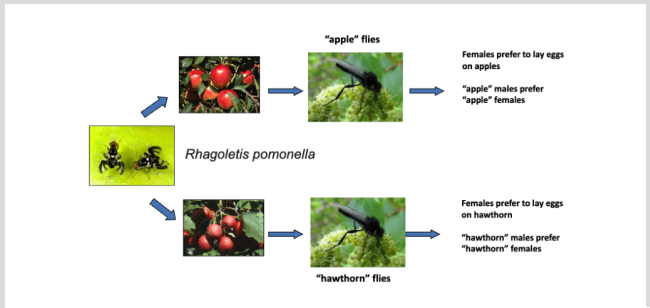
3. Sympatric Speciation

- **Speciation occurs without a geographical barrier.**
- Populations live in the **same geographic area**.
- Gene flow becomes reduced because of biological or genetic differences.



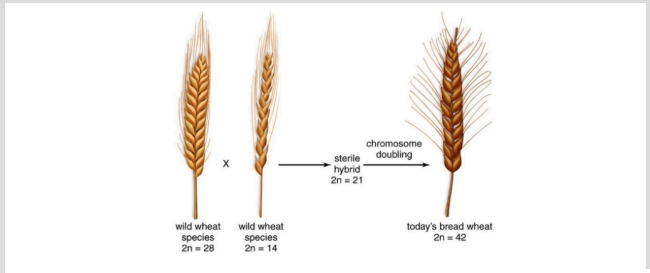
Sympatric via Behavioral Isolation

- Differences in **behavior** prevent organisms from mating with each other.



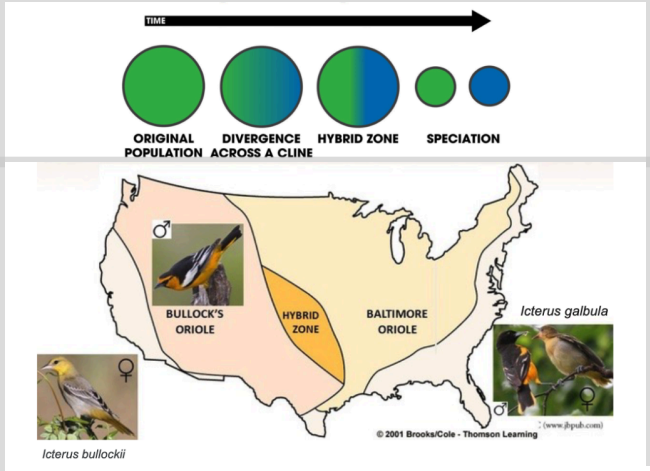
Sympatric via Polyploidy

- **Polyploidy** = cells have more than two paired sets of chromosomes.
- Commonly important in plants.
- Can create reproductive isolation very quickly.



4. Parapatric Speciation

- **Speciation occurs when populations live in a large area but mostly mate with nearby individuals.**
- No major physical barrier is present.
- Populations experience **slightly different habitats**.
- These differences can eventually lead to speciation.



Reproductive Isolation

- **Reproductive isolation = biological barriers that prevent two different species from producing viable, fertile offspring.**

- Helps maintain the **identity/integrity of species**.
- It does not apply perfectly to every organism because some different species can produce **fertile hybrids**.

Two Types

Prezygotic

- Prevents reproduction **before fertilization**.

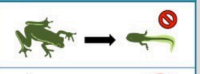
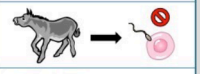
Postzygotic

- Acts **after fertilization** and prevents successful reproduction or development.

Remember:

Pre = before

Post = after

Pre-zygotic Isolating Mechanisms		Example	
Temporal	Occurs when two species mate at different times of year	Frogs live in same pond but breed during different seasons (summer vs spring)	
Ecological	Occurs when two species occupy different habitats	Lions and tigers can potentially interbreed, but usually occupy different habitats	
Behavioural	Occurs when two species have different courtship behaviours	Certain groups of birds will only respond to species-specific mating calls	
Mechanical	Occurs when physical differences prevent copulation / pollination	Certain breeds of dog are morphologically incapable of mating due to size	
Post-zygotic Isolating Mechanisms		**Examples**	
Hybrid Inviability	Hybrids are produced but fail to develop to reproductive maturity	Certain types of frogs form hybrid tadpoles that die before they can become a frog	
Hybrid Infertility	Hybrids fail to produce functional gametes (sterility)	Mules are sterile hybrids resulting from mating between a horse and a donkey	
Hybrid Breakdown	F_1 hybrids are fertile, but F_2 generation fails to develop properly	The offspring of hybrid copepods have less potential for survival or reproduction	

Rates / Tempo of Speciation

Gradualism

Evolution happens slowly and gradually.

- Changes occur through **small, periodic changes** in the gene pool.
- **Intermediate phenotypes** can be observed.
- Species slowly change over long periods of time.

Easy idea:

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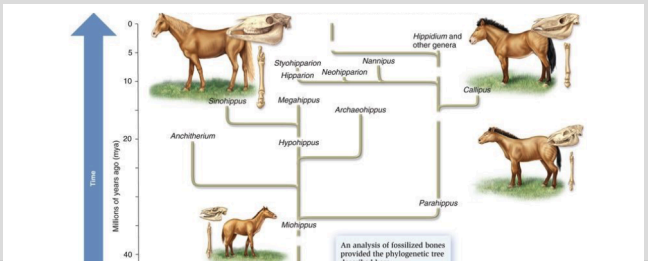
Small changes build up over time.



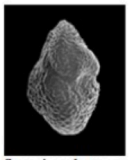
Punctuated Equilibrium

Evolution happens in rapid bursts separated by long periods of little or no change.

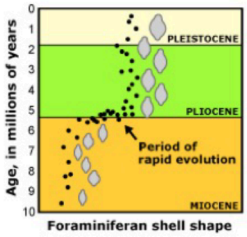
- Long periods of **little evolutionary change**.
- Followed by relatively **rapid evolutionary change**.
- Intermediate forms may be absent from the fossil record.

Easy idea:

Long stability → rapid change → stability.



Scanning electron micrograph of a foraminiferan



Quick Review

Concept	Main Idea
Typological	Species are identified by physical form
Nominalistic	Species are human-made categories
Biological	Species can interbreed and share a gene pool
Evolutionary	Species have their own evolutionary history
Ecological	Species occupy a particular niche
Phylogenetic	Species are the smallest diagnosable evolutionary groups
Allopatric	Speciation through geographical separation
Peripatric	Small isolated group forms a new species
Sympatric	Speciation without geographical separation
Parapatric	Neighboring populations diverge despite no major barrier
Gradualism	Slow, continuous evolutionary change
Punctuated equilibrium	Long stability + rapid evolutionary change