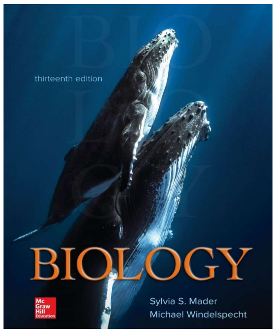

Biology

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Michael Windelspecht

Chapter 17
Speciation and Macroevolution
Lecture Outline

See separate FlexArt PowerPoint slides for all figures and tables pre-inserted into PowerPoint without notes.

17-1

17.1 How New Species Evolve

Macroevolution

- Evolution on a large scale
- Best observed within the fossil record
- Involves the origin of species, also called speciation
- **Speciation**
  - Splitting of one species into two or more species
  - Final result of changes in the gene pool's allelic and genotypic frequencies

17-2

What Is a Species? (2)

Morphological species concept

- Based on analysis of **diagnostic traits** distinguishing one species from another
  - Species can be distinguished anatomically by one or more distinct physical characteristics.
  - This method was used by Linnaeus.
  - Most species are described this way.
  - This held up for 200 years.
  - But, bacteria and other microorganisms do not have many measurable traits.

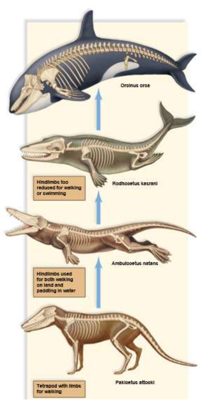
17-3

What Is a Species? (3)

The **evolutionary species concept** distinguishes species from one another based on morphological (structural) traits.

- Critical traits for distinguishing species are called diagnostic traits.
- It was used to explain speciation in the fossil record.
- It implies that members of a species share a distinct evolutionary pathway.
- Since fossils don't provide information about color, soft tissue anatomy, or behavioral traits they are of limited use.

Evolutionary Species Concept



Jump to Evolutionary Species Concept Long Description

What Is a Species? (4)

The **phylogenetic species concept** is used to identify species based on a common ancestor.

- It is based on a single ancestor for two or more different groups.
  - For you and your cousins, your grandmother is a common ancestor.

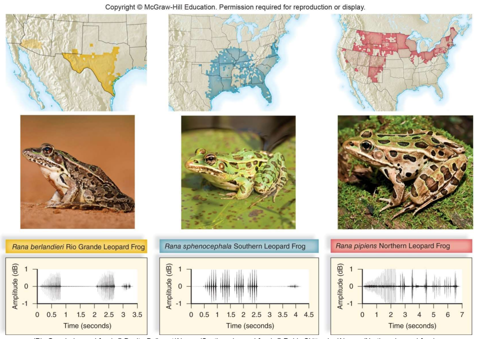
How New Species Evolve (1)

Biological Species Concept

- Populations of the same species breed only among themselves.
- They experience **reproductive isolation** from other such populations.
- Very few species are actually tested for reproductive isolation.
- A group of birds collectively called flycatchers all look similar but do not reproduce with one another, so they are different species.
- Leopard frogs live in different habitats, have a different courtship song, and are different species.

17-7

How New Species Evolve (2)



(Rio Grande leopard frog): © Danita Delimont/Alamy; (Southern leopard frog): © Robin Chittenden/Alamy; (Northern leopard frog): © Michelle Gilders/Alamy

Jump to How New Species Evolve (2) Long Description

17-8

How New Species Evolve (3)

Reproductive isolating mechanisms inhibit gene flow between species.

Two general types:

- **Prezygotic isolating mechanisms**
- **Postzygotic isolating mechanisms**

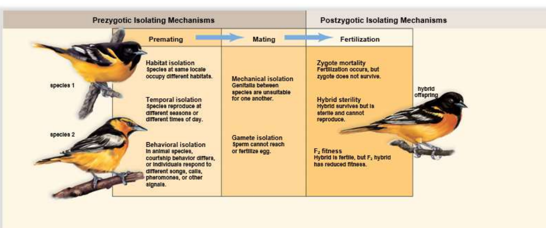
17-9

How New Species Evolve (4)

Prezygotic isolating mechanisms prevent mating attempts or make it unlikely that fertilization will be successful.

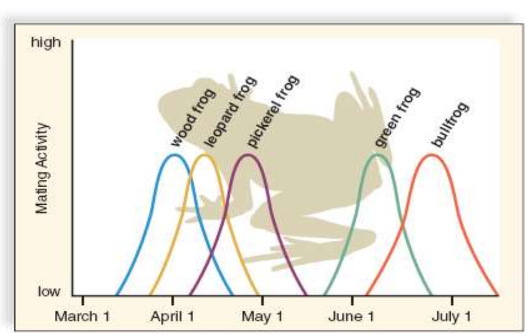
- ***Habitat Isolation*** – species occupy different habitats
- ***Temporal Isolation*** – each reproduces at a different time
- ***Behavioral Isolation*** – courtship patterns for recognizing mates differ
- ***Mechanical Isolation*** – incompatible animal genitalia or plant floral structures
- ***Gamete Isolation*** – gametes that meet do not fuse to become a zygote

Reproductive Barriers



Jump to Reproductive Barriers Long Description

Temporal Isolation



Jump to Temporal Isolation Long Description

Prezygotic Isolating Mechanism

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Jump to Prezygotic Isolating Mechanism Long Description 17-13

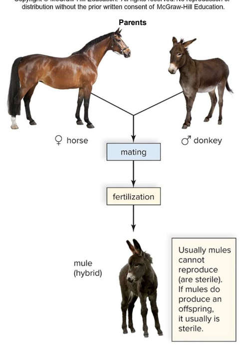
How New Species Evolve (5)

Postzygotic Isolating Mechanisms – Prevent hybrid offspring from developing or breeding

- **Hybrid Inviability** – hybrid zygote is not viable and dies
- **Hybrid Sterility** – hybrid zygote develops into a sterile adult
  - Mules, for example, the offspring of a cross between a female horse and a male donkey, are usually sterile and cannot reproduce.

17-14

Postzygotic Isolating Mechanism



(photos): (horse): ©Purplequeue/Shutterstock RF; (donkey): ©Eric Isselée/Getty RF; (mule): ©Radius Images/Alamy RF

17-15

17.2 Modes of Speciation

Speciation:

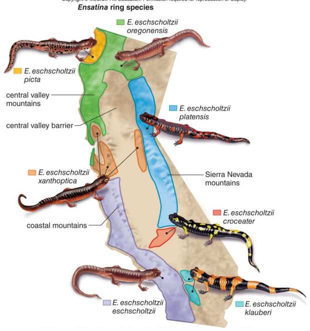
- The splitting of one species into two, or
- The transformation of one species into a new species over time

Two modes:

- **Allopatric Speciation**
  - Microevolutionary processes such as genetic drift and natural selection alter the gene pool of each population independently.
  - When differences become large enough, reproductive isolation may occur and new species are formed.
  - Two geographically isolated populations of one species become different species over time.
  - It can be due to differing selection pressures in differing environments.

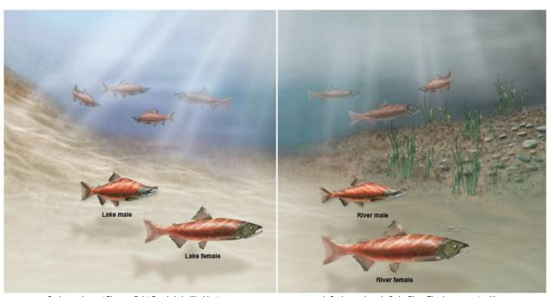
17-16

Allopatric Speciation



Jump to Allopatric Speciation Long Description 17-17

Allopatric Speciation Among Sockeye Salmon



a. Sockeye salmon at Pleasure Point Beach, Lake Washington

b. Sockeye salmon In Cedar River. The river connects with Lake Washington.

Jump to Allopatric Speciation Among Sockeye Salmon Long Description 17-18

Modes of Speciation (1)

Two modes:

- **Sympatric Speciation**
  - One population develops into two or more reproductively isolated groups.
  - There is no prior geographic isolation.
  - Example: Midas and arrow cichlid fish; the arrow cichlid evolved from a population of midas cichlids adapted to living and feeding in an open water habitat.
  - In plants, sympatric speciation often involves **polyploidy** (a chromosome number beyond the diploid [2n] number).
    - Tetraploid hybridization in plants
      - Results in self-fertile species that are reproductively isolated from either parental species

17-19

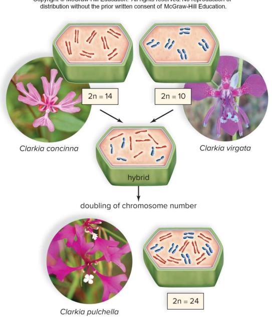
Modes of Speciation (2)

Sympatric Speciation

- A polyploid plant can reproduce with itself, but cannot reproduce with the 2n population because not all the chromosomes would be able to pair during meiosis.
- Two types of polyploidy are known:
  - **Autoploidy** occurs when a diploid plant produces diploid gametes due to nondisjunction during meiosis.
    - If diploid gamete fuses with a haploid gamete, a triploid plant results.
    - A triploid (3n) plant is sterile and cannot produce offspring because the chromosomes cannot pair during meiosis.
  - **Alloploidy** is a more complicated process than autoploidy.
    - Requires two different but related species of plants
    - Hybridization followed by doubling of the chromosomes

17-20

Alloploidy



(photos): (Clarkia concinna): ©Steffen Hauser/ botanikfoto/Alamy; (Clarkia virgata): ©2016 Christopher Bronny; (Clarkia pulchella): ©age fotostock/Alamy

Jump to Alloploidy Long Description

17-21

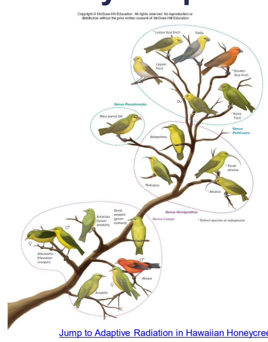
Modes of Speciation (3)

Adaptive Radiation

- It occurs when a single ancestral species rapidly gives rise to a variety of new species as each adapts to a specific environment.
- Many instances of adaptive radiation involve sympatric speciation following the removal of a competitor, predator, or a change in the environment.
- Allopatric speciation can also cause a population to undergo adaptive radiation.

17-22

Adaptive Radiation in Hawaiian Honeycreepers



Jump to Adaptive Radiation in Hawaiian Honeycreepers Long Description 17-23

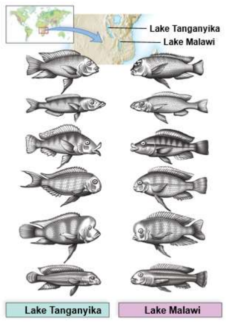
Modes of Speciation (4)

Convergent Evolution

- Occurs when a similar biological trait evolves in two unrelated species as a result of exposure to similar environments.
  - Traits evolving in this manner are termed **analogous** traits.
    - Similar function, but different origin
    - Example: bird wing vs. bat wing
    - Opposite of analogous is homologous—traits are similar because they evolved from a common ancestor.
    - Example: wings of butterflies and moths, since both evolved from Lepidoptera

17-24

Convergent Evolution of Africa Lake Fish



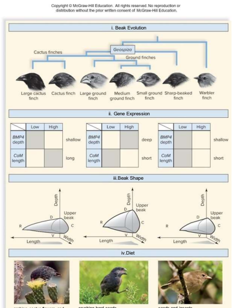
Jump to Convergent Evolution of Africa Lake Fish Long Description

Genetic Basis of Beak Size and Shape in Finches – Nature of Science Reading (1)

Darwin's finches are an example of how many species originate from a common ancestor.

- Over time, each species of finch adapted to a unique way of life.
- Beak shape and size are related to their diets.
- Increases or decreases in gene activity fine tune beak morphology.
- *BMP-4* and calmodulin (*CaM*) genes regulate the length and depth of the beaks.
  - The cactus finch has a low level of *BMP-4* and a high level of *CaM* and has a shallow, long beak.
  - The ground finch has the opposite pattern and a short, deep beak.

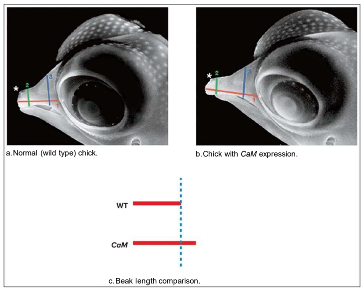
Genetic Basis of Beak Size and Shape in Finches – Nature of Science Reading (2)



(photos): (left): ©Kevin Schafer/Corbis/Getty Images; (center): ©Don Johnston/Getty Images; (right): ©Ralph Lee Hopkins/Getty RF

Jump to Genetic Basis of Beak Size and Shape in Finches – Nature of Science Reading (2) Long Description

Genetic Basis of Beak Size and Shape in Finches – Nature of Science Reading (3)



a. Normal (wild type) chick.

b. Chick with *CaM* expression.

c. Beak length comparison.

(photos): ©Dr. Arkhat Abzhanov, Harvard University, Dept. of OEB

Jump to Genetic Basis of Beak Size and Shape in Finches – Nature of Science Reading (3) Long Description 17-28

17.3 Principles of Macroevolution

Macroevolution

- It is the evolution at the species or higher level of classification.
- Some evolutionists support a *gradualistic model*.
  - Evolution at the species level occurs gradually.
  - Speciation occurs after populations become isolated.
  - Each group continues its own evolutionary pathway.
  - The gradualistic model suggests that it is difficult to indicate when speciation occurred.

17-29

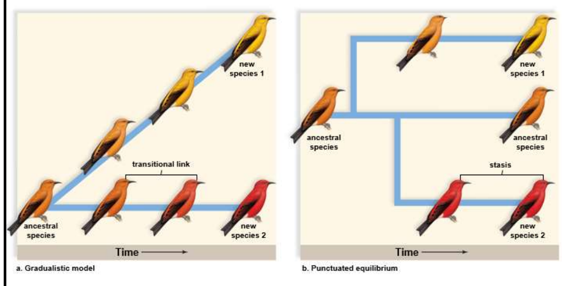
Principles of Macroevolution (1)

Macroevolution

- Some paleontologists support the *punctuated equilibrium model*.
  - This model states that periods of equilibrium are punctuated by speciation.
  - Species can appear quite suddenly.
  - The assembly of species in the fossil record can be explained by periods of equilibrium interrupted by abrupt speciation.
  - Some fossil species can be explained by the gradualistic model and others by the punctuated equilibrium model.
    - Stabilizing selection can keep species in equilibrium for long periods.

17-30

Gradualistic and Punctuated Equilibrium Models



Jump to Gradualistic and Punctuated Equilibrium Models Long Description 17-31

Principles of Macroevolution (3)

Macroevolution is not goal-oriented.

- The evolution of the horse (*Equus*)
- The first probable members of the horse family lived about 57 Million Years Ago.
  - *Hyracotherium* survived for 20 million years.
  - Horse evolution has been studied since the 1870s.
  - This genus represented a model for gradual, straight-line evolution with the modern horse as its “goal.”
  - Three trends were particularly evident during the evolution of the horse:
    - Increase in overall size
    - Toe reduction
    - Change in tooth size and shape

17-32

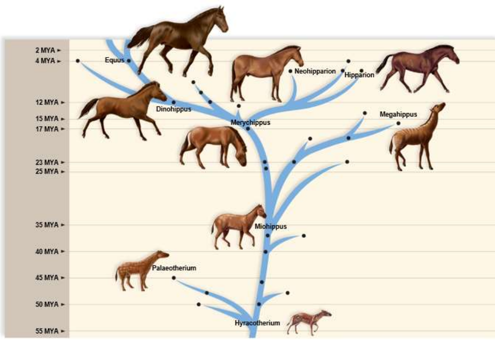
Principles of Macroevolution (4)

Macroevolution is not goal-oriented.

- Discovery of more fossils has led to recognition that:
  - The lineage of a horse is complicated by the presence of many ancestors with varied traits.
    - The direct ancestor of *Equus* is not known.
    - Each ancestral species was adapted to its environment.
  - Speciation, diversification, and extinction are common occurrences in the fossil record.

17-33

Simplified Family Tree of *Equus*



Jump to Simplified Family Tree of *Equus* Long Description

17-34