# Chapter 24

# The Origin of Species

PowerPoint Lectures for
***Biology, Seventh Edition***
*Neil Campbell and Jane Reece*

**Lectures by Chris Romero**



- Overview: The "Mystery of Mysteries"
- Darwin explored the Galápagos Islands
  - And discovered plants and animals found nowhere else on Earth

**Figure 24.1**



- The origin of new species, or speciation
  - Is at the focal point of evolutionary theory, because the appearance of new species is the source of biological diversity
- Evolutionary theory
  - Must explain how new species originate in addition to how populations evolve
- Macroevolution
  - Refers to evolutionary change above the species level



- Two basic patterns of evolutionary change can be distinguished
  - Anagenesis
  - Cladogenesis

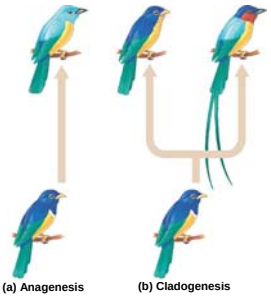


**Figure 24.2** **(a) Anagenesis** **(b) Cladogenesis**



- Concept 24.1: The biological species concept emphasizes reproductive isolation
- *Species*
  - Is a Latin word meaning "kind" or "appearance"



## The Biological Species Concept

- The biological species concept
  - Defines a species as a population or group of populations whose members have the potential to interbreed in nature and produce viable, fertile offspring but are unable to produce viable fertile offspring with members of other populations

**(a) Similarity between different species.** The eastern meadowlark (*Sturnella magna,* left) and the western meadowlark (*Sturnella neglecta,* right) have similar body shapes and colorations. Nevertheless, they are distinct biological species because their songs and other behaviors are different enough to prevent interbreeding should they meet in the wild.

**(b) Diversity within a species.** As diverse as we may be in appearance, all humans belong to a single biological species (*Homo sapiens*), defined by our capacity to interbreed.

**Figure 24.3 A, B**



## *Reproductive Isolation*

- Reproductive isolation
  - Is the existence of biological factors that impede members of two species from producing viable, fertile hybrids
  - Is a combination of various reproductive barriers



- Prezygotic barriers
  - Impede mating between species or hinder the fertilization of ova if members of different species attempt to mate
- Postzygotic barriers
  - Often prevent the hybrid zygote from developing into a viable, fertile adult



- Prezygotic and postzygotic barriers

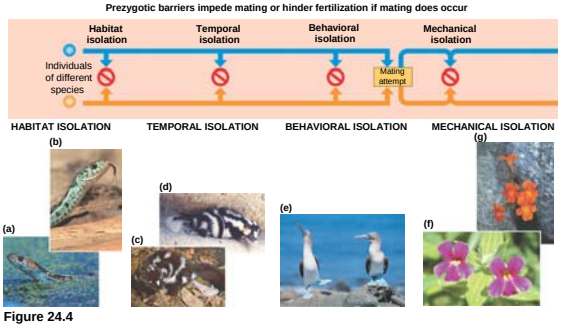
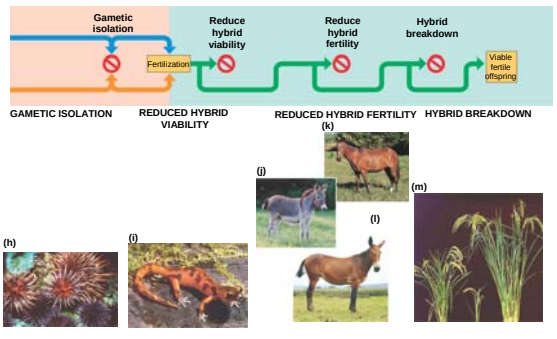



**Figure 24.4**








## *Limitations of the Biological Species Concept*

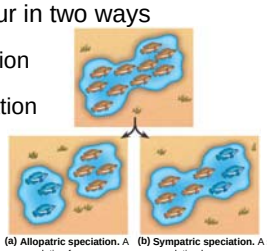
- The biological species concept cannot be applied to
  - Asexual organisms
  - Fossils
  - Organisms about which little is known regarding their reproduction

## Other Definitions of Species

- The morphological species concept
  - Characterizes a species in terms of its body shape, size, and other structural features
- The paleontological species concept
  - Focuses on morphologically discrete species known only from the fossil record
- The ecological species concept
  - Views a species in terms of its ecological niche
- The phylogenetic species concept
  - Defines a species as a set of organisms with a unique genetic history



- Concept 24.2: Speciation can take place with or without geographic separation
- Speciation can occur in two ways
  - Allopatric speciation
  - Sympatric speciation



**(a) Allopatric speciation.** A population forms a new species while geographically isolated from its parent population.

**(b) Sympatric speciation.** A small population becomes a new species without geographic separation.

**Figure 24.5 A, B**



## Allopatric ("Other Country") Speciation

- In allopatric speciation
  - Gene flow is interrupted or reduced when a population is divided into two or more geographically isolated subpopulations



- Once geographic separation has occurred
  - One or both populations may undergo evolutionary change during the period of separation


**Figure 24.6**



- In order to determine if allopatric speciation has occurred
  - Reproductive isolation must have been established

**EXPERIMENT** Diane Dodd, of Yale University, divided a fruit-fly population, raising some populations on a starch medium and others on a maltose medium. After many generations, natural selection resulted in divergent evolution: Populations raised on starch digested starch more efficiently, while those raised on maltose digested maltose more efficiently. Dodd then put flies from the same or different populations in mating cages and measured mating frequencies.

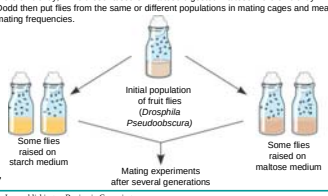
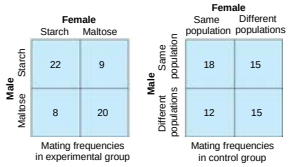



**Figure 24.7**



**RESULTS** When flies from "starch populations" were mixed with flies from "maltose populations," the flies tended to mate with like partners. In the control group, flies taken from different populations that were adapted to the same medium were about as likely to mate with each other as with flies from their own populations.




**CONCLUSION** The strong preference of "starch flies" and "maltose flies" to mate with like adapted flies, even if they were from different populations, indicates that a reproductive barrier is forming between the divergent populations of flies. The barrier is not absolute (some mating between starch flies and maltose flies did occur) but appears to be under way after several generations of divergence resulting from the separation of these allopatric populations into different environments.

## Sympatric ("Same Country") Speciation

- In sympatric speciation
  - Speciation takes place in geographically overlapping populations



## *Polyploidy*

- Polyploidy
  - Is the presence of extra sets of chromosomes in cells due to accidents during cell division
  - Has caused the evolution of some plant species



- An autopolyploid
  - Is an individual that has more than two chromosome sets, all derived from a single species

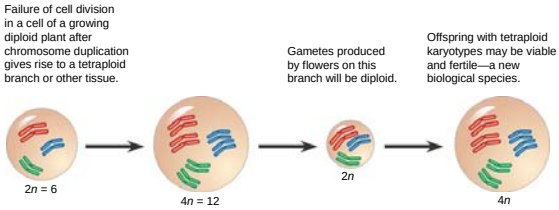



**Figure 24.8**



- An allopolyploid
  - Is a species with multiple sets of chromosomes derived from different species

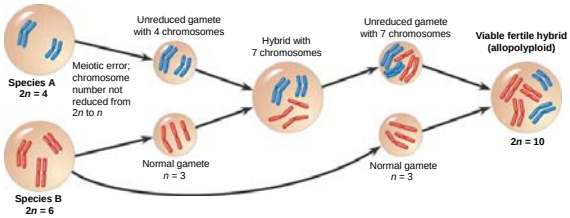



**Figure 24.9**



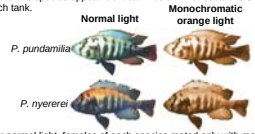
## *Habitat Differentiation and Sexual Selection*

- Sympatric speciation
  - Can also result from the appearance of new ecological niches



- In cichlid fish
  - Sympatric speciation has resulted from nonrandom mating due to sexual selection

**EXPERIMENT** Researchers from the University of Leiden placed males and females of *Pundamilia pundamilia* and *P. nyererei* together in two aquarium tanks, one with natural light and one with a monochromatic orange lamp. Under normal light, the two species are noticeably different in coloration; under monochromatic orange light, the two species appear identical in color. The researchers then observed the mating choices of the fish in each tank.




**RESULTS** Under normal light, females of each species mated only with males of their own species. But under orange light, females of each species mated indiscriminately with males of both species. The resulting hybrids were viable and fertile.

**CONCLUSION** The researchers concluded that mate choice by females based on coloration is the main reproductive barrier that normally keeps the gene pools of these two species separate. Since the species can still interbreed when this prezygotic behavioral barrier is breached in the laboratory, the genetic divergence between the species is likely to be small. This suggests that speciation in nature has occurred relatively recently.

**Figure 24.10**

## Allopatric and Sympatric Speciation: A Summary

- In allopatric speciation
  - A new species forms while geographically isolated from its parent population
- In sympatric speciation
  - The emergence of a reproductive barrier isolates a subset of a population without geographic separation from the parent species



## Adaptive Radiation

- Adaptive radiation
  - Is the evolution of diversely adapted species from a common ancestor upon introduction to new environmental opportunities

Figure 24.11



- The Hawaiian archipelago
  - Is one of the world's great showcases of adaptive radiation


Figure 24.12



## Studying the Genetics of Speciation

- The explosion of genomics
  - Is enabling researchers to identify specific genes involved in some cases of speciation

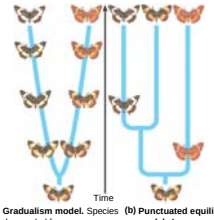


## The Tempo of Speciation

- The fossil record
  - Includes many episodes in which new species appear suddenly in a geologic stratum, persist essentially unchanged through several strata, and then apparently disappear
- Niles Eldredge and Stephen Jay Gould coined the term punctuated equilibrium to describe these periods of apparent stasis punctuated by sudden change



- The punctuated equilibrium model
  - Contrasts with a model of gradual change throughout a species' existence




(a) **Gradualism model.** Species descended from a common ancestor gradually diverge more and more in their morphology as they acquire unique adaptations.

(b) **Punctuated equilibrium model.** A new species changes most as it buds from a parent species and then changes little for the rest of its existence.

Figure 24.13

- Concept 24.3: Macroevolutionary changes can accumulate through many speciation events
- Macroevolutionary change
  - Is the cumulative change during thousands of small speciation episodes



## Evolutionary Novelties

- Most novel biological structures
  - Evolve in many stages from previously existing structures



- Some complex structures, such as the eye
  - Have had similar functions during all stages of their evolution

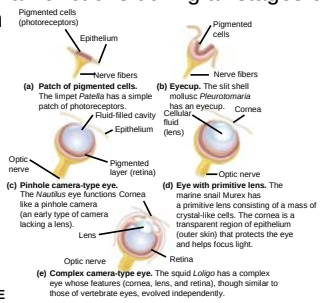



**Figure 24.14 A–E**



## Evolution of the Genes That Control Development

- Genes that program development
  - Control the rate, timing, and spatial pattern of changes in an organism's form as it develops into an adult



## *Changes in Rate and Timing*

- Heterochrony
  - Is an evolutionary change in the rate or timing of developmental events
  - Can have a significant impact on body shape



- Allometric growth
  - Is the proportioning that helps give a body its specific form

**(a) Differential growth rates in a human.** The arms and legs lengthen more during growth than the head and trunk, as can be seen in this conceptualization of an individual at different ages all rescaled to the same height.

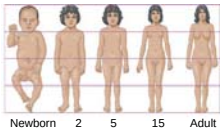
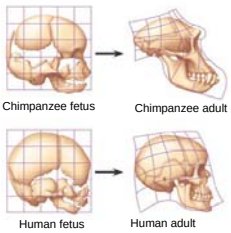



**Figure 24.15 A**

- Different allometric patterns
  - Contribute to the contrasting shapes of human and chimpanzee skulls




**(b) Comparison of chimpanzee and human skull growth.** The fetal skulls of humans and chimpanzees are similar in shape. Allometric growth transforms the rounded skull and vertical face of a newborn chimpanzee into the elongated skull and sloping face characteristic of adult apes. The same allometric pattern of growth occurs in humans, but with a less accelerated elongation of the jaw relative to the rest of the skull.

**Figure 24.15 B**



- Heterochrony
  - Has also played a part in the evolution of salamander feet

**(a) Ground-dwelling salamander.** A longer time peroid for foot growth results in longer digits and less webbing.

**(b) Tree-dwelling salamander.** Foot growth ends sooner. This evolutionary timing change accounts for the shorter digits and more extensive webbing, which help the salamander climb vertically on tree branches.

**Figure 24.16 A, B**



- In paedomorphosis
  - The rate of reproductive development accelerates compared to somatic development
  - The sexually mature species may retain body features that were juvenile structures in an ancestral species

**Figure 24.17**



## *Changes in Spatial Pattern*

- Substantial evolutionary change
  - Can also result from alterations in genes that control the placement and organization of body parts



- Homeotic genes
  - Determine such basic features as where a pair of wings and a pair of legs will develop on a bird or how a flower's parts are arranged



- The products of one class of homeotic genes called *Hox* genes
  - Provide positional information in the development of fins in fish and limbs in tetrapods

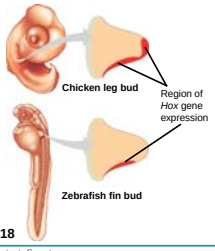



**Figure 24.18**

- The evolution of vertebrates from invertebrate animals
  - Was associated with alterations in *Hox* genes

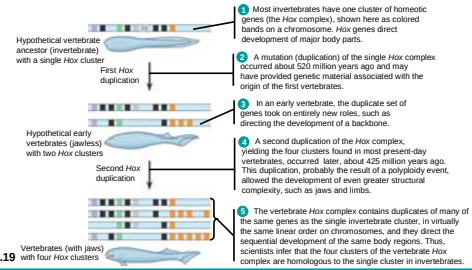



**Figure 24.19** with four *Hox* clusters



## Evolution Is Not Goal Oriented

- The fossil record
  - Often shows apparent trends in evolution that may arise because of adaptation to a changing environment

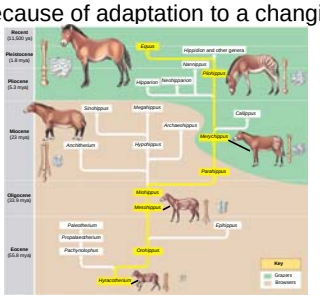



**Figure 24.20**



- According to the species selection model
  - Trends may result when species with certain characteristics endure longer and speciate more often than those with other characteristics
- The appearance of an evolutionary trend
  - Does not imply that there is some intrinsic drive toward a particular phenotype