BIG IDEA I

The process of evolution drives the diversity and unity of life.

Enduring Understanding 1.C

Life continues to evolve within a changing environment.

Essential Knowledge 1.C.1

Speciation and extinction have occurred throughout the Earth's history.

PowerPoint® Lecture Presentations for

Biology

Eighth Edition

Neil Campbell and Jane Reece

Lectures by Chris Romero, updated by Erin Barley with contributions from Joan Sharp

Essential Knowledge 1.C.1: *Speciation and extinction have occurred throughout the Earth's history.*

- **Learning Objectives:**
  - **(1.20)** The student is able to *analyze data* related to questions of speciation and extinction throughout the Earth's history.
  - **(1.21)** The student is able to *design a plan* for collecting data to investigate the scientific claim that speciation and extinction have occurred throughout the Earth's history.

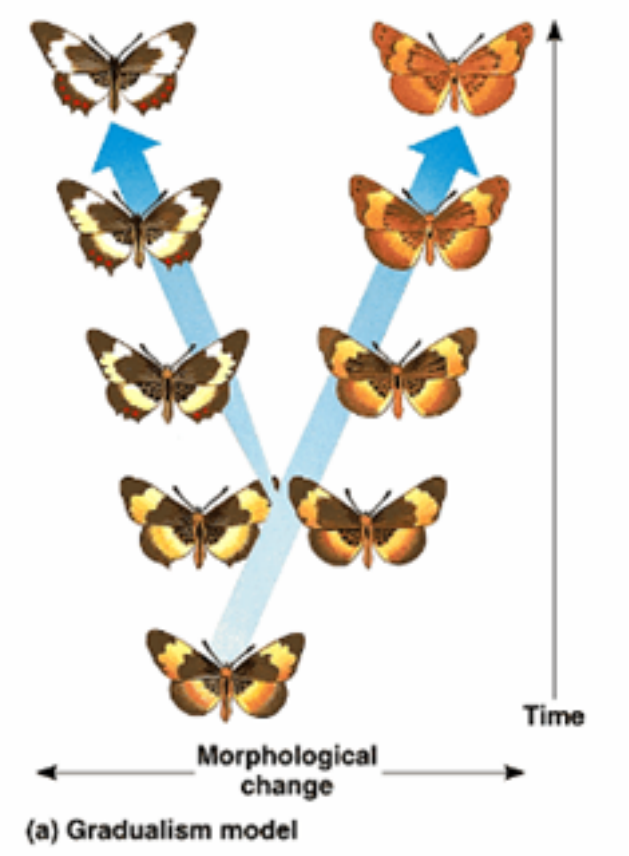
Speciation rates can vary, especially when adaptive radiation occurs when new habitats become available.

- Speciation can be slow and **gradual** or, as described by **punctuated equilibrium**, can occur in "bursts" followed by relatively quiet periods.
- At times of ecological stress, extinction rates can be rapid, and mass extinctions are often followed by **adaptive radiation**, the rapid evolution of species when new habitats/niches become available.

Fig. 24-17

Gradualism

Punctuated Equilibrium



Species descended from a common ancestor gradually diverge more and more in morphology as they acquire unique adaptations.

A new species changes most as it buds from a parent species, and then changes little for the rest of its existence.

What is Speciation?

- **Speciation**, the origin of new species, is at the focal point of evolutionary theory because it results in diversity of life forms.
- Evolutionary theory must explain how new species originate and how populations evolve.
  - **Microevolution** consists of adaptations that evolve within a population, confined to one gene pool.
  - **Macroevolution** refers to evolutionary change above the species level.

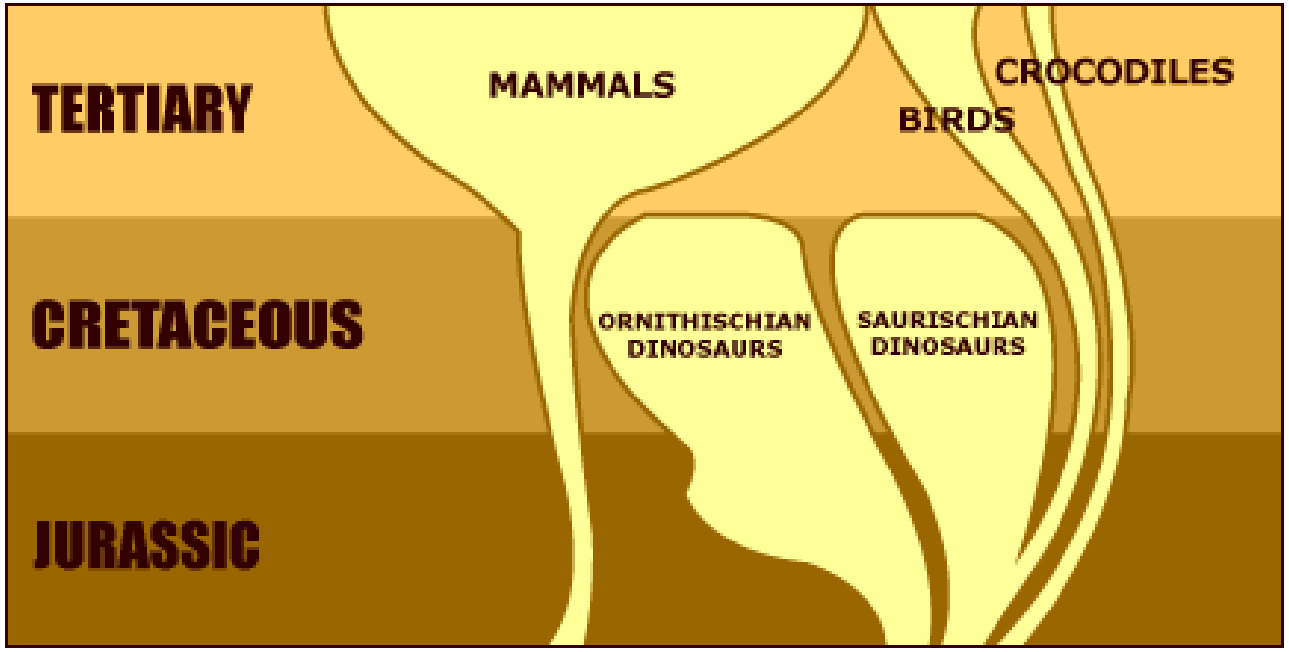
Fig. 24-2

(a) Similarity between different species

(b) Diversity within a species

Adaptive Radiation Events Lead to Rapid Speciation

- Adaptive radiation *typically occurs when NEW NICHES BECOME AVAILABLE - when a few organisms make their way to new, often distant areas or when environmental changes cause numerous extinctions, opening up ecological niches for the survivors.*



Rates of Speciation

- Many questions remain concerning how long it takes for new species to form, or how many genes need to differ between species
- Broad patterns in speciation can be studied using the fossil record, morphological data, or molecular data
- Speciation can occur rapidly or slowly and can result from changes in few or many genes.

Patterns in the Fossil Record

- The fossil record includes examples of species that appear suddenly, persist essentially unchanged for some time, and then apparently disappear
- The term **punctuated equilibrium** is used to describe periods of apparent stasis punctuated by sudden change
- The punctuated equilibrium model contrasts with a model of gradual change in a species' existence

What is an Extinction Event?

- In biology and ecology, **extinction** is the end of an organism or of a group of organisms (taxon), normally a species.
- The moment of extinction is generally considered to be the death of the last individual of the species, although the capacity to breed and recover may have been lost before this point.
- Because a species' potential range may be very large, determining this moment is difficult, and is usually done retrospectively.
- Species become extinct when they are no longer able to survive in changing conditions or against superior competition.
- A typical species becomes extinct within 10 million years of its first appearance, although some species, called living fossils, survive with virtually no morphological change for hundreds of millions of years.
- Most extinctions have occurred naturally, prior to *Homo sapiens* walking on Earth: it is estimated that 99.9% of all species that have ever existed are now extinct.

Species extinction rates are rapid at times of ecological stress.

- ***Illustrative Examples include:***
  - Five Major Extinctions
  - Human Impact on Ecosystems and Species Extinction Rates
  - Watch this extinction video on YouTube:
    - http://www.youtube.com/watch?v=GeBqGLbHUfw

The "Big Five" Mass Extinction Events

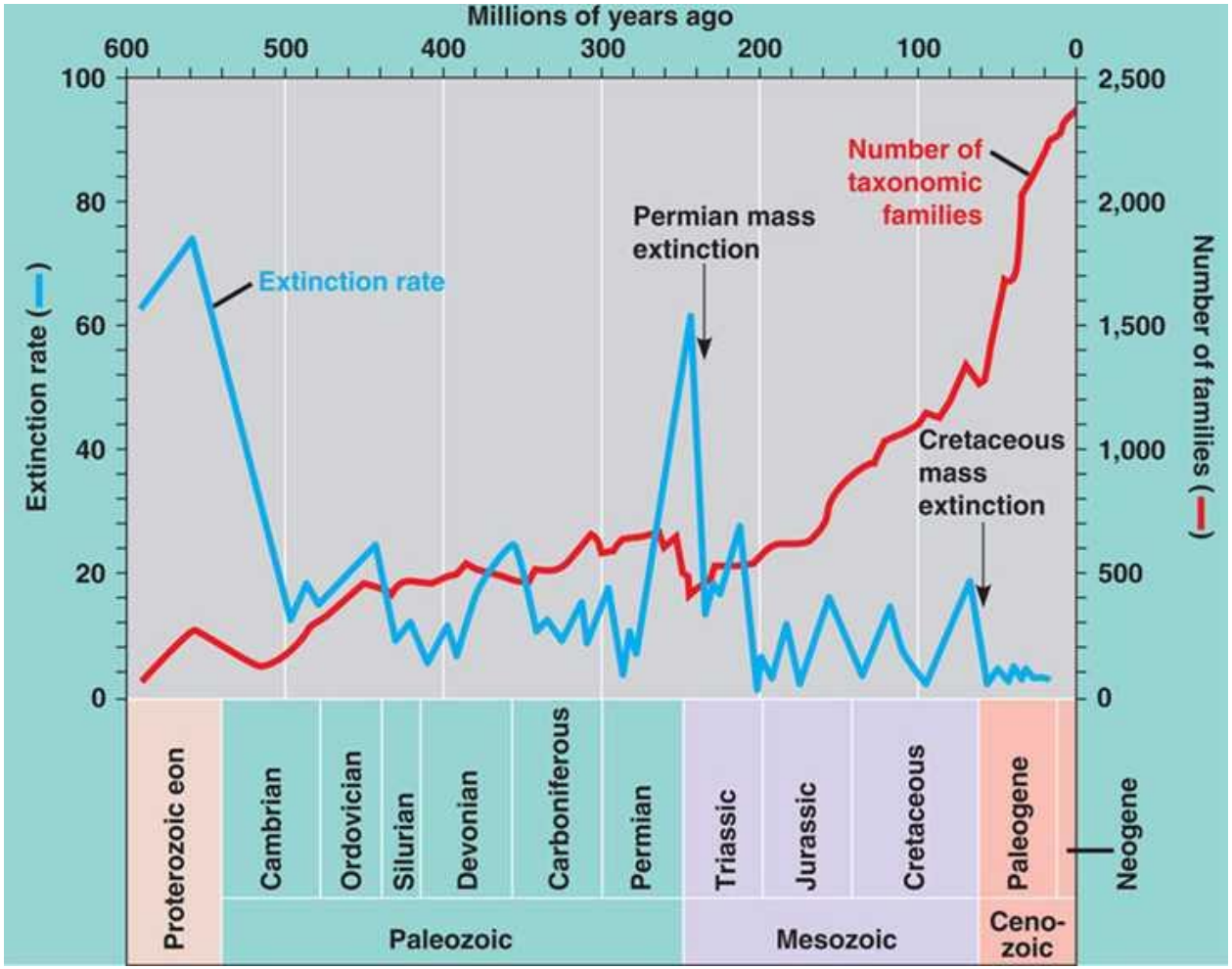
Mass Extinction	Time of Extinction	Organisms Greatly Reduced or Made Extinct
End of the Ordovician period	443 million years ago	Trilobites, brachiopods, echinoderms, and corals
End of the Devonian period	354 million years ago	Marine families on tropical reefs, corals, brachiopods, and bivalves
End of the Permian period	248 million years ago	Trilobites, mollusks, brachiopods, and many vertebrates
End of the Triassic period	206 million years ago	Mollusks, sponges, marine vertebrates, and large amphibians
End of the Cretaceous period	65 million years ago	Ammonites, dinosaurs, brachiopods, bivalves, and echinoderms

The fossil record shows that the overwhelming majority of species that ever lived are now extinct.

Although extinction occurs on a regular basis, at certain times disruptive global environmental changes have caused the rate of extinction to increase dramatically – and a mass extinction results – in which large #s of species become extinct.

The five major extinctions illustrate that species extinction rates are rapid at times of ecological stress. In each of the "Big Five" mass extinctions, 50% or more of Earth's marine species became extinct.

Consequences of Mass Extinctions



Human Impact on Extinction Rates

- Currently, environmental groups and some governments are concerned with the extinction of species caused by humanity, and are attempting to combat further extinctions through a variety of conservation programs.
- Humans can cause extinction of a species through overharvesting, pollution, habitat destruction, introduction of new predators and food competitors, overhunting, and other influences.
- Explosive, unsustainable human population growth is an essential cause of the extinction crisis.
- According to the International Union for Conservation of Nature (IUCN), 784 extinctions have been recorded since the year 1500 (to the year 2004), the arbitrary date selected to define "modern" extinctions, with many more likely to have gone unnoticed (several species have also been listed as extinct since the 2004 date).

BIG IDEA I

The process of evolution drives the diversity and unity of life.

Enduring Understanding 1.C

Life continues to evolve within a changing environment.

Essential Knowledge 1.C.2

Speciation may occur when two populations become reproductively isolated from each other.

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Essential Knowledge 1.C.2: *Speciation may occur when two populations become reproductively isolated from each other.*

- **Learning Objectives:**
  - **(1.22)** The student is able to *use data* from a real or simulated population(s), based on graphs or models of types of selection, to *predict* what will happen to the population in the future.
  - **(1.23)** The student is able to *justify the selection of data* that address questions related to reproductive isolation and speciation.
  - **(1.24)** The student is able to *describe* speciation in an isolated population and *connect it* to change in gene frequency, change in environment, natural selection and/or genetic drift.

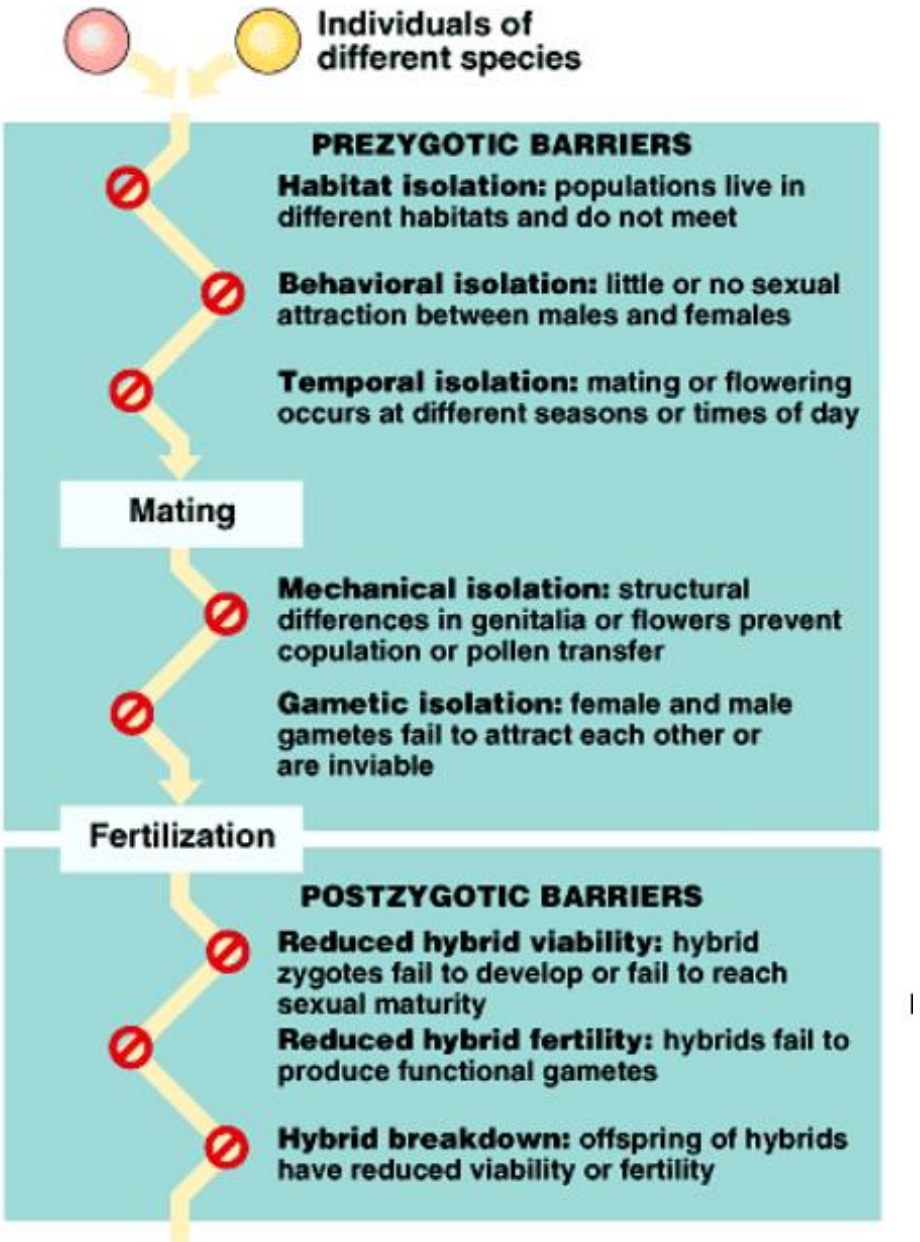
Speciation results in diversity of life forms.

- The **biological species concept** states that a **species** is a group of populations whose members have the potential to interbreed in nature and produce viable, fertile offspring; they do not breed successfully with other populations.
- Gene flow between populations holds the phenotype of a population together – ***this can prevent speciation!***

New species arise from reproductive isolation over time.

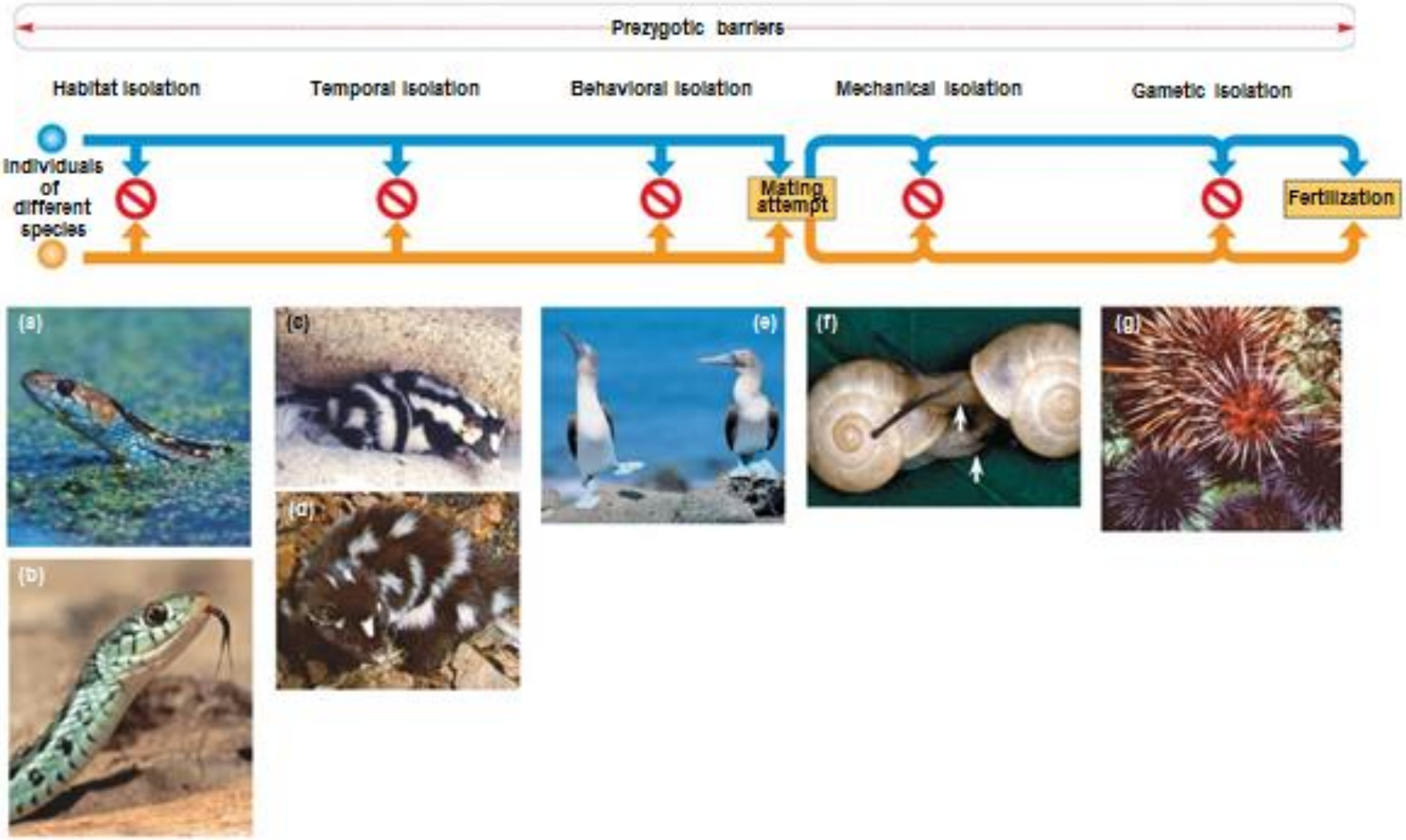
- The key to speciation is **reproductive isolation**:
  - **Reproductive isolation** is the existence of biological factors (barriers) that impede two species from producing viable, fertile offspring.
- Reduction of genetic variation within a given population can increase the differences between populations of the same species.
  - **Hybrids** are the offspring of crosses between different species.
- Reproductive isolation can be classified by whether factors act before or after fertilization:
  - Prezygotic Barriers
  - Postzygotic Barriers

Barriers to Speciation



Prezygotic Barriers to Gene Flow

- **Prezygotic barriers** block fertilization from occurring by:
  - Impeding different species from attempting to mate
  - Preventing the successful completion of mating
  - Hindering fertilization if mating is successful

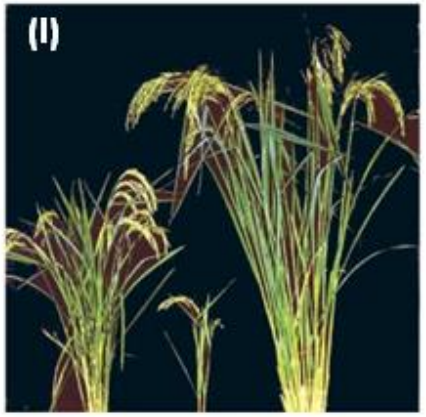


Postzygotic Barriers to Gene Flow

- **Postzygotic barriers** prevent the hybrid zygote from developing into a viable, fertile adult:
  - **Reduced Hybrid Viability:** genetic incompatibility between the two species may abort the development of the hybrid at some embryonic stage or produce frail offspring.
  - **Reduced Hybrid Fertility:** even if the hybrid offspring are vigorous, they may be infertile and cannot backbreed to either parent.
  - **Reduced Hybrid Breakdown:** in some cases, first generation hybrids are viable and fertile, but, when they mate with either parent or with each other, the next generation is feeble or sterile.

Postzygotic barriers

Reduced Hybrid Viability | Reduced Hybrid Fertility | Hybrid Breakdown



Modes of Speciation

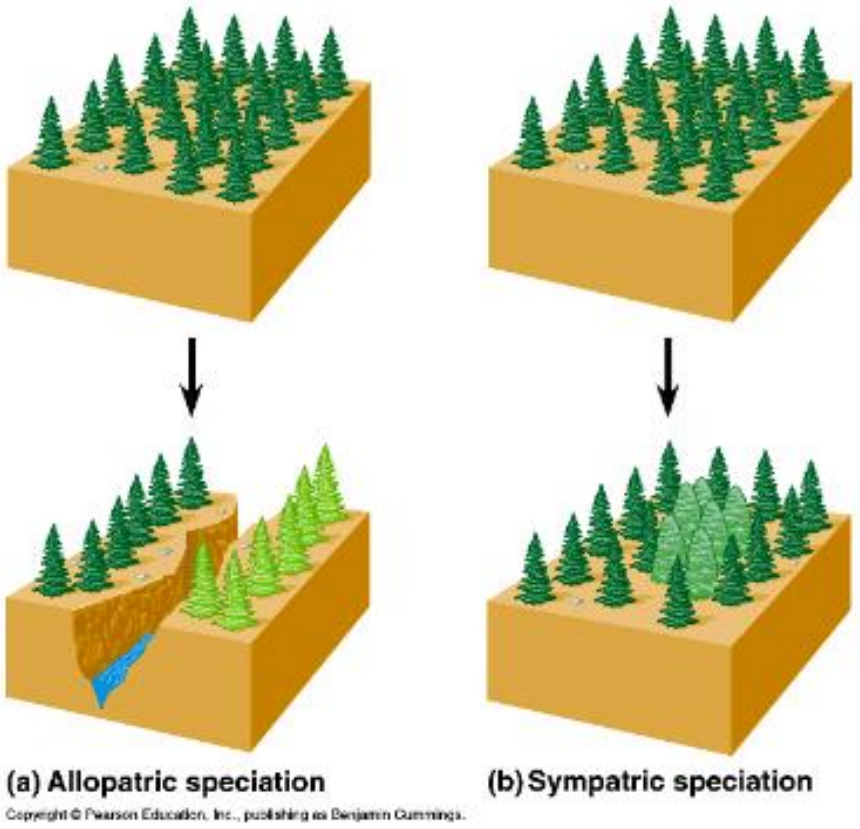
- Species can be physically separated by a geographic barrier such as an ocean or a mountain range, or various post-zygotic mechanisms can maintain reproductive isolation and prevent gene flow.
- Speciation can take place *with or without* geographic separation.
- Speciation can occur in two ways:
  - Allopatric speciation
  - Sympatric speciation

Two Modes of Speciation

http://bcs.whfreeman.com/thelifewire/content/chp24/2402001.html

(a) A population forms a new species while geographically isolated from its parent population

(b) A small population becomes a new species without geographic separation from its parent population



Allopatric ("Other Country") Speciation

- In **allopatric speciation**, gene flow is interrupted or reduced when a population is divided into geographically isolated subpopulations.
  - New species forms while geographically isolated from an ancestor.
  - Modern examples – adaptive radiation on island chains.
- The definition of *barrier* depends on the ability of a population to disperse.
- Separate populations may evolve independently through mutation, natural selection, and genetic drift.

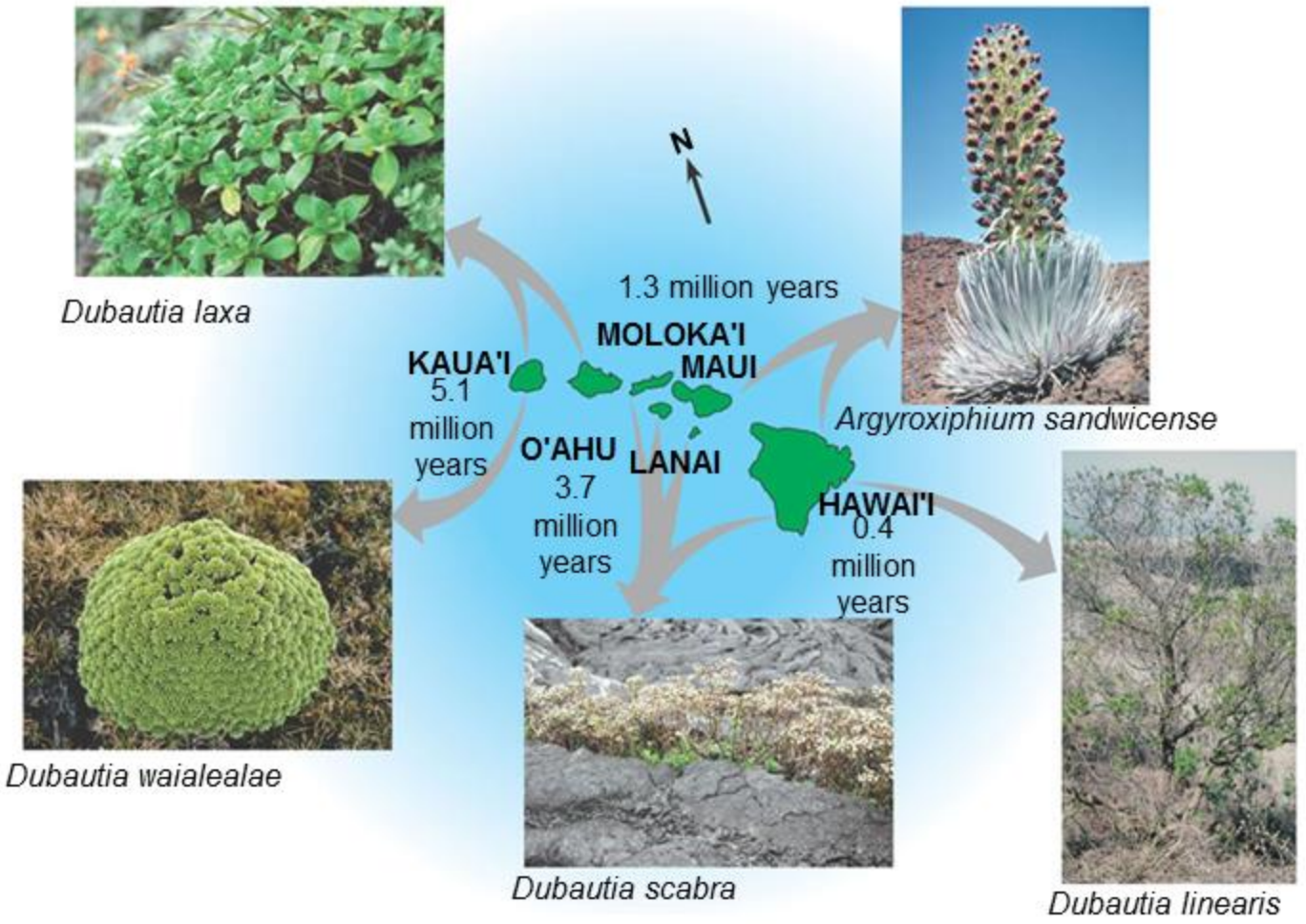
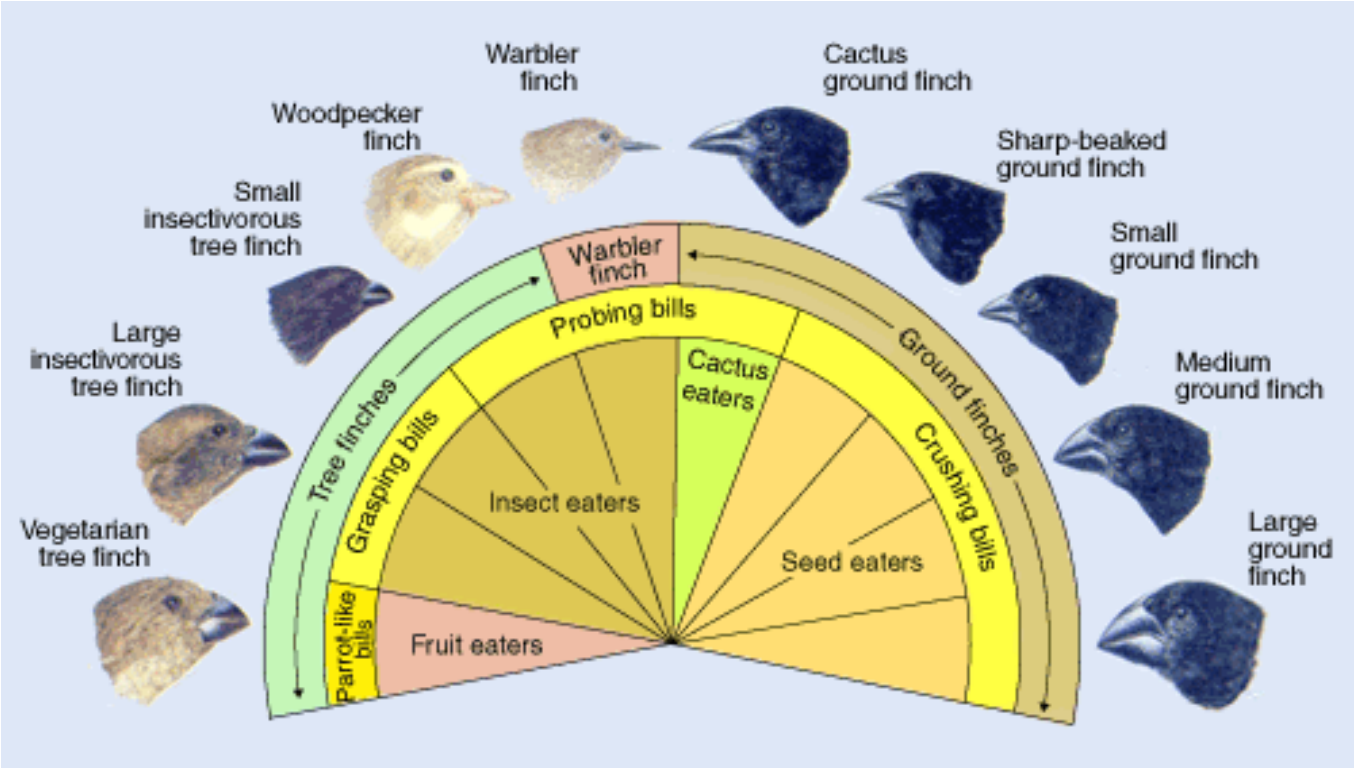

Dubautia laxa
N
1.3 million years
MOLOKA'I
KAUA'I
5.1
million
years
MAUI
O'AHU
3.7
million
years
LANAI
HAWAI'I
0.4
million
years
Argyroxiphium sandwicense
Dubautia waialealae
Dubautia scabra
Dubautia linearis

Figure 24.12

Adaptive Radiation & Speciation in Darwin's Finches



1. <u>Geographic isolation</u> from mainland leads to genetic drift.
2. New selective pressures in various environments.
3. Adaptive traits reflecting new environmental pressures leads to speciation (allopatric).

Sympatric ("Same Country") Speciation

- Speciation can occur when biological barriers prevent gene flow in *overlapping* populations as seen in
  - autopolyploidy
  - allopolyploidy
  - habitat differentiation
  - sexual selection
- In sympatric speciation, speciation takes place in geographically overlapping populations

Polyploidy

https://www.youtube.com/watch?v=LjKT6rZRC-Q

- A species may originate from an accident during cell division that results in extra sets of chromosomes, a condition called *polyploidy*.
- Polyploidy exists in 2 forms:
  - *Autopolyploidy* - an individual that has more than two chromosome sets that are all derived from a single species.
    - *I.e.* failure of cell division could double a cell's chromosome number from a diploid (2n) to a tetraploid (4n).
  - *Allopolyploidy* - a fertile individual that has more than 2 chromosome sets as a result of two different species interbreeding and combining their chromosomes
    - *I.e.* hybrid.

Autopolploidy

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

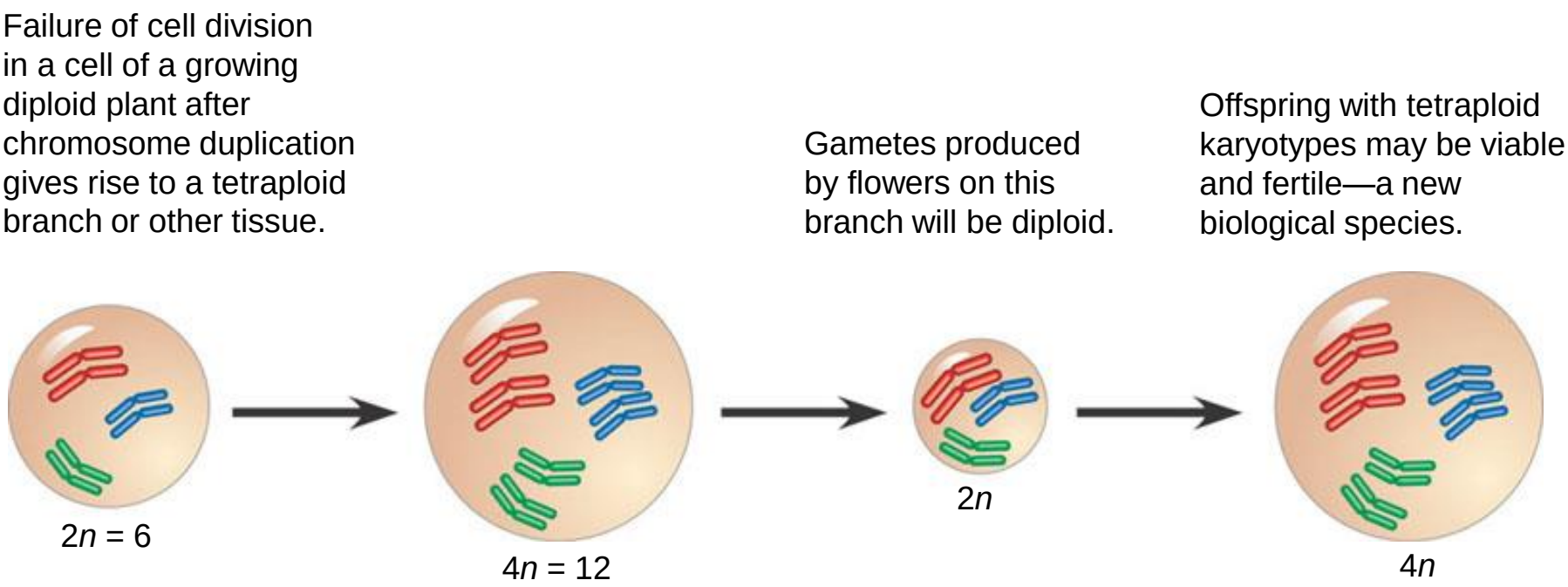


Figure 24.8

Allopolyploidy

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

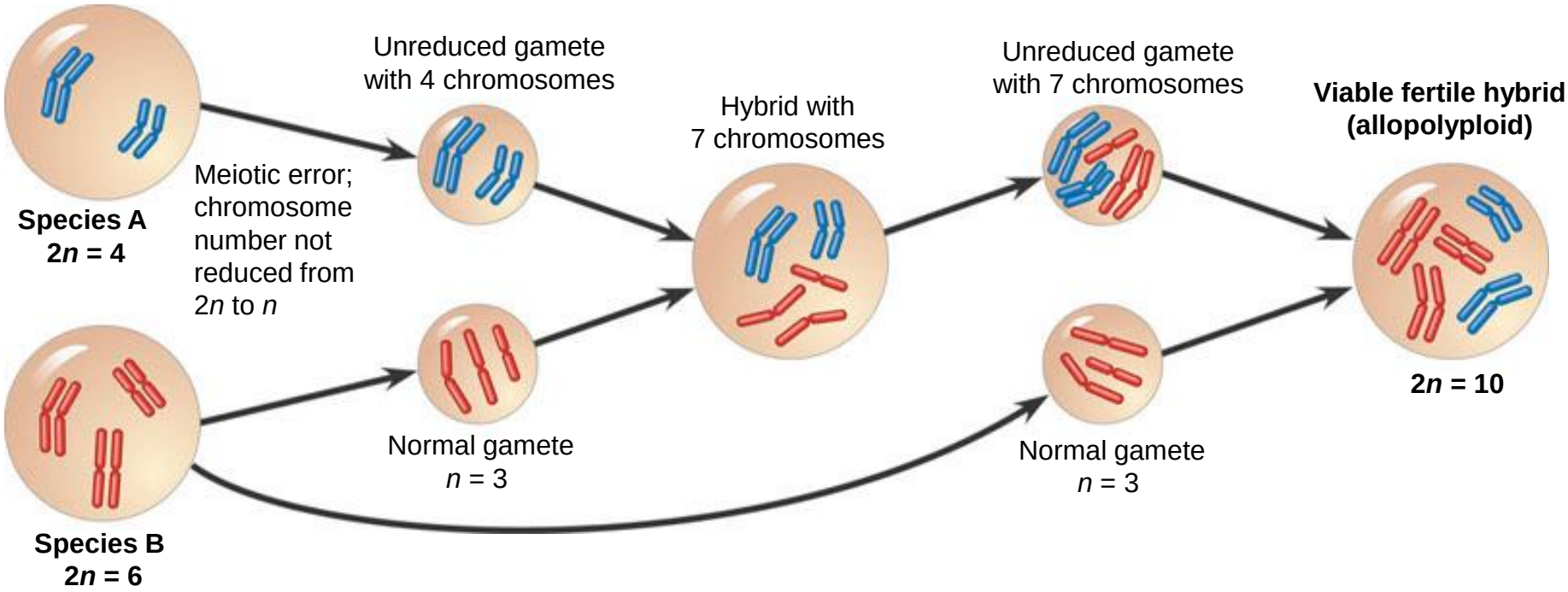
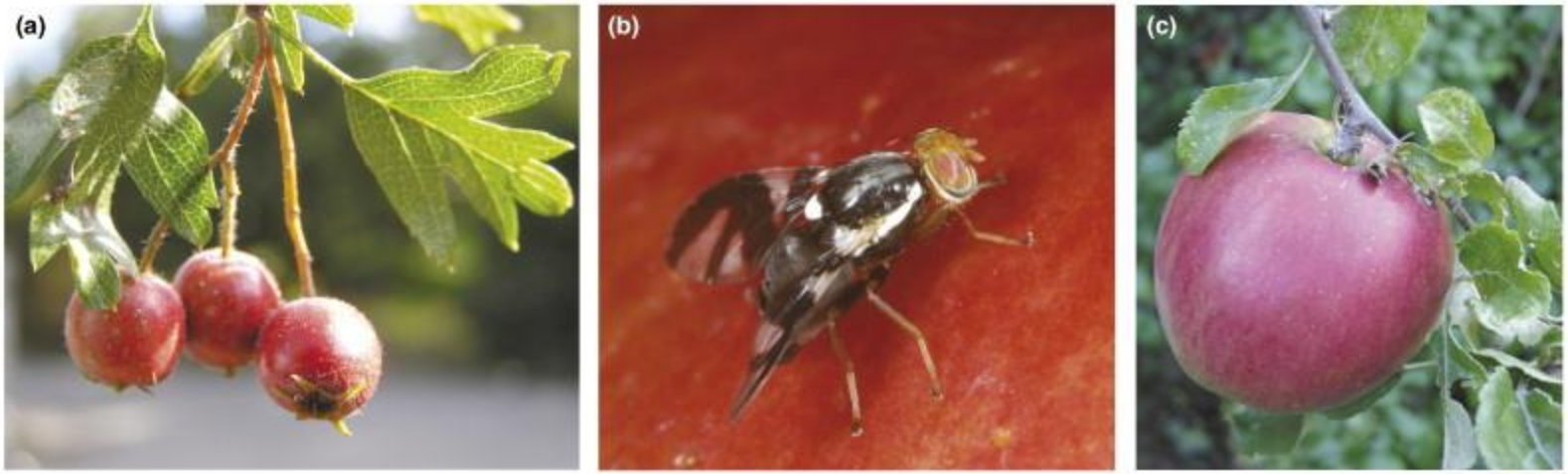


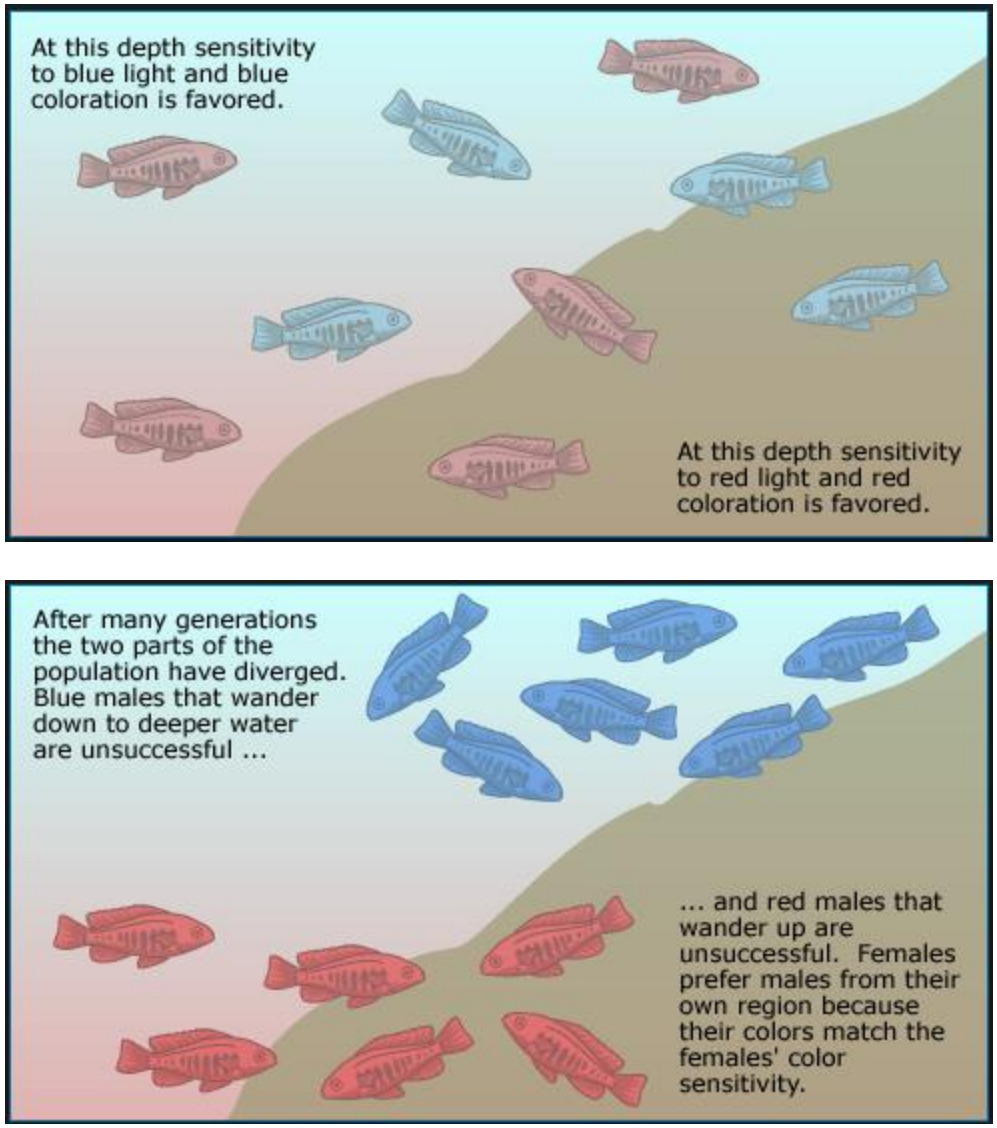
Figure 24.9

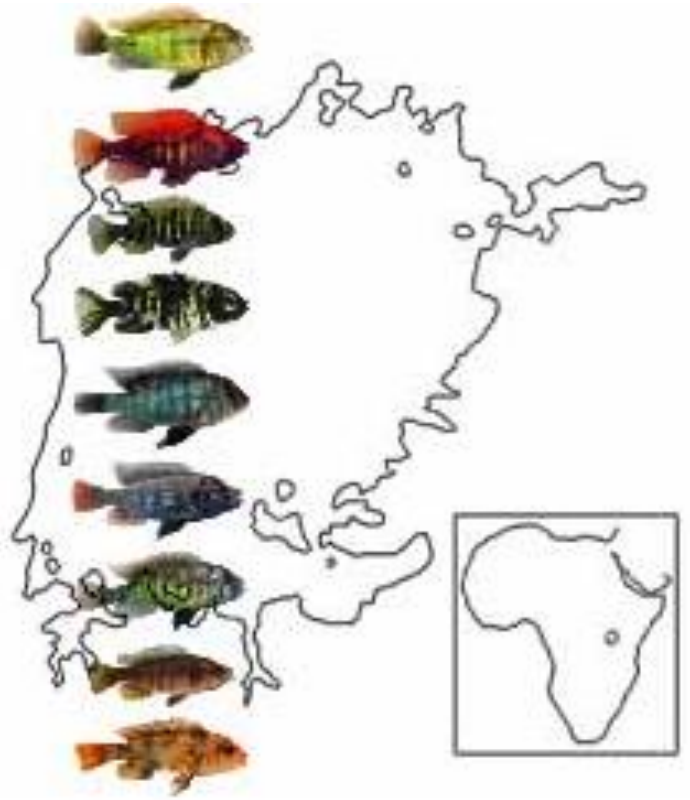
Habitat Differentiation

- Sympatric speciation can also occur when genetic factors enable a subpopulation to exploit a habitat or resource not used by the parent population.



Sexual Selection – Figure 24.12





Allopatric and Sympatric Speciation: A Review

- In *allopatric speciation*, geographic isolation restricts gene flow between populations
  - Reproductive isolation may then arise by natural selection, genetic drift, or sexual selection in the isolated populations
  - Even if contact is restored between populations, interbreeding is prevented
- In *sympatric speciation*, a reproductive barrier isolates a subset of a population without geographic separation from the parent species
  - Sympatric speciation can result from polyploidy, natural selection, or sexual selection

BIG IDEA I

The process of evolution drives the diversity and unity of life.

Enduring Understanding 1.C

Life continues to evolve within a changing environment.

Essential Knowledge 1.C.3

Populations of organisms continue to evolve.

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Essential Knowledge 1.C.3: *Populations of organisms continue to evolve.*

- **Learning Objectives:**
  - **(1.25)** The student is able to *describe a model* that represents evolution within a population.
  - **(1.26)** The student is able to *evaluate given data sets* that illustrate evolution is an ongoing process.

Scientific evidence supports the idea that evolution has occurred in all species and continues to occur.

- ***Illustrative Examples include*:**
  - Chemical Resistance: mutations for resistance to antibiotics, pesticides, herbicides or chemotherapy drugs occur in the *absence* of the chemical.
  - Emergent Diseases: mutations that allow diseases to expand their host range.
  - Observed Directional Phenotypic Changes: Grant's observations of Darwin's finches in the Galapagos.
  - Eukaryotic examples such as the evolution of a structure or process such as heart chambers, limbs, the brain and the immune system.

Chemical Resistance

- Chemotherapy resistance occurs when cancers that have been responding to a therapy suddenly begin to grow. In other words, the cancer cells are resisting the effects of the chemotherapy. There are several possible reasons for chemotherapy resistance:
  - Some of the cells that are not killed by the chemotherapy mutate (change) and become resistant to the drug. Once they multiply, there may be more resistant cells than cells that are sensitive to the chemotherapy.
  - Gene amplification. A cancer cell may produce hundreds of copies of a particular gene. This gene triggers an overproduction of protein that renders the anticancer drug ineffective.
  - Cancer cells may pump the drug out of the cell as fast as it is going in using a molecule called p-glycoprotein. Cancer cells may stop taking in the drugs because the protein that transports the drug across the cell wall stops working.
  - The cancer cells may learn how to repair the DNA breaks caused by some anti-cancer drugs.
  - Cancer cells may develop a mechanism that inactivates the drug.

Emergent Diseases

- **Read** Article:
  - Understanding Emerging and Re-emerging Diseases at http://www.ncbi.nlm.nih.gov/books/NBK20370/

Direct Observations of Phenotypic Change

- **Read** Articles:
  - Natural Selection: Empirical Studies in the Wild at ***ncse.com/files/pub/evolution/excerpt--evolution.pdf***
  - Natural Selection in Real Time at *http://www.pbs.org/wgbh/evolution/educators/course/session4/elaborate_b_pop1.html*