Analyzing Gene Pools

- A gene pool
  - consists of all the alleles in a population at any one time and
  - is a reservoir from which the next generation draws its alleles.
- Alleles in a gene pool occur in certain frequencies.

Analyzing Gene Pools

- Alleles can be symbolized by
  - *p* for the relative frequency of the dominant allele in the population,
  - *q* for the frequency of the recessive allele in the population, and
  - $p + q = 1$.
- Note that if we know the frequency of either allele in the gene pool, we can subtract it from 1 to calculate the frequency of the other allele.

Figure 13.UN01

$$p + q = 1$$

Frequency of Dominant allele (p)

Frequency of Recessive allele (q)

Analyzing Gene Pools

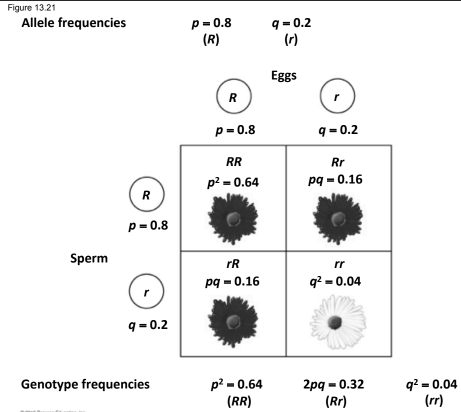
- Genotype frequencies can be calculated from allele frequencies (if the gene pool is stable = not evolving).
- The Hardy-Weinberg formula
  - $p^2 + 2pq + q^2 = 1$
  - can be used to calculate the frequencies of genotypes in a gene pool from the frequencies of alleles.

Figure 13.UN02

$$p^2 + 2pq + q^2 = 1$$

- p^2: Frequency of homozygotes for one allele
- $2pq$: Frequency of heterozygotes
- q^2: Frequency of homozygotes for alternate allele

Figure 13.21



Population Genetics and Health Science

– The Hardy-Weinberg formula can be used to calculate the percentage of a human population that carries the allele for a particular inherited disease.

Population Genetics and Health Science

– PKU
- is a recessive allele that prevents the breakdown of the amino acid phenylalanine and
- occurs in about one out of every 10,000 babies born in the United States.

– People with PKU must strictly regulate their dietary intake of the amino acid phenylalanine.

Microevolution as Change in a Gene Pool

– How can we tell if a population is evolving?

– A non-evolving population is in genetic equilibrium, also known as **Hardy-Weinberg equilibrium**, meaning the population's gene pool is constant over time.

– From a genetic perspective, evolution can be defined as a generation-to-generation change in a population's frequencies of alleles, sometimes called **microevolution**.

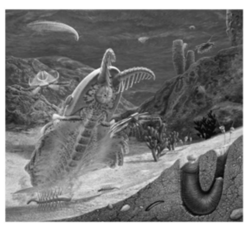
New species may form over long periods of time

- In the **graduated model**, a species acquires small adaptations to its environment over millions of years.

New species may form relatively rapidly

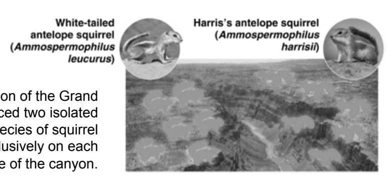
- In the **punctuated equilibrium model,** there are periods of stasis interrupted by occasional bursts of speciation.

530 million years ago during a period called the Cambrian explosion, the rate of evolution was an order of magnitude higher than the normal rate. (It still required millions of years.)



New species may form after geographic isolation

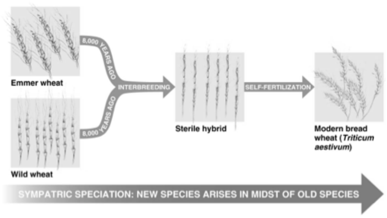
- **Allopatric speciation** may occur when a physical barrier isolates populations.



The formation of the Grand Canyon produced two isolated habitats. One species of squirrel is now found exclusively on each side of the canyon.

New species may form within a parent species

- **Sympatric speciation** may occur quite suddenly due to large-scale genetic changes. (There is no physical barrier.)



Natural Selection: A Closer Look

- Of all causes of microevolution, only natural selection promotes adaptation.
- Evolutionary adaptation results from
  - chance, in the random generation of genetic variability, and
  - sorting, in the unequal reproductive success among the varying individuals.

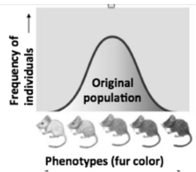
Evolutionary Fitness

- **Relative fitness** is
  - the contribution an individual makes to the gene pool of the next generation
  - relative to the contributions of other individuals.

Figure 13.28 Relative fitness of some flowering plants depends in part on competition in attracting pollinators.

Three General Outcomes of Natural Selection

- If we graph the coat color of a population of mice, we get a bell-shaped curve.
- If natural selection favors certain fur-color phenotypes,
  - the populations of mice will change over the generations and
  - three general outcomes are possible.



Three General Outcomes of Natural Selection

1. **Directional selection** shifts the overall makeup of a population by selecting in favor of one extreme phenotype.
2. **Disruptive selection** can lead to a balance between two or more contrasting phenotypic forms in a population.
3. **Stabilizing selection** favors intermediate phenotypes, occurs in relatively stable environments, and is the most common.

Sexual Selection

- **Sexual selection** is a form of natural selection in which individuals with certain traits are more likely than other individuals to obtain mates.
- **Sexual dimorphism** is a distinction in appearance between males and females not directly associated with reproduction or survival.

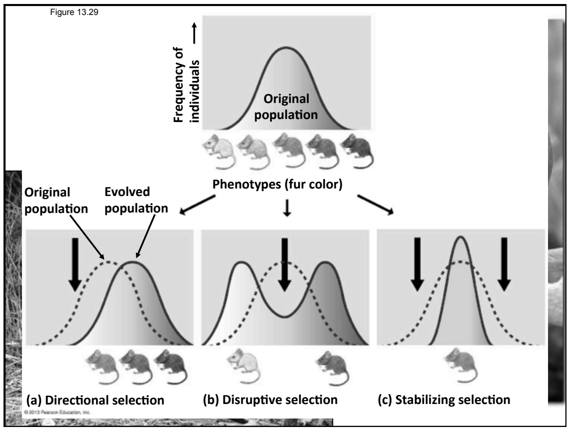
Figure 13.30

(a) Sexual dimorphism in a finch species **(b) Competing for mates**

Figure 13.30

(a) Sexual dimorphism in a finch species (b) Competing for mates

Figure 13.29



(a) Directional selection (b) Disruptive selection (c) Stabilizing selection

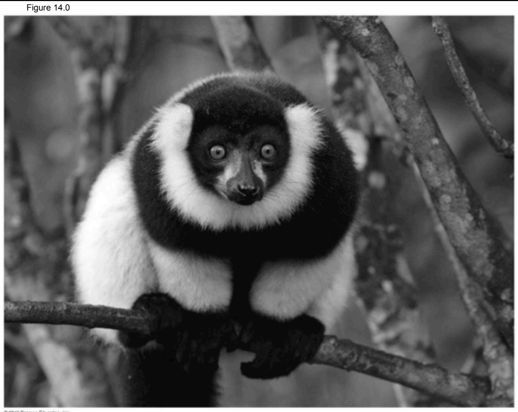
Chapter 14

How Biological Diversity Evolves

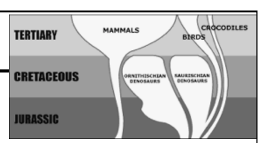
Biology and Society: The Sixth Mass Extinction

- Over the past 540 million years, the fossil record reveals five periods of extinction when 50–90% of living species suddenly died out.

Figure 14.0



Biology and Society: The Sixth Mass Extinction



- Our current rate of extinction, over the past 400 years, indicates that we may be living in, and contributing to, the sixth mass extinction period.
- Mass extinctions pave the way for the evolution of new and diverse forms, but it takes millions of years for Earth to recover.

Mechanisms of Speciation

- A key event in the potential origin of a species occurs when a population is somehow cut off from other populations of the parent species.
- Species can form by
  - **allopatric speciation**, due to geographic isolation, or
  - **sympatric speciation**, without geographic isolation.

Figure 14.6

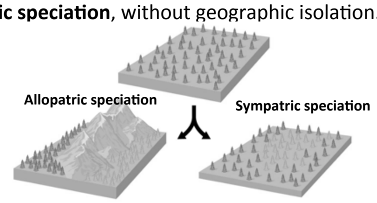
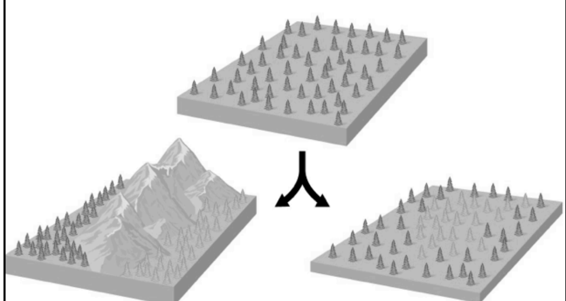
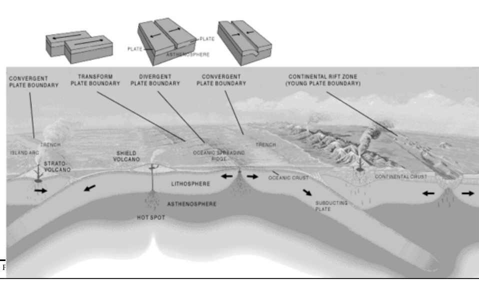


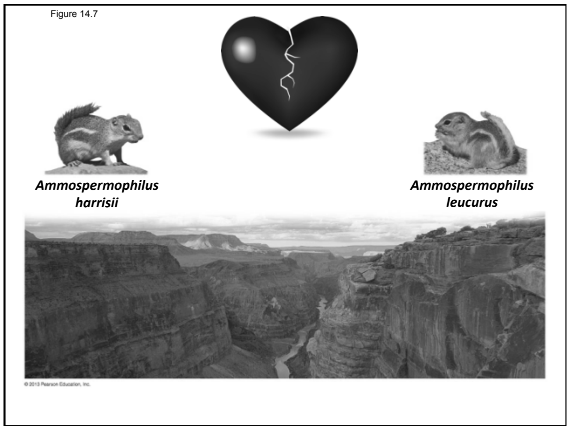
Figure 14.6



Allopatric Speciation

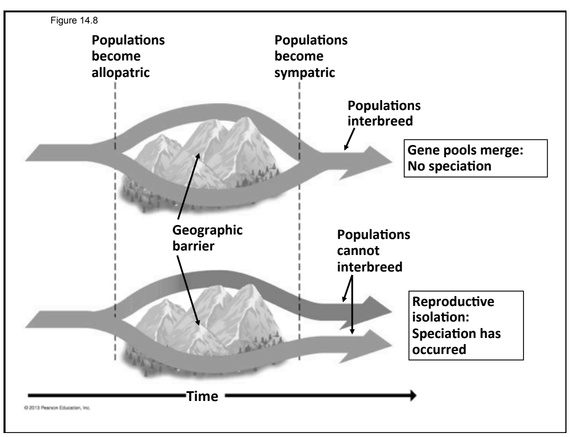
- Geologic processes can
  - fragment a population into two or more isolated populations and
  - contribute to allopatric speciation.





Allopatric Speciation

- Speciation occurs with the evolution of reproductive barriers between *(genes don't mix with the reso the pop)*
  - the isolated population and
  - its parent population.
- Even if the two populations should come back into contact at some later time, the reproductive barriers will keep them as separate species.



Sympatric Speciation

- Sympatric speciation occurs in populations that live in the same geographic area.
- An accident during cell division that results in an extra set of chromosomes is a common route to sympatric speciation in plants.
- Many polyploid species arise from the hybridization of two parent species.

Sympatric Speciation

- Many domesticated plants are the result of sympatric speciation, including
  - oats,
  - potatoes,
  - bananas,
  - peanuts,
  - apples,
  - coffee, and
  - wheat.

http://evolution.berkeley.edu/evosite/evo101/VC1eSympatric.shtml

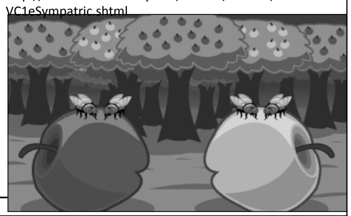
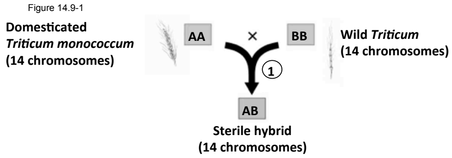


Figure 14.9-1



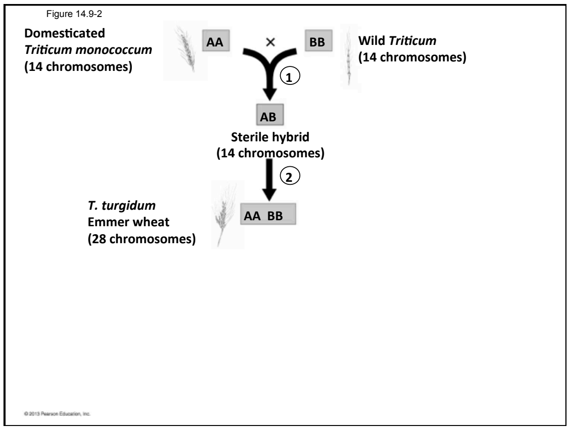


Figure 14.9-2
Domesticated
Triticum monococcum
(14 chromosomes)
AA
×
BB
Wild Triticum
(14 chromosomes)
1
AB
Sterile hybrid
(14 chromosomes)
2
T. turgidum
Emmer wheat
(28 chromosomes)
AA BB

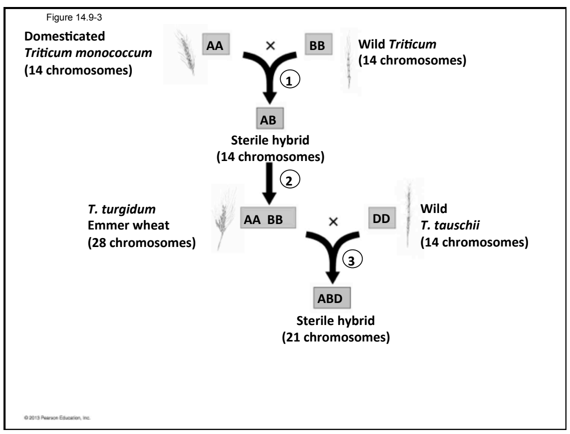


Figure 14.9-3
Domesticated
Triticum monococcum
(14 chromosomes)
AA
×
BB
Wild Triticum
(14 chromosomes)
1
AB
Sterile hybrid
(14 chromosomes)
2
T. turgidum
Emmer wheat
(28 chromosomes)
AA BB
×
DD
Wild
T. tauschii
(14 chromosomes)
3
ABD
Sterile hybrid
(21 chromosomes)

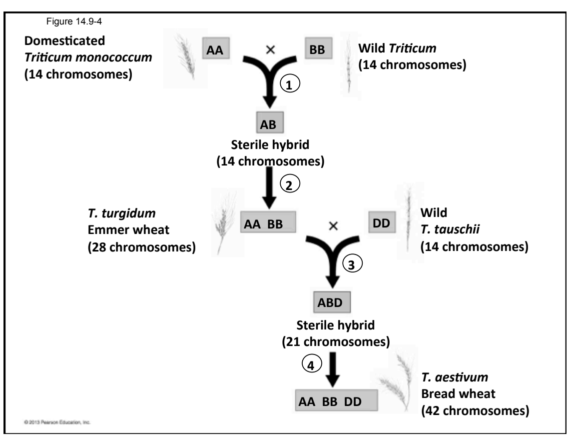


Figure 14.9-4
Domesticated
Triticum monococcum
(14 chromosomes)
AA
×
BB
Wild Triticum
(14 chromosomes)
1
AB
Sterile hybrid
(14 chromosomes)
2
T. turgidum
Emmer wheat
(28 chromosomes)
AA BB
×
DD
Wild
T. tauschii
(14 chromosomes)
3
ABD
Sterile hybrid
(21 chromosomes)
4
AA BB DD
T. aestivum
Bread wheat
(42 chromosomes)

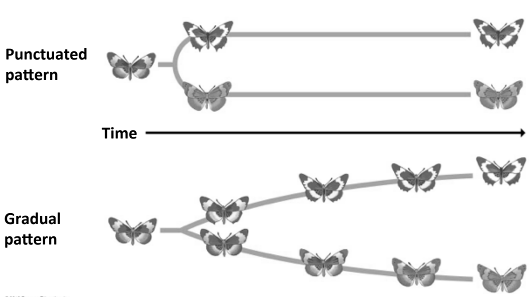
Figure 14.9a

What Is the Pace of Speciation?

– There are two contrasting patterns for the pace of evolution:

1. the gradual pattern, in which big changes (speciations) occur by the steady accumulation of many small changes, and
2. the **punctuated equilibria** pattern, in which there are
   – long periods of little apparent change (equilibria) interrupted (punctuated) by
   – relatively brief periods of rapid change.

Figure 14.10

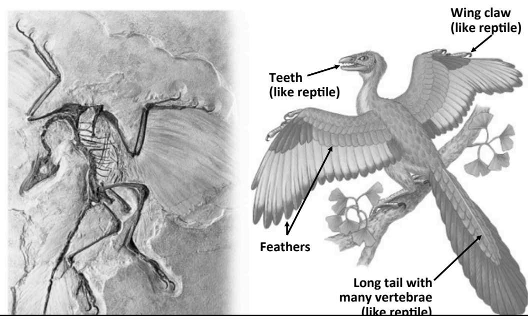


THE EVOLUTION OF BIOLOGICAL NOVELTY

– What accounts for the dramatic differences between dissimilar groups?

Adaptation of Old Structures for New Functions

Birds: are derived from a lineage of earthbound reptiles and evolved flight from flightless ancestors.



Adaptation of Old Structures for New Functions

– An exaptation is
  - a structure that evolves in one context but becomes adapted for another function and
  - a type of evolutionary remodeling.
– Exaptations can account for the evolution of novel structures.

Adaptation of Old Structures for New Functions

– Bird wings are modified forelimbs that were previously adapted for non-flight functions, such as
  - thermal regulation,
  - courtship displays, and/or
  - camouflage.

– The first flights may have been only glides or extended hops as the animal pursued prey or fled from a predator.

Evo-Devo: Development and Evolutionary Novelty

– **Evo-devo**, evolutionary developmental biology, is the study of the evolution of developmental processes in multicellular organisms.

Evo-Devo: Development and Evolutionary Novelty

– Homeotic genes are master control genes that regulate
  - the rate,
  - timing, and
  - spatial pattern of changes in an organism's form as it develops from a zygote into an adult.

– Mutations in homeotic genes can profoundly affect body form.

Evo-Devo: Development and Evolutionary Novelty

- **Paedomorphosis**
  - is the retention into adulthood of features that were solely juvenile in ancestral species and
  - has occurred in the evolution of
    - axolotl salamanders and
    - humans.

PLAY Animation: Allometric Growth

Figure 14.12

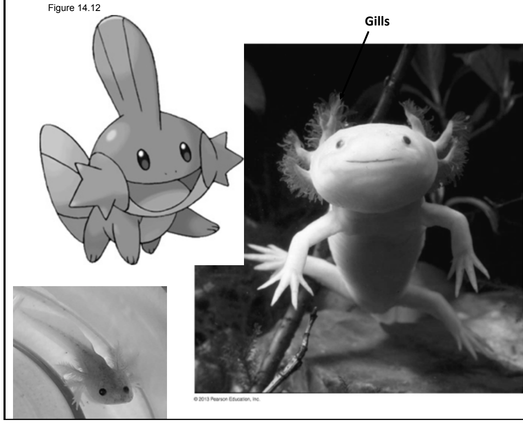
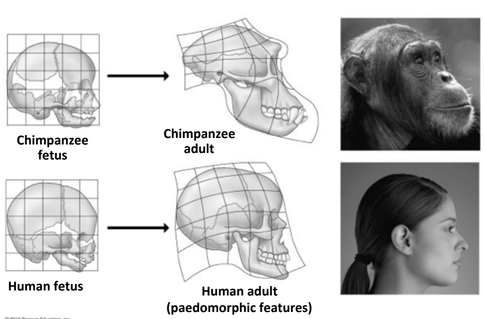


Figure 14.13



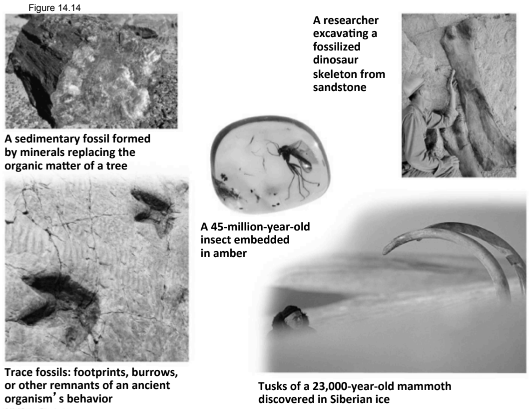
EARTH HISTORY AND MACROEVOLUTION

– Macroevolution is closely tied to the history of Earth.

Geologic Time and the Fossil Record

– The fossil record is
- the sequence in which fossils appear in rock strata and
- an archive of macroevolution.

Figure 14.14



Geologic Time and the Fossil Record

– Geologists have established a **geologic time scale** that divides Earth's history into a consistent sequence of geologic periods.

PLAY Animation: The Geologic Record

PLAY Animation: Macroevolution

Table 14.1

Table 14.1 The Geologic Time Scale

Geologic Time	Period	Epoch	Age (millions of years ago)	Some Important Events in the History of Life
Cenozoic era	Quaternary	Recent	0.01	Historical time
		Pleistocene	1.8	Ice ages; humans appear
	Tertiary	Pliocene	5	Origin of genus *Homo*
		Miocene	23	Continued speciation of mammals and angiosperms
		Oligocene	34	Origins of many primate groups, including apes
		Eocene	56	Angiosperm dominance increases; origins of most living mammalian orders
		Paleocene	65	Major speciation of mammals, birds, and pollinating insects
Mesozoic era	Cretaceous		145	Flowering plants (angiosperms) appear; many groups of organisms, including most dinosaur lineages, become extinct at end of period (Cretaceous extinctions)
	Jurassic		200	Gymnosperms continue as dominant plants; dinosaurs become dominant
	Triassic		251	Cone-bearing plants (gymnosperms) dominate landscape; speciation of dinosaurs, early mammals, and birds
Paleozoic era	Permian		299	Extinction of many marine and terrestrial organisms (Permian extinctions); speciation of reptiles; origins of mammal-like reptiles and most living orders of insects
	Carboniferous		359	Extensive forests of vascular plants; first seed plants; origin of reptiles; amphibians become dominant
	Devonian		416	Diversification of bony fishes; first amphibians and insects
	Silurian		444	Early vascular plants dominate land
	Ordovician		488	Marine algae are abundant; colonization of land by diverse fungi, plants, and animals
	Cambrian		542	Origin of most living animal phyla (Cambrian explosion)
Precambrian			600	Diverse algae and soft-bodied invertebrate animals appear
			635	Oldest animal fossils
			2,100	Oldest eukaryotic fossils
			2,700	Oxygen begins accumulating in atmosphere
			3,500	Oldest fossils known (prokaryotes)
			4,600	Approximate time of origin of Earth

Relative Time Span
Cenozoic
Mesozoic
Paleozoic
Pre-cambrian