

### What Is the Pace of Speciation?

- There are two contrasting patterns for the pace of evolution:
  1. The gradual pattern, in which big changes (speciation's) occur by the steady accumulation of many small changes, and
  2. The **punctuated equilibrium** pattern, in which there are
    - Long periods of little apparent change (equilibria) interrupted (punctuated) by
    - Relatively brief periods of rapid change.

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Figure 14.10

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### THE EVOLUTION OF BIOLOGICAL NOVELTY

- What accounts for the dramatic differences between dissimilar groups?

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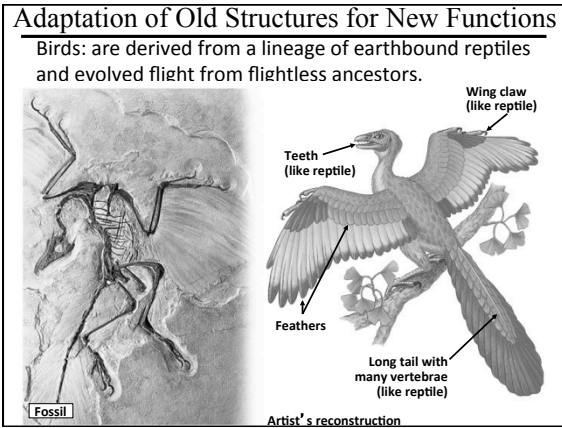
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**Adaptation of Old Structures for New Functions**

- 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.

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**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.

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Evo-Devo: Development and Evolutionary Novelty

- **Evo-devo**, evolutionary developmental biology, is the study of the evolution of developmental processes in multicellular organisms.
- **Homeotic genes** are master control genes that regulate
  - **Rate**,
  - **Timing**
  - **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**.

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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 © 2013 Pearson Education, Inc. Animation: Allometric growth

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
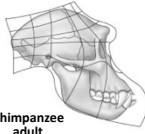
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
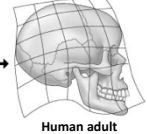
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Figure 14.13


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**EARTH HISTORY AND  
MACROEVOLUTION**

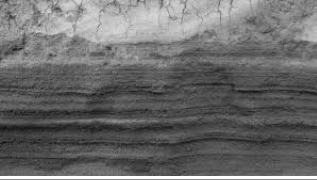
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– Macroevolution is closely tied to the history of Earth.

**Geologic Time and the Fossil Record**

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



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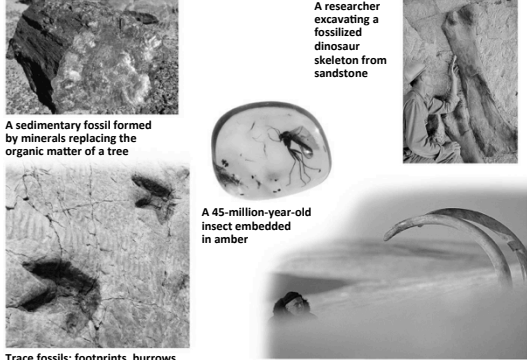
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Figure 14.14



**A sedimentary fossil formed by minerals replacing the organic matter of a tree**

**A 45-million-year-old insect embedded in amber**

**Trace fossils: footprints, burrows, or other remnants of an ancient organism's behavior**

**Tusks of a 23,000-year-old mammoth discovered in Siberian ice**

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**Geologic Time and the Fossil Record**

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– 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

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**Geologic Time and the Fossil Record**

- Fossils are reliable chronological records only if we can determine their ages, using
  - the *relative age* of fossils, revealing the order in which groups of species evolved, and/or
  - the *absolute age* of fossils, requiring other methods such as radiometric dating.

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**Geologic Time and the Fossil Record**

- **Radiometric dating**
  - is the most common method for dating fossils,
  - is based on the decay of radioactive isotopes, and
  - helped establish the geologic time scale.

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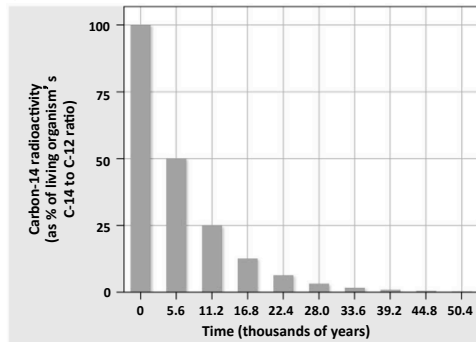
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Figure 14.15a



Radioactive decay of carbon-14  
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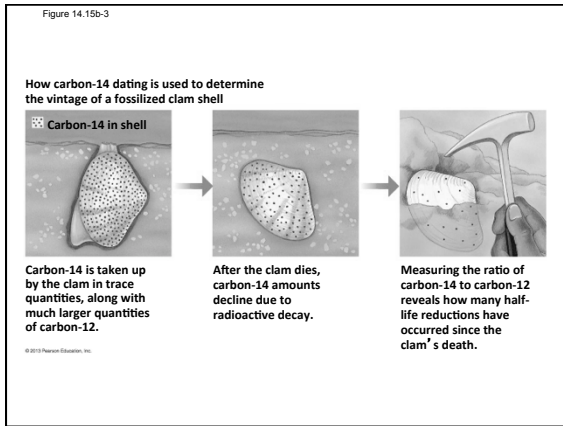
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**Plate Tectonics and Macroevolution**

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– The continents are not locked in place.

- Continents drift about Earth's surface on plates of crust floating on a flexible layer of hot, underlying material called the mantle.

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**Plate Tectonics and Macroevolution**

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– About 250 million years ago,

- plate movements formed the supercontinent Pangaea,
- the total amount of shoreline was reduced,
- ocean basins increased in depth,
- sea levels dropped,
- the dry continental interior increased in size, and
- many extinctions occurred.

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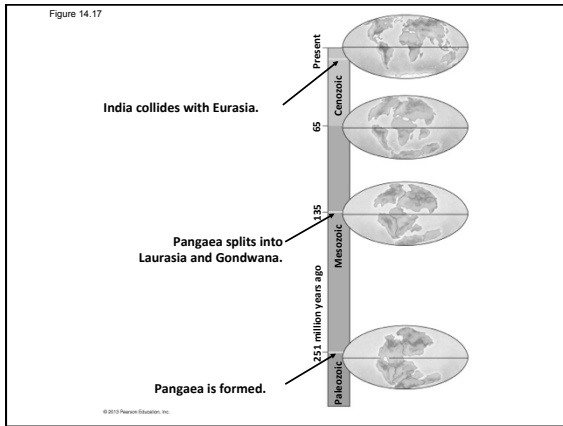
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**Plate Tectonics and Macroevolution**

- About 180 million years ago,
  - Pangaea began to break up,
  - large continents drifted increasingly apart,
  - climates changed, and
  - the organisms of the different biogeographic realms diverged.

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**Plate Tectonics and Macroevolution**

- Plate tectonics helps to explain
  - why Mesozoic reptiles in Ghana (West Africa) and Brazil look so similar and
  - how marsupials were free to evolve in isolation in Australia.

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**Mass Extinctions and Explosive Diversifications of Life**

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- The fossil record reveals that five mass extinctions have occurred over the last 540 million years.
- The Permian mass extinction
  - occurred at about the time the merging continents formed Pangaea (250 million years ago) and
  - claimed about 96% of marine species.

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**Mass Extinctions and Explosive Diversifications of Life**

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- The Cretaceous extinction
  - occurred at the end of the Cretaceous period, about 65 million years ago,
  - included the extinction of all the dinosaurs except birds, and
  - permitted the rise of mammals.

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**The Process of Science:  
Did a Meteor Kill the Dinosaurs?**

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- The fossil record reveals that five mass extinctions have occurred over the last 540 million years.
- In each of these events, 50% or more of Earth's species died out.
- Of all the mass extinctions, those marking the ends of the Permian and Cretaceous periods have been the most intensively studied.

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**The Process of Science:  
Did a Meteor Kill the Dinosaurs?**

- **Observation:** About 65 million years ago, the fossil record shows that
  - the climate cooled,
  - seas were receding,
  - many plant species died out,
  - dinosaurs (except birds) became extinct, and
  - a thin layer of clay rich in iridium was deposited.

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**The Process of Science:  
Did a Meteor Kill the Dinosaurs?**

- **Question:** Is the iridium layer the result of fallout from a huge cloud of dust that billowed into the atmosphere when a large meteor or asteroid hit Earth?
- **Hypothesis:** The mass extinction 65 million years ago was caused by the impact of an extraterrestrial object.
- **Prediction:** A huge impact crater of the right age should be found somewhere on Earth's surface.

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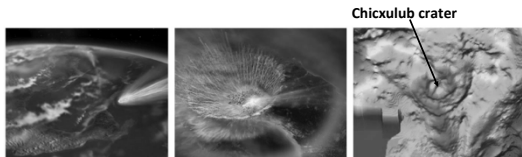
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Figure 14.18-3



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**Evolution Connection:  
Rise of the Mammals**

- Fossil evidence indicates that
  - mammals first appeared about 180 million years ago but
  - the number of mammalian species
    - remained steady and low in number until about 65 million years ago and
    - greatly increased after most of the dinosaurs became extinct.

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**Evolution Connection:  
Rise of the Mammals**

- Throughout the process of evolution by natural selection, this pattern of death and renewal is repeated throughout the history of life on Earth.

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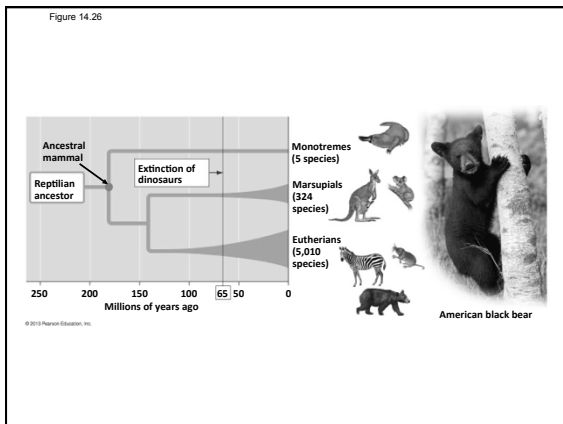
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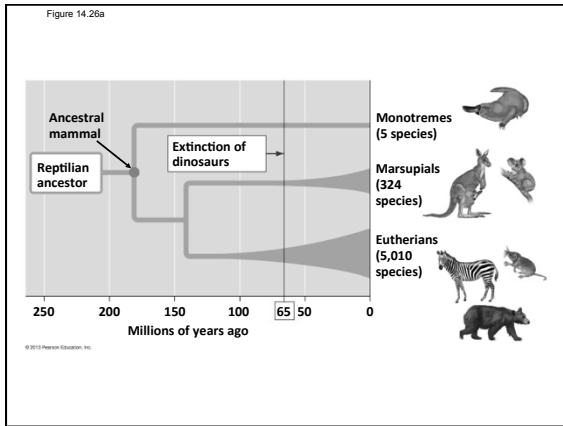
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