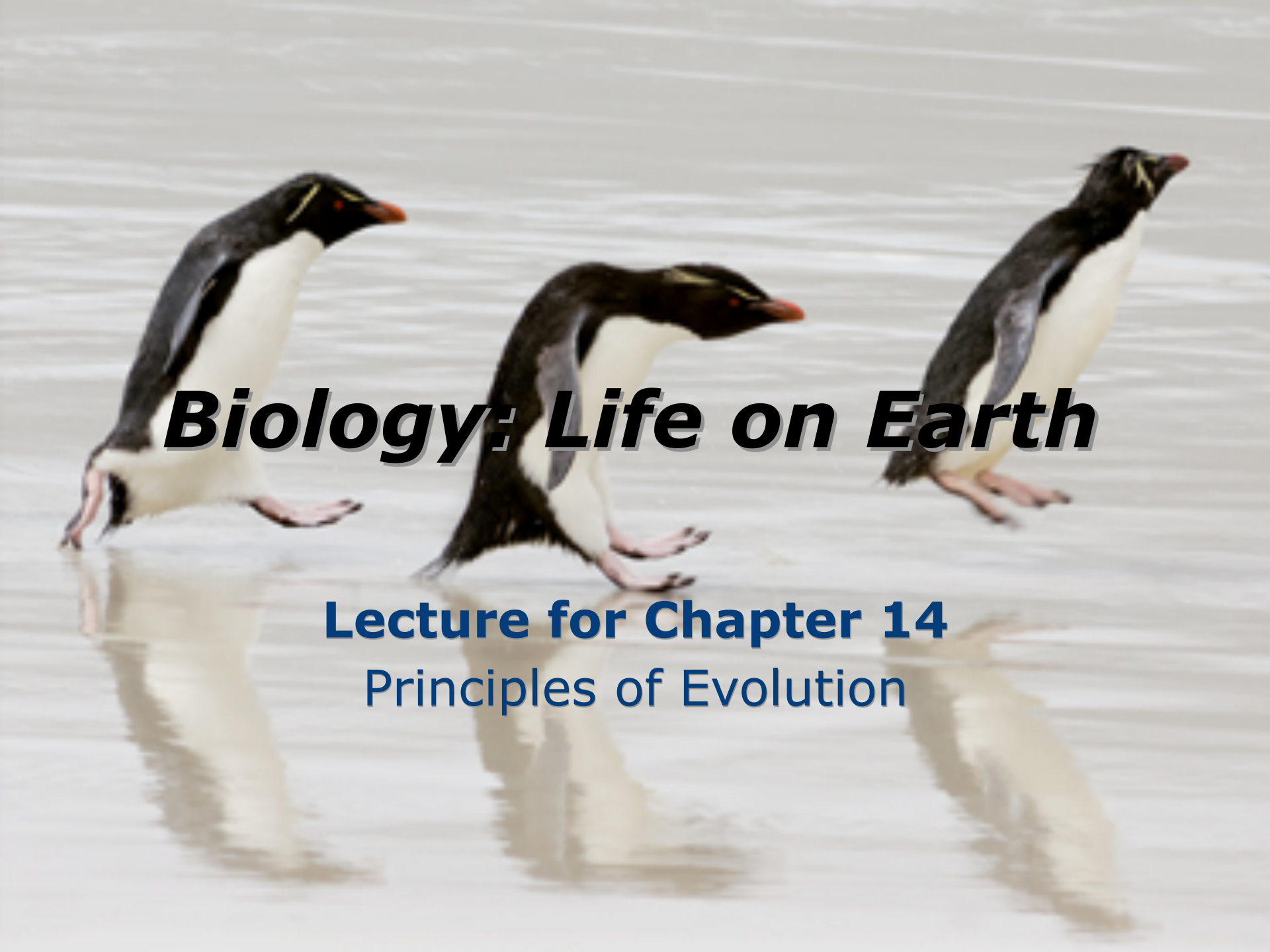


Biology: Life on Earth

Lecture for Chapter 14

Principles of Evolution

Chapter 14 Opener Biology: Life on Earth, 8/e

Chapter 14 Outline

- 14.1 How Did Evolutionary Thought Evolve? p. 278
- 14.2 How Do We Know That Evolution Has Occurred? p. 282
- 14.3 How Does Natural Selection Work? p. 288
- 14.4 What Is The Evidence That Populations Evolve by Natural Selection? p. 289

Section 14.1 Outline

- **14.1 How Did Evolutionary Thought Evolve?**
  - Early Biological Thought Did Not Include the Concept of Evolution
  - Exploration of New Lands Revealed a Staggering Diversity of Life
  - A Few Scientists Speculated That Life Had Evolved
  - Fossil Discoveries Showed That Life Has Changed Over Time

Section 14.1 Outline (cont.)

- Some Scientists Devised Nonevolutionary Explanations for Fossils
- Geology Provided Evidence That Earth Is Exceedingly Old
- Some Pre-Darwinian Biologists Proposed Mechanisms for Evolution
- Darwin and Wallace Proposed a Mechanism of Evolution

Evolutionary Thought

- Evolution by natural selection is a unifying theme for all of biology
- The foundation of evolutionary thought developed gradually over centuries
- Main ideas of evolution were not widely accepted until after Charles Darwin published *On the Origin of Species* in 1859

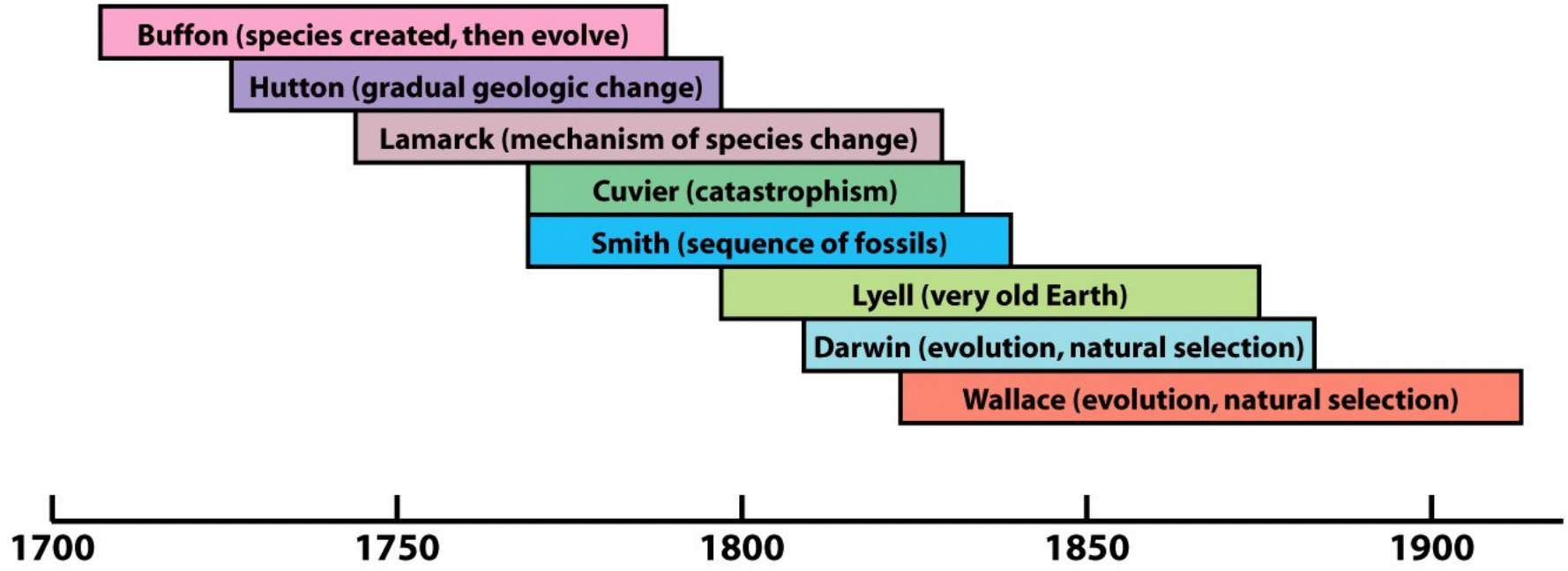


Figure 14-1 Biology: Life on Earth, 8/e

Early Biological Thought

- Heavily influenced by theology
  - All organisms were created simultaneously
  - Each distinct life-form was permanently fixed and did not change over time

Early Biological Thought

- Expressed by ancient Greek philosophers
  - Plato (427-347 B.C.)
  - Aristotle (384-322 B.C.) arranged all organisms on a linear scale of increasing complexity (“ladder of Nature”)

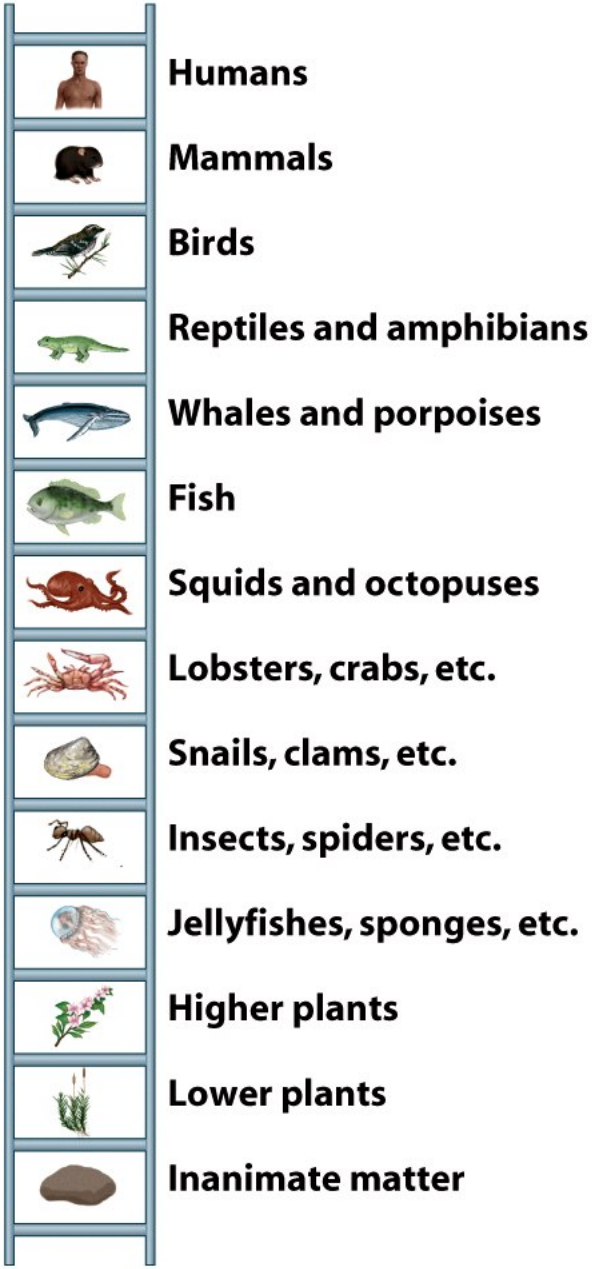


Figure 14-2 Biology: Life on Earth, 8/e

Exploration of New Lands

- Number of species was greater than expected
- Some species closely resembled one another
- Some naturalists concluded that similar species may have developed from a common ancestor

Speculation That Life Had Evolved

- Comte de Buffon (1707-1788) proposed that some modern species had evolved through natural processes
- Idea was not accepted
  - Did not provide a mechanism for evolution
  - Earth was not old enough to allow time for the process of evolution

Fossils

- Fossils showed that life had changed over time
- **Fossils** are the remains or impressions of organisms that lived in the past
- Most are found in sedimentary rock

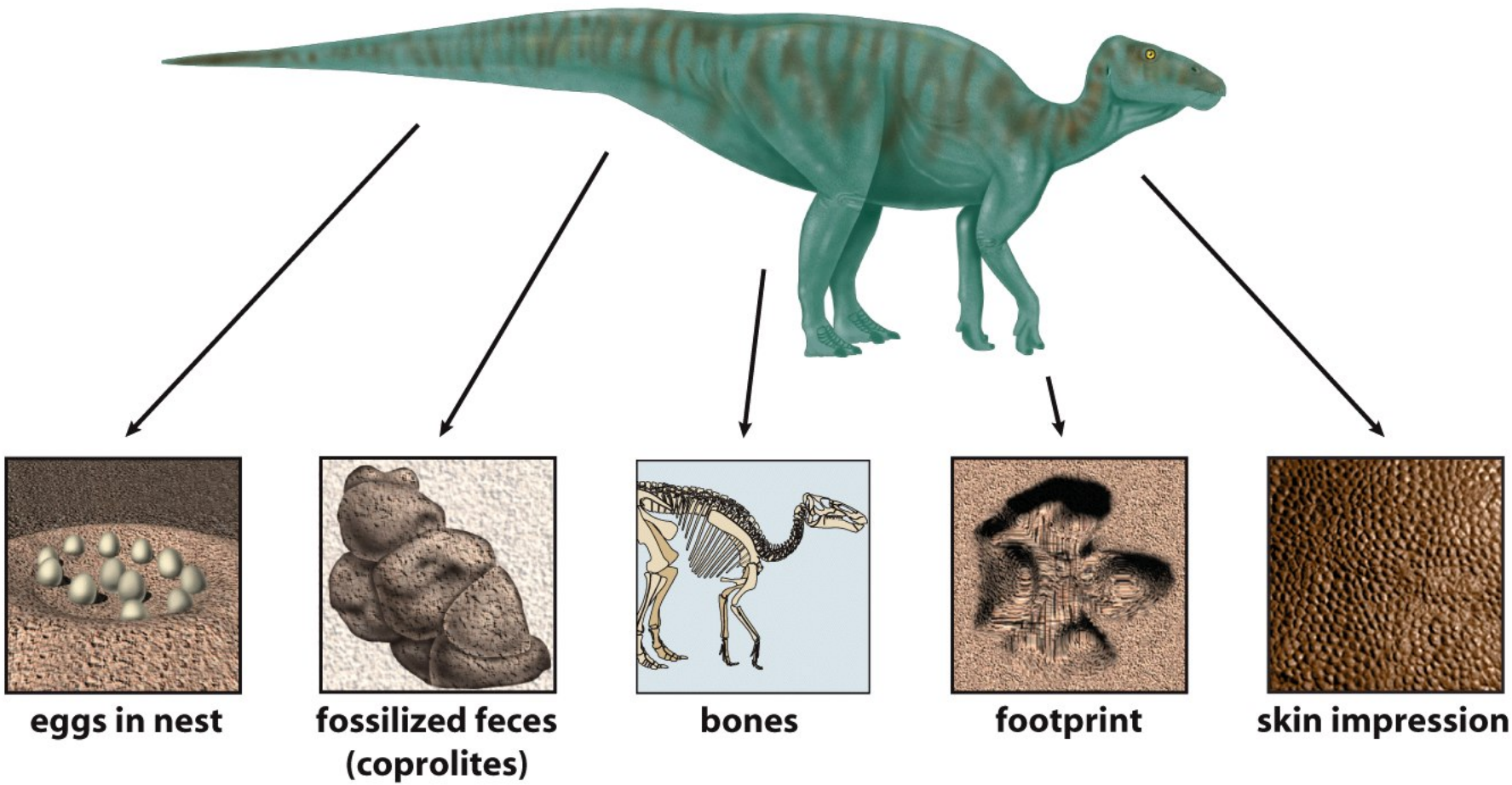


Figure 14-3 Biology: Life on Earth, 8/e

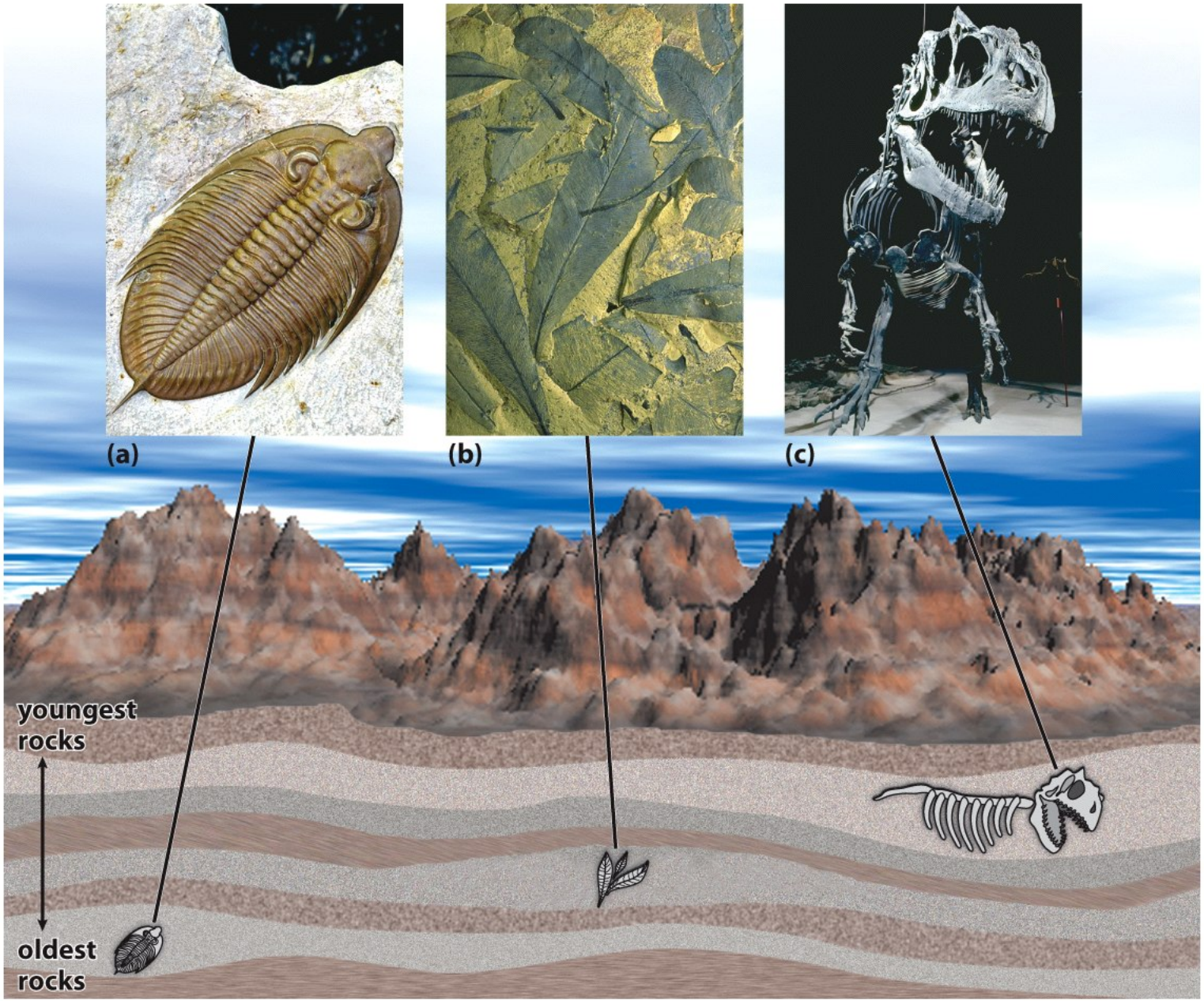


Figure 14-4 Biology: Life on Earth, 8/e

Fossils

- Certain fossils were always found in the same layers of rock
- Organization of fossils and rock layers was consistent
- The deeper (older) the layer, the more dissimilar the fossils from modern organisms
- Many fossils were of *extinct* organisms

Nonevolutionary Explanations

- Georges Cuvier (1769-1832) proposed theory of **catastrophism** which hypothesized that
  - High numbers of species were created originally
  - A series of catastrophes produced rock layers and destroyed many species, preserving some as fossils
  - Modern day species are the survivors of these catastrophies

Earth Is Exceedingly Old

- James Hutton (1726-1797) and Charles Lyell (1797-1875) studied geologic processes (wind, water, earthquakes, volcanism)
- Developed theory of **uniformitarianism** (geologic change resulted from slow, continuous actions similar to those at work today)

Earth Is Exceedingly Old

- Rock formations reflect repeated cycles of geologic change occurring over vast periods of time
- Conclusions:
  - Earth was older than the 6,000 years proposed by theologians
  - There was enough time for evolution to occur

Pre-Darwin Proposal

- Jean Baptiste Lamarck (1744-1829) proposed that organisms evolved through **inheritance of acquired characteristics**
  - Organisms are modified during their lifetime through use or disuse of different parts
  - These modifications are passed to offspring
- Inheritance of acquired characteristics mechanism was **rejected** when it was determined that acquired characteristics are not heritable

Darwin and Wallace

- By mid-1880s the concept of evolution was increasingly accepted
- 1858 Charles Darwin and Alfred Russel Wallace independently
  - Provided evidence for its occurrence
  - Proposed the mechanism through which it occurs

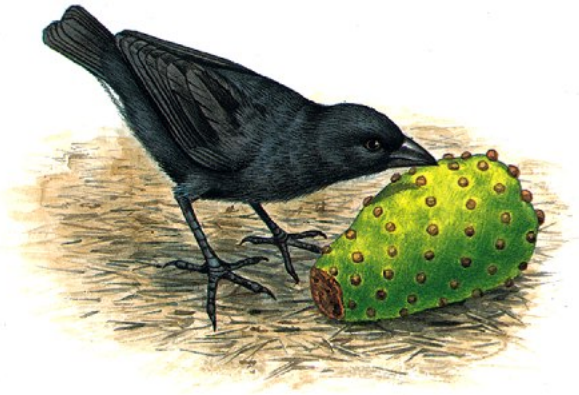
Darwin and Wallace

- Darwin and Wallace shared experiences that shaped their thinking
  - Aware that fossils showed a trend of increasing complexity
  - Aware of Hutton and Lyell's proposal that Earth is extremely old

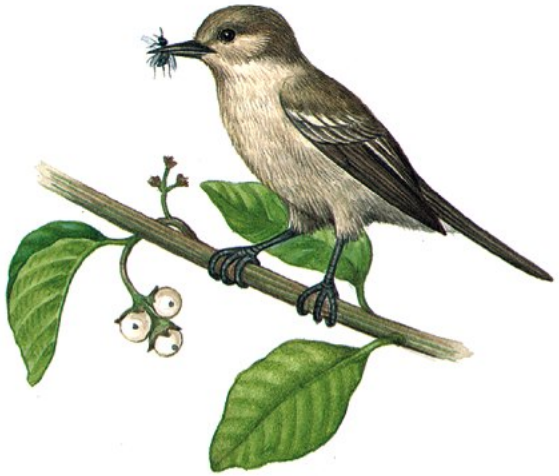
Darwin and Wallace

- Darwin and Wallace shared experiences
  - Traveled extensively studying tropical plants and animals
  - Observed that similar species differed only in a few ecologically important features

(a) Large ground finch, beak suited to large seeds



(b) Small ground finch, beak suited to small seeds



(c) Warbler finch, beak suited to insects

(d) Vegetarian tree finch, beak suited to leaves

Figure 14-5 Biology: Life on Earth, 8/e

Darwin and Wallace

- Darwin and Wallace independently proposed that organisms evolved by natural selection
- Both presented papers to the Linnaean Society in London (1858)
- Darwin published *On the Origin of Species by Means of Natural Selection* in 1859

Section 14.2 Outline

- **14.2 How Do We Know That Evolution Has Occurred?**
  - Fossils Provide Evidence of Evolutionary Change Over Time
  - Comparative Anatomy Gives Evidence of Descent with Modification
  - Embryological Similarity Suggests Common Ancestry
  - Modern Biochemical and Genetic Analyses Reveal Relatedness Among Diverse Organisms

Evolution Widely Accepted Today

- Overwhelming body of evidence in multiple areas of science supports evolution

Evidence from Fossils

- Fossils of ancient species tend to be simpler in form than modern species
- Several series of fossils have been found that exhibit the evolution of body structures over time
- One series reveals that modern whales evolved from land-dwelling ancestors

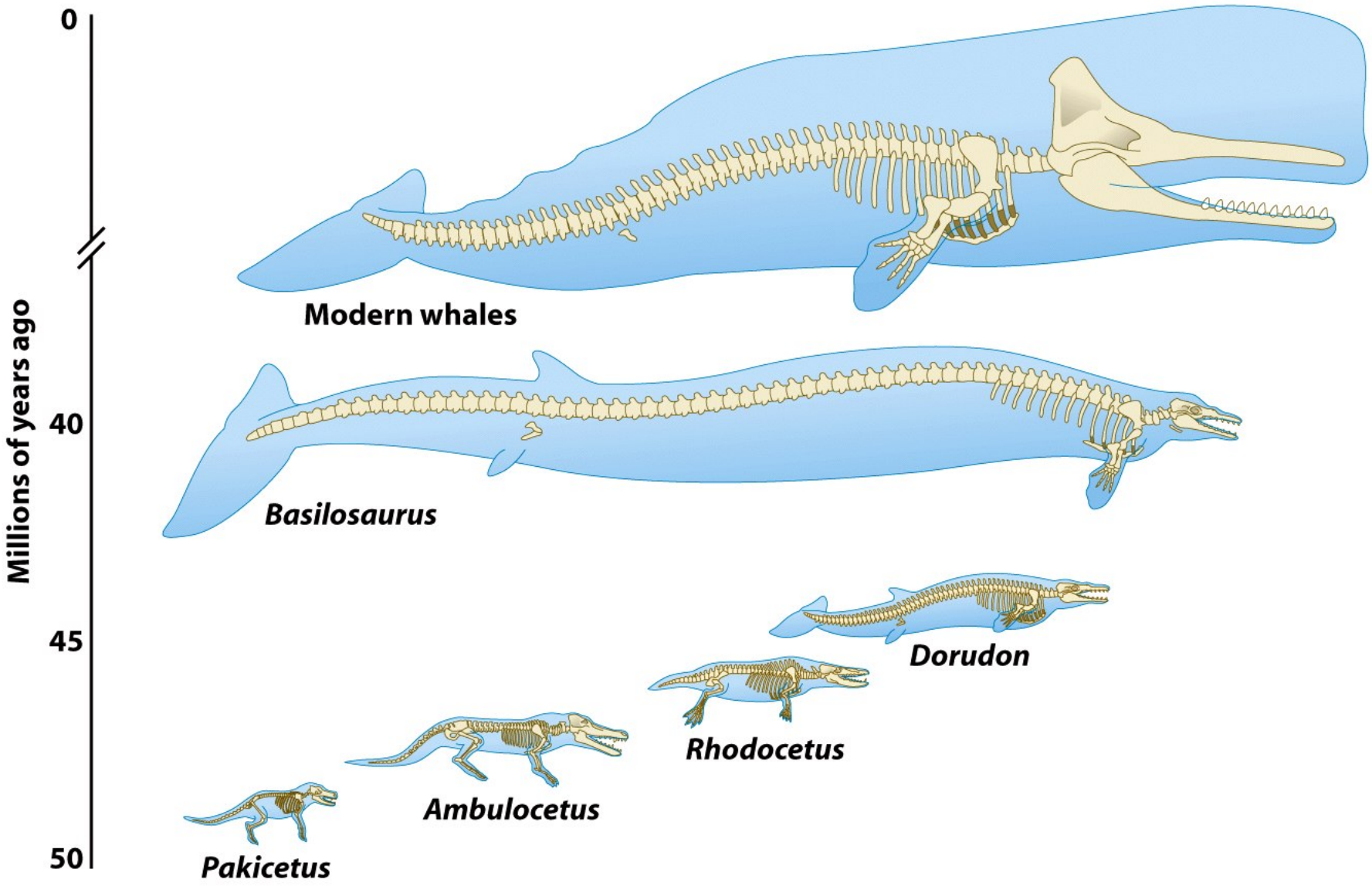


Figure 14-6 Biology: Life on Earth, 8/e

Comparative Anatomy

- Homologous structures provide evidence of common ancestry
- **Homologous structures** are structures that have the same evolutionary origin despite their current appearance or function
- Bird and mammalian forelimbs are homologous structures

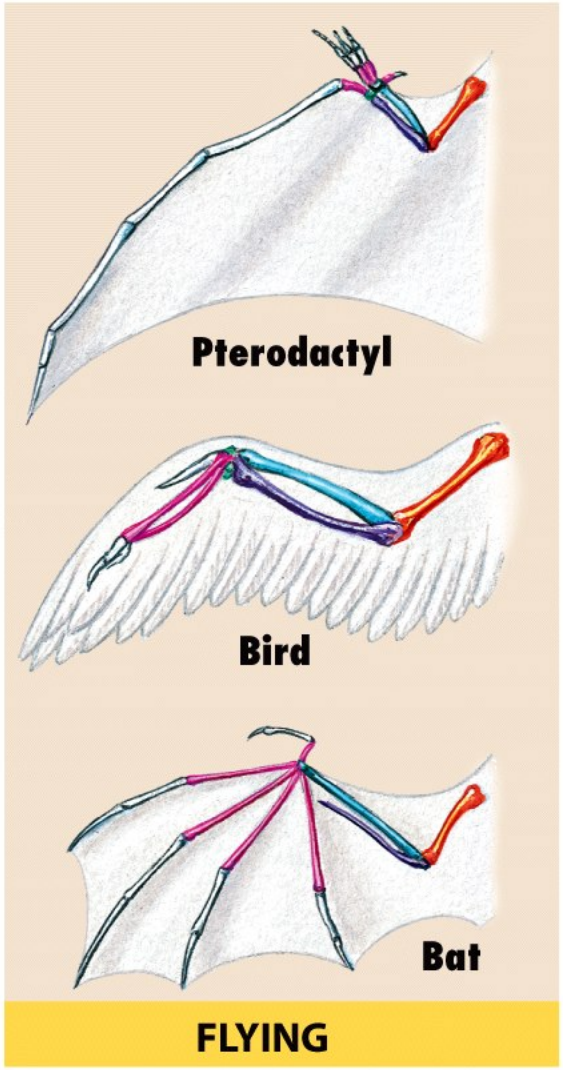


Figure 14-7 Biology: Life on Earth, 8/e

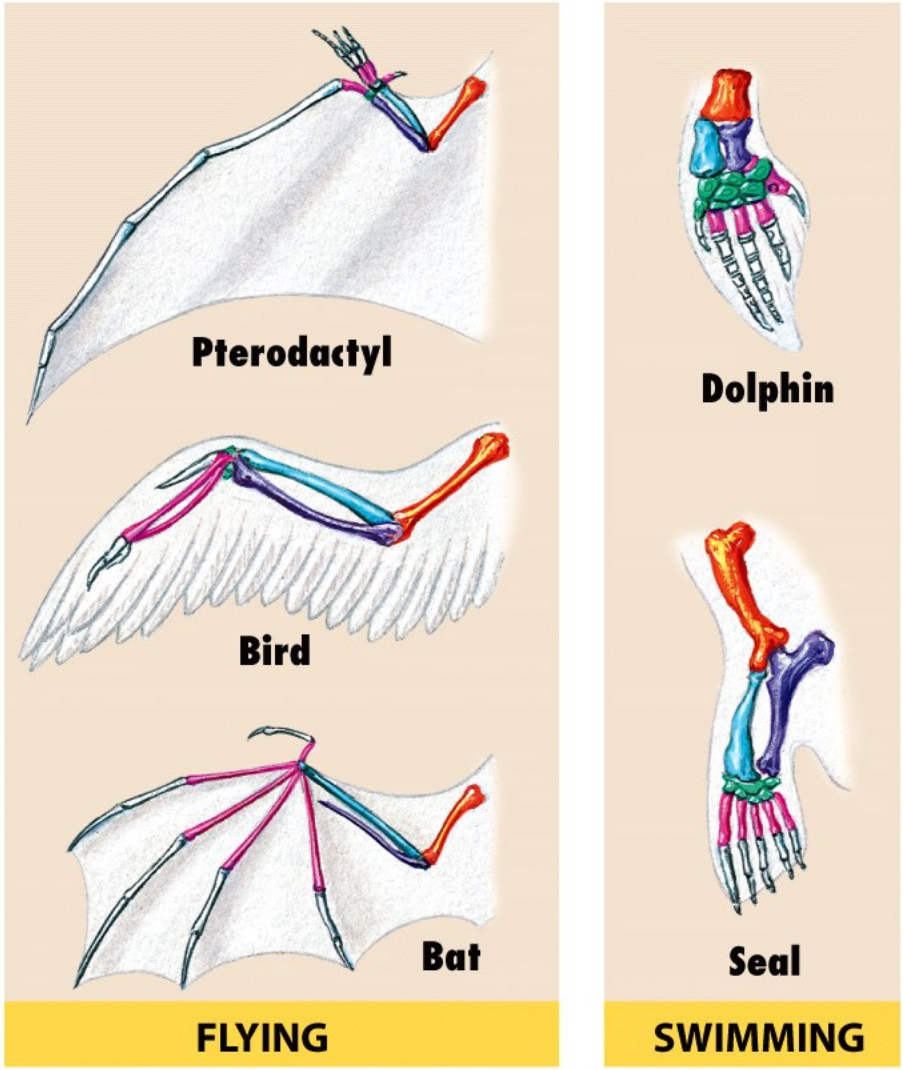


Figure 14-7 Biology: Life on Earth, 8/e

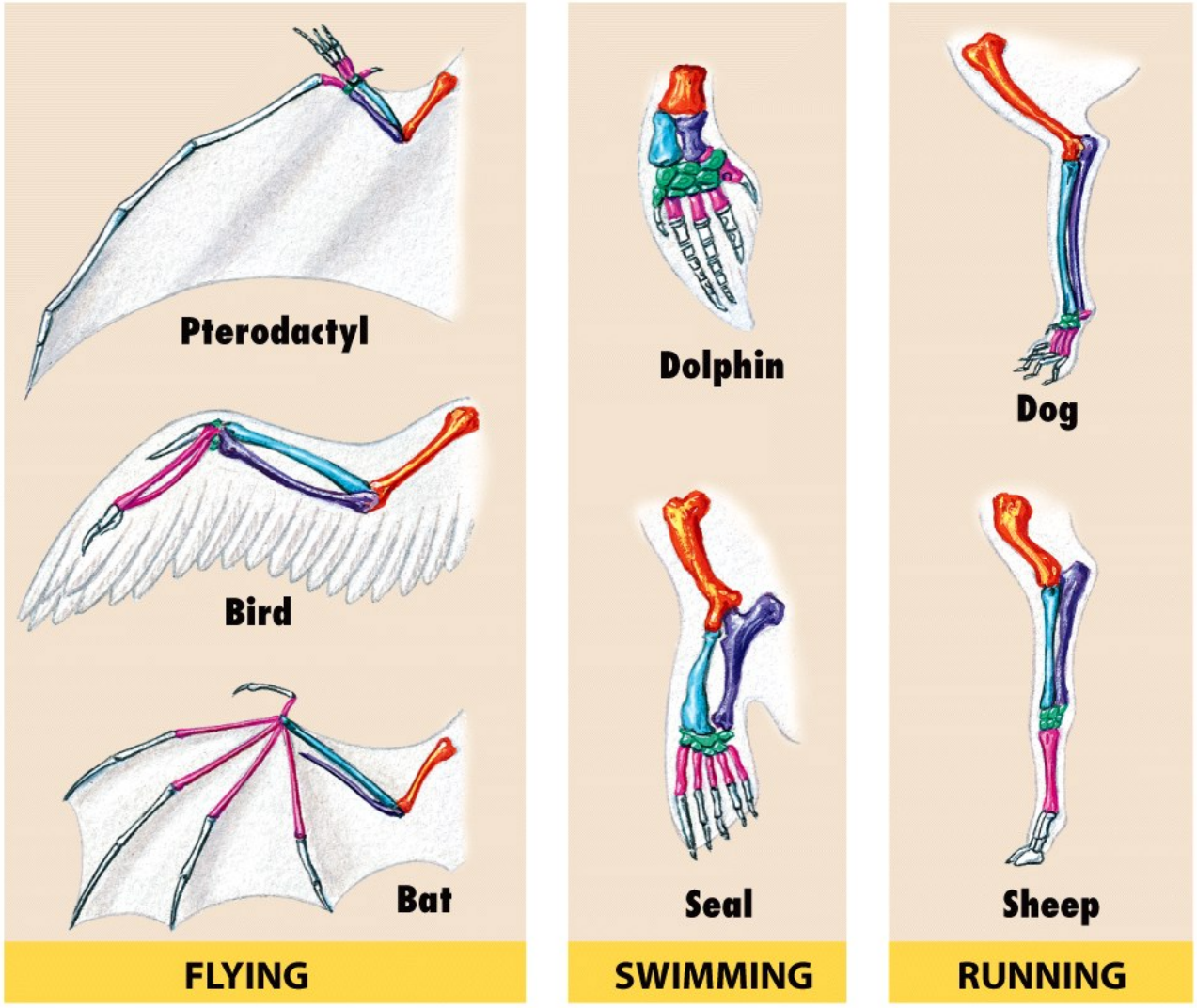


Figure 14-7 Biology: Life on Earth, 8/e

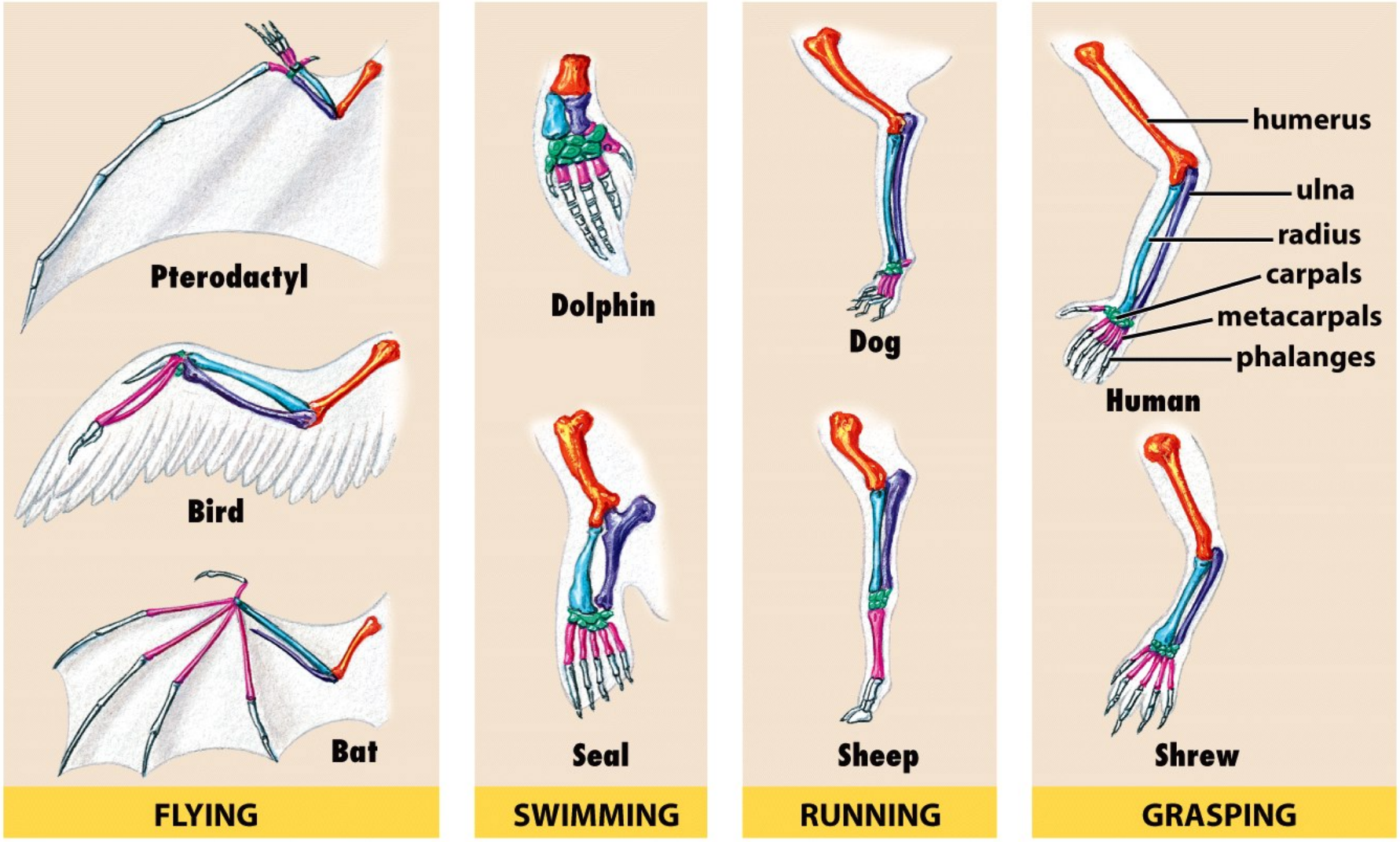


Figure 14-7 Biology: Life on Earth, 8/e

Comparative Anatomy

- **Vestigial structures** are remnants of structures that are inherited from ancestors
  - Had important functions in ancestors
  - Serve no obvious purpose in present day organism
- Vestigial structures include:
  - Molar teeth in vampire bats
  - Pelvic bones in whales and certain snakes

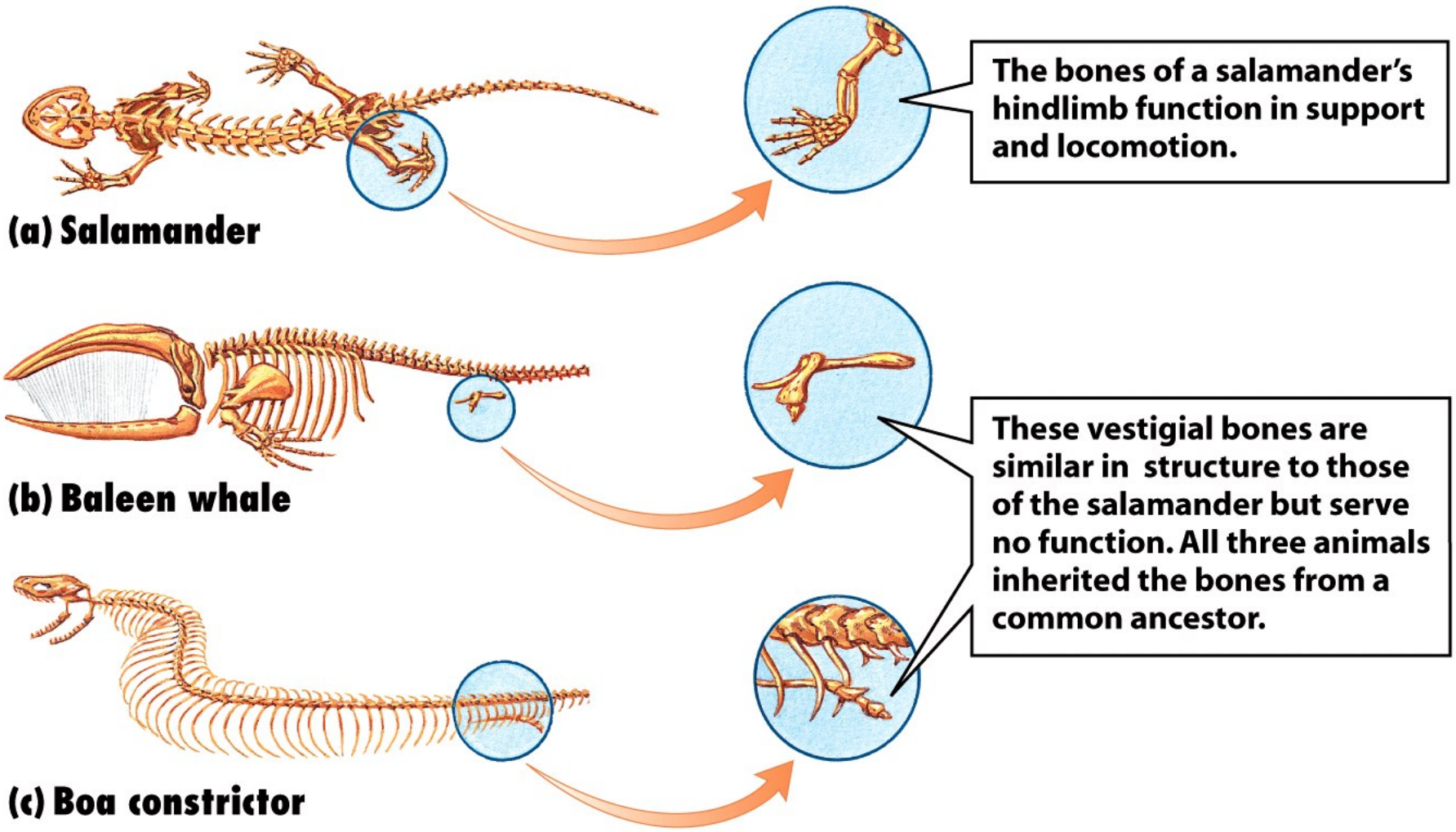


Figure 14-8 Biology: Life on Earth, 8/e

Comparative Anatomy

- **Analogous structures** are structures that are outwardly similar in appearance, but differ in their evolutionary origin
- Analogous structures include
  - Wings of insects and birds
  - Streamlined shapes of seals and penguins

Figure 14-9a Biology: Life on Earth, 8/e

Figure 14-9b Biology: Life on Earth, 8/e

Figure 14-9c Biology: Life on Earth, 8/e

Figure 14-9d Biology: Life on Earth, 8/e

Comparative Anatomy

- Analogous structures result from convergent evolution rather than descent from a common ancestor
- **Convergent evolution** occurs when similar environmental pressures and natural selection give rise to similar (analogous) structures in distantly related organisms

Embryology

- All vertebrate embryos, resemble one another in their early development
- All vertebrate embryos possess genes that direct development of gill slits and a tail
- These genes were inherited from a common ancestor

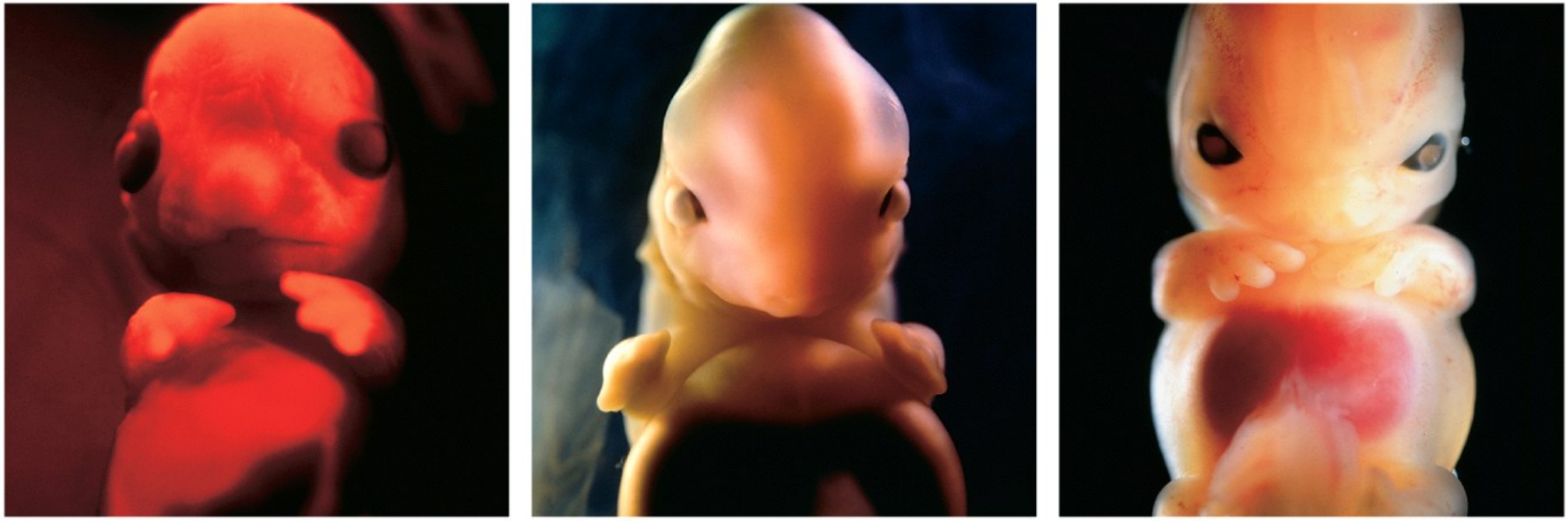


Figure 14-10 Biology: Life on Earth, 8/e

Embryology

- Adult fish retain gills and tail because the genes are active throughout their embryonic development
- Humans are born without gills and a tail because the genes are active only during early embryonic development

Biochemistry and Genetics

- All organisms share related biochemical processes:
  - All cells use DNA as genetic blueprint
  - All use RNA, ribosomes, and approximately the same genetic code for translation
  - All use roughly the same set of 20 amino acids to build proteins
  - All use ATP to transfer energy

Biochemistry and Genetics

- Striking genetic similarities between organisms imply evolutionary relatedness
- e.g. the DNA nucleotide sequence of the human and mouse cytochrome c gene is very similar, suggesting shared ancestry

Figure 14-11 Biology: Life on Earth, 8/e

Section 14.3 Outline

- **14.3 How Does Natural Selection Work?**
  - Darwin and Wallace's Theory Rests on Four Postulates
  - Natural Selection Modifies Populations Over Time

Evolution by Natural Selection

- Darwin and Wallace proposed that life's diverse forms arose through process of descent with modification
  - Individuals in each generation differ slightly from the members of the preceding generation
  - Over long time periods, small differences accumulate to produce major transformations

Evolution by Natural Selection

- Proposed process of evolution based on four postulates regarding populations

Evolution by Natural Selection

- **Postulate 1:** Individual members of a population differ from one another in many respects
  - Variations arise purely by chance resulting from random mutations in DNA
  - Differences are obvious in many physical characteristics and extend to molecular level

Figure 14-12 Biology: Life on Earth, 8/e

Evolution by Natural Selection

- **Postulate 2:** At least some of the differences among members of a population are due to characteristics that may be passed from parent to offspring
  - However, the mechanism of inheritance was not understood at this point in time

Evolution by Natural Selection

- **Postulate 3:** In each generation, some individuals in a population survive and reproduce successfully but others do not
  - Darwin observed that many more individuals are born than survive
  - Some individuals have more offspring than others

Evolution by Natural Selection

- **Postulate 4:** Individuals with advantageous traits survive longest and leave the most offspring, a process known as **natural selection**

Evolution by Natural Selection

- Gregor Mendel's theories of inheritance (1865) confirmed Darwin's assumption that certain traits are heritable
- New variations arise by chance as a result of random mutations in DNA
- New variations may be good, bad, or neutral

Populations Evolve

- Natural selection acts on individuals within a population; however, it is the population that changes over time

Section 14.4 Outline

- **14.4 What Is the Evidence That Populations Evolve by Natural Selection?**
  - Controlled Breeding Modifies Organisms
  - Evolution by Natural Selection Occurs Today

Controlled Breeding

- **Artificial selection** is selective breeding to produce plants and animals that possess desirable traits
- Modern dogs descended from wolves
- In only a few thousand years, humans artificially selected for all breeds of modern dogs

Figure 14-13a Biology: Life on Earth, 8/e

Figure 14-13b Biology: Life on Earth, 8/e

Controlled Breeding

- Humans have created tremendous variation in several species over relatively short periods of time through artificial selection
- Isn't it plausible that much larger changes could result from hundreds of millions of years of natural selection?

Natural Selection Today

- Examples include:
  - Coloration in Trinidadian guppies
  - Pesticide resistance
  - Experimental introductions of *Anolis sagrei* lizards

Coloration

- Female guppies prefer to mate with brightly colored males; however, brightly colored males are more likely to be eaten by predators
  - Males found in areas *lacking* predators were brightly colored
  - Males found in areas *with* predators were duller by comparison (predators eliminated brightly colored males before they could reproduce)

Coloration

- Conclusion: When fewer predators are present, brighter coloration can evolve
- Conclusion was confirmed
  - Predators were introduced to previously predator-free areas (males were brightly colored)
  - Within a few generations male guppies in those areas evolved to become less colorful

Figure 14-14 Biology: Life on Earth, 8/e

Pesticide Resistance

- Numerous insect pests have evolved resistance to pesticides
  - Roaches developed resistance to Combat®, an insecticide bait that acted as an agent of natural selection
  - Resistant roaches possessed a rare mutation that caused them to dislike glucose, the main attractant in Combat®

Pesticide Resistance

- At least one insect species is resistant to every pesticide in existence

Experiments

- Small groups of *Anolis sagrei* lizards were introduced onto 14 small Bahamian islands with thinly-branched bushes and no trees
  - Lizards were originally from Staniel Cay, an island with thickly-branched trees
  - Their long legs were adaptive for maneuvering in these trees
- The introduced lizards thrived and reproduced

Experiments

- After 14 years, comparisons were made between lizards on the Bahamian islands and those of Staniel Cay
- Lizards on all 14 Bahamian islands had shorter, thinner legs

Figure 14-15 Biology: Life on Earth, 8/e

Experiments

- Conclusion: Individuals with shorter, thinner legs evolved because they were able to escape predators better than their longer-legged ancestors in the new environment

Natural Selection of Phenotypes

1. The variations on which natural selection works are produced by mutations that arise *spontaneously*

Natural Selection of Phenotypes

2. Natural selection selects for organisms that are best adapted to a particular environment
   - If the environment changes, a previously advantageous trait may become disadvantageous