

普通生物学

第14~18章、第23~24章

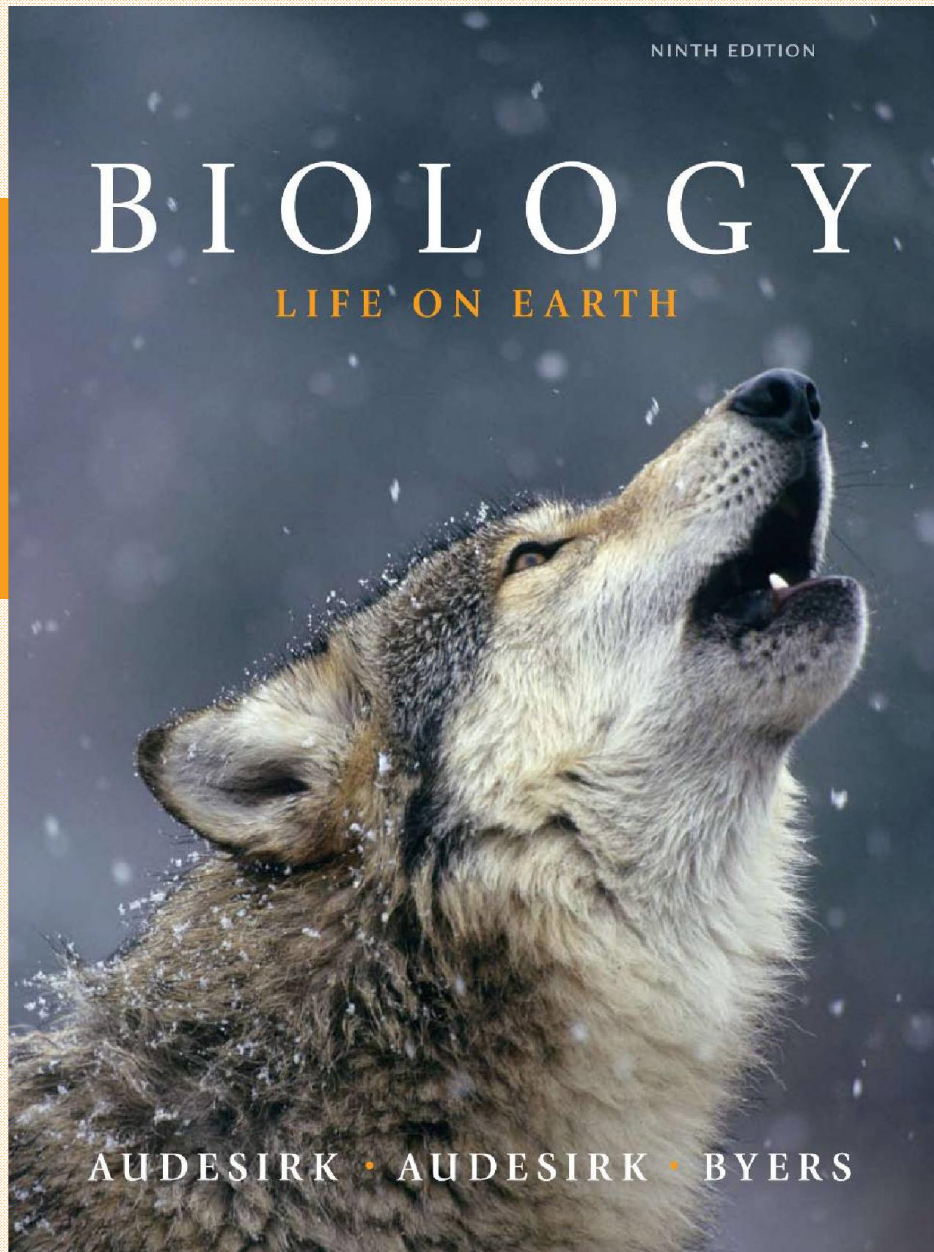
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Lecture Outlines by Gregory Ahearn,
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Chapter 14

Principles of Evolution

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Chapter 14 At a Glance

- 14.1 How Did **Evolutionary Thought** Evolve?
- 14.2 How Does **Natural Selection** Work?
- 14.3 How Do We Know That **Evolution** Has Occurred?
- 14.4 What Is the Evidence That **Populations Evolve** By Natural Selection?

14.1 How Did Evolutionary Thought Evolve?

- **Evolution(进化)** is the change over time in the characteristics of **a population(种群)**
- Evolution by natural selection is **a unifying theme** for all of biology
- The foundation of evolutionary thought developed gradually over centuries
- The main ideas of evolution were not widely accepted until after Charles Darwin published ***On the Origin of Species* 《物种起源》** in 1859

14.1 How Did Evolutionary Thought Evolve?

- **Early biological thought did not include the concept of evolution**
 - Pre-Darwinian thought held that all organisms were created simultaneously by God, and that each distinct life-form was permanently fixed and did not change over time
 - These beliefs were heavily influenced by theology
 - Plato (427–347 B.C.) proposed that each object on Earth was merely a temporary reflection of its divinely inspired “ideal form”
 - Aristotle (384–322 B.C.) arranged all organisms on a linear scale of increasing complexity (the “ladder of Nature”)

Aristotle's Ladder of Nature

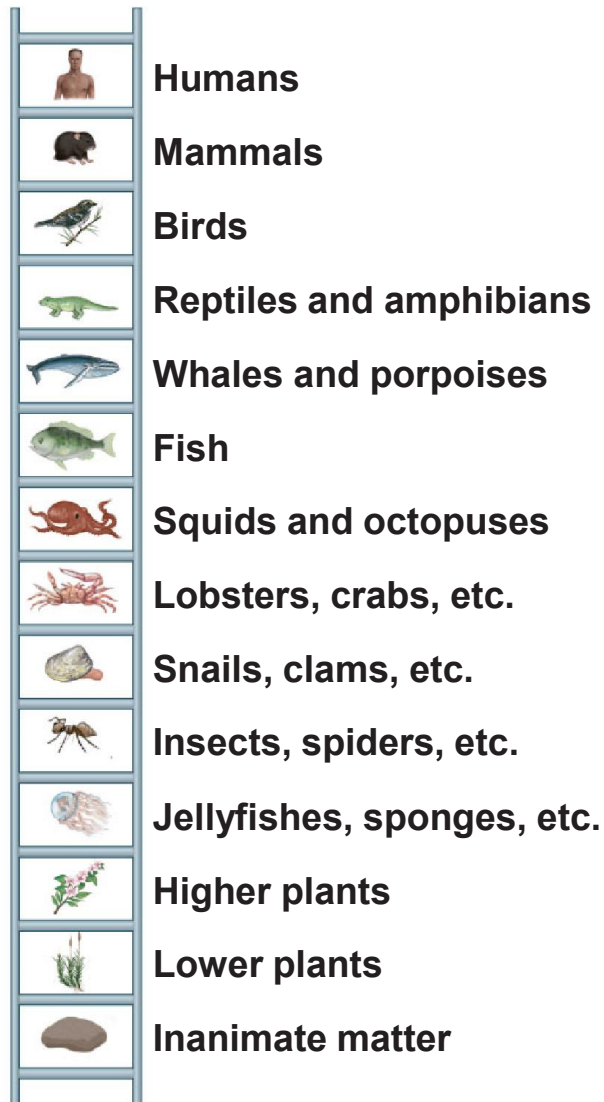


Fig. 14-2

14.1 How Did Evolutionary Thought Evolve?

- **Exploration of new lands revealed a staggering diversity of life**
 - Early explorers often took naturalists along to catalogue the plant and animal life they found
 - The number of species was far greater than expected

A Timeline of the Roots of Evolutionary Thought

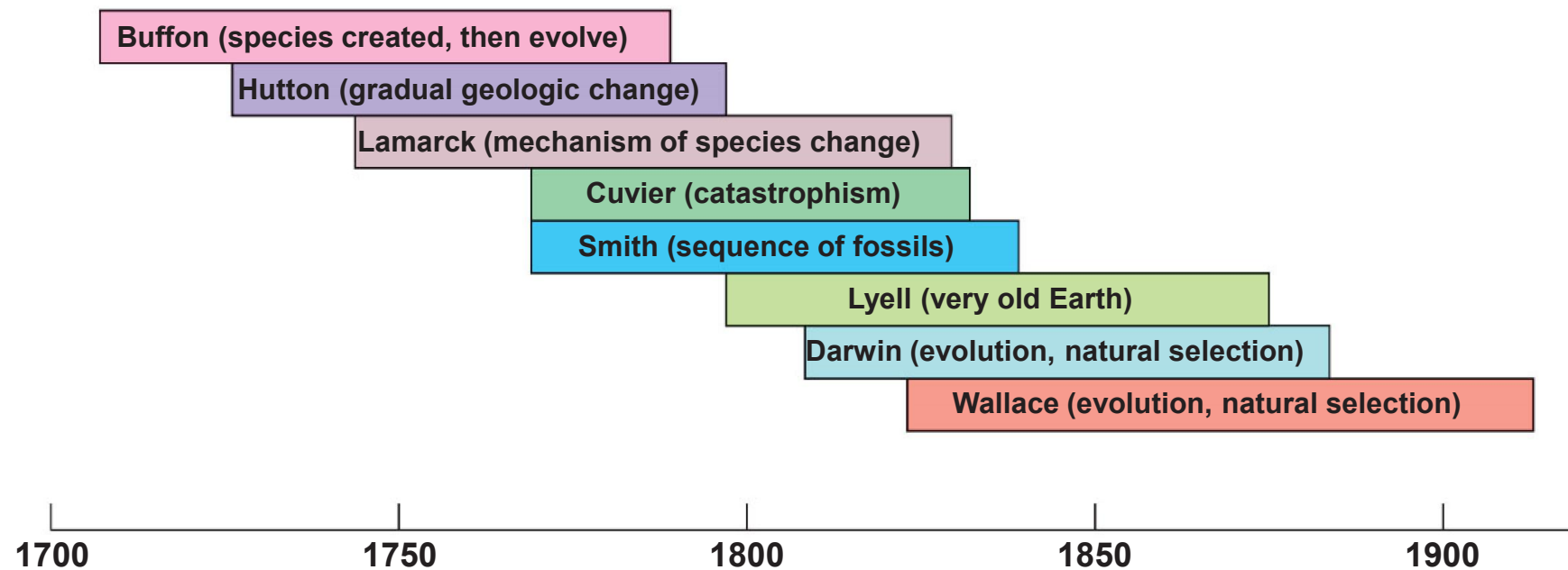


Fig. 14-1

14.1 How Did Evolutionary Thought Evolve?

- **Exploration of new lands revealed a staggering diversity(多样性) of life (continued)**
 - The vast numbers of species observed allowed naturalists to see patterns that had not emerged before
 - They noticed, for example, that each area had its own distinctive set of species
 - They also observed that some species closely resembled one another yet differed in some characteristics
 - To some naturalists, these patterns seemed inconsistent with the idea that species were fixed and unchanging

14.1 How Did Evolutionary Thought Evolve?

- **A few scientists speculated that life had evolved**
 - George Louis LeClerc (Comte de Buffon; 1707–1788) proposed that some modern species had evolved through natural processes, having originated at creation from a small number of founding species

14.1 How Did Evolutionary Thought Evolve?

- **Fossil discoveries showed that life has changed over time**
 - **Fossils(化石)**, the preserved remains or traces of organisms that died long ago, showed that organisms appeared to change over time
 - Fossils were discovered in many forms
 - Some were the petrified remains of bones, wood, shells, or their impressions left in mud
 - Other fossil remains included tracks, burrows, pollen, eggs, and feces
 - Most are found in sedimentary rock

Types of Fossils

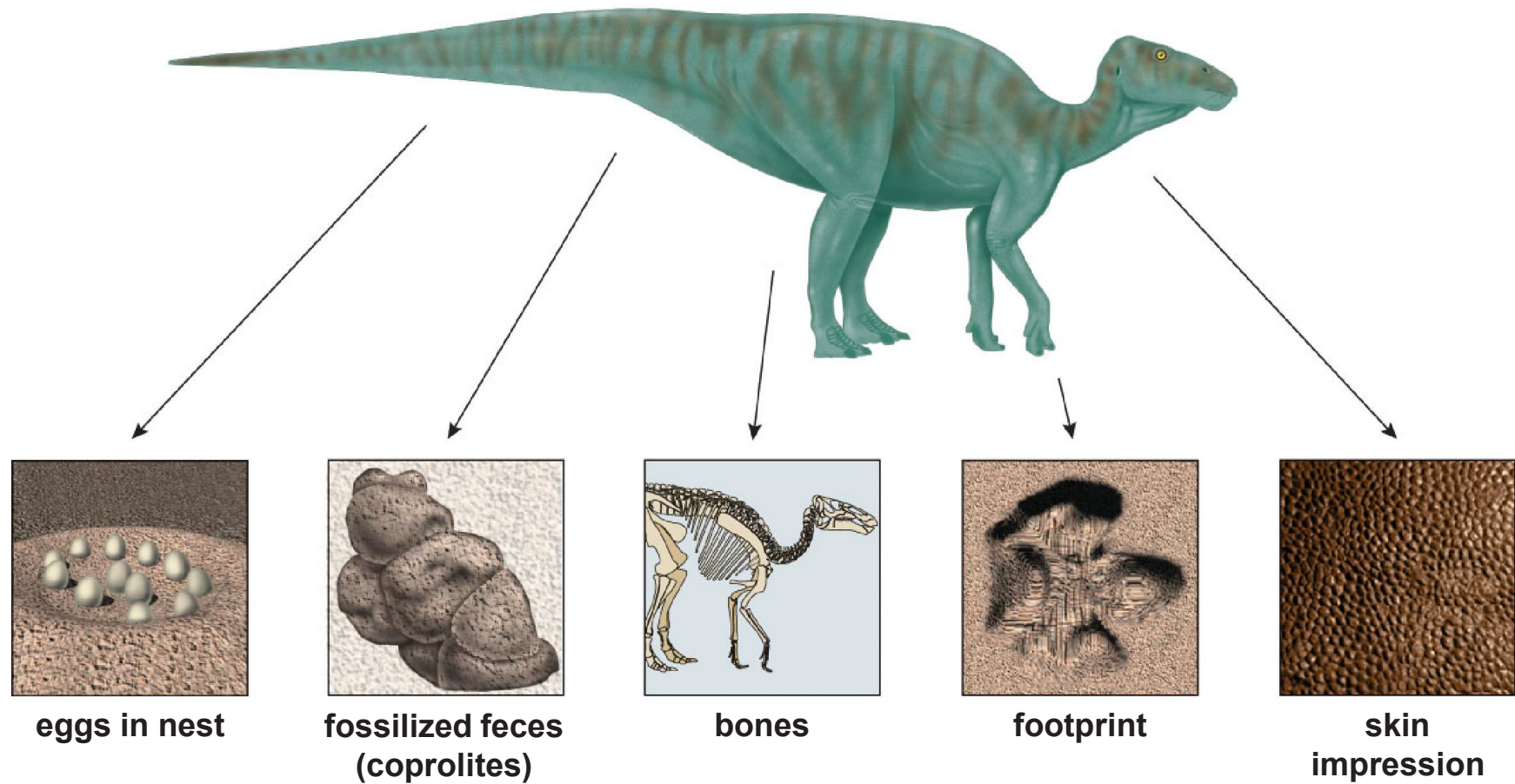


Fig. 14-3

14.1 How Did Evolutionary Thought Evolve?

- **Fossil discoveries showed that life has changed over time (continued)**
 - The British surveyor William Smith (1769–1839), who studied rock layers and the fossils embedded in them, recognized that certain fossils were always found in the same layers of rock
 - Many rocks occur in layers, with newer layers positioned over older layers
 - Further, the organization of fossils and rock layers was consistent with fossils of a given type always in the same layers

14.1 How Did Evolutionary Thought Evolve?

- **Fossil discoveries showed that life has changed over time (continued)**
 - Most fossils found in the oldest layers were very different from modern organisms
 - The resemblance to modern organisms gradually increased in progressively younger rocks
 - Many of the fossilized species were extinct

14.1 How Did Evolutionary Thought Evolve?

- **Fossil discoveries showed that life has changed over time (continued)**
 - The fossil evidence led many naturalists to a revolutionary conclusion
 - Different types of organisms had lived at different times in the past
 - This countered the view that species were created at one time and did not change afterwards

Fossils of Extinct Organisms

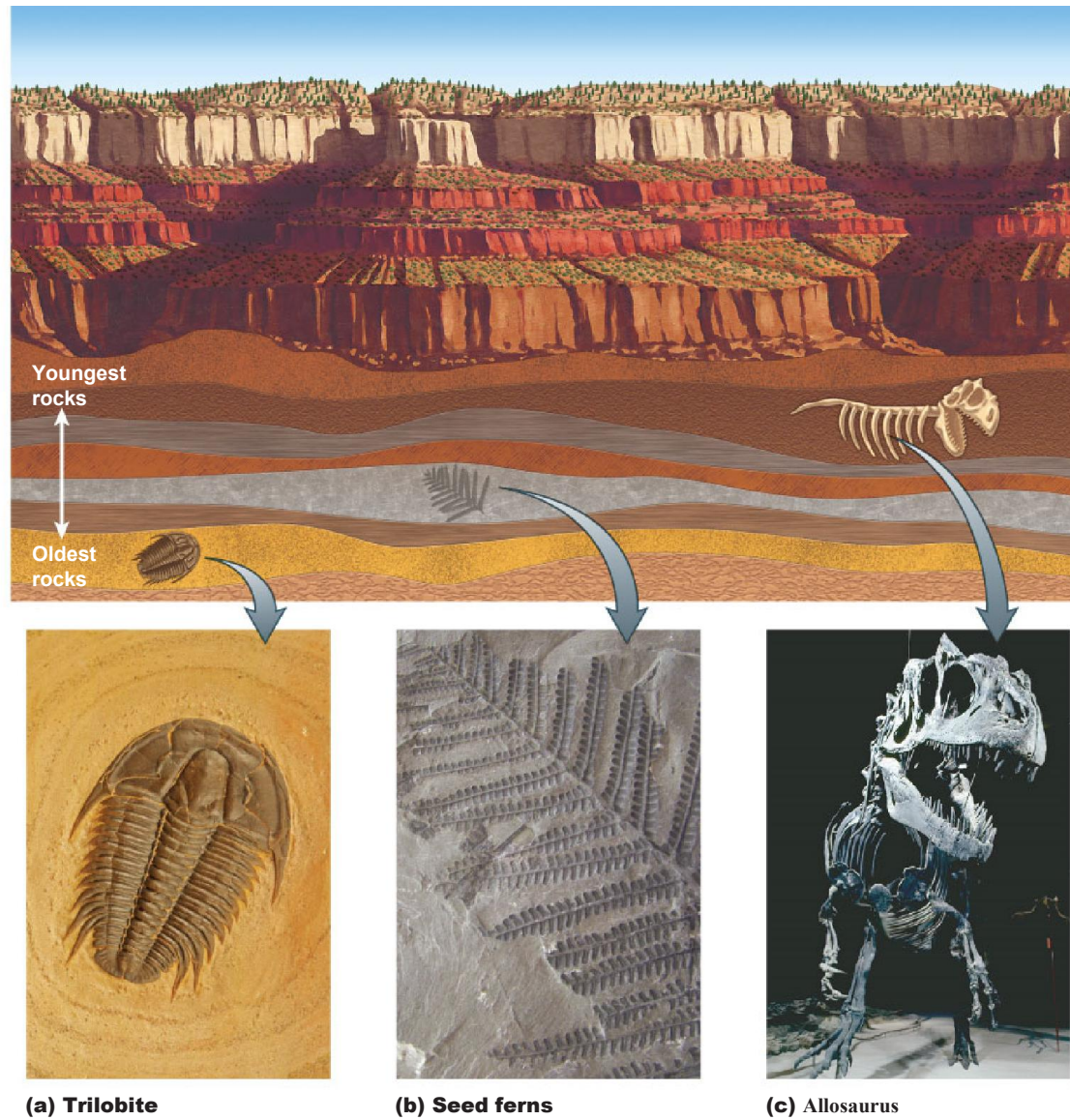


Fig. 14-4

14.1 How Did Evolutionary Thought Evolve?

- **Some scientists devised non-evolutionary explanations for fossils**
 - To account for the existence of extinct species while preserving the notion of a single creation by God, Georges Cuvier (1769–1832) proposed the theory of *catastrophism*(灾变论)
 - 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 catastrophes

14.1 How Did Evolutionary Thought Evolve?

- **Geology(地质学)** provided evidence that the **Earth is exceedingly old**
 - James Hutton (1726–1797) and Charles Lyell (1797–1875) considered the forces of wind, water, earthquakes, and volcanoes
 - They developed the theory of *uniformitarianism* (渐变论), which stated that geologic change resulted from slow, continuous actions similar to those at work today

14.1 How Did Evolutionary Thought Evolve?

- **Geology provided evidence that earth is exceedingly old (continued)**
 - Rock formations reflect repeated cycles of geologic change occurring over vast periods of time
 - Floods lay down layers of sediment, which turn into sedimentary rock
 - Volcanoes periodically erupt, laying down new layers of lava

14.1 How Did Evolutionary Thought Evolve?

- **Geology provided evidence that the Earth is exceedingly old (continued)**
 - The geological evidence led to several conclusions
 - Earth is far older than **the 6,000 years proposed by theologians**
 - There was enough time for evolution to occur
 - Modern geologists estimate that **the Earth is about 4.5 billion years old**

14.1 How Did Evolutionary Thought Evolve?

- **Some pre-Darwin biologists proposed mechanisms for evolution**
 - Jean Baptiste Lamarck (1744–1829) proposed that organisms evolved through the inheritance of acquired characteristics
 - The idea of inheritance of acquired characteristics was not rejected until long after Lamarck's death, when geneticists such as Mendel began to understand how traits are passed on and that acquired characteristics are not heritable

14.1 How Did Evolutionary Thought Evolve?

- **Darwin and Wallace proposed a mechanism of evolution**
 - By the mid-1880s, a growing number of biologists had concluded that present-day species had evolved from earlier ones
 - The mechanism for how this occurred was still unexplained
 - In 1858, Charles Darwin and Alfred Russel Wallace independently provided evidence of the occurrence of evolution and proposed the mechanism through which it occurs

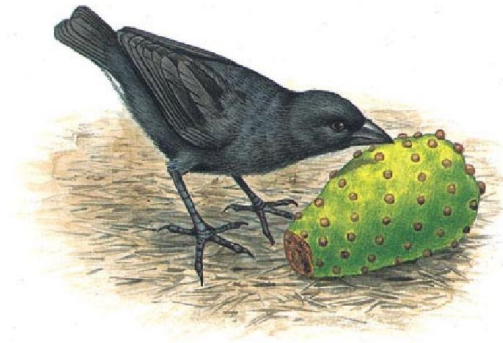
14.1 How Did Evolutionary Thought Evolve?

- **Darwin and Wallace proposed a mechanism of evolution (continued)**
 - Darwin and Wallace shared experiences that shaped their thinking
 - They both had traveled extensively and studied plants and animals in detail
 - Both had observed that some species differ in only a few traits
 - Both knew that fossils showed a trend of increasing complexity
 - Both were aware of Hutton and Lyell's proposal that the Earth is extremely old
 - Their experiences led both Darwin and Wallace to conclude **that species do change over time and to seek an explanation**

Darwin's Finches, Residents of the Galápagos Islands (加拉帕戈斯群岛)



(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

Fig. 14-5

14.1 How Did Evolutionary Thought Evolve?

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

14.2 How Does Natural Selection Work?

- **Darwin and Wallace proposed that life's diverse forms arose through the 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

14.2 How Does Natural Selection Work?

- **Darwin and Wallace's theory rests on four postulates (四个假设)**
 - **Postulate 1:** Individual members of a population differ from one another in many respects
 - We now know that variations arise purely by chance resulting from random mutations in DNA
 - The differences are obvious in many physical characteristics and extend to the molecular level

Variation in a Population of Snails



Fig. 14-6

14.2 How Does Natural Selection Work?

- **Darwin and Wallace's theory rests on four postulates (continued)**
 - **Postulate 2:** At least some of the differences between 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

14.2 How Does Natural Selection Work?

- **Darwin and Wallace's theory rests on four postulates (continued)**
 - **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

14.2 How Does Natural Selection Work?

- **Darwin and Wallace's theory rests on four postulates (continued)**
 - **Postulate 4:** Individuals with advantageous traits survive longest and leave the most offspring, a process known as **natural selection** (自然选择)
 - In the competition to survive and reproduce, winners are determined not by chance but by the traits they possess

14.2 How Does Natural Selection Work?

- **Natural selection modifies populations over time**
 - Natural selection acts on individuals within a population; however, it is the population that changes over time
 - Over generations, the population changes, as the percentage of individuals inheriting favorable traits increases
 - An individual cannot evolve, but a population can

14.3 How Do We Know That Evolution Has Occurred?

- **Evolution is widely accepted today**
- **An overwhelming body of evidence in multiple areas of science supports the theory of evolution**
 - Fossils provide evidence of evolutionary change over time
 - **Comparative anatomy(比较解剖学)** gives evidence of descent with modification
 - **Embryological(胚胎学的)** similarity suggests common ancestry
 - **Modern biochemical and genetic** analyses reveal relatedness among diverse organisms

14.3 How Do We Know That Evolution Has Occurred?

- **Fossils provide evidence of evolutionary change over time**
 - 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
 - These fossil series suggest that new species evolved from, and replaced, previous species
 - One series reveals that modern whales evolved from land-dwelling ancestors

The Evolution of the Whale

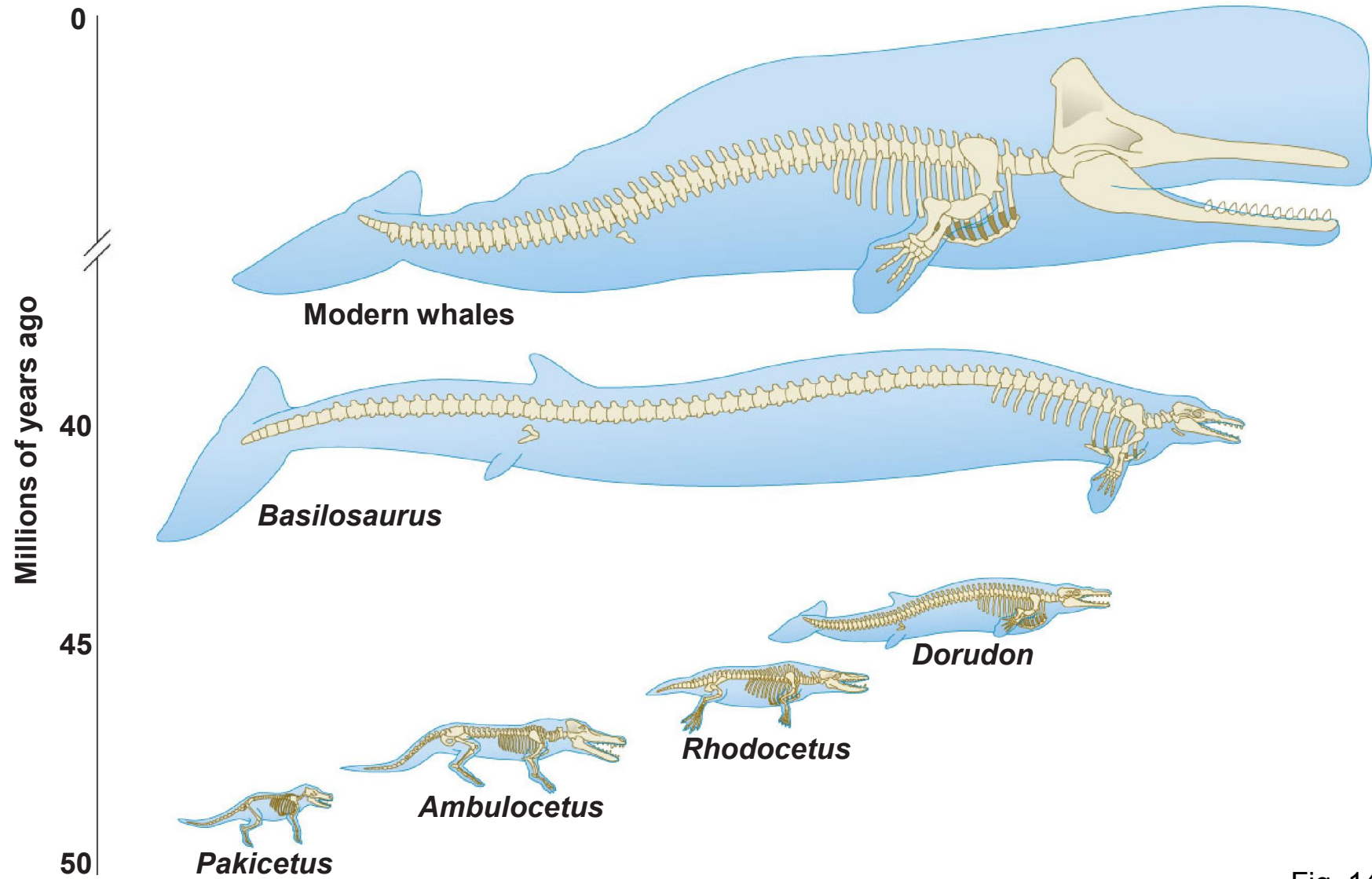


Fig. 14-7

14.3 How Do We Know That Evolution Has Occurred?

- **Comparative anatomy gives evidence of descent with modification**
 - Comparing the bodies of organisms of different species can reveal similarities that can be explained only by shared ancestry
 - Comparing the bodies of organisms of different species can reveal differences that could result only from evolutionary change during descent from a common ancestor

14.3 How Do We Know That Evolution Has Occurred?

- Comparative anatomy gives evidence of descent with modification (*continued*)
 - Homologous structures provide evidence of common ancestry
 - **Homologous structures** (同源构造) are structures that have the same evolutionary origin despite their current appearance or function

14.3 How Do We Know That Evolution Has Occurred?

- **Homologous structures provide evidence of common ancestry (continued)**
 - Bird and mammalian forelimbs are homologous structures
 - The forelimbs are used for flying, swimming, running, and grasping
 - Despite their different uses, they have strong anatomical similarities
 - Such similarity is exactly what we would expect if bird and mammal forelimbs(前肢) were derived from a common ancestor

Homologous Structures

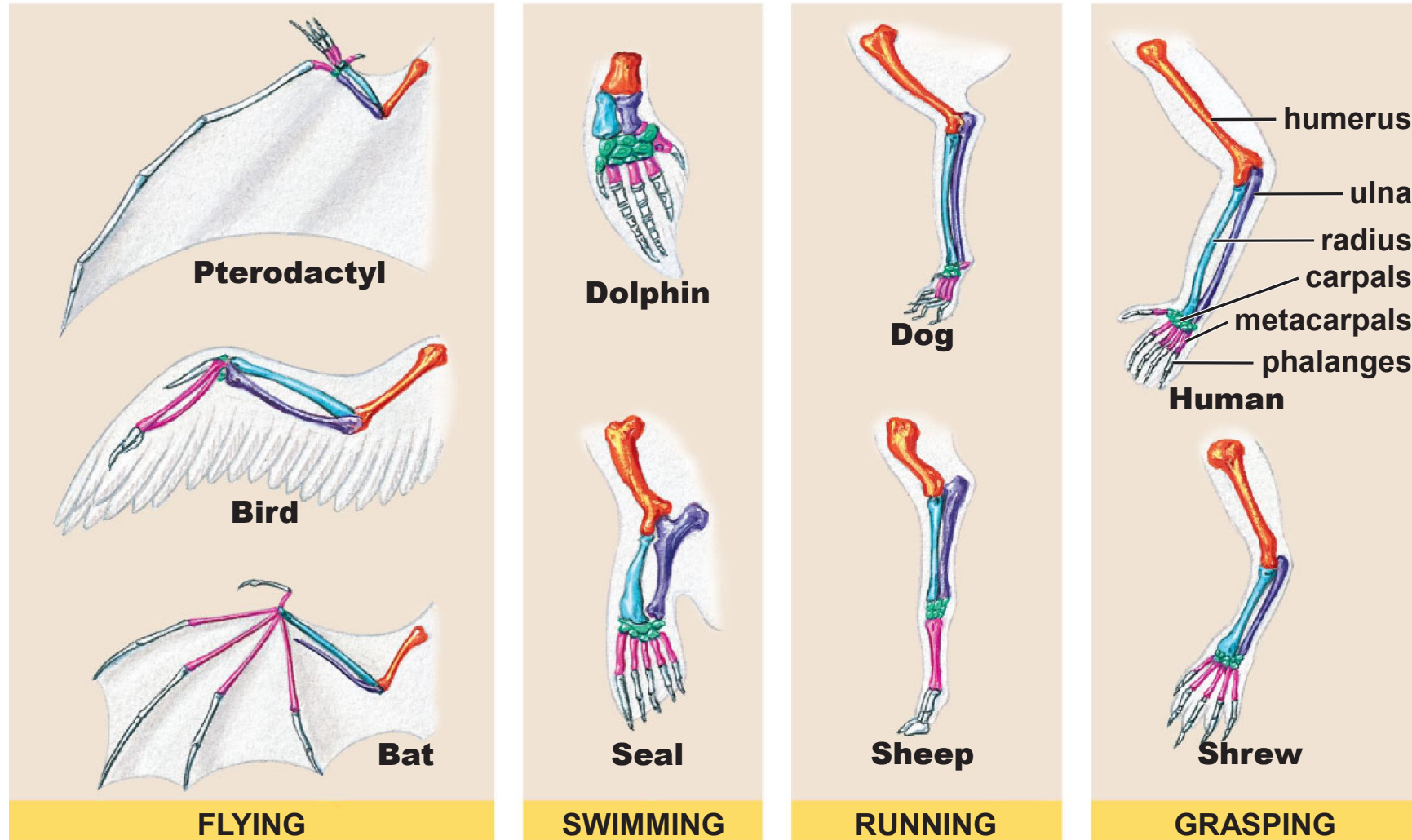


Fig. 14-8

14.3 How Do We Know That Evolution Has Occurred?

- Comparative anatomy gives evidence of descent with modification (*continued*)
 - Vestigial structures provide evidence of evolution
 - **Vestigial structures** (退化构造) are remnants of structures that are inherited from ancestors
 - **Molar teeth** (臼齿) in **vampire bats** (吸血蝠) (which live on a diet of blood and, therefore, don't chew their food) are vestigial structures

14.3 How Do We Know That Evolution Has Occurred?

- Comparative anatomy gives evidence of descent with modification (*continued*)
 - Pelvic bones(盆骨) in whales and in certain snakes also serve no function in modern species
 - Evolutionary theory suggests that as the animals evolved into new habitats, some of their structures that made them less fit were reduced to the point of insignificance

Vestigial Structures

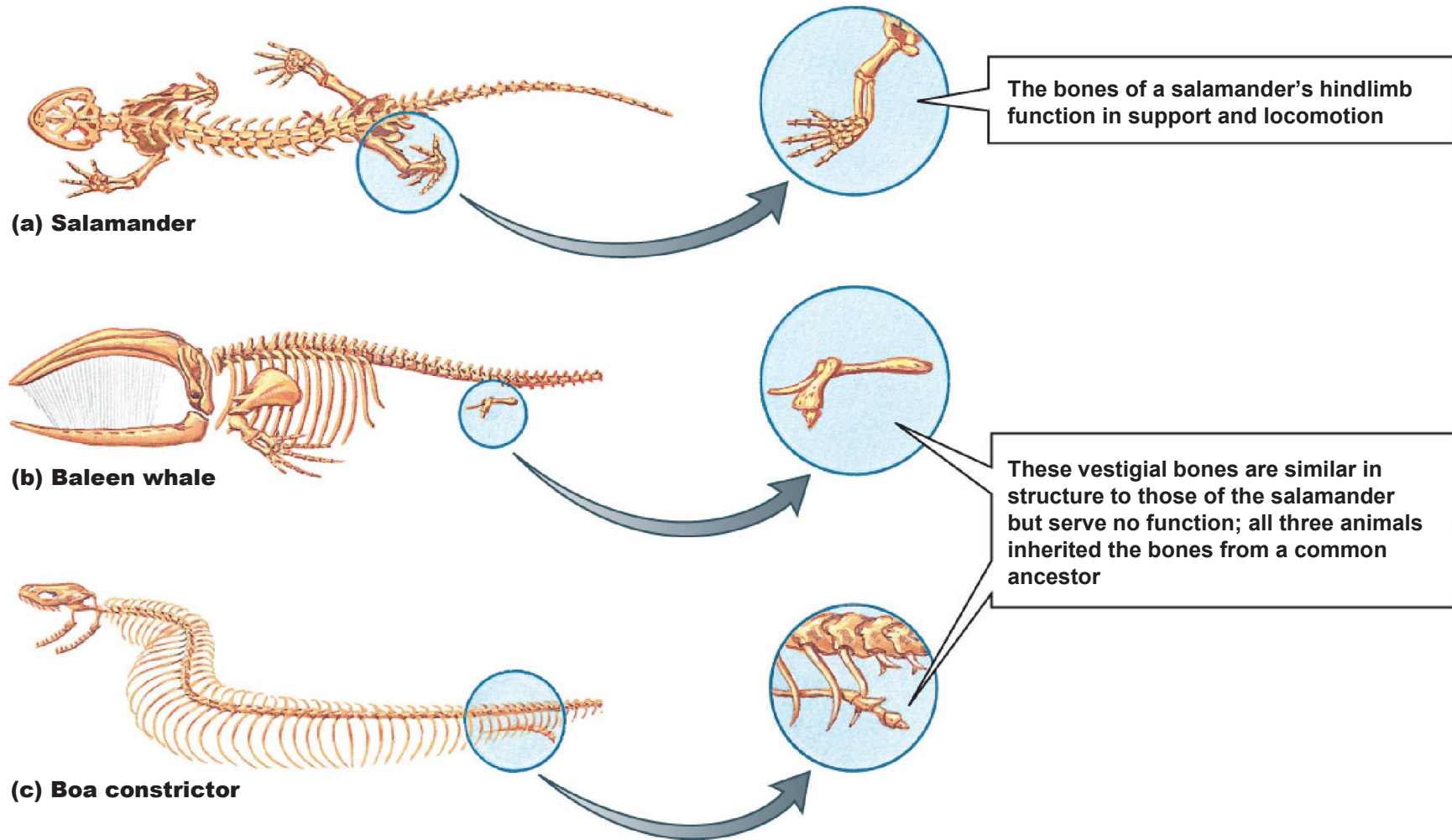


Fig. 14-9

14.3 How Do We Know That Evolution Has Occurred?

- **Comparative anatomy gives evidence of descent with modification (continued)**
 - Some anatomical similarities do not stem from common ancestry, but instead result from **convergent evolution(趋同进化)**, in which natural selection causes non-homologous structures that serve similar functions to resemble one another
 - **Analogous structures(同功结构)** are structures that are outwardly similar in appearance, but differ in their evolutionary origin
 - Analogous structures are typically very different in internal anatomy because the parts are not derived from common ancestral structures

14.3 How Do We Know That Evolution Has Occurred?

- **Comparative anatomy gives evidence of descent with modification (continued)**
 - The wings of insects and birds are analogous structures
 - Because natural selection favored flight in both birds and insects, the two groups evolved superficially similar structures

Analogous Structures



(a) Damselfly



(b) Swallow

Fig. 14-10

14.3 How Do We Know That Evolution Has Occurred?

- **Embryological similarity suggests common ancestry**
 - All vertebrate embryos resemble one another in their early development
 - All vertebrate embryos possess genes that direct development of gill slits and a tail
 - Adult fish retain gills and tail because the genes are active throughout their embryonic development

14.3 How Do We Know That Evolution Has Occurred?

- **Embryological similarity suggests common ancestry (continued)**
 - Humans are born without gills and a tail because the genes are active only during early embryonic development
 - By evolutionary theory, the explanation for this is that ancestral vertebrates possessed genes that directed the development of gills and tails, and all their descendants still have those genes

Embryological Stages Reveal Evolutionary Relationships



(a) Lemur



(b) Pig



(c) Human

Fig. 14-11

14.3 How Do We Know That Evolution Has Occurred?

- **Modern biochemical and genetic analyses reveal relatedness among diverse organisms**
 - All organisms share related biochemical processes
 - All cells use DNA as a 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

14.3 How Do We Know That Evolution Has Occurred?

- **Modern biochemical and genetic analyses reveal relatedness among diverse organisms (continued)**
 - Striking genetic similarities between organisms imply evolutionary relatedness
 - For example, the DNA nucleotide sequence of the human and the mouse cytochrome c gene is very similar, suggesting shared ancestry

Molecular Similarity Shows Evolutionary Relationships



Fig. 14-12

14.4 What Is the Evidence That Populations Evolve by Natural Selection?

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

Dog Diversity Illustrates Artificial Selection



(a) Gray wolf



(b) Diverse dogs

Fig. 14-13

14.4 What Is the Evidence That Populations Evolve by Natural Selection?

- **Controlled breeding modifies organisms (continued)**
 - 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?

14.4 What Is the Evidence That Populations Evolve by Natural Selection?

- **Evolution by natural selection occurs today**
 - Examples include:
 - Coloration in Trinidadian guppies
 - Pesticide resistance
 - Experimental introductions of *Anolis sagrei* lizards

14.4 What Is the Evidence That Populations Evolve by Natural Selection?

- **Evolution by natural selection(自然选择) occurs today (continued)**
 - 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(食肉动物)** were duller by comparison (predators eliminated brightly colored males before they could reproduce)

14.4 What Is the Evidence That Populations Evolve by Natural Selection?

- **Evolution by natural selection occurs today (continued)**
 - The conclusion was that when fewer predators are present, brighter coloration can evolve
 - An experiment confirmed the conclusion
 - Predators were introduced to previously predator-free areas (where males were brightly colored)
 - Within a few generations, male guppies in those areas evolved to become less colorful

Guppies Evolve to Become More Colorful in Predator-free Environments



Fig. 14-14

14.4 What Is the Evidence That Populations Evolve by Natural Selection?

- **Numerous insect pests have evolved a resistance to pesticides**
 - In Florida, the insecticide bait Combat[®] was successfully used to kill **roaches** (蟑螂)
 - However, a few roaches possessed a rare mutation that caused them to dislike glucose, the main attractant in Combat[®]
 - Because the roaches that did not eat the Combat[®] bred successfully, soon the mutation spread throughout the population, rendering the insecticide ineffective
 - Combat[®] had acted as an agent of natural selection
- Every pesticide in existence has fostered a resistance in at least one of the insect species it is designed to kill

14.4 What Is the Evidence That Populations Evolve by Natural Selection?

- **Evolution by natural selection occurs today (continued)**
 - Small groups of *Anolis sagrei* lizards were introduced onto 14 small **Bahamian islands**(巴哈马群岛) 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 on the thick branches of these trees
 - The introduced lizards thrived and reproduced

14.4 What Is the Evidence That Populations Evolve by Natural Selection?

- **Evolution by natural selection occurs today (continued)**
 - 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

14.4 What Is the Evidence That Populations Evolve by Natural Selection?

- **Evolution by natural selection occurs today (continued)**
 - Natural selection appeared to favor individuals with shorter, thinner legs because they were able to move more agilely along the thinner vegetation of their new islands
 - Because they could move more agilely, they were able to escape predators better than their longer-legged ancestors in the new environment
 - More of the shorter-legged lizards survived to pass their genes for shorter legs on

Anole Leg Size Evolves in Response to a Changed Environment



Fig. 14-15

14.4 What Is the Evidence That Populations Evolve by Natural Selection?

- **Evolution by natural selection occurs today (continued)**
 - The variations on which natural selection works are produced by mutations that arise *spontaneously*
 - **Natural selection selects for organisms that are best adapted to a particular environment**
 - If the environment changes, a previously advantageous trait may become disadvantageous