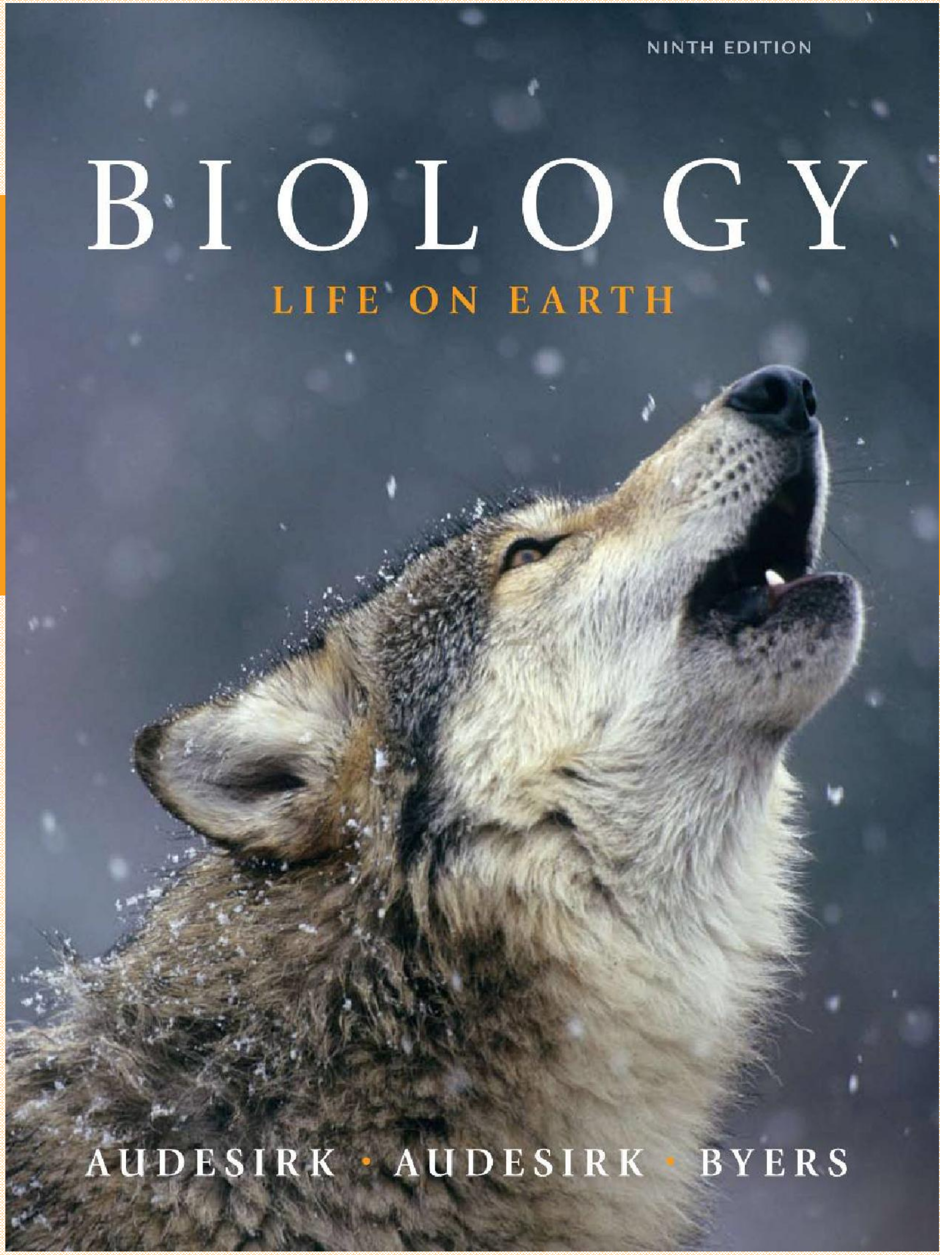


Chapter 17

The History of Life

Lecture Outlines by Gregory Ahearn,
University of North Florida

Chapter 17 At a Glance

- 17.1 How Did Life Begin?
- 17.2 What Were the Earliest Organisms Like?
- 17.3 What Were the Earliest Multicellular Organisms Like?
- 17.4 How Did Life Invade the Land?
- 17.5 What Role Has Extinction Played in the History of Life?
- 17.6 How Did Humans Evolve?

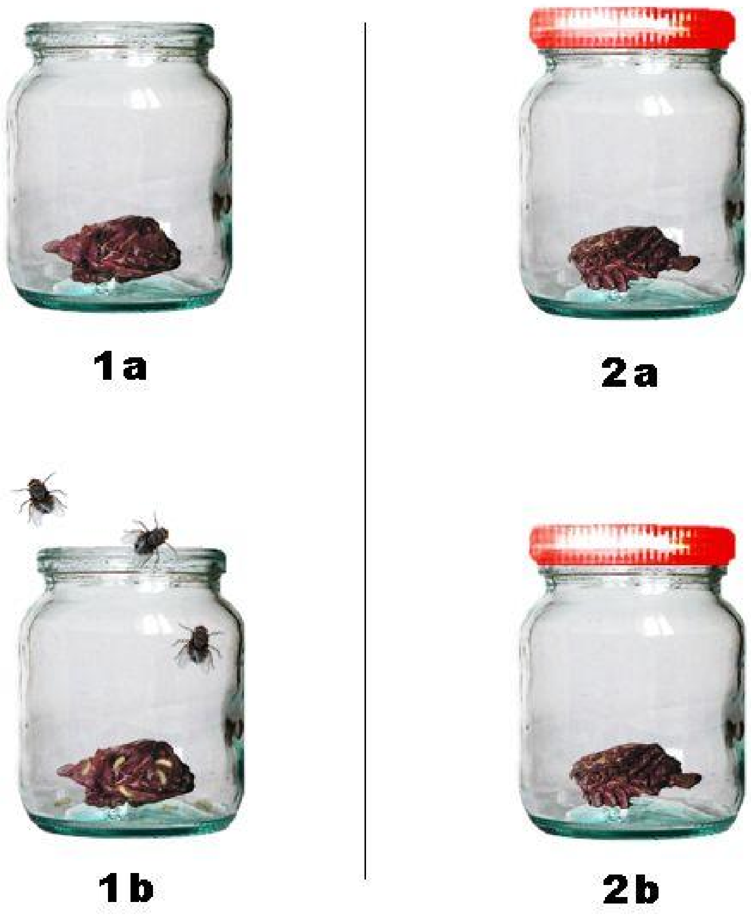
17.1 How Did Life Begin?

- **Spontaneous generation (自然发生) is the proposal that living organisms can arise from nonliving matter**
- Medieval beliefs reflected the concept of spontaneous generation
  – Maggots were thought to arise from meat
  – Microbes were thought to arise from broth
  – Mice were thought to arise from mixtures of sweaty shirts and wheat

17.1 How Did Life Begin?

- **Experiments refuted spontaneous generation**
  - The maggots-from-meat idea was disproved by Francesco Redi in 1668
    - No maggots developed when he kept flies away from uncontaminated meat
  - The broth-to-microorganism idea was disproved by Louis Pasteur and John Tyndall in the mid-1800s
    - Microorganisms did not appear in sterile broth unless the broth was first exposed to existing microorganisms in the surrounding environment

- Redi's experiment on abiogenesis



Spontaneous Generation Refuted

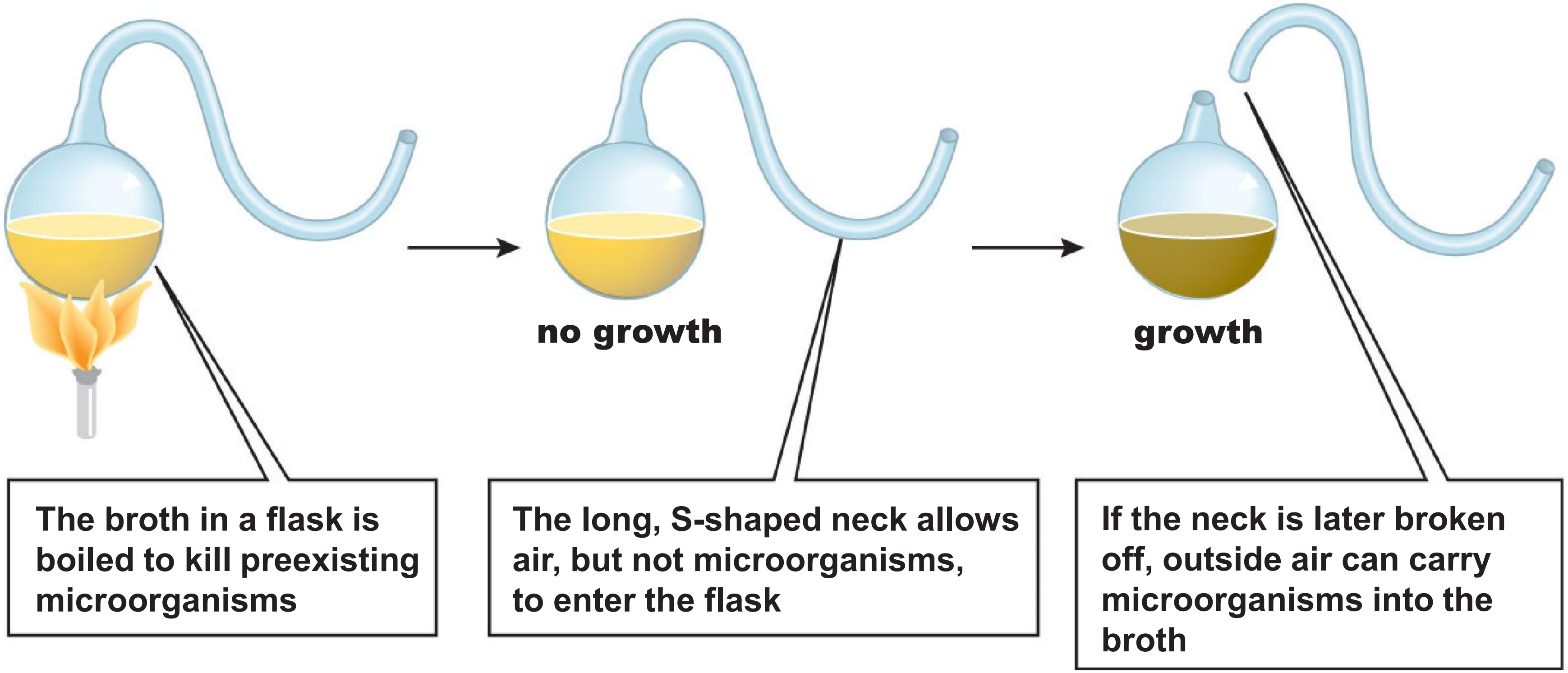


Fig. 17-1

17.1 How Did Life Begin?

- **Did spontaneous generation occur on early Earth?**
- Pasteur did *not* prove that spontaneous generation never happened
  - He showed only that it does not happen under present-day conditions in an oxygen-rich atmosphere

17.1 How Did Life Begin?

- **In the 1920s, Alexander Oparin and John Haldane proposed concepts on which modern scientific ideas about the origin of life are based**
  - They speculated that the atmosphere of early Earth contained little oxygen because an oxygen-rich atmosphere would not have permitted the spontaneous formation of complex organic molecules
    - Oxygen's high reactivity with chemical bonds would have prevented large molecules from forming

17.1 How Did Life Begin?

- **In the 1920s, Alexander Oparin and John Haldane proposed concepts on which modern scientific ideas about the origin of life are based (continued)**
  - Some kinds of molecules could persist in the lifeless environment of early Earth better than others and would therefore become more common over time
    - This gradual selection of molecules was termed prebiotic chemical evolution(生命起源前的化学进化)
  - They proposed that the molecules became increasingly more complex and eventually gave rise to life

17.1 How Did Life Begin?

- **Oparin and Haldane envisioned that prebiotic chemical evolution occurred in three stages**
  1. Prebiotic synthesis and accumulation of small organic molecules formed a pool of building blocks
  2. Small organic molecules combined to form larger molecules
  3. Progressively more complex molecules eventually gave rise to living organisms

17.1 How Did Life Begin?

- **In 1953, Stanley Miller and Harold Urey set out to simulate the first stage of prebiotic evolution in the laboratory**
  - They noted that the atmosphere of early Earth probably contained methane (CH_4), ammonia (NH_3), hydrogen (H_2), and water vapor (H_2O), but no oxygen
  - They simulated early Earth's atmosphere by mixing the gases in a flask and adding an electrical discharge to simulate lightning
    - Simple organic molecules appeared after a few days

The Experimental Apparatus of Stanley Miller and Harold Urey

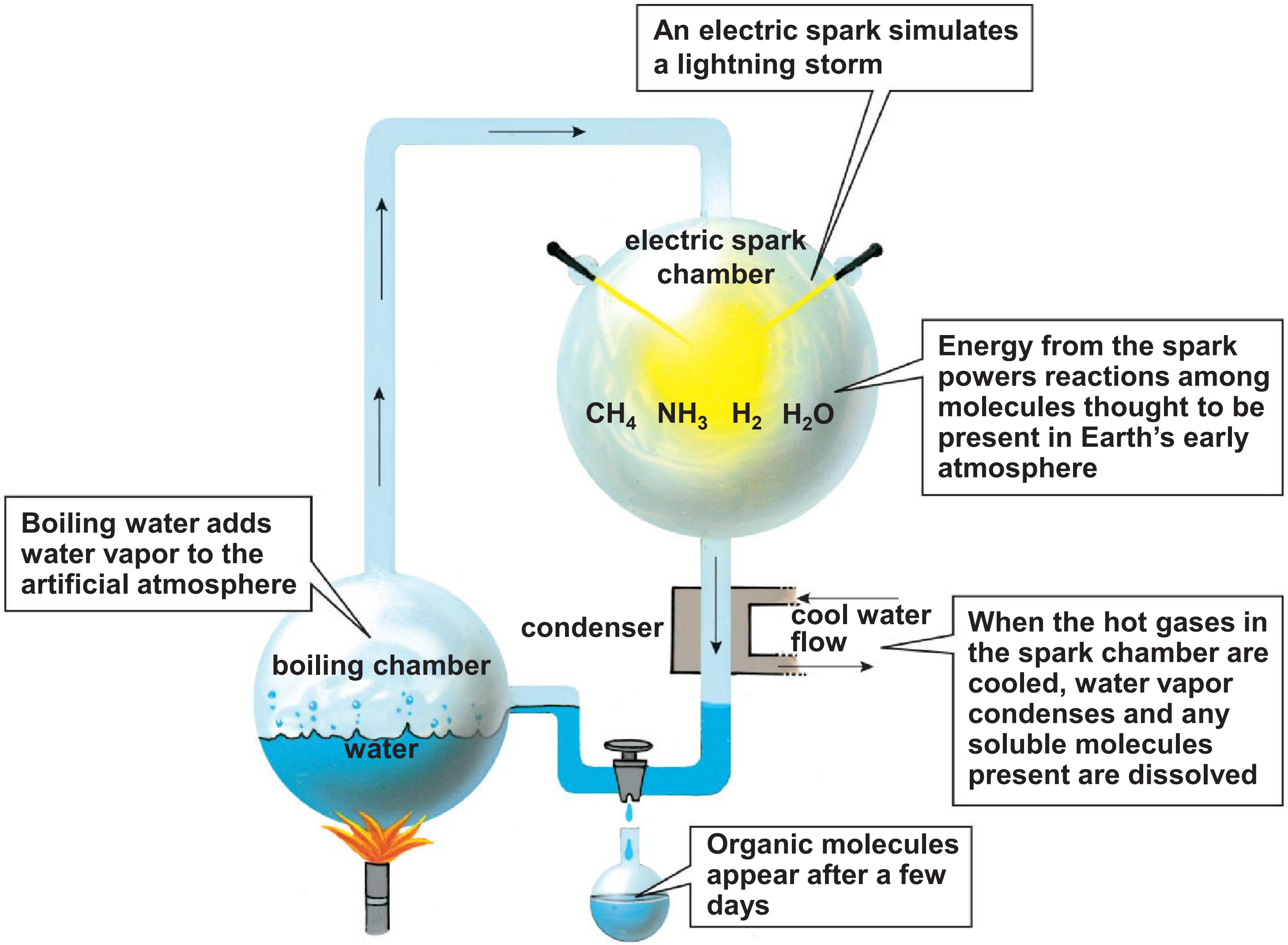


Fig. 17-2

17.1 How Did Life Begin?

- **Similar experiments by Miller and others have produced amino acids, short proteins, nucleotides, and ATP**
- Modern geochemists believe the early atmosphere was somewhat different from that modeled in Miller and Urey’s experiments
  - Additional experiments with more realistic (but still oxygen-free) simulated atmospheres have also yielded organic molecules

17.1 How Did Life Begin?

- **More recent experiments have demonstrated that multiple types of energy could have produced the molecules of life**
  – Electrical discharge, UV light, and heat were equally effective

17.1 How Did Life Begin?

- **Additional organic molecules probably arrived from space when meteorites and comets(陨石和慧星) crashed into the Earth's surface**
  - Analysis of present-day meteorites recovered from impact craters on Earth has revealed that some meteorites contain relatively high concentrations of amino acids and other simple organic molecules
  - When small molecules known to be present in space were placed under space-like conditions of very low temperature and pressure and bombarded with UV light, larger organic molecules were produced

17.1 How Did Life Begin?

- **RNA may have been the first self-reproducing molecule**
  - DNA was probably not the first self-reproducing molecule
    - DNA replication requires large complexes of protein, which themselves are coded for by DNA
    - This chicken-and-egg interdependency makes DNA an unlikely candidate for self-replication

17.1 How Did Life Begin?

- **RNA may have been the first self-reproducing molecule (continued)**
  – Thomas Cech and Sidney Altman (1980s) discovered an RNA molecule (a **ribozyme 核酶**) that could catalyze a chemical reaction, a role that was thought to be performed only by protein enzymes

A Ribozyme

Fig. 17-3

17.1 How Did Life Begin?

- **RNA may have been the first self-reproducing molecule (continued)**
  - Since Cech and Altman's initial discovery, dozens of naturally occurring ribozymes have been found that catalyze reactions, including:
    - Cutting other RNA molecules
    - Splicing together different RNA fragments
    - Attaching amino acids to growing proteins

17.1 How Did Life Begin?

- **Discovery of ribozymes led to the hypothesis that RNA preceded the origin of DNA, in an "RNA world"**
  - In the RNA world, RNA preceded DNA in two functional ways
    - RNA was the information-carrying genetic molecule
    - RNA served as the enzyme catalyst for its own replication

17.1 How Did Life Begin?

- **Discovery of ribozymes led to the hypothesis that RNA preceded the origin of DNA, in an “RNA world” (continued)**
  - This first self-reproducing ribozyme probably wasn’t very good at its job and produced copies with lots of errors
    - Natural selection acted on these errors to improve the function of these early ribozymes
    - With increased speed and accuracy of replication, these variant ribozymes reproduced, copying themselves and displacing less efficient molecules

17.1 How Did Life Begin?

- **Over time, DNA replaced RNA as the information-carrying genetic molecule, and RNA took on its present role as an intermediary between DNA and protein**
  – The process by which this occurred is unknown

17.1 How Did Life Begin?

- **Self-replicating molecules must be contained within some kind of enclosing membrane**
  - Vesicles(囊泡) are a naturally occurring possibility
    - Vesicles are small, hollow spheres formed from lipids and proteins
    - Vesicles have been formed artificially by agitating water containing proteins and lipids, as might occur in wave action

17.1 How Did Life Begin?

- **Certain vesicles (protocells) may have contained organic molecules, including ribozymes, and would have been the precursors of living cells**
  - The membranes would have served to sequester the molecules of life and to protect them from extraneous ribozymes
  - After sufficient time, these protocells may have developed the ability to divide and pass on copies of their enclosed ribozymes to daughter protocells
  - The transition from protocell to living cell was a continuous process, with no sharp boundary between one state and the next

17.1 How Did Life Begin?

- But did all this happen?
  - Despite a great diversity of assumptions, experiments, and contradictory hypotheses in origin-of-life research, certain facts support the central tenets
    - **The experiments of Miller and others show that organic molecules, along with simple membrane-like structures, would have formed on early Earth**
    - **Given enough time and a sufficiently large pool of reactant molecules, even extremely rare events can occur many times**
    - **There was ample time and space for these rare events to lead to the development of life**

17.2 What Were the Earliest Organisms Like?

- Earth formed about 4.5 billion years ago
- Life arose 3.9 to 3.5 billion years ago during the Precambrian(前寒武纪) era
  - The oldest fossil organisms found to date are estimated to be about 3.5 billion years old
- Geologists and paleontologists have devised a hierarchical naming system of eras, periods, and epochs to delineate the immense span of geological time

Early Earth

Fig. 17-4

Table 17-1 The History of Life on Earth

Step 1

Table 17-1 The History of Life on Earth

Era	Period	Epoch	Millions of years ago	Major events
Cenozoic	Quaternary	Recent	0.01–present	Evolution of genus *Homo*
		Pleistocene	1.8–0.01	
	Tertiary	Pliocene	5–1.8	Widespread flourishing of birds, mammals, insects, and flowering plants
		Miocene	23–5	
		Oligocene	38–23	
		Eocene	54–38	
		Paleocene	65–54	
Mesozoic	Cretaceous		146–65	Flowering plants appear and become dominant Mass extinction of marine and terrestrial life, including dinosaurs
	Jurassic		208–146	Dominance of dinosaurs and conifers First birds
	Triassic		245–208	First mammals and dinosaurs Forests of gymnosperms and tree ferns
Paleozoic	Permian		286–245	Massive marine extinctions, including trilobites Flourishing of reptiles and the decline of amphibians
	Carboniferous		360–286	Forests of tree ferns and club mosses Dominance of amphibians and insects First reptiles and conifers
	Devonian		410–360	Fishes and trilobites flourish First amphibians, insects, seeds, and pollen
	Silurian		440–410	Many fishes, trilobites, and mollusks First vascular plants
	Ordovician		505–440	Dominance of arthropods and mollusks in the ocean Invasion of land by plants and arthropods First fungi
	Cambrian		544–505	Marine algae flourish Origin of most marine invertebrate phyla First fishes
Precambrian			About 1,000	First animals (soft-bodied marine invertebrates)
			1,200	First multicellular organisms
			2,000	First eukaryotes
			2,200	Accumulation of free oxygen in the atmosphere
			3,500	Origin of photosynthesis (in cyanobacteria)
			3,900–3,500	First living cells (prokaryotes)
			4,000–3,900	Appearance of the first rocks on Earth
			4,600	Origin of the solar system and Earth

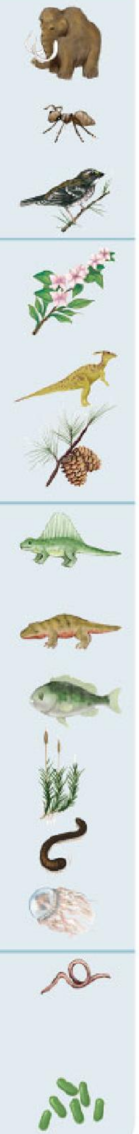


Table 17-1 The History of Life on Earth

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Precambrian			About 1,000	First animals (soft-bodied marine invertebrates)
			1,200	First multicellular organisms
			2,000	First eukaryotes
			2,200	Accumulation of free oxygen in the atmosphere
			3,500	Origin of photosynthesis (in cyanobacteria)
			3,900–3,500	First living cells (prokaryotes)
			4,000–3,900	Appearance of the first rocks on Earth
			4,600	Origin of the solar system and Earth

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		Oligocene	38–23	
		Eocene	54–38	
		Paleocene	65–54	

Table 17-1, 1 of 4

17.2 What Were the Earliest Organisms Like?

- **The first organisms were anaerobic prokaryotes(厌养原核生物)**
  - The first cells to arise in the Earth's oceans were **prokaryotes**, cells that lack a membrane-bound nucleus
    - These primitive bacteria probably obtained nutrients and energy by absorbing organic molecules from their environment
    - Since early Earth lacked oxygen gas, these first cells metabolized organic molecules anaerobically

17.2 What Were the Earliest Organisms Like?

- **Eventually, some cells evolved the ability to use the energy of sunlight for synthesis of complex, high-energy molecules**
  – This marked the evolution of photosynthesis (光合作用)

17.2 What Were the Earliest Organisms Like?

- **Photosynthesis requires sunlight, CO_2, and hydrogen**
  - The earliest source of hydrogen is believed to have been hydrogen sulfide (硫化氢)
  - Eventually, water replaced hydrogen sulfide as the source of hydrogen, and photosynthesis became water-based

17.2 What Were the Earliest Organisms Like?

- **Water-based photosynthesis resulted in an increase in atmospheric oxygen**
  - Water-based photosynthesis releases oxygen gas as a by-product
  - Initially, oxygen combined with iron in the Earth's crust to form iron oxide (rust)
  - Subsequently, oxygen began accumulating in the atmosphere
    - Chemical analysis of rocks suggests that significant levels of atmospheric oxygen first appeared about 2.3 billion years ago

17.2 What Were the Earliest Organisms Like?

- **Aerobic metabolism(有氧代谢) arose in response to the stress of an oxygen-rich atmosphere**
  - Because it is so reactive, oxygen is a poison to many anaerobic bacteria
    - The accumulation of oxygen in the atmosphere of early Earth probably exterminated many anaerobic organisms
  - The increase in oxygen provided the environmental pressure for the evolution of aerobic metabolism

17.2 What Were the Earliest Organisms Like?

- **The next great advance in the age of microbes was the ability to use oxygen in metabolism**
  - This ability provides a defense against the chemical action of oxygen
  - Being able to use oxygen also channels oxygen's destructive power through aerobic respiration to generate useful energy for the cell
    - The evolution of aerobic metabolism was significant because aerobic organisms can harvest more energy per food molecule than anaerobic organisms

17.2 What Were the Earliest Organisms Like?

- **Some organisms acquired membrane-enclosed organelles(细胞器)**
  - As prokaryotes(原核生物) began to proliferate, some developed the ability to engulf smaller ones
    - These early predators(捕食者), lacking both photosynthesis and aerobic metabolism, processed their prey very inefficiently

17.2 What Were the Earliest Organisms Like?

- **Some organisms acquired membrane-enclosed organelles (continued)**
  - The ability to compartmentalize functions inside the cell through internal membrane formation greatly improved the efficiency of the early cells
    - The first **eukaryotes(真核生物)** (cells that possess membrane-bound organelles) appeared about 1.7 billion years ago

17.2 What Were the Earliest Organisms Like?

- **Mitochondria and chloroplasts may have arisen from engulfed bacteria**
  - The **endosymbiont hypothesis(内吞说, 内共生说)** proposes that early eukaryotic cells acquired the precursors of mitochondria and chloroplasts by engulfing certain types of bacteria
  - These cells and the bacteria trapped inside them gradually entered into a symbiotic relationship(共生关系), a close association between different types of organisms

The Probable Origin of Mitochondria and Chloroplasts in Eukaryotic Cells

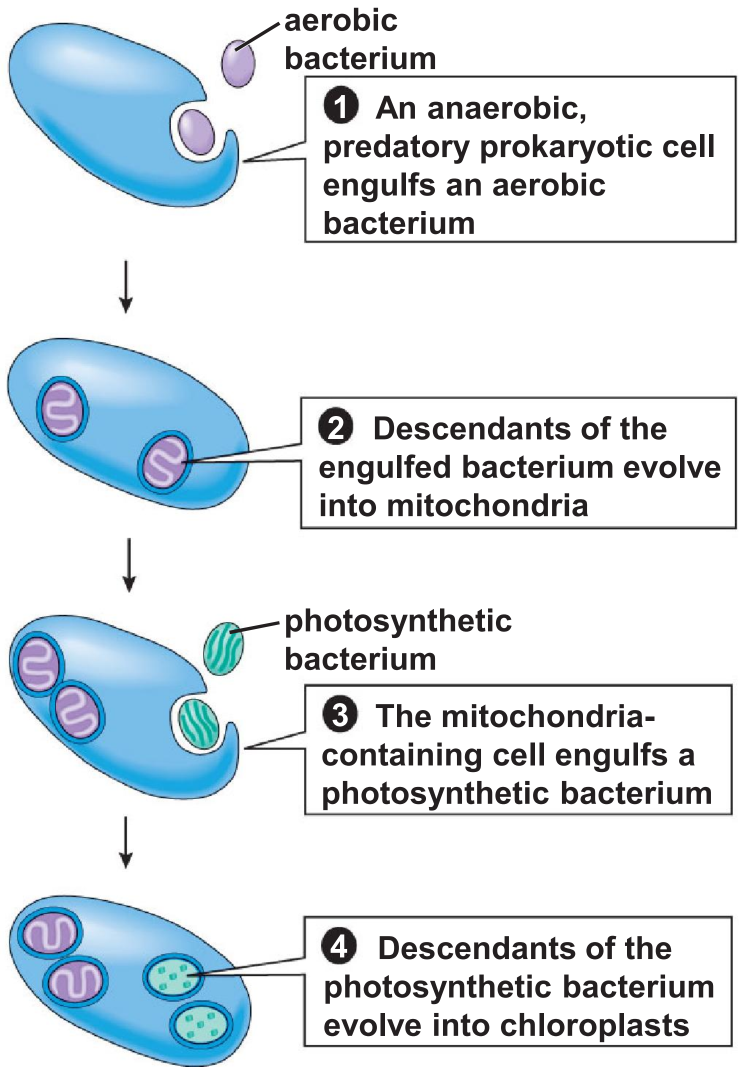


Fig. 17-5

17.2 What Were the Earliest Organisms Like?

- **The evidence for the endosymbiont hypothesis is strong**
  - Many biochemical features are shared by eukaryotic organelles and living bacteria
  - Mitochondria, chloroplasts, and centrioles contain their own supply of DNA
    - This DNA is considered to be the remnants of the DNA originally contained within the engulfed bacteria

17.2 What Were the Earliest Organisms Like?

- **The evidence for the endosymbiont hypothesis is strong (continued)**
  - Modern cells, called *living intermediates*, host bacterial endosymbionts
    - The amoeba *Pelomyxa palustris* harbors aerobic bacteria
    - A variety of corals, some clams, a few snails, and at least one species of *Paramecium* harbor photosynthetic bacteria

17.2 What Were the Earliest Organisms Like?

- The evidence for the endosymbiont hypothesis is strong (continued)
  – The fact that modern cells host bacterial endosymbionts suggests that similar symbiotic associations could have occurred almost 2 billion years ago and led to the first eukaryotic cells

17.3 What Were the Earliest Multicellular Organisms Like?

- **Once predation evolved, increased cell size became an advantage**
  - Larger cells could more easily engulf smaller cells and were less likely to be engulfed themselves
  - Larger cells could move faster after prey and away from predators

17.3 What Were the Earliest Multicellular Organisms Like?

- **Size, however, also presents a disadvantage**
  - The larger a cell becomes, the less surface membrane is available per unit volume of cytoplasm
  - Therefore, it becomes more difficult for sufficient amounts of oxygen and nutrients to diffuse in and waste products to diffuse out as cells get larger

17.3 What Were the Earliest Multicellular Organisms Like?

- **The first multicellular organisms appeared in the seas about 1.2 billion years ago**
  - These first multicellular organisms were algae that arose from single-celled eukaryotic cells containing chloroplasts

17.3 What Were the Earliest Multicellular Organisms Like?

- **The first multicellular organisms appeared in the seas about 1.2 billion years ago**
  - Multicellularity would have provided at least two advantages for these seaweeds(海藻)
    - Large, many-celled algae would have been difficult for single-celled predators to engulf
    - Specialization of cells would have allowed plants to develop rootlike structures to anchor themselves in the brightly lit waters of the shoreline and leaflike structures to capture the sunlight

17.3 What Were the Earliest Multicellular Organisms Like?

- **Fossil traces of animal tracks and burrows have been found in 1 billion-year-old rocks**
- **The earliest fossils of the animals themselves were of invertebrates(无脊椎动物) (animals lacking backbones) collected from rocks 610 million to 544 million years old**
  - The oldest rock layers included fossils of ancestral **sponges(海棉)** and **jellyfish(水母)**
  - Subsequent rock layers revealed fossils of ancestral worms, mollusks(软体动物), and arthropods(节肢动物)

17.3 What Were the Earliest Multicellular Organisms Like?

- **The full range of modern invertebrate animals, however, does not appear in the fossil record until the Cambrian (寒武纪) periodof the Paleozoic era (古生代)(544 million years ago)**
  - The Cambrian period was marked by an "explosion" in animal diversity
  - Almost all of major groups of animals on Earth today were already present in the early Cambrian era
    - The apparently sudden appearance of so many different kinds of animals suggests these groups actually arose earlier, but that their early evolutionary history is not preserved in the fossil record

17.3 What Were the Earliest Multicellular Organisms Like?

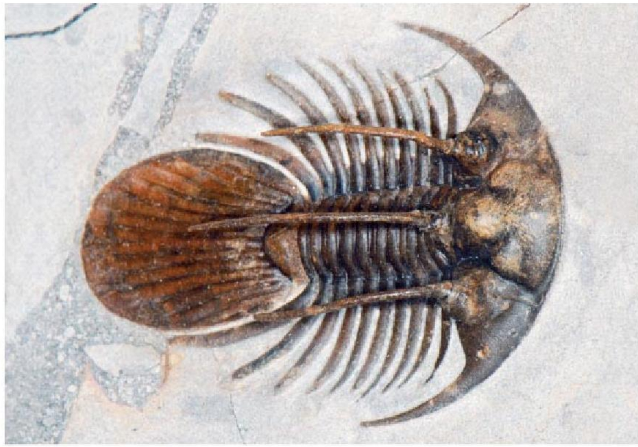
- **Predation favored the evolution of mobility and the senses**
  – The coevolution of predator and prey favored animals that were more mobile
  – The evolution of efficient movement was often associated with the evolution of greater sensory capabilities and more complex nervous systems

17.3 What Were the Earliest Multicellular Organisms Like?

- **Predation favored the evolution of mobility and the senses (continued)**
  - By the Silurian(志留纪) period (440 million to 410 million years ago), life in Earth's seas included an array of anatomically complex animals
    - Examples of animals from this period include trilobites(三叶虫), ammonites(菊石), and the chambered nautilus(鹦鹉螺) (which exists today nearly unchanged from its original form)

Diversity of Ocean Life During the Silurian Period

(a) Silurian scene



(b) Trilobite

(c) Ammonite

(d) *Nautilus*

Fig. 17-7

17.3 What Were the Earliest Multicellular Organisms Like?

- **Skeletons improved mobility and offered better protection**
  - Many of the Paleozoic animal species developed increased mobility, in part owing to the origin of hard external body coverings known as **exoskeletons** (外骨骼)

17.3 What Were the Earliest Multicellular Organisms Like?

- **Skeletons improved mobility and offered better protection (continued)**
  – About 530 million years ago, one group of animals—the fishes—developed a new form of body support and muscle attachment: an internal skeleton (内骨骼)
  – They were the first vertebrates (脊椎动物) (animals with backbones)

17.3 What Were the Earliest Multicellular Organisms Like?

- **Skeletons improved mobility and offered better protection (continued)**
  - By 400 million years ago, fishes were a diverse and prominent group
  - Over time, fish became the dominant predators in the oceans
    - Fish were faster than invertebrates
    - Fish possessed more acute senses and larger brains than invertebrates

17.4 How Did Life Invade the Land?

- **After more than 3 billion years of a strictly watery existence, life came ashore**
- **Land-invading organisms faced various obstacles**
  - They had to support their own weight instead of relying on the buoyancy of water
  - They had to locate water instead of simply being surrounded by it
  - They needed to protect their gametes from desiccation

17.4 How Did Life Invade the Land?

- **The vast empty spaces of the Paleozoic landmass represented a tremendous evolutionary opportunity**
- **The move on to land was particularly advantageous for plants**
  – Photosynthesis was far more effective freed from the light-absorbing qualities of water
  – Soils had untapped sources of nutrients, whereas seawater was low in some nutrients, particularly nitrogen and phosphorus
  – The land was free of predators on plants, whereas the sea was teeming with them

17.4 How Did Life Invade the Land?

- **Some plants became adapted to life on dry land**
  - In moist soils at the water's edge, a few small green algae began to grow
  - About 475 million years ago, some of these algae gave rise to the first multicellular land plants

The Swamp Forest of the Carboniferous(石炭纪) Period

Fig. 17-8

17.4 How Did Life Invade the Land?

- **After land plants evolved, animals invaded land**
  - The first animals to inhabit land were the **arthropods(节肢动物)**, invertebrates with jointed appendages and an external skeleton
    - This group today includes insects, spiders, scorpions(蝎子), centipedes(蜈蚣), and crabs
    - The exoskeleton gave arthropods an advantage because it is waterproof and provides support against the force of gravity
    - Arthropods dominated the Earth for tens of millions of years

17.4 How Did Life Invade the Land?

- **After land plants evolved, animals invaded land (continued)**
  - Amphibians evolved from lobefin(叶状鳍) fishes
  - Lobefin fishes appeared about 400 million years ago

17.4 How Did Life Invade the Land?

- **After land plants evolved, animals invaded land (continued)**
  - **Lobefins(叶状鳍)** had two features that enabled their descendants to colonize land
    - They had an outpouching of the digestive tract that could be filled with air and serve as a primitive lung
    - They had leg-like, fleshy fins(鳍) with which they crawled about on the bottoms of shallow, quiet waters
  - Their ability to crawl and to store oxygen allowed lobefins to move across land to look for a new home when their pond dried up

A Fish That Walks on Land

Fig. 17-9

17.4 How Did Life Invade the Land?

- **After land plants evolved, animals invaded land (continued)**
  - The benefits of feeding on land and moving from pool to pool favored the evolution of a group of animals that could stay out of water for longer periods and move about
  - With improvements in lungs and legs, the lobefins gave rise to amphibians(两栖动物) about 350 million years ago

17.4 How Did Life Invade the Land?

- **After land plants evolved, animals invaded land (continued)**
  - Amphibians(两栖动物) were not fully adapted to life on land
    - Their lungs were only small sacs, so they had to breathe, in part, through moistened skin, which restricted their movements to areas near water
    - Their sperm and eggs had to be deposited in a watery environment
  - Amphibians flourished until the climate turned dry (286 million years ago)

17.4 How Did Life Invade the Land?

- **After land plants evolved, animals invaded land (continued)**
  - A group of amphibians adapting to a drier climate evolved into reptiles
  - **Reptiles (爬行动物)** exhibit three major adaptations to life on land
    - Shelled, waterproof eggs that enclose a supply of water for the developing embryo(胚胎)
    - Scaly, waterproof skin that help prevent the loss of body water to the dry air
    - Improved lungs

17.4 How Did Life Invade the Land?

- **After land plants evolved, animals invaded land (continued)**
  - As the climate dried during the Permian period(二迭纪), reptiles became the dominant land vertebrates

17.4 How Did Life Invade the Land?

- **After land plants evolved, animals invaded land (continued)**
  - A few tens of millions of years later, when the climate returned to more moist and stable conditions, the age of dinosaurs(恐龙时代) began
  - The variety of dinosaur forms was enormous—predators and plant eaters, land-dwellers, sea-dwellers, and flying forms
    - Dinosaurs flourished for more than 100 million years

17.4 How Did Life Invade the Land?

- **After land plants evolved, animals invaded land (continued)**
  - The last dinosaurs became extinct around 65 million years ago
  - It's uncertain why dinosaurs went extinct, but it's believed that the effects of a huge meteorite(陨石) strike contributed to their disappearance

A Reconstruction of a Cretaceous Forest

Fig. 17-10

17.4 How Did Life Invade the Land?

- **After land plants evolved, animals invaded land (continued)**
  - – Even during the age of dinosaurs, many small reptiles existed
  - – Because small animals have a larger surface area per unit of weight than larger animals do, heat loss is a problem for small animals
    - – Many species of small reptiles dealt with heat loss by retaining a slow metabolism or by being active only when the air temperature is sufficiently warm

17.4 How Did Life Invade the Land?

- **After land plants evolved, animals invaded land (continued)**
  - One group of reptiles solved the heat loss problem by evolving insulation in the form of feathers
    - Feathers arose through evolutionary modification of scales
  - Further lengthening and strengthening of the feathers enabled their owners to fly
    - This group became the birds

17.4 How Did Life Invade the Land?

- **After land plants evolved, animals invaded land (continued)**
  - Reptiles gave rise to mammals(哺乳动物)
  - **Mammals** were distinguished by the following characteristics:
    - Hair, which provided insulation
    - Mammary glands, which provided nourishing milk to their young
    - A uterus(子宫), which made live birth possible

17.4 How Did Life Invade the Land?

- **After land plants evolved, animals invaded land (continued)**
  - The earliest fossil mammal unearthed thus far is almost 200 million years old
  - Early mammals coexisted with the dinosaurs
  - The largest known mammal from the dinosaur era was about the size of a modern raccoon(浣熊), but most were far smaller than that
  - When the dinosaurs went extinct, however, mammals colonized the habitats(栖息地) left empty by the extinctions

17.5 What Role Has Extinction Played in the History of Life?

- **The overall trend has been for species to arise at a faster rate than they disappear, so the number of species on Earth has tended to increase over time**

17.5 What Role Has Extinction Played in the History of Life?

- **Evolutionary history has been marked by periods of mass extinction**
  - Mass extinction occurs when large numbers of species disappear within a relatively short time
  - The most catastrophic mass extinction(大量消亡) was the Permian(二叠纪) extinction (245 million years ago)
    - More than 50% of the world's families and 90% of the world's marine species disappeared

Mass Extinctions

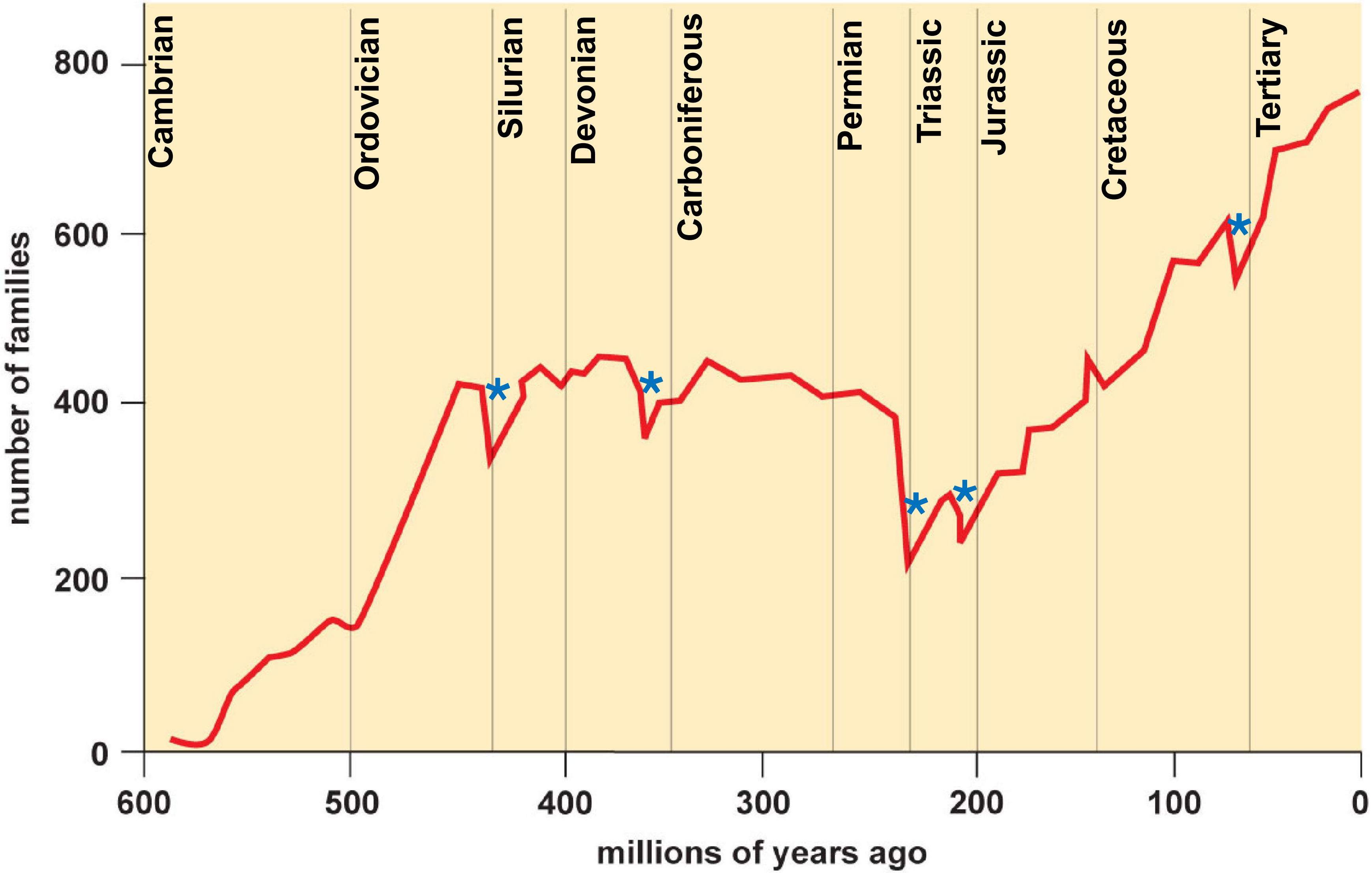


Fig. 17-11

17.5 What Role Has Extinction Played in the History of Life?

- **There appear to be two major causes of mass extinctions**
  – Changes in climate
  – Catastrophic events

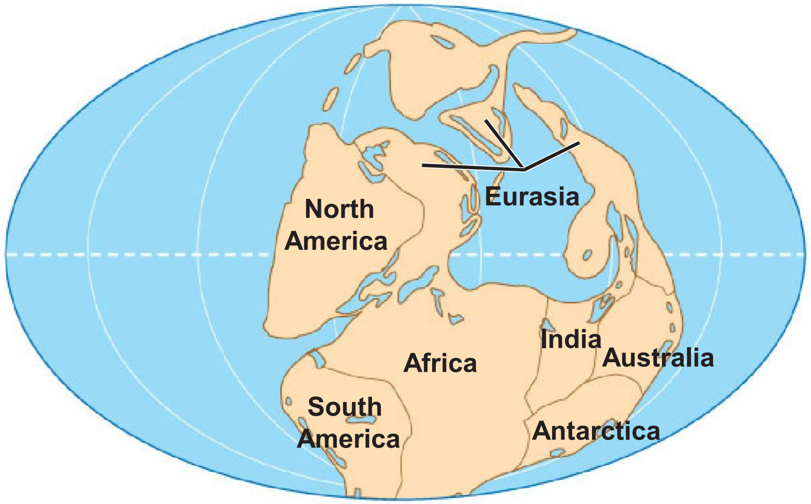
17.5 What Role Has Extinction Played in the History of Life?

- **Climate change contributed to mass extinctions**
  - Geological data indicate that most mass extinctions coincided with periods of climate change
    - When climate changes, organisms that are adapted for survival in one climate may be unable to survive in a drastically different climate

17.5 What Role Has Extinction Played in the History of Life?

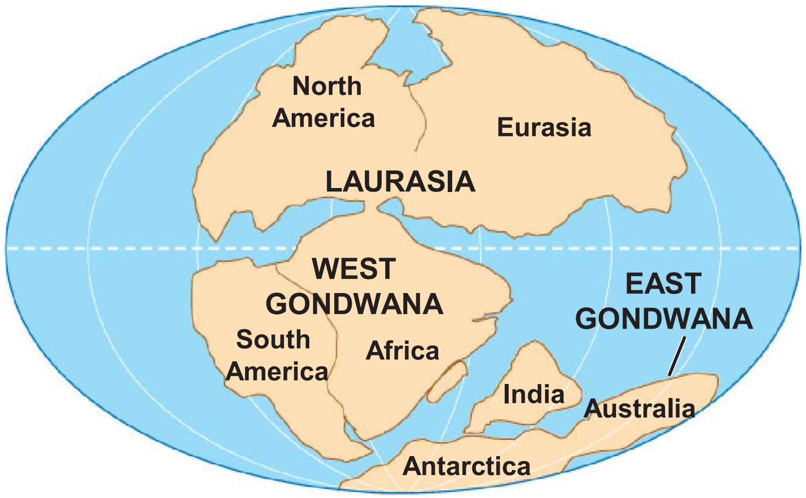
- **Climate change contributed to mass extinctions (continued)**
  - One cause of climate change is continental drift(大陆漂移)
    - Continental drift is the result of **plate tectonics(板块构造)**, the theory that the Earth's crust is divided into irregular plates that rest on a fluid layer and converge, diverge, and slip past one another
    - Over geological time, entire continents have drifted into radically different climates, causing massive extinctions of organisms that couldn't adapt

Continental Drift from Plate Tectonics



(a) 340 million years ago

(b) 225 million years ago



(c) 135 million years ago

(d) Present

Fig. 17-12

17.5 What Role Has Extinction Played in the History of Life?

- **Catastrophic events may have caused the worst mass extinctions**
  - Geologists have found evidence of massive volcanic eruptions
    - However, even if enormous, such eruptions would directly affect only a relatively small portion of Earth’s surface

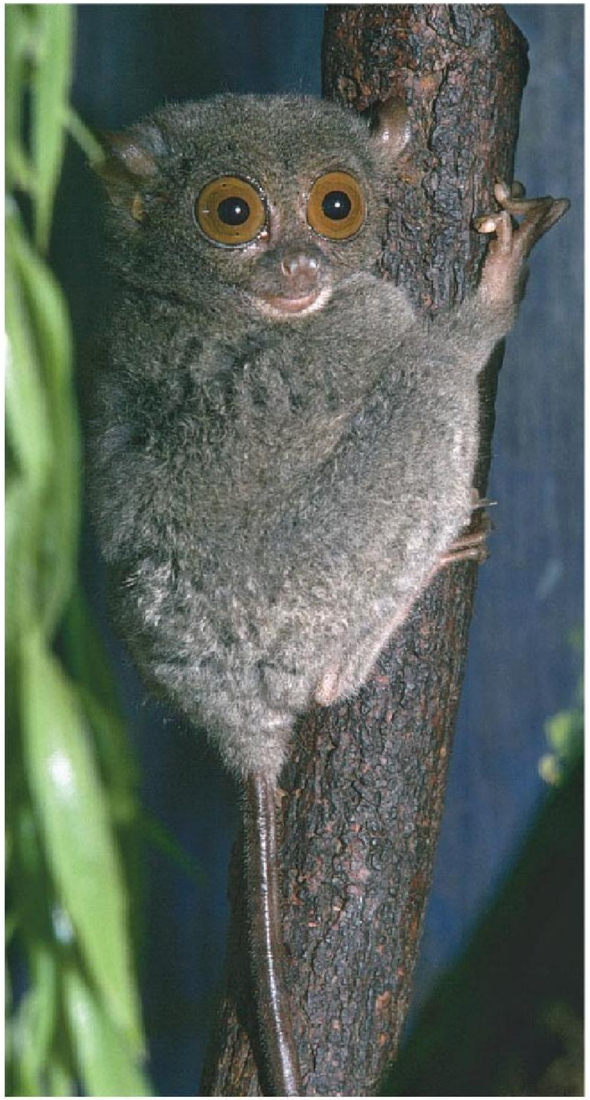
17.5 What Role Has Extinction Played in the History of Life?

- **Catastrophic events may have caused the worst mass extinctions (continued)**
  - Meteorite impacts have been proposed as a possible cause of mass extinction
    - In the early 1980s, Luis and Walter Alvarez proposed that a meteor strike was responsible for the extinction of the dinosaurs 65 million years ago
    - Researchers have identified the 100-mile-wide Chicxulub crater as the impact site of a giant meteorite—10 miles in diameter—at the time of the dinosaurs' disappearance

17.6 How Did Humans Evolve?

- **Humans inherited some early primate adaptations for life in trees**
  - **Primates** include tarsiers(跗猴), lemurs(狐猴), monkeys, apes(猿), and humans
  - The oldest primate fossils are 55 million years old
    - Because so few primate fossils have been found, far older primates may have existed
  - The earliest primates are believed to have fed on fruits and leaves, and to have been adapted for life in the trees
  - Many of the adaptations are shared by primates across geological time

Representative Primates



(a) Tarsier

(b) Lemur

(c) Macaque

Fig. 17-13

17.6 How Did Humans Evolve?

- **Humans inherited some early primate adaptations for life in trees (continued)**
  - Binocular vision (双目观察)provided early primates with accurate depth perception
    - Two large, forward-facing eyes with overlapping fields of view permitted early primates to gauge distances as they moved through the trees
  - Modern primates have excellent color vision, which helps them pick out food, and it's likely their early ancestors did too

17.6 How Did Humans Evolve?

- **Humans inherited some early primate adaptations for life in trees (continued)**
  - Early primates had long, grasping fingers that could wrap around and hold onto tree limbs
    - The grasping primate hand evolved in humans to provide both precision and power grips

17.6 How Did Humans Evolve?

- **Humans inherited some early primate adaptations for life in trees (continued)**
  - An enlarged brain facilitated hand-eye coordination and complex social interactions
    - A large brain would have been an adaptive advantage during complex locomotion through trees requiring precise hand-eye coordination
    - If the sociality seen in primates promoted increased survival and reproduction, the benefits to individuals of successful social interaction might have favored the evolution of a larger brain

17.6 How Did Humans Evolve?

- **The oldest hominin fossils are from Africa**
  – Hominins include humans and extinct humanlike primates
  – Comparisons of human DNA with that of apes suggest that the two diverged between 5 and 8 million years ago
  – *Sahelanthropus tchadensis* lived more than 6 million years ago
    – *Sahelanthropus* exhibits human-like and ape-like characteristics

The Earliest Hominin

Fig. 17-14

17.6 How Did Humans Evolve?

- The oldest hominin fossils are from Africa *(continued)*
  - *Ardipithecus ramidus* and *Orrorin tugenensis* lived between 4 million and 6 million years ago
  - Knowledge of these earliest hominins is limited because few specimens, and only partial skeletons, have been found
  - The first well-known hominin line, the genus *Australopithecus* (南方古猿), arose about 4 million years ago

17.6 How Did Humans Evolve?

- **The earliest hominins could stand and walk upright**
  - The earliest australopithecines(更新世灵长类动物) (collectively, the various species of *Australopithecus*(南方古猿)) possessed knee joints that permitted *bipedal*(两足动物) (upright, two-legged) locomotion
    - Four-million-year-old fossilized footprints confirm that early australopithecines sometimes walked upright

17.6 How Did Humans Evolve?

- **The earliest hominins could stand and walk upright (continued)**
  - An upright stance was significant in the evolution of hominins because it freed their hands from use in walking
    - Later hominins were thus able to carry weapons, manipulate tools, and perform the other mechanical actions of modern *Homo sapiens*

17.6 How Did Humans Evolve?

- **The australopithecines**
  - Several species of *Australopithecus* have been identified from fossils
  - *Australopithecus anamensis* was unearthed near an ancient lake bed in Kenya from sediments that were dated as between 3.9 million and 4.1 million years old

17.6 How Did Humans Evolve?

- **The australopithecines (continued)**
  - *Australopithecus afarensis*—from the Afar region of Ethiopia—is believed to have given rise to two distinct forms
    - *A. africanus* was small, about the same size as *afarensis*, and was, like *afarensis*, an omnivore
    - *A. robustus* and *A. boisei* were larger than their forebearers and were herbivorous
  - All australopithecines were extinct by 1.2 million years ago

17.6 How Did Humans Evolve?

- **The genus Homo**
  - The genus *Homo* diverged from the australopithecine line 2.5 million years ago
  - *Homo habilis* appeared 2.5 million years ago
    - The bodies and brains of *H. habilis* were larger than those of the australopithecines
    - However, *H. habilis* retained ape-like long arms and short legs
  - *Homo ergaster* appeared 2 million years ago
    - This species had limb proportions more like those of modern humans

17.6 How Did Humans Evolve?

- **The genus Homo (continued)**
  - *Homo ergaster* is believed by many to be the common ancestor of two distinct groups
    - *H. erectus* (直立人) was the first hominin species to leave Africa, approximately 1.8 million years ago
    - *H. heidelbergensis*, in turn, split into two branches
      - Some migrated to Europe and gave rise to *H. neanderthalensis*
      - Those remaining in Africa gave rise to *H. sapiens* (modern man)

A Possible Evolutionary Tree for Humans

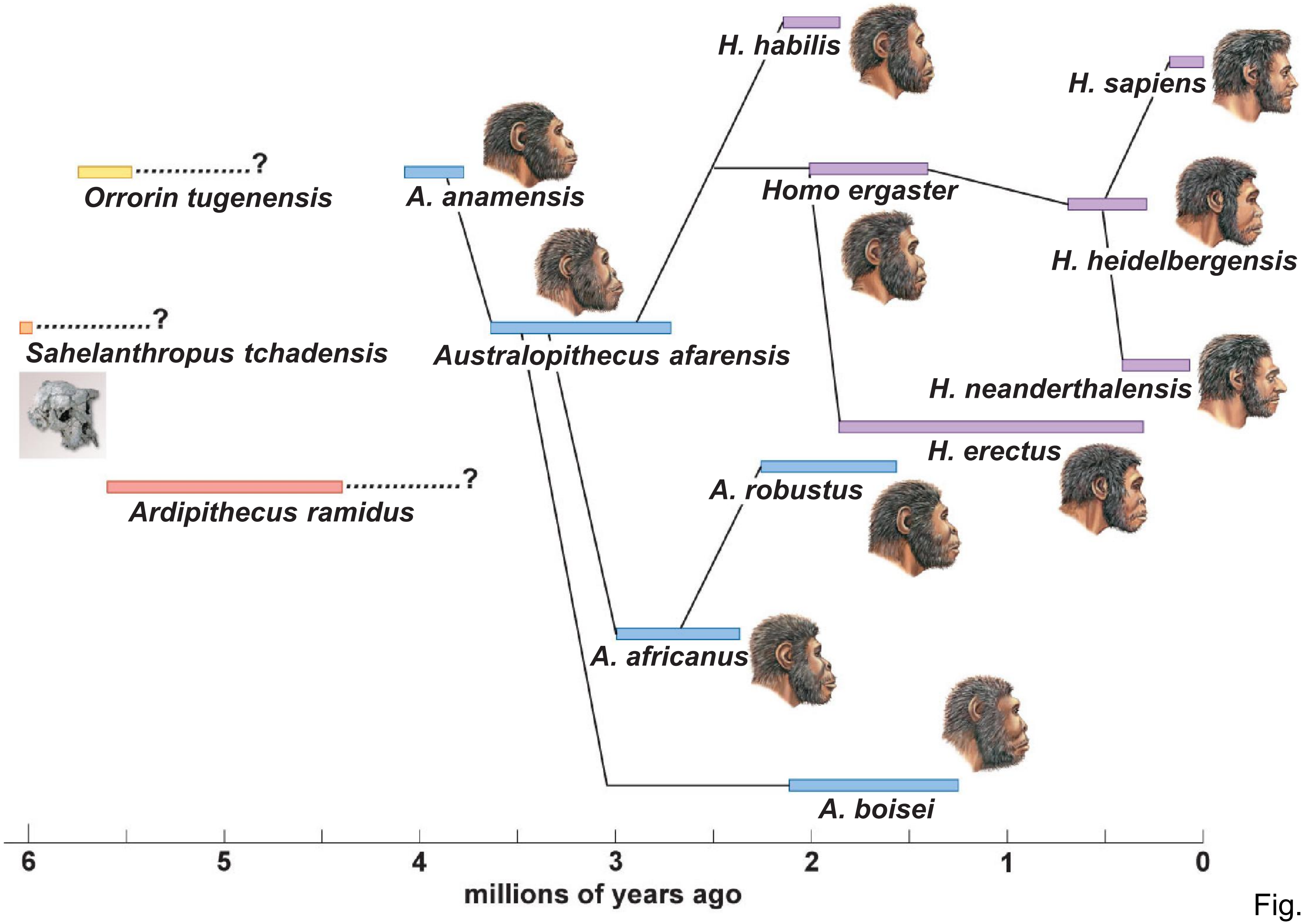


Fig. 17-15

17.6 How Did Humans Evolve?

- **Hominin evolution is closely tied to the development of tools**
  - *Homo habilis* produced fairly crude chopping tools that were unchipped on one end to hold in the hand
  - *Homo ergaster* produced finer tools that were typically sharp all the way around the stone
    - Some of these may have been tied to spears
  - *Homo neanderthalensis* produced exceptionally fine tools with extremely sharp edges made by flaking off tiny bits of stone

Representative Hominin Tools

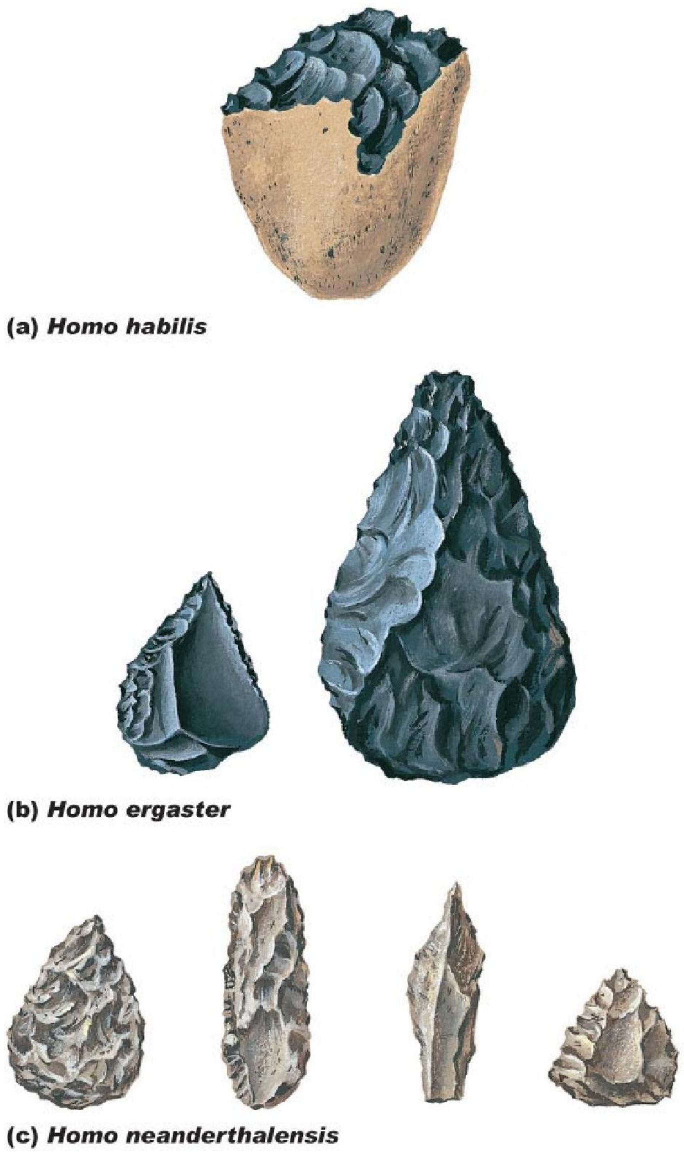


Fig. 17-16

17.6 How Did Humans Evolve?

- **Neanderthals(穴居人) had large brains and excellent tools**
  - Neanderthals lived in Europe and Asia from 150,000 to 30,000 years ago
  - They were heavily muscled, had brains slightly larger than those of modern humans, walked fully erect, and constructed finely crafted stone tools

17.6 How Did Humans Evolve?

- **Neanderthals had large brains and excellent tools (continued)**
  - Neanderthals were once believed to be a variety of *H. sapiens*; however, molecular evidence indicates that they are a separate species
    - Neanderthals diverged from the branch leading to *Homo sapiens* 500,000 years ago, long before *H. sapiens* emerged

17.6 How Did Humans Evolve?

- **Neanderthals had large brains and excellent tools (continued)**
  - There is no evidence that Neanderthals ever developed an advanced culture that included such characteristically human endeavors as art, music, and rituals

17.6 How Did Humans Evolve?

- **Homo sapiens appeared in Africa about 160,000 years ago**
- European and Middle Eastern *H. sapiens* appeared about 90,000 years ago and were known as Cro-Magnons克鲁马努人(旧石器时代晚期在欧洲的高加索人种)

17.6 How Did Humans Evolve?

- **Cro-Magnons**
  - Cro-Magnons had domed heads, smooth brows, and prominent chins
  - Cro-Magnons also made precision instruments
    - Bone flutes
    - Ivory sculptures
    - Evidence of elaborate burial ceremonies

Paleolithic Burial

Fig. 17-17

17.6 How Did Humans Evolve?

- **Cro-Magnons (continued)**
  - Unlike their predecessors, Cro-Magnons created remarkable cave paintings that made use of sophisticated artistic techniques
  - Cro-Magnons coexisted with Neanderthals(尼安德特人) in Europe and the Middle East for as many as 50,000 years
  - It is not known why the Neanderthals became extinct

The Sophistication of Cro-Magnon People

Fig. 17-18

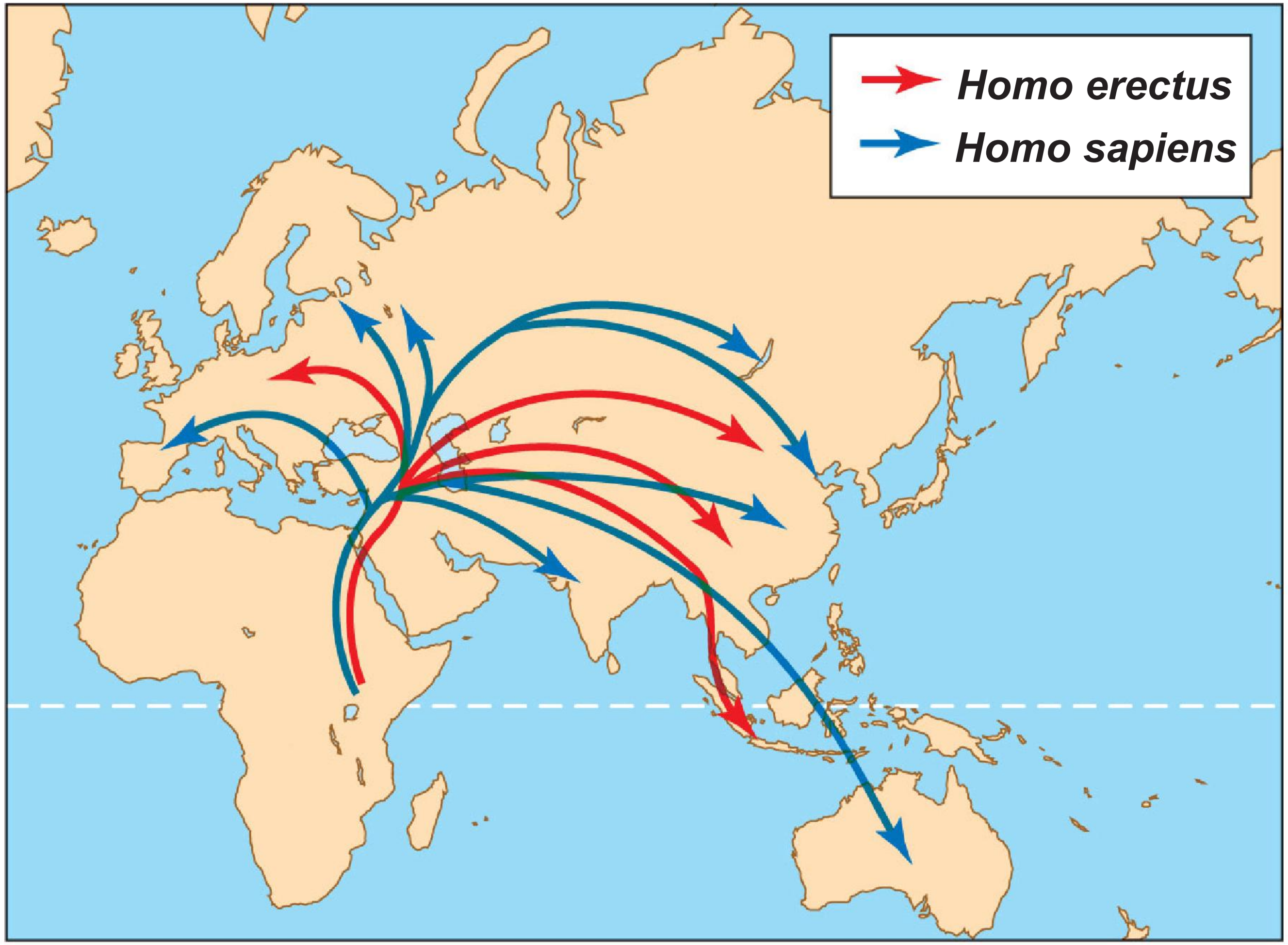
17.6 How Did Humans Evolve?

- **Two hypotheses have been proposed for the evolution of Homo sapiens**
  - The “African replacement” hypothesis
  - The “multiregional origin” hypothesis

17.6 How Did Humans Evolve?

- **The "African replacement" hypothesis**
  - Members of the genus *Homo* made repeated long-distance migrations out of Africa beginning 1.8 million years ago
  - *H. sapiens* emerged from Africa about 150,000 years ago and spread across the Near East, Europe, and Asia
  - The dispersing *H. sapiens* populations replaced all other hominins

Competing Hypotheses for the Evolution of *Homo sapiens*



(a) African replacement hypothesis

Fig. 17-19a

17.6 How Did Humans Evolve?

- **The "multiregional origin" hypothesis**
  - *H. erectus* emerged from Africa 1.8 million years ago and spread across the Near East, Europe, and Asia
  - Continued migrations and interbreeding occurred among widespread *H. erectus* populations
  - Regional populations of *H. erectus* evolved into *H. sapiens*

Competing Hypotheses for the Evolution of *Homo sapiens*

(b) Multiregional hypothesis

Fig. 17-19b

17.6 How Did Humans Evolve?

- **The evolutionary origin of large brains may be related to meat consumption**
  - Highly developed brains may have evolved in response to increasingly complex social interactions, such as the cooperative hunting of large game
  - If the distribution of this group-hunted meat was best accomplished by individuals with large brains, then natural selection may have favored such individuals

17.6 How Did Humans Evolve?

- **The archeological evidence about human behavior is hard to come by**
  - The distinctively human characteristics made possible by a large brain include the following
    - Language
    - Abstract thought
    - Advanced culture
  - Early humans capable of language and symbolic thought would not necessarily have created artifacts that indicated these capabilities

17.6 How Did Humans Evolve?

- **Human evolution has come to be dominated by cultural evolution**
  - Cultural evolution is the evolution of information and behaviors that are transmitted from generation to generation by learning

17.6 How Did Humans Evolve?

- **The evolutionary success of humans is the result of cultural evolution and a series of technological revolutions**
  - The development of tools increased the efficiency with which food and shelter could be acquired

17.6 How Did Humans Evolve?

- **The evolutionary success of humans is the result of cultural evolution and a series of technological revolutions (continued)**
  - During the agricultural revolution about 10,000 years ago, people discovered how to grow crops and domesticate animals
    - Because the amount of food increased dramatically, the human population rose as well from around 5 million at the beginning of the revolution to about 750 million in 1750

17.6 How Did Humans Evolve?

- **The evolutionary success of humans is the result of cultural evolution and a series of technological revolutions (continued)**
  - The industrial revolution gave rise to the modern economy and its attendant improvements in public health
    - Longer lives and lower infant mortality led to truly explosive population growth

17.6 How Did Humans Evolve?

- **Human cultural evolution and the accompanying increases in human population have made humans an important agent of natural selection with respect to other life forms**

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