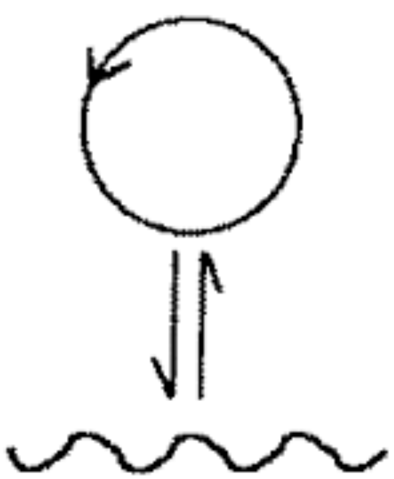
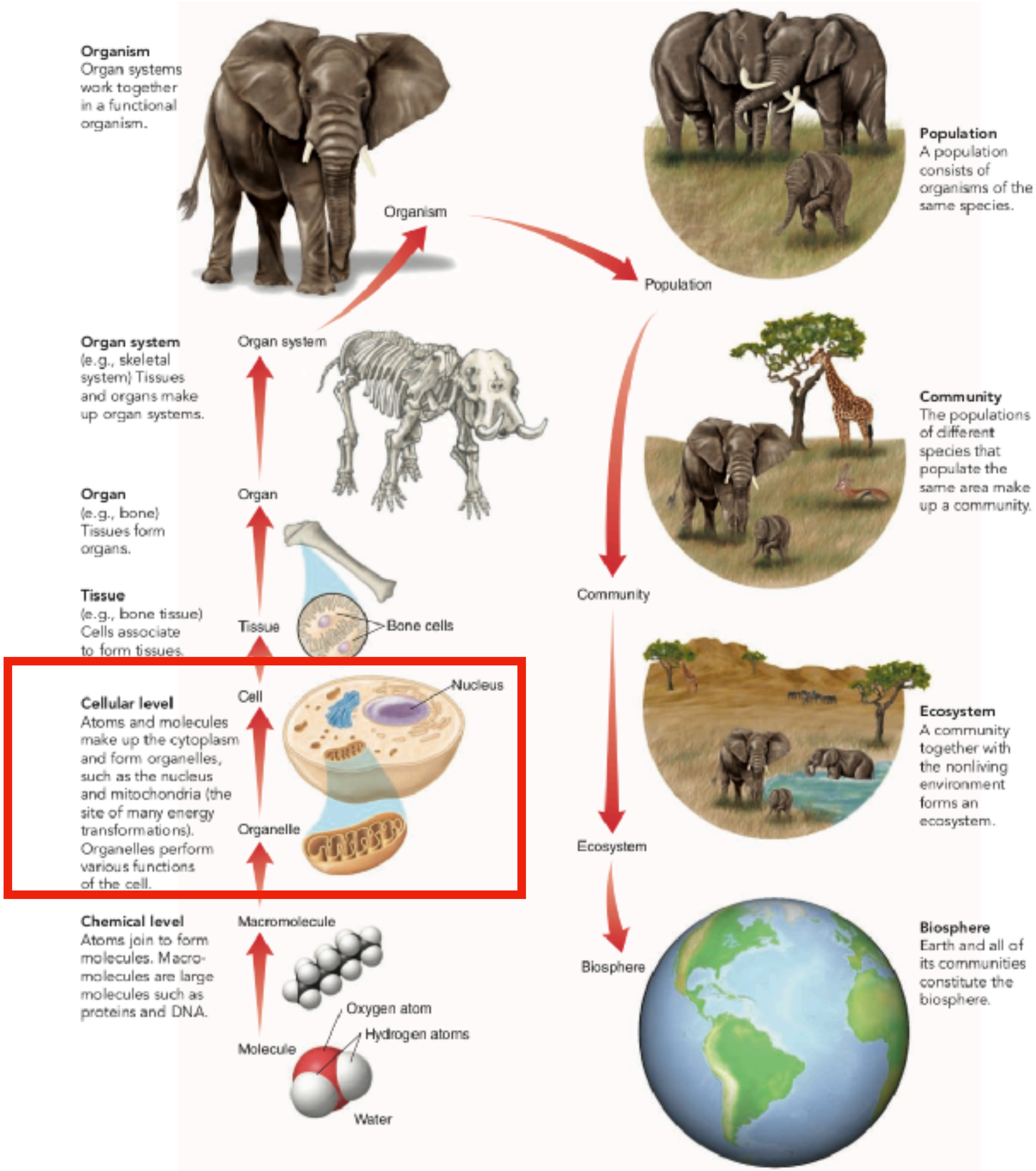
I. Origen de la Vida y Diversidad de Organismos

Día	Fecha	Módulo	Clase/Actividad
Martes	6-8-2019	4	Introducción al curso: Atributos de los seres vivos
		5	Niveles de Organización Biológica
Jueves	8-8-2019	4	Origen de la Vida en la Tierra
		5	Fundamentos de Taxonomía & Sistemática
Martes	13-8-2019	4	Diversidad I: Bacteria & Arquea
		5	Diversidad II: Reino Protista
			Feriado
Martes	20-8-2019	4	Diversidad III: Reino Plantae, Evolución
		5	Diversidad III: Reino Plantae, Diversidad
Jueves	22-8-2019	4	Diversidad IV: Reino Fungi
		5	Diversidad V: Animalia I
Martes	27-8-2019	4	Diversidad V: Animalia II
		5	Diversidad V: Animalia III

Niveles de organización biologica



células

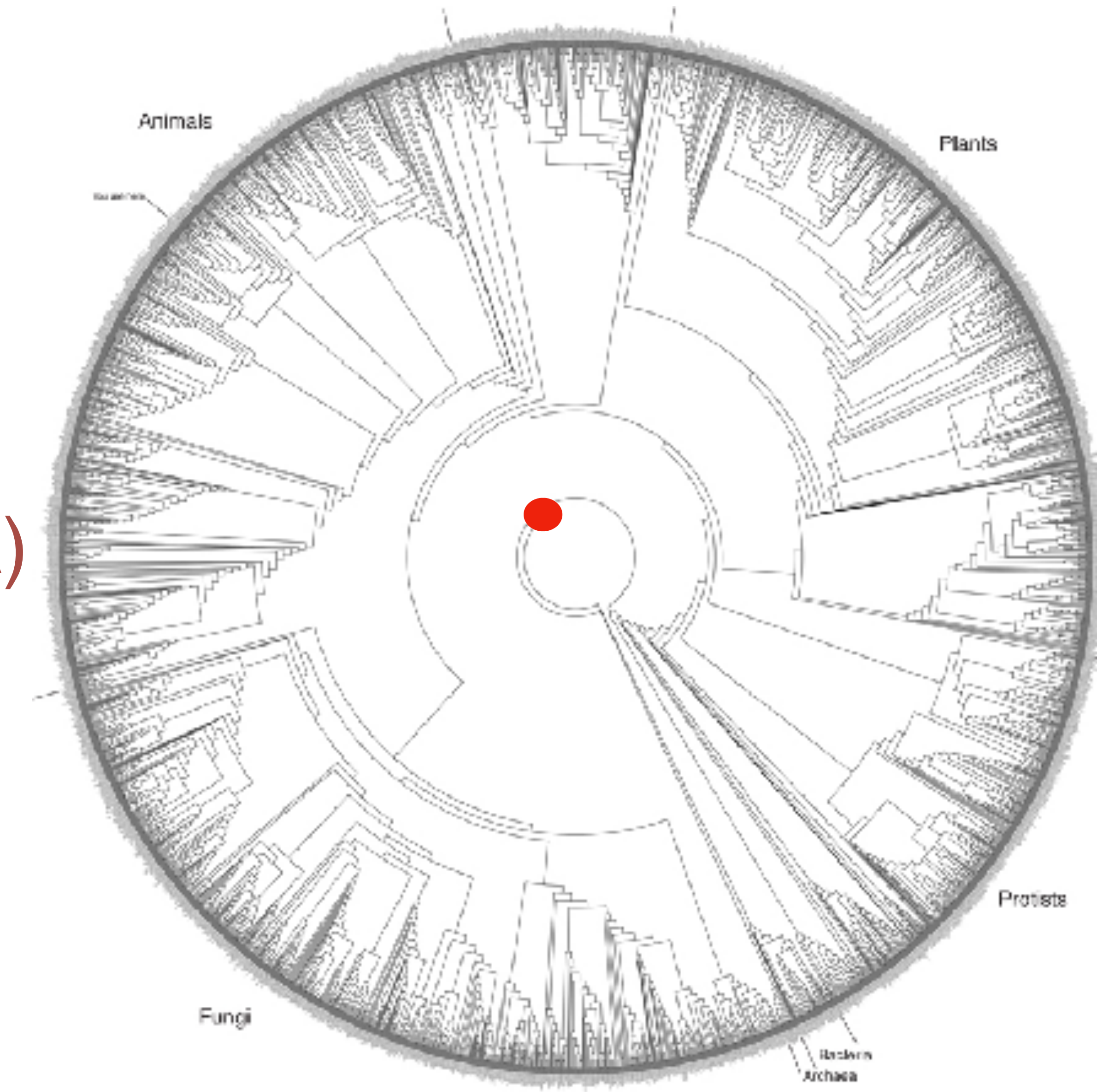


21.1 CHEMICAL EVOLUTION ON EARLY EARTH

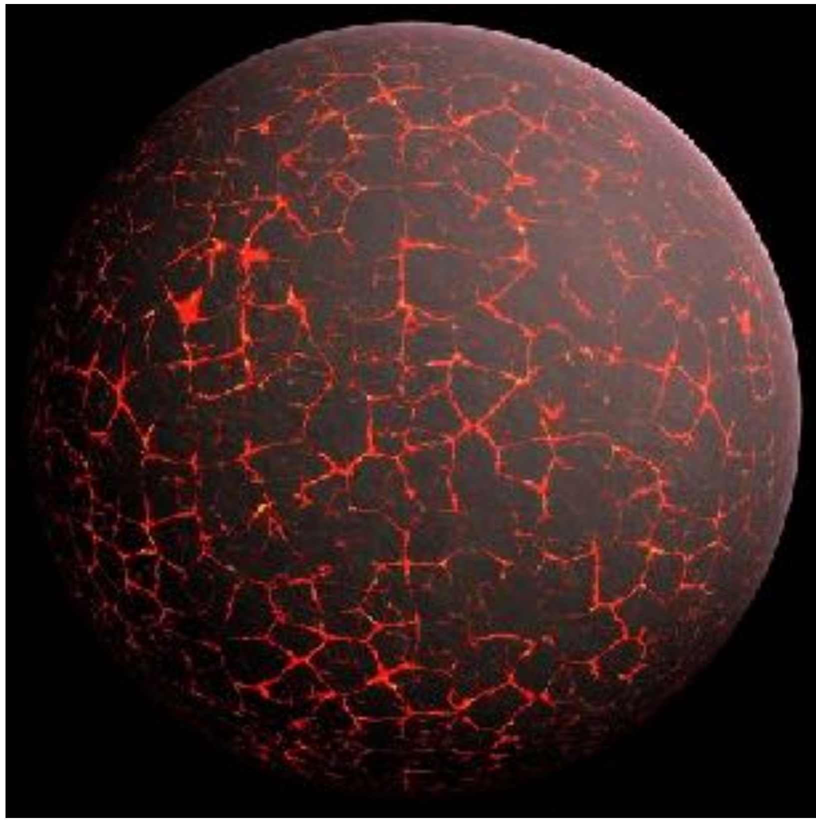
LEARNING OBJECTIVES

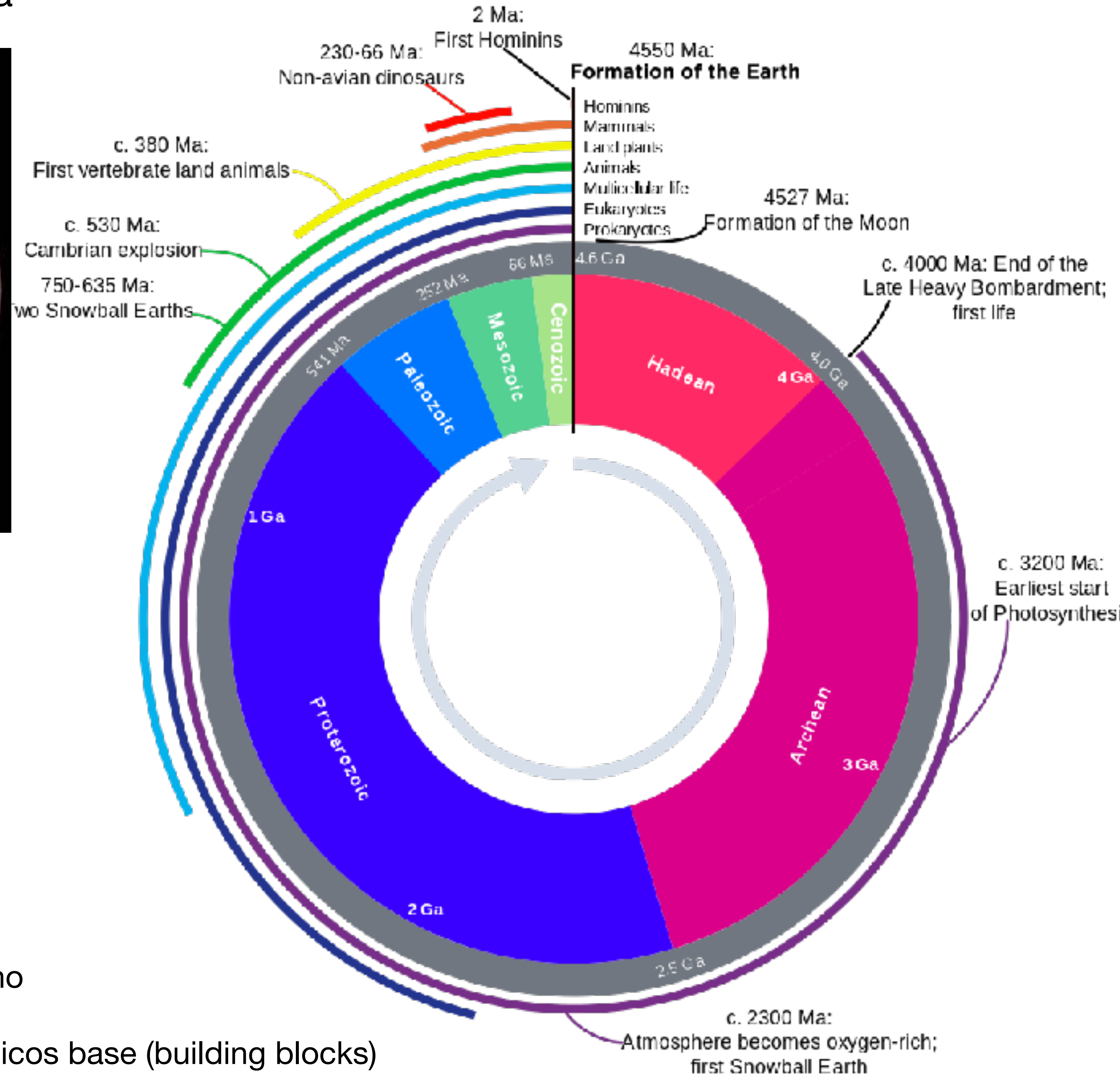
1 Describe the conditions that scientists think existed on early Earth.
2 Contrast the prebiotic soup hypothesis and the iron–sulfur world hypothesis.

Last Universal Common Ancestor (LUCA)



Origen de la vida en la Tierra





4 Condiciones:

1.- poco o nada de oxigeno
2.- fuente de energia
3.- disponibilidad de químicos base (building blocks)
4.- tiempo

Origen de la vida: metabolismo o células primero?

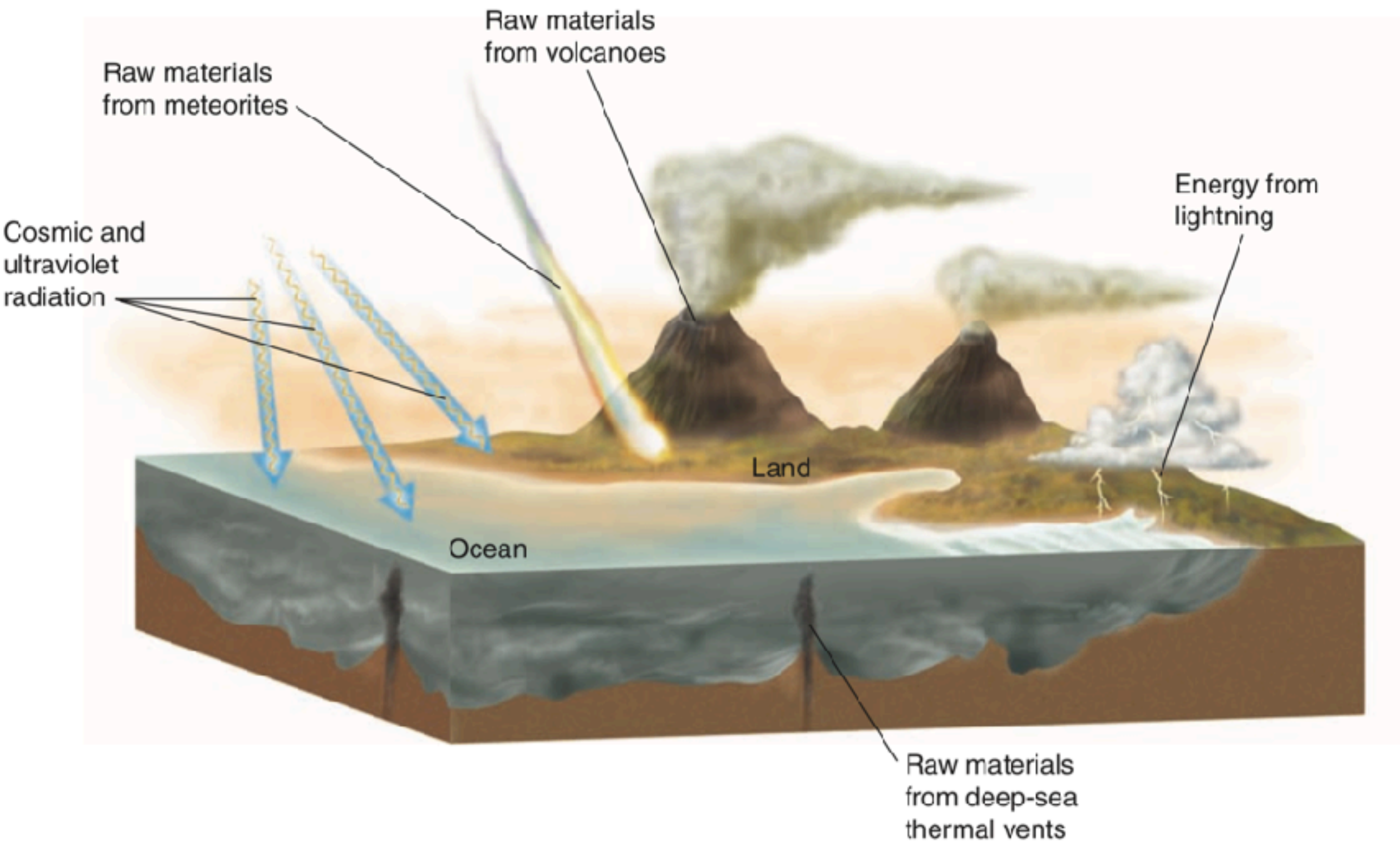


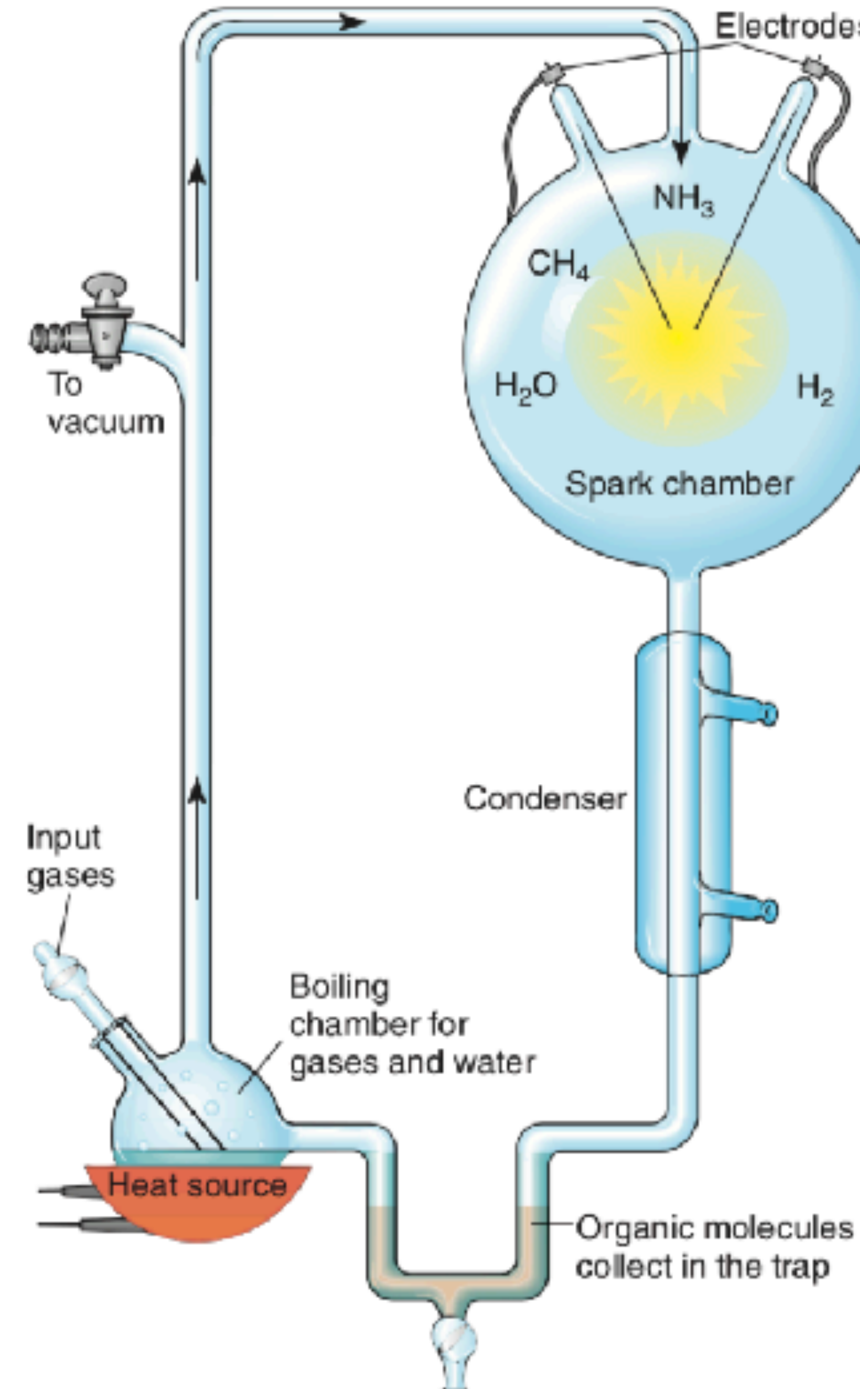
FIGURE 21-1 Conditions on early Earth

Organic molecules may have been produced at Earth's surface

Oparin, Haldane; 1920

Idea: "sea of organic soup."

experiment: Miller & Urey, 1959



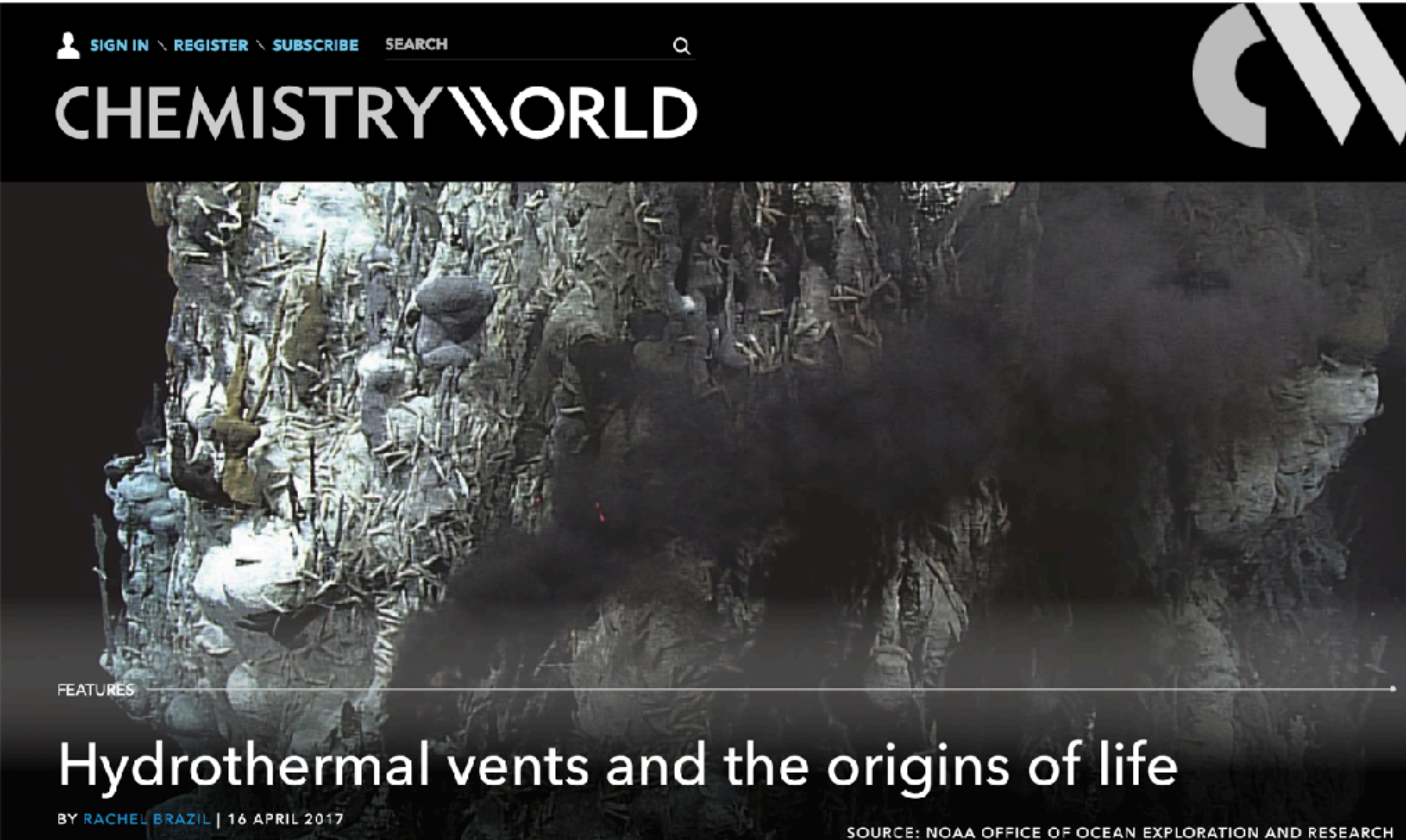
RESULTS AND CONCLUSION: The gases present in the flask reacted together, and in one week a variety of simple organic compounds, such as amino acids, accumulated in the trap at the bottom. Thus, the formation of organic molecules—the first step in the origin of life—can be produced from simple precursors.

Source: Miller, S. L., and H. C. Urey. "Organic Compound Synthesis on the Primitive Earth." *Science*, Vol. 130, July 1959.

FIGURE 21-2 *Animated* Miller and Urey's experiment in chemical evolution

Organic molecules may have formed at hydrothermal vents

From polymers to complex structures?



https://www.chemistryworld.com/features/hydrothermal-vents-and-the-origins-of-life/3007088.article

21.2 THE FIRST CELLS

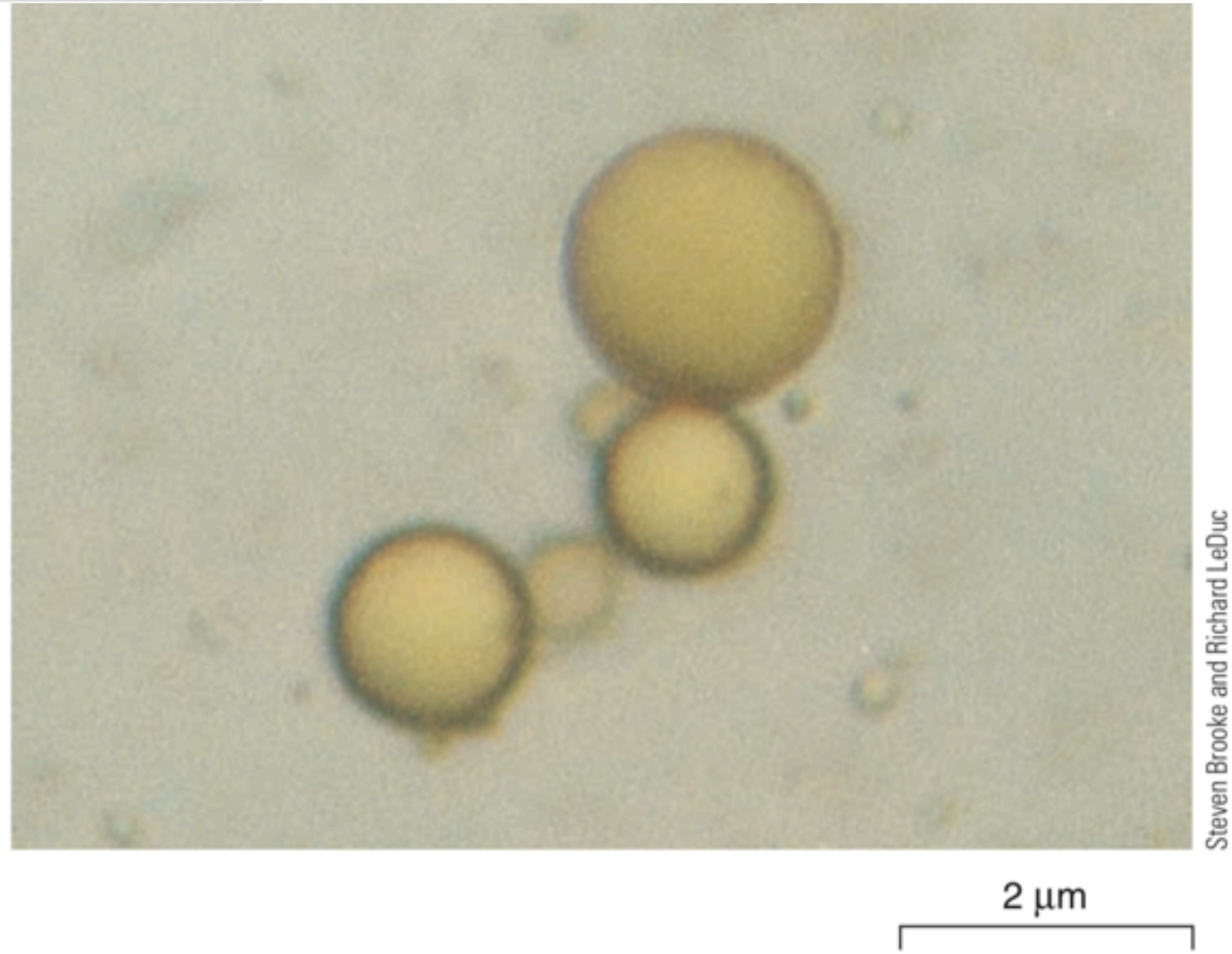


FIGURE 21-3 Microspheres

These tiny protobionts exhibit some of the properties of life.

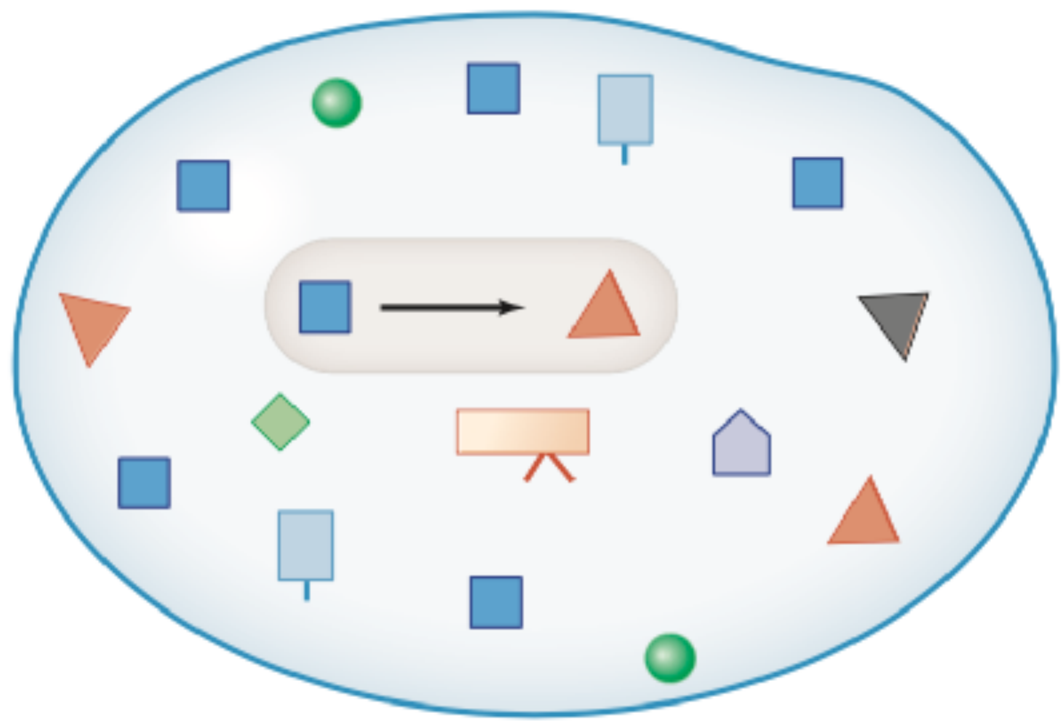
LEARNING OBJECTIVES

3 Outline the major steps hypothesized to have occurred in the origin of cells.

4 Explain how the evolution of photosynthetic autotrophs affected both the atmosphere and other organisms.

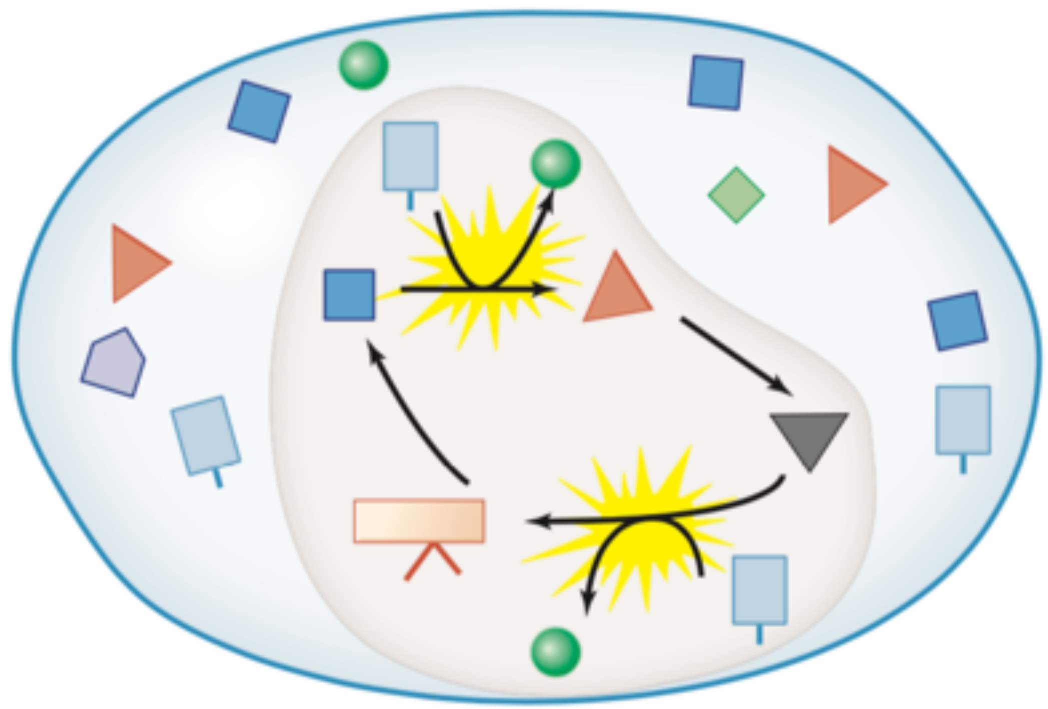
5 Describe the hypothesis of serial endosymbiosis.

The origin of a simple metabolism within a membrane boundary may have occurred early in the evolution of cells



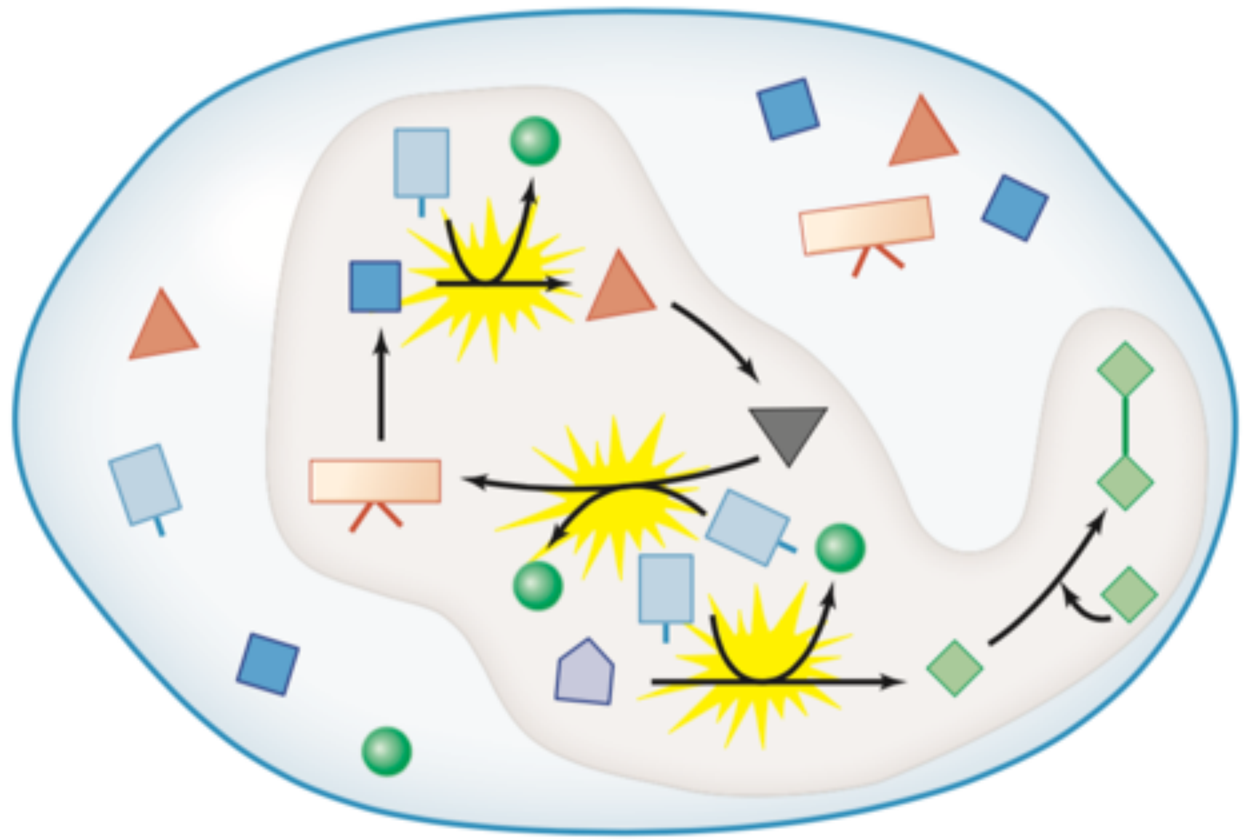
(a) Within a membranous boundary, chemical reactions occur among simple molecules.

The origin of a simple metabolism within a membrane boundary may have occurred early in the evolution of cells



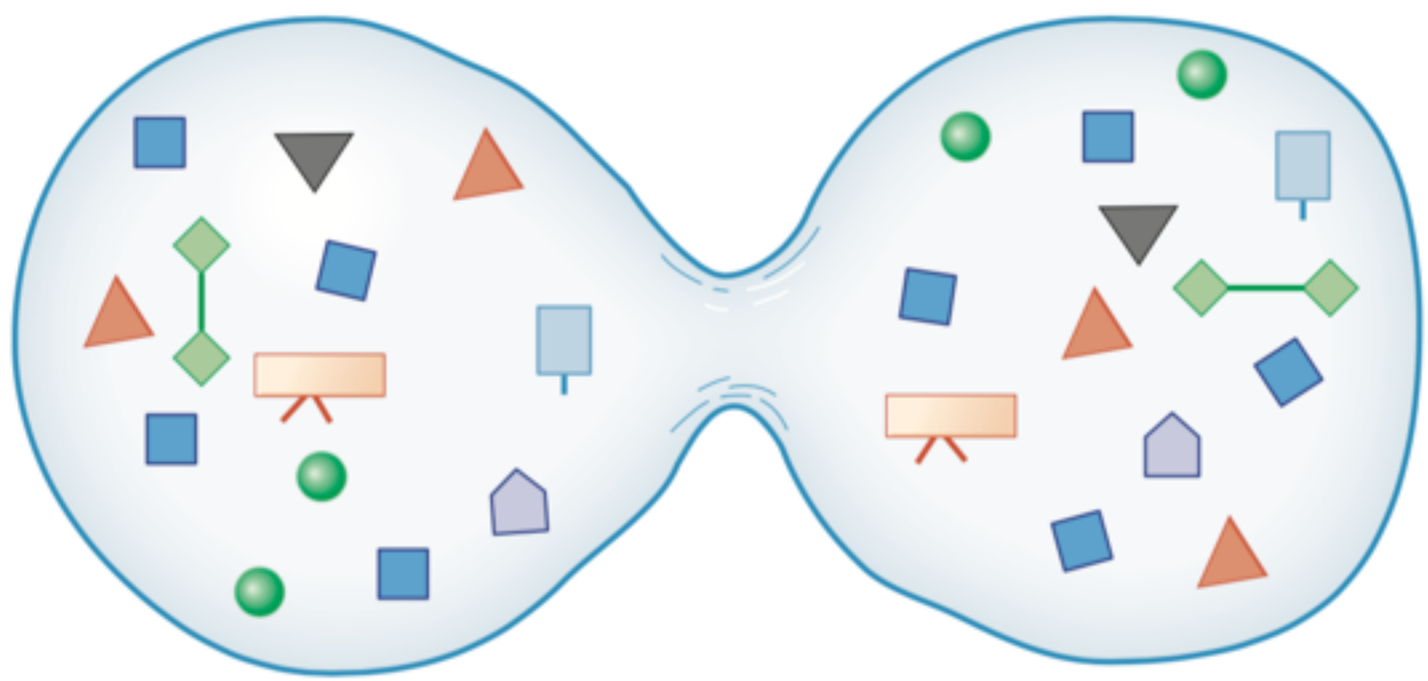
(b) A source of energy is coupled to the chemical reaction sequence.

The origin of a simple metabolism within a membrane boundary may have occurred early in the evolution of cells



(c) As the pre-cell system continues to evolve, its size and organization increase.

The origin of a simple metabolism within a membrane boundary may have occurred early in the evolution of cells



(d) The pre-cell system develops the ability to reproduce.

Molecular reproduction was a crucial step in the origin of cells

RNA world (information first)

RNA

DNA ⟵ RNA ⟶ protein

DNA → RNA → protein

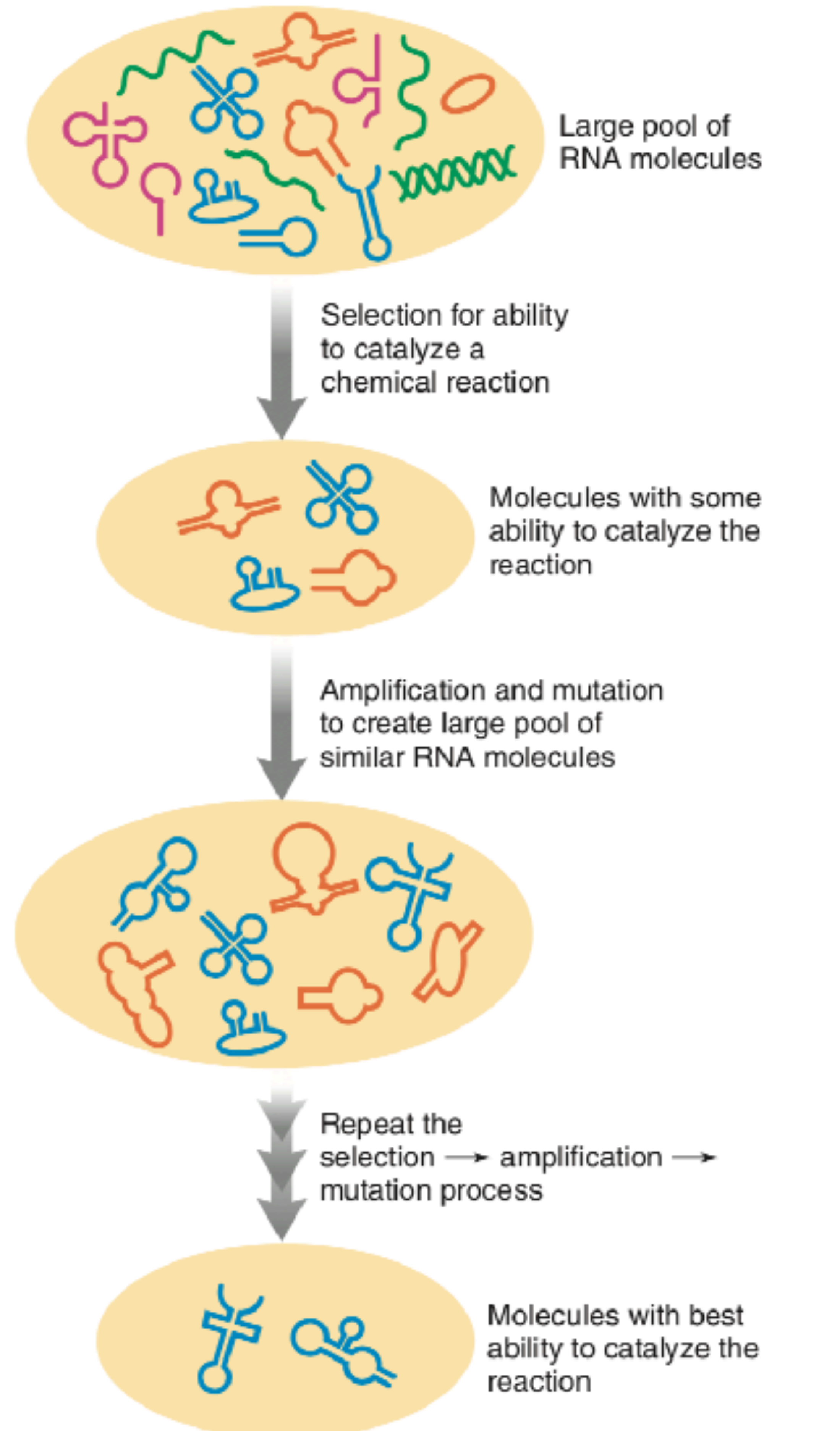
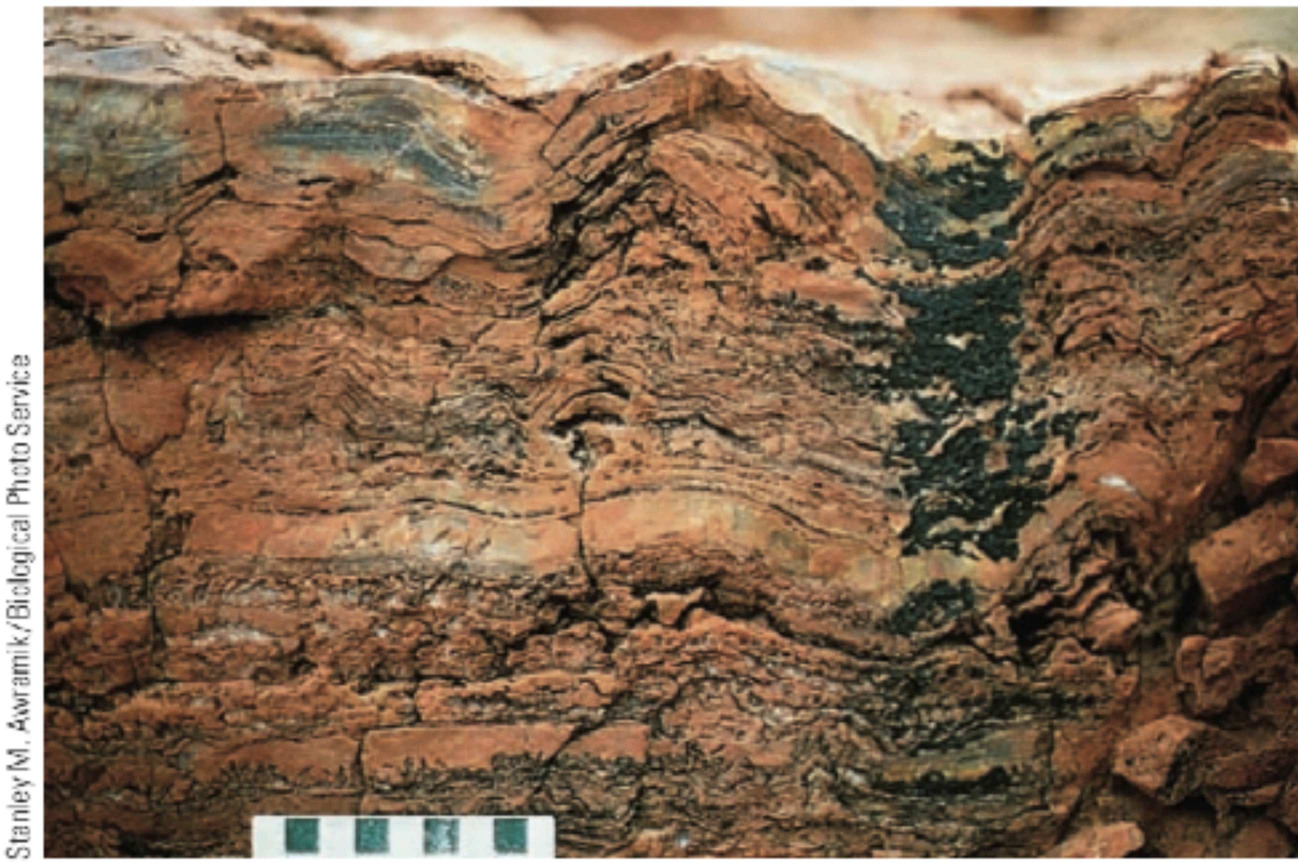


FIGURE 21-5 In vitro evolution of RNA molecules

Biological evolution began with the first cells

Fred Bavendam / Peter Arnold, Inc.

(a) These living stromatolites at Hamlin Pool in Western Australia consist of mats of cyanobacteria (unicellular photosynthetic prokaryotes) and minerals such as calcium carbonate. They are several thousand years old.



Stanley M. Awramik / Biological Photo Service

(b) Cutaway view of a fossil stromatolite showing the layers of microorganisms and sediments that accumulated over time. This stromatolite, also from Western Australia, is about 3.5 billion years old.

FIGURE 21-6 Stromatolites

The first cells were probably heterotrophic

Primitive **heterotrophs** consumed organic molecules that had formed spontaneously

—ie, sugars, nucleotides, and amino acids.

By fermenting these organic compounds, they obtained the energy

Fermentation is an anaerobic process, first cells were almost certainly **anaerobes.**

First photosynthetic organisms may have appeared as early as 3.5 bya

Photosynthesis requires

light energy

source of electrons, used to reduce CO_2 to form organic molecules such as glucose.

Most likely, the first photosynthetic **autotrophs**—

used the energy of sunlight to split hydrogen-rich molecules such as H_2S,

releasing elemental sulfur (not oxygen) in the process.

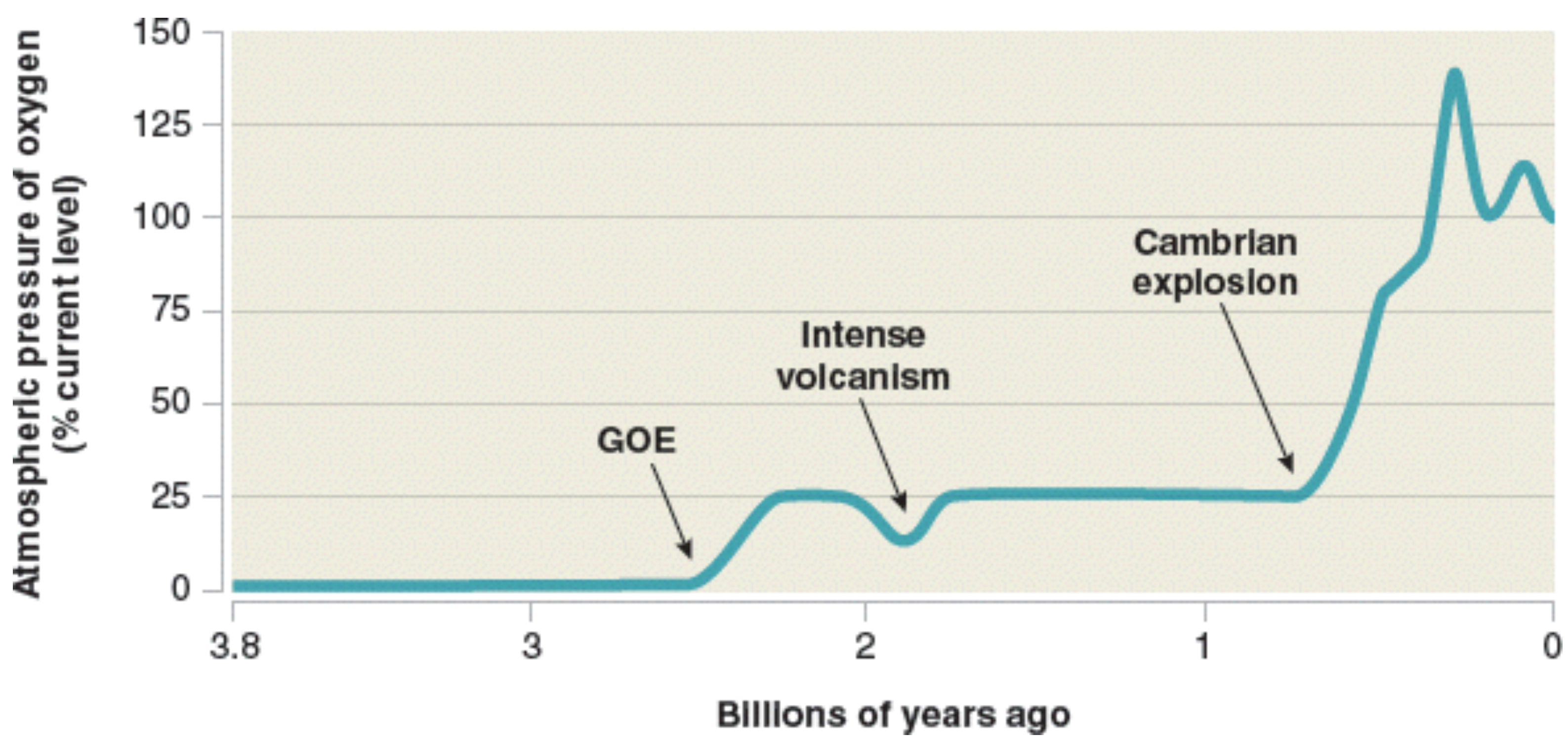
The **first** autotrophs to obtain hydrogen electrons by **splitting *water*** were the **cyanobacteria.**

Water was abundant on early Earth and the selective advantage of splitting water allowed cyanobacteria to thrive

The process of splitting water released oxygen as a gas (O_2)

Initially, oxygen released during photosynthesis **oxidized minerals in the ocean** and in Earth's crust,

oxygen did not begin to accumulate in for a long time



Eventually, however, oxygen levels increased in the ocean and the atmosphere

Aerobes appeared after oxygen increased in the atmosphere

Based on sulfur isotope data from ancient rocks in South Africa

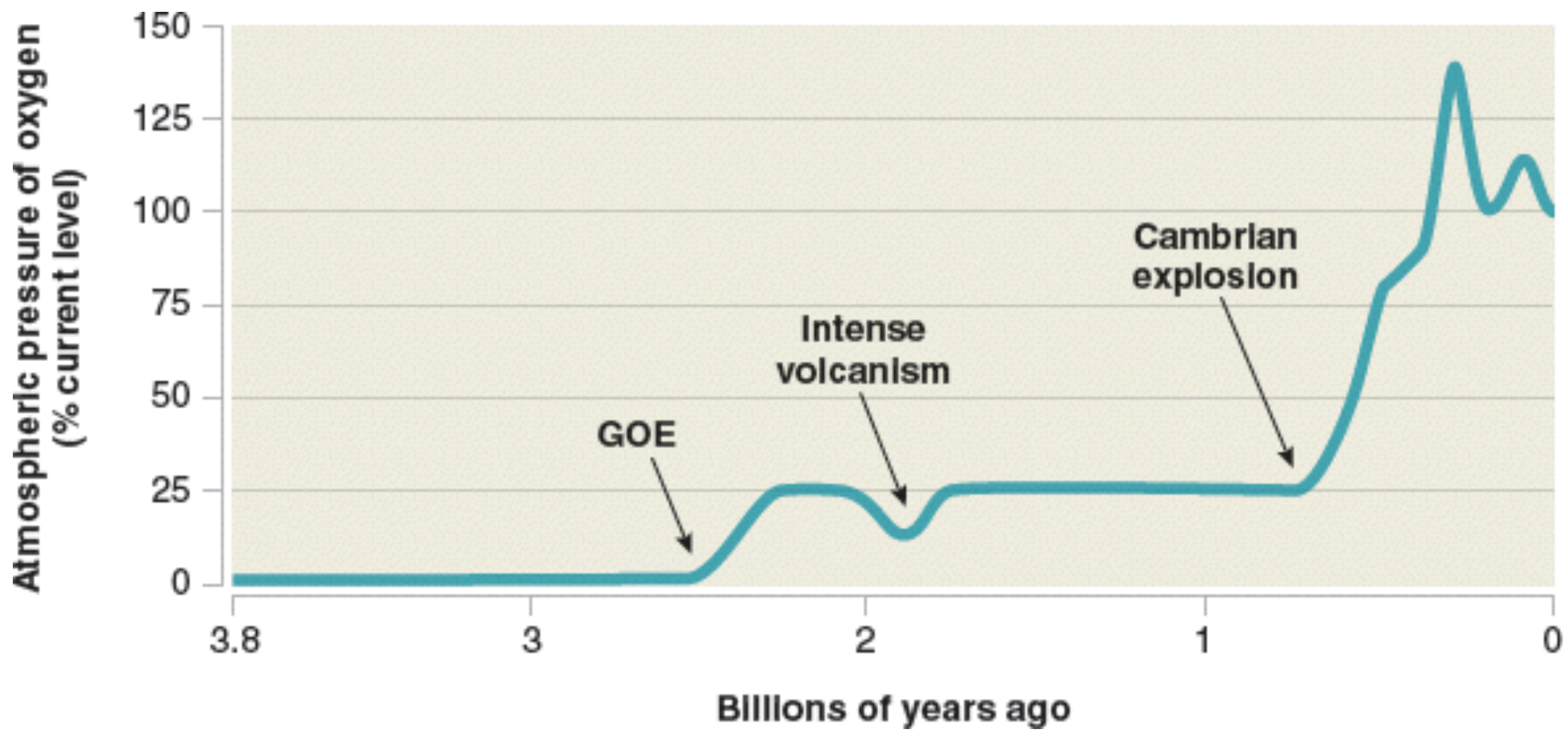
cyanobacteria had produced enough oxygen to

begin significantly changing the composition of the atmosphere by 2.4 bya.

The increase in atmospheric oxygen affected life profoundly

oxygen poisoned *obligate anaerobes*

Some anaerobes, however, survived in environments where oxygen did not penetrate



adaptations evolved in others that **neutralized the oxygen** so it could not harm them

Carbon thus started cycling in the biosphere,

from the nonliving physical environment **to** photosynthetic organisms,

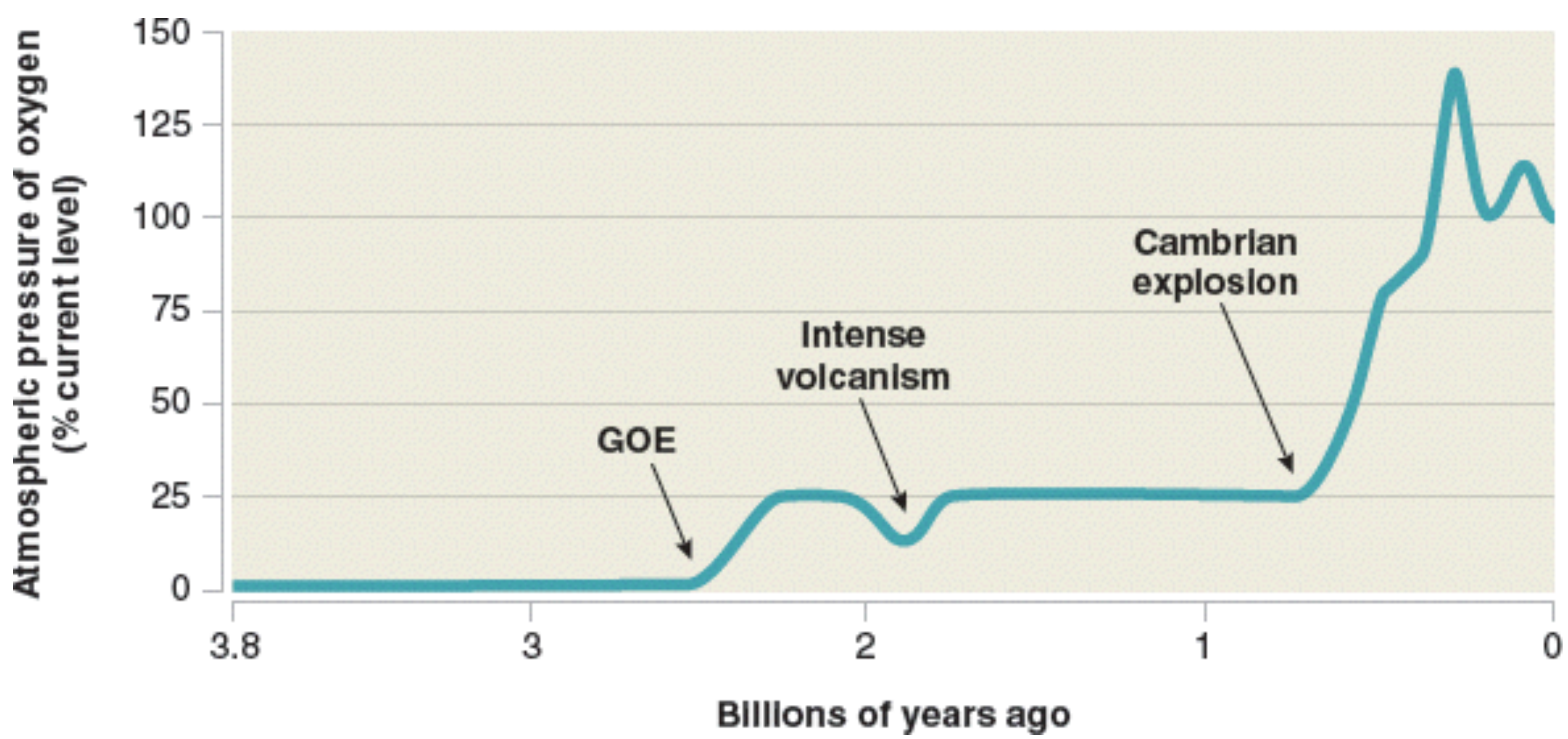
to heterotrophs that **ate** the photosynthetic organisms

Aerobic respiration released carbon **back into** the physical environment, and the carbon cycle continued.

In a similar manner, **molecular oxygen** was **produced** by photosynthesis and **used** during aerobic respiration.

aerobes, a respiratory pathway evolved that *used* **oxygen to extract more energy** from food

Aerobic respiration was joined with the existing anaerobic process of glycolysis



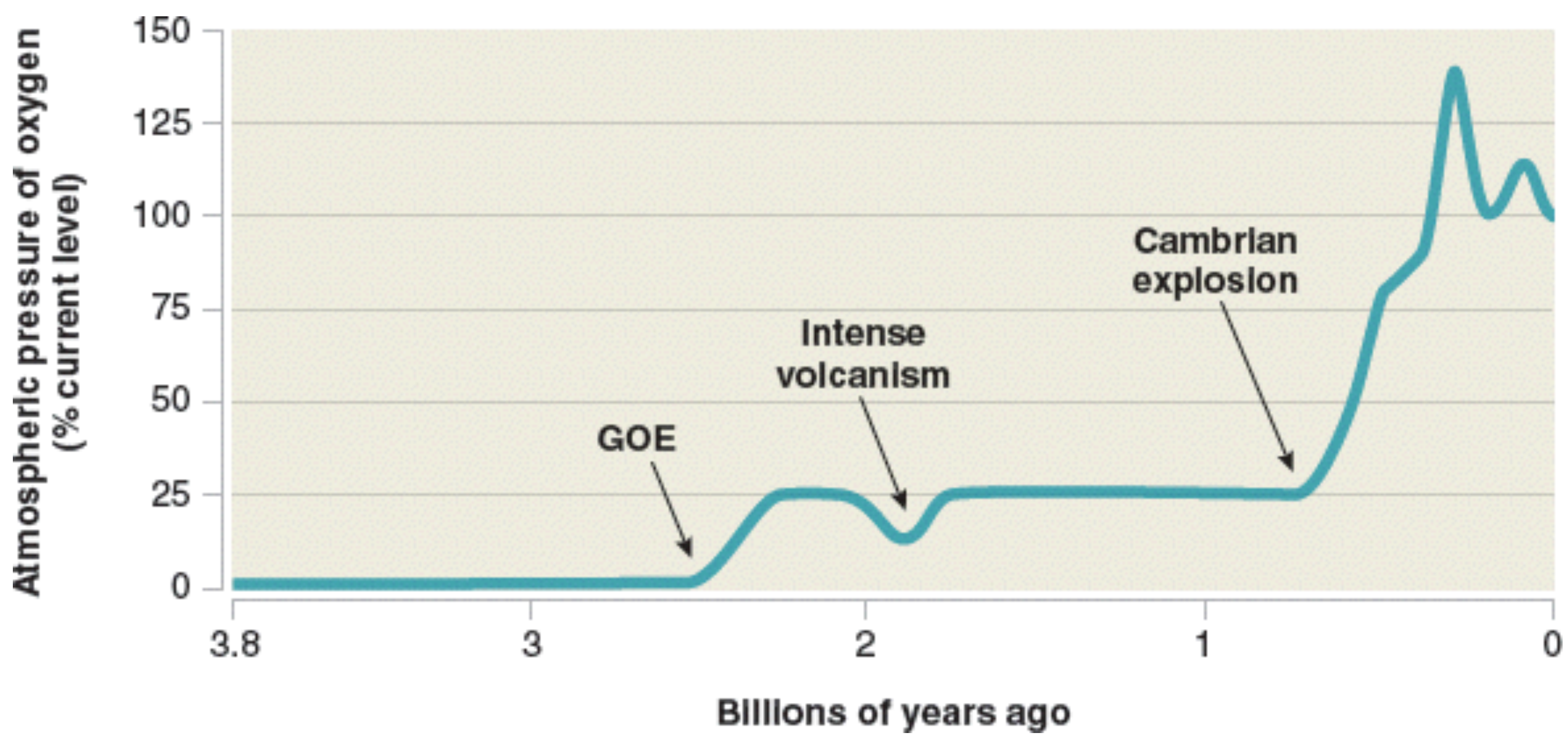
Organisms that respire aerobically gain much more energy from glucose than anaerobes gain by fermentation

As a result, the **newly evolved aerobic organisms were more efficient** and more competitive than anaerobes

Today the majority of organisms (plants, animals, and most fungi, protists, archaea, and bacteria) use aerobic respiration; only a few archaea and bacteria and even fewer protists and fungi are anaerobic

Photosynthetic organisms used carbon dioxide as a source of carbon for synthesizing organic compounds.

The evolution of **aerobic respiration stabilized** both **oxygen** and **carbon dioxide** levels in the biosphere.



This **raw material would have been depleted** from the atmosphere **without the advent of aerobic respiration**, which released carbon dioxide as a waste product from the complete breakdown of **organic molecules**.

Another **significant consequence** of photosynthesis occurred in the upper atmosphere, where molecular oxygen reacted to form **ozone (O3)**

With the ozone layer's **protection from** the mutagenic effect of ultraviolet radiation, organisms could live closer to the surface in aquatic environments and eventually move onto land.

The **energy in ultraviolet radiation** may have been necessary to form organic molecules, however, their abiotic synthesis decreased.

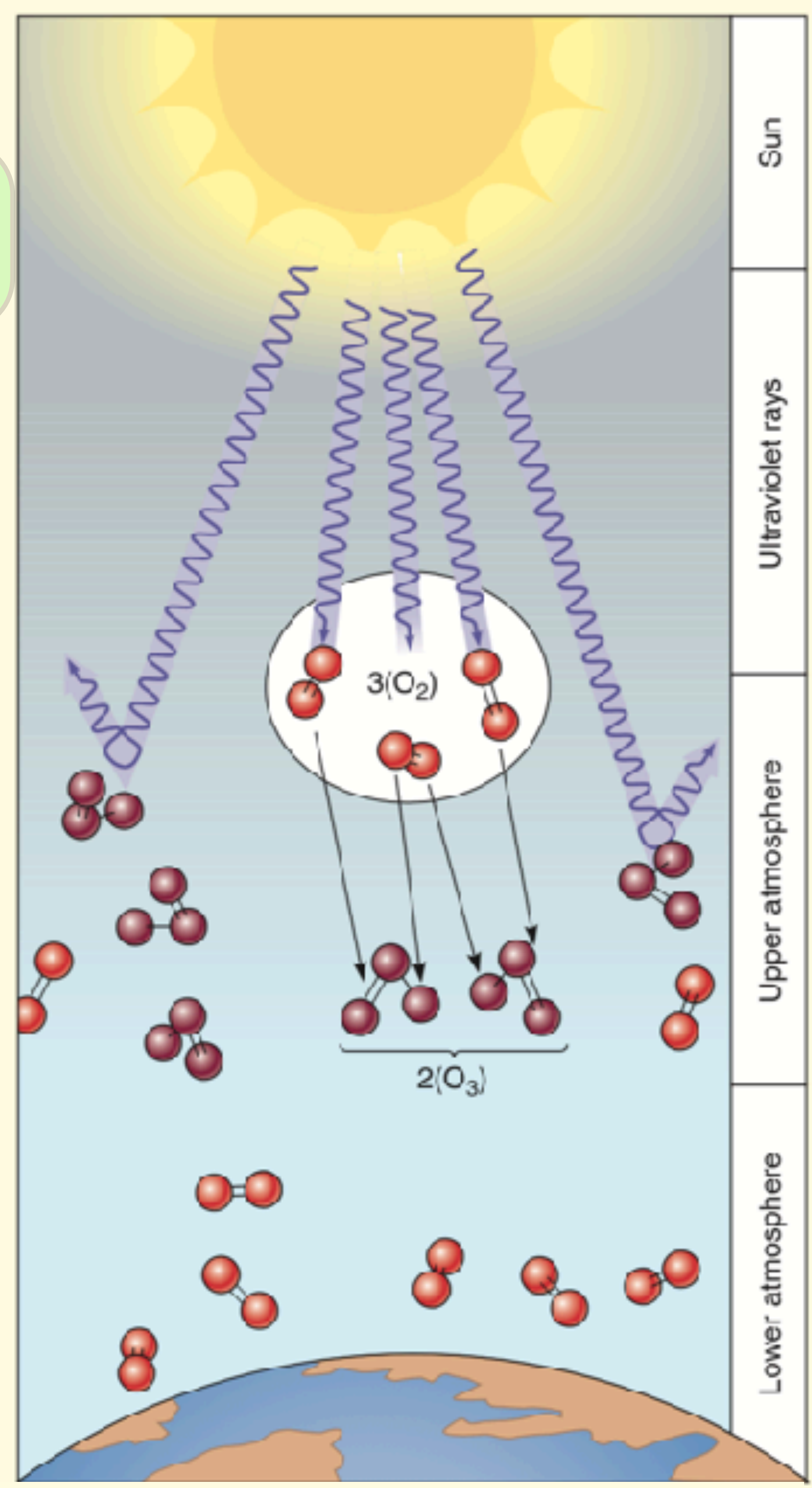
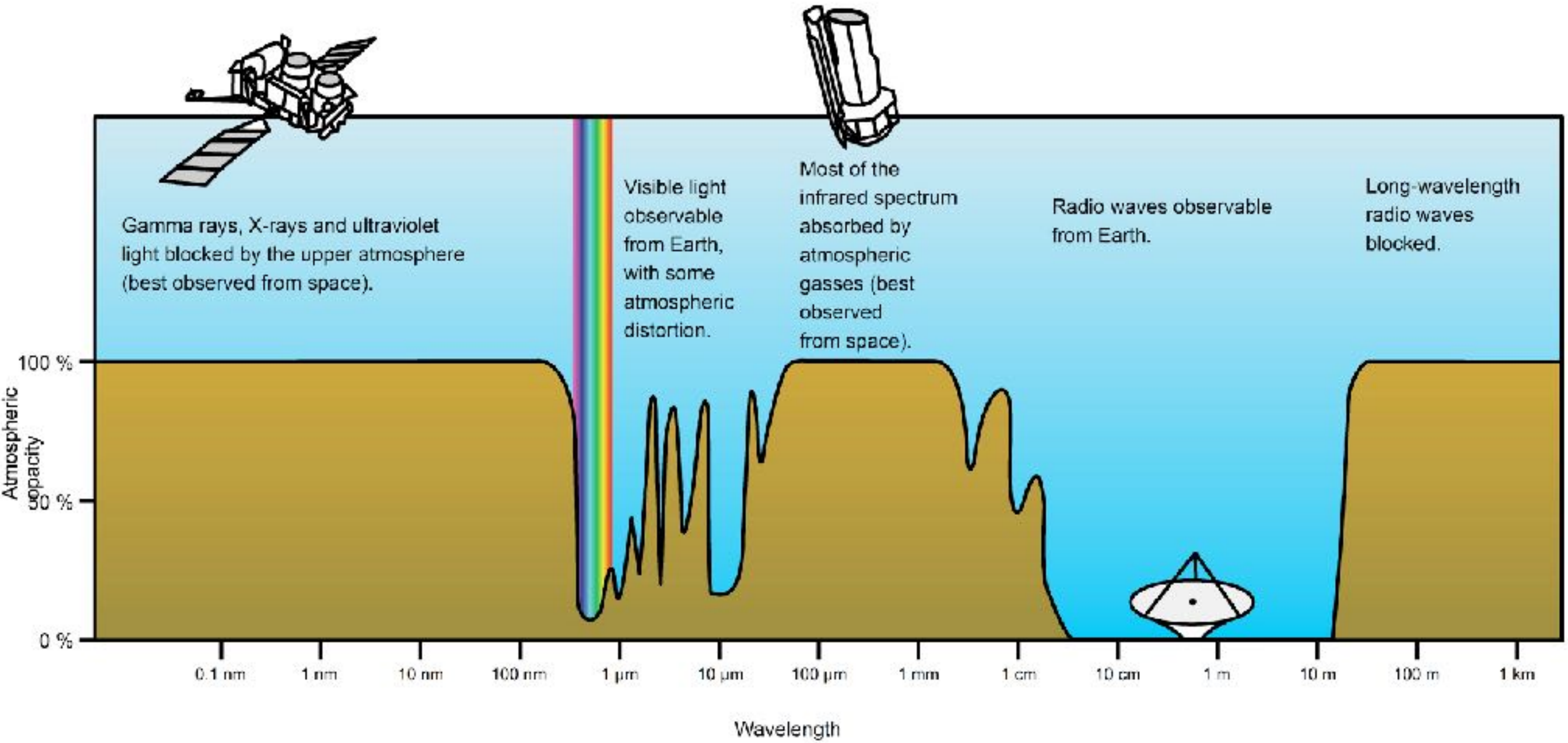


FIGURE 21-7 The formation of ozone



Gamma rays, X-rays and ultraviolet light blocked by the upper atmosphere (best observed from space).
Visible light observable from Earth, with some atmospheric distortion.
Most of the infrared spectrum absorbed by atmospheric gasses (best observed from space).
Radio waves observable from Earth.
Long-wavelength radio waves blocked.
100 %
50 %
0 %
Atmospheric opacity
0.1 nm
1 nm
10 nm
100 nm
1 µm
10 µm
100 µm
1 mm
1 cm
10 cm
1 m
10 m
100 m
1 km
Wavelength

Eukaryotic cells descended from prokaryotic cells

Chloroplasts apparently evolved from photosynthetic bacteria (cyanobacteria)

mitochondria presumably evolved from aerobic bacteria (perhaps ancient purple bacteria)

Thus, **eukaryotic cells** were **assemblages of** formerly free-living prokaryotes

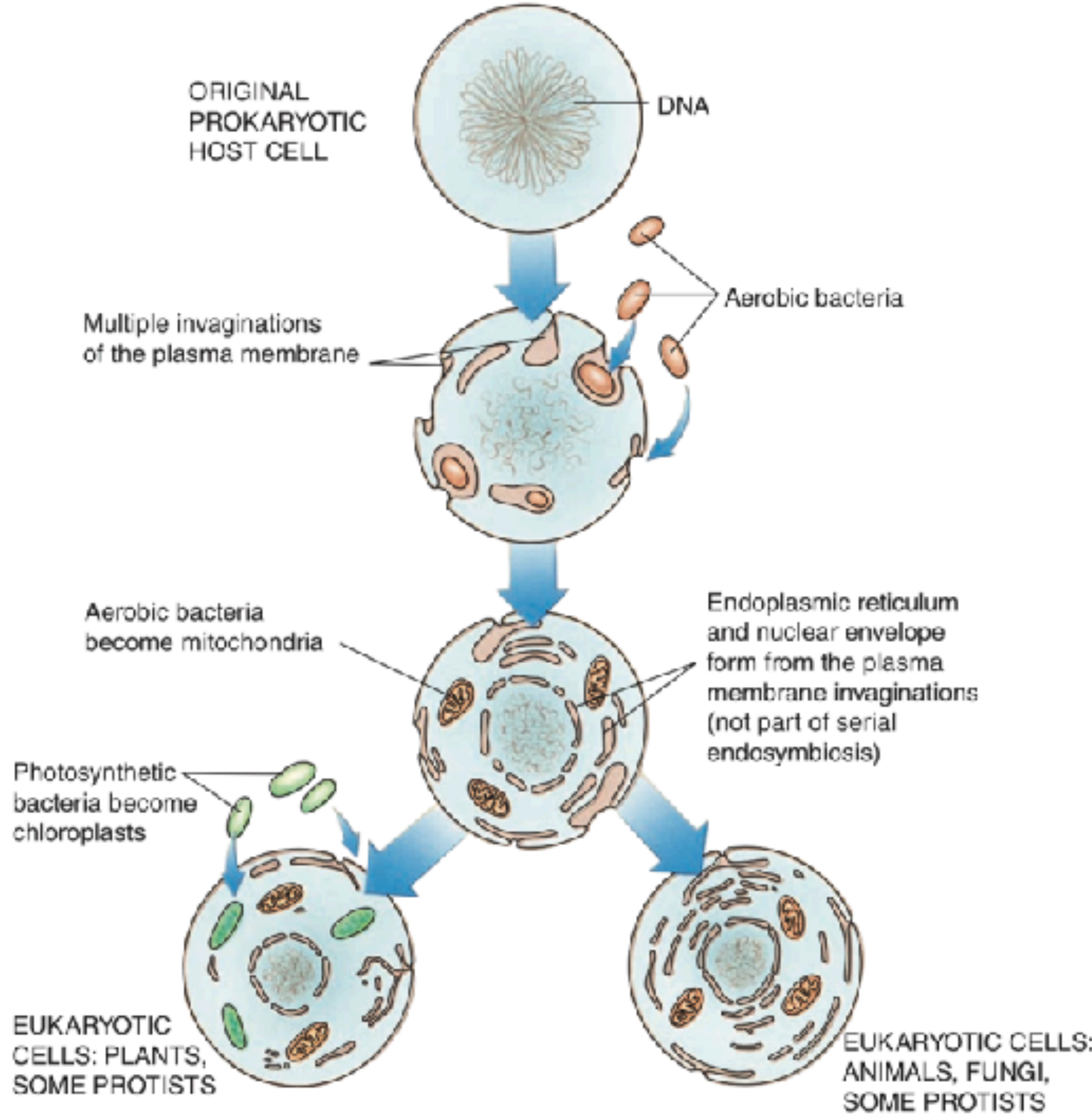


FIGURE 21-8 *Animated* Serial endosymbiosis

Evidence:

is that mitochondria and chloroplasts possess some (although not all) of their **own genetic material** and **translational components** and their **own ribosomes** (which resemble bacterial rather than eukaryotic ribosomes).

Mitochondria and chloroplasts also possess some of the **machinery for protein synthesis** and **conduct protein synthesis** on a limited scale independent of the nucleus. It is possible to **poison** mitochondria and chloroplasts with an **antibiotic that affects bacteria** but not eukary- otic cells.

21.3 THE HISTORY OF LIFE

Rocks from the Ediacaran period contain fossils of cells and simple animals

Chase Studio/Photo Researchers, Inc.

FIGURE 21-9 Reconstruction of life in an Ediacaran sea

The organisms shown here are based on fossils from the Ediacara Hills of South Australia, although similar associations have been found in Ediacaran rocks from every continent except Antarctica. Shown are organisms that

Proterozoic eon		Ediacaran period	600 mya	Algae and soft-bodied invertebrates diversify
		Early Proterozoic period	2500 mya	Eukaryotes evolve
Archaean eon			4600 mya	Oldest known rocks; prokaryotes evolve; atmospheric oxygen begins to increase

Eon	Era	Period	Epoch	Time*	Some Important Biological Events
	Paleozoic era	Devonian period		416 mya	First forests; gymnosperms appear; many trilobites; wingless insects appear; fishes with jaws appear and diversify; amphibians appear
		Silurian period		444 mya	Vascular plants appear; coral reefs common; jawless fishes diversify; terrestrial arthropods
		Ordovician period		488 mya	Fossil spores of terrestrial plants (bryophytes?); invertebrates dominant; coral reefs appear; first fishes appear
		Cambrian period		542 mya	Bacteria and cyanobacteria; algae; fungi; age of marine invertebrates; first chordates
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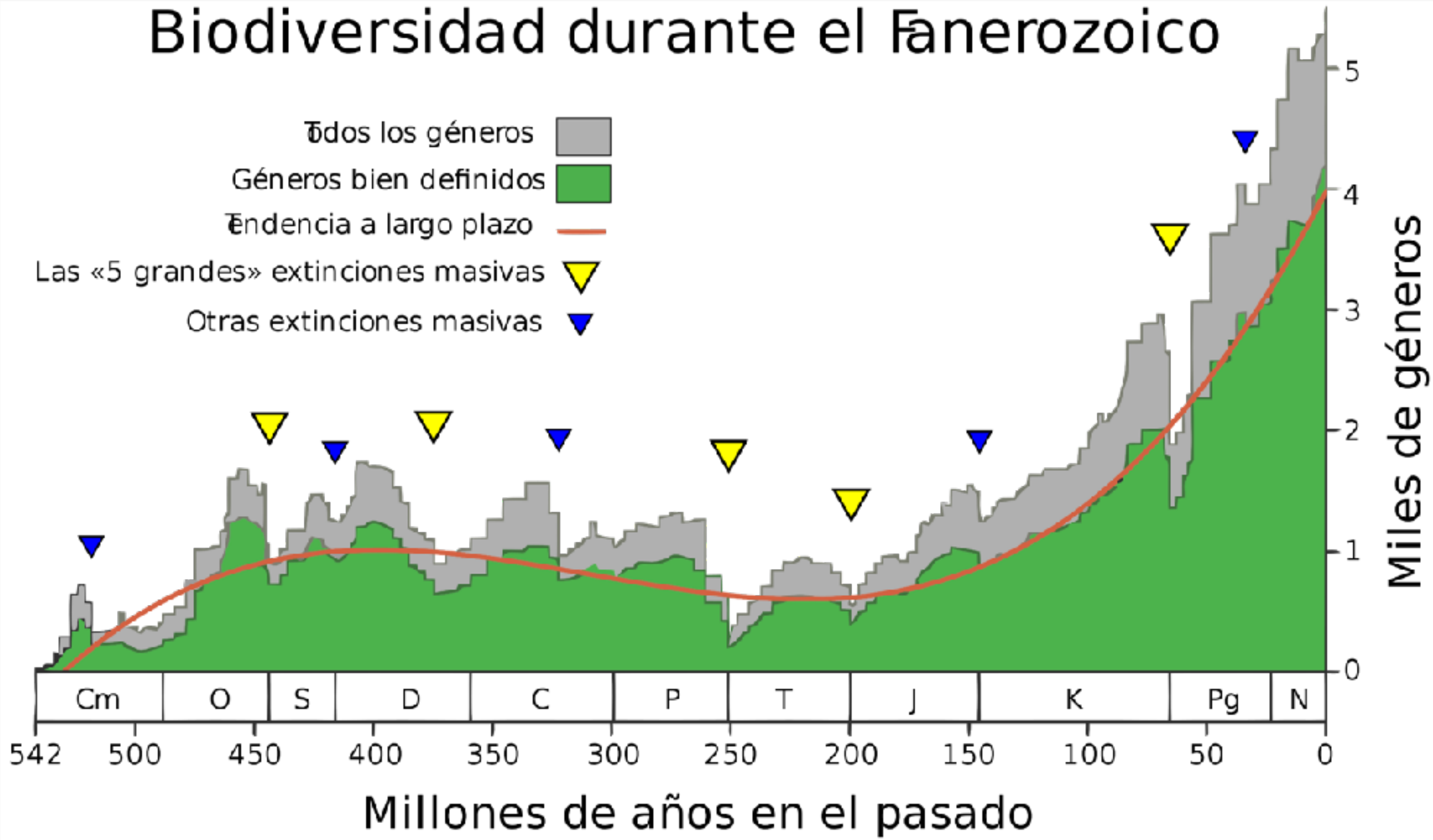
		Early Proterozoic period		2500 mya	Eukaryotes evolve
Archaean eon				4600 mya	Oldest known rocks; prokaryotes evolve; atmospheric oxygen begins to increase





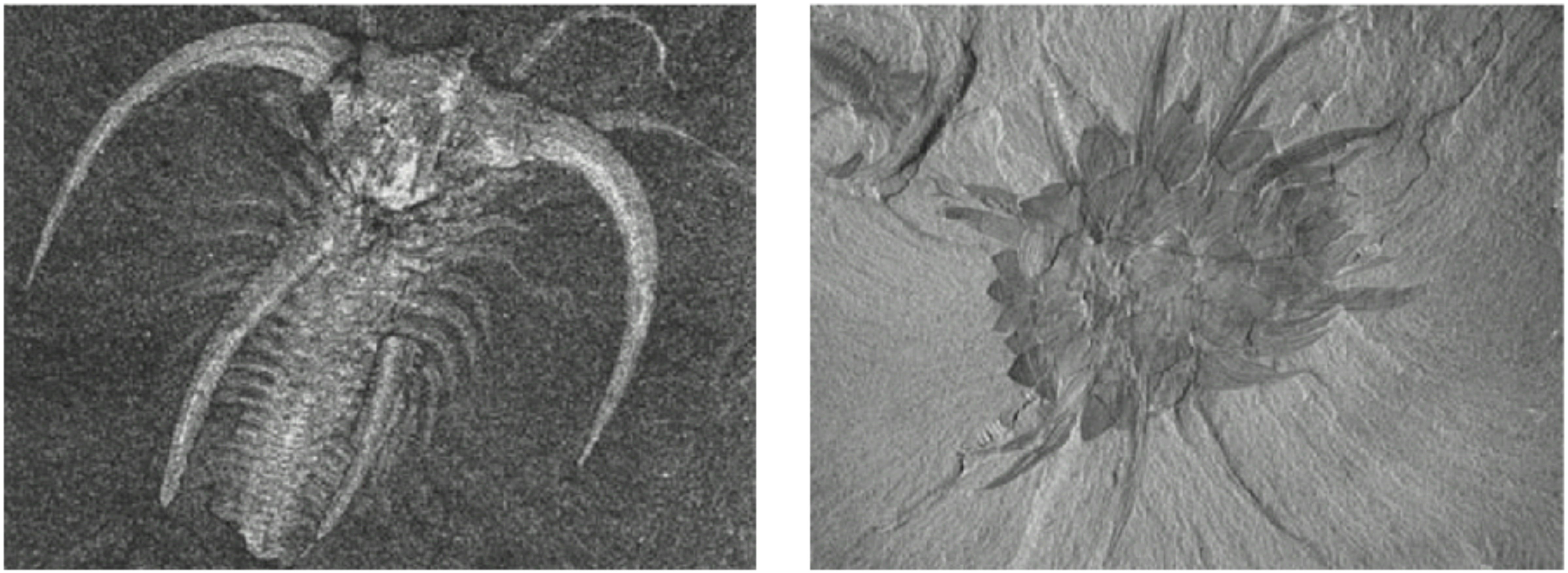


Rohde, R.A., and Muller, R.A. (2005-03). "Cycles in fossil diversity". *Nature* **434**: 208-210

A diversity of organisms evolved during the Paleozoic era

Cambrian period. For about 40 million years, evolution was in such high gear, with the sudden appearance of many new animal body plans, that this period is called the **Cambrian Radiation**

Both: National Museum of Natural History, Courtesy of Chip Clark © 2006 Smithsonian Institute

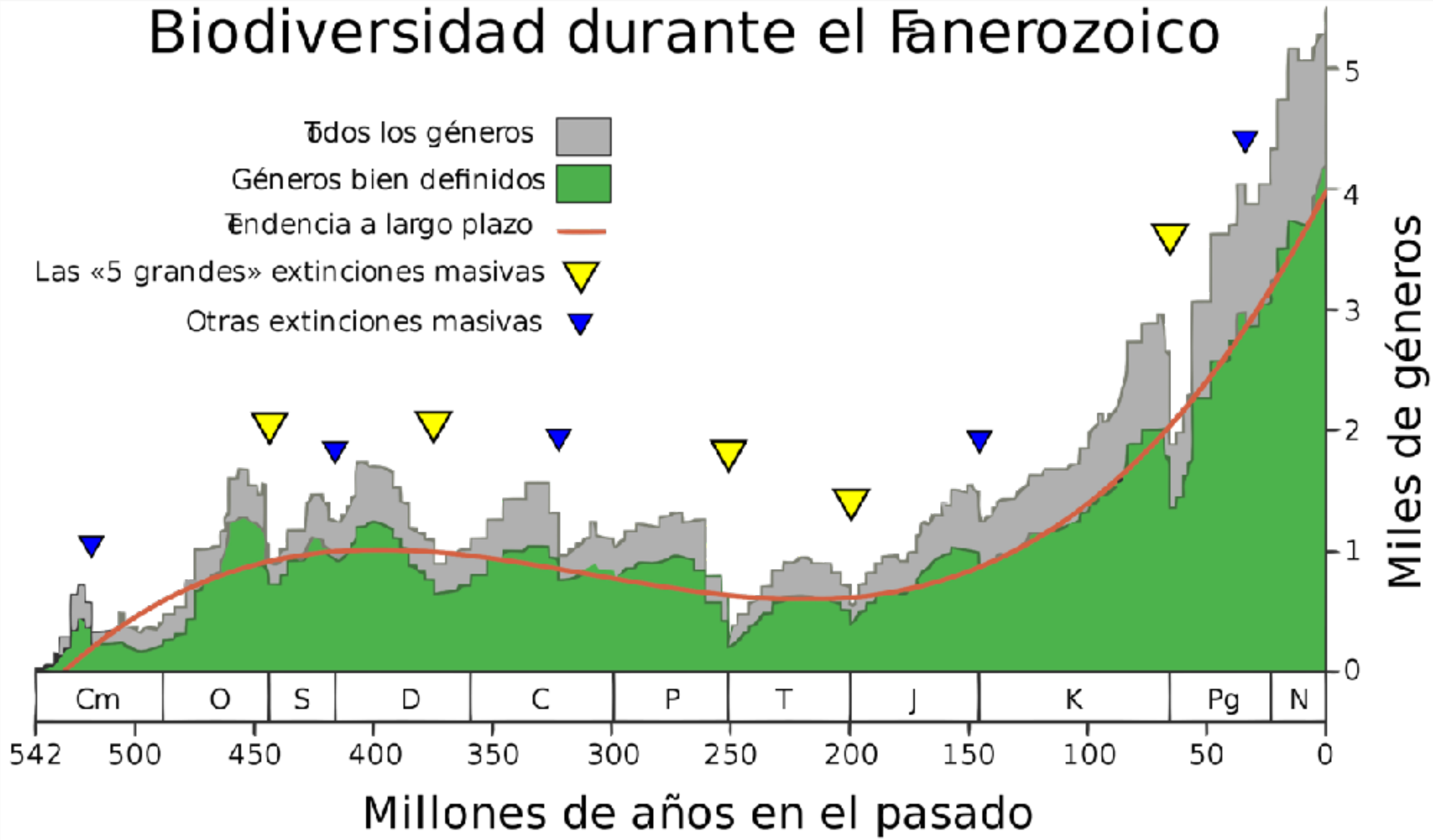


(a) *Marrella splendens* was a small arthropod with 26 body segments. It is the most abundant fossil arthropod found in the Burgess Shale.

(b) *Wiwaxia* was a bristle-covered marine worm that was distantly related to earthworms. It had scaly armor and needlelike spines for protection.

FIGURE 21-10 Fossils from the Cambrian Radiation

These fossils were discovered in the Burgess Shale in the Canadian Rockies of British Columbia.



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		Early Proterozoic period		2500 mya	Eukaryotes evolve
Archaean eon				4600 mya	Oldest known rocks; prokaryotes evolve; atmospheric oxygen begins to increase





Ordovician period another burst of evolutionary diversification

Lacking jaws, fishes typically had round or slitlike mouth

During the **Silurian period**

jawless fishes diversified considerably,

and jawed fishes first appeared.

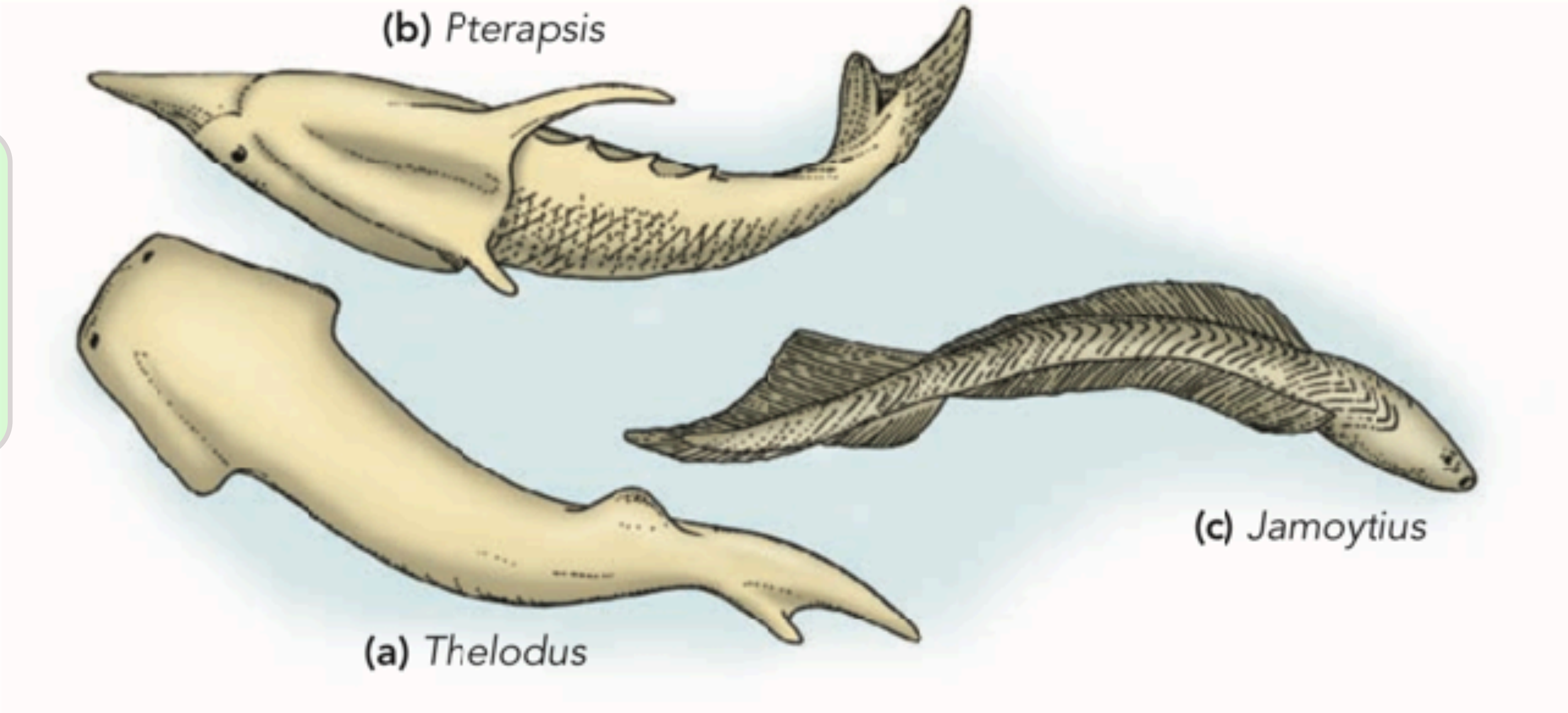


FIGURE 21-11 Ostracoderms

Ostracoderms, primitive jawless fishes that lived in the Ordovician, Silurian, and Devonian periods, ranged from 10 to 50 cm (4 to 20 in) in length.

Ordovician deposits also contain fossil spores of terrestrial (land-dwelling) plants, suggesting the colonization of land had begun

All air-breathing land animals discovered in Silurian. rocks were arthropods

Silurian period: evidence of terrestrial plants and air-breathing animals

Break

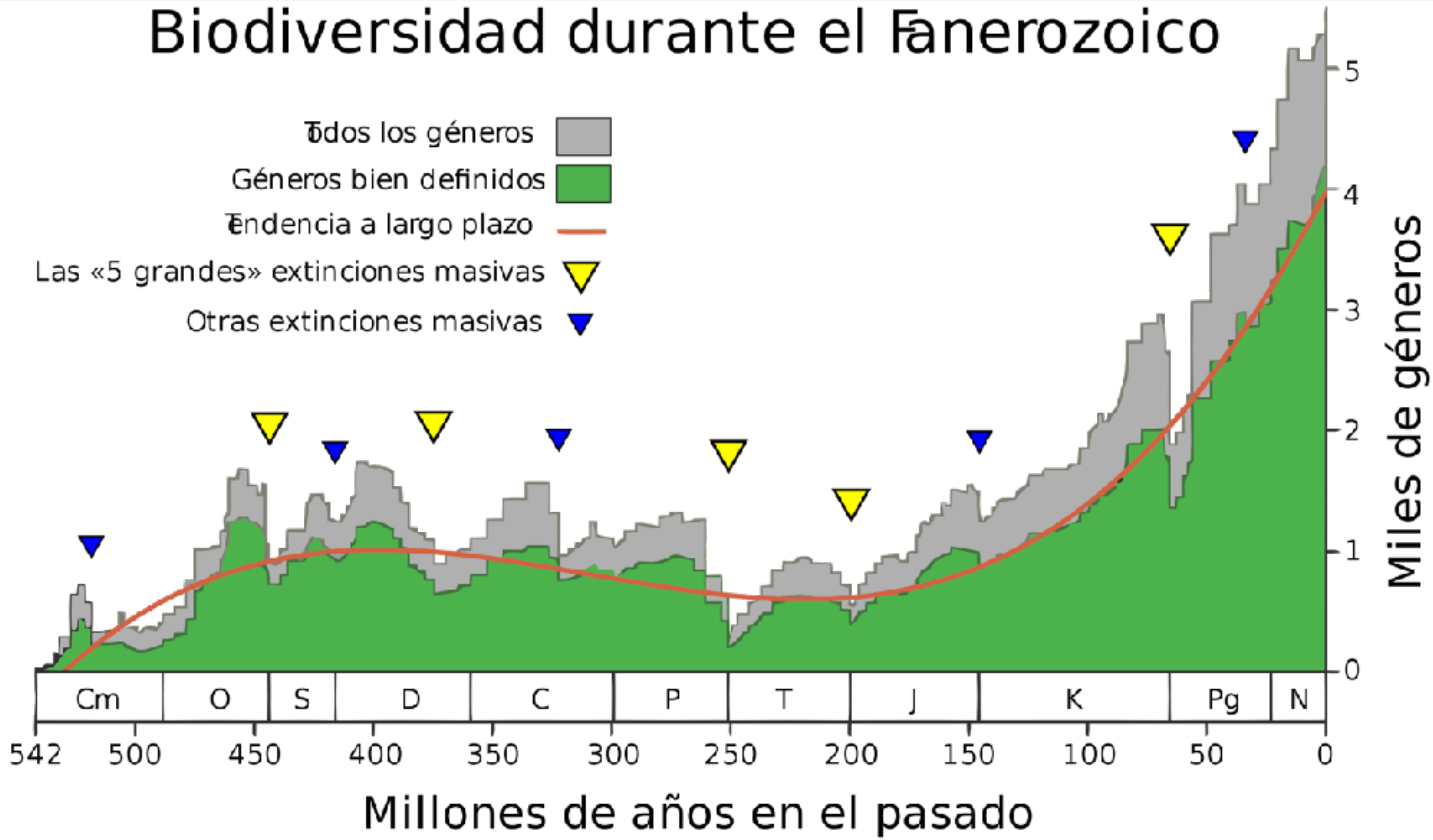
From an ecological perspective,

energy flow from plants to animals probably occurred via detritus (organic debris from decomposing organisms), rather than directly from living plant material.

FIGURE 21-12 Reconstruction of a Carboniferous forest

Plants of this period included giant ferns, horsetails, club mosses, seed ferns, and early gymnosperms.

The **Carboniferous period** is named for the great swamp forests whose remains persist today as major coal deposits. Much of the land during this time was covered with low swamps filled with horsetails, club mosses, ferns, seed ferns, and gymnosperms, which are seed-bearing plants such as conifers.



Rohde, R.A., and Muller, R.A. (2005-03). "Cycles in fossil diversity". *Nature* **434**: 208-210

Amphibians,

which underwent an **adaptive radiation** and exploited both aquatic and terrestrial ecosystems,

were the dominant terrestrial carnivores of the Carboniferous period.

Reptiles first appeared and diverged to form two major lines at this time.

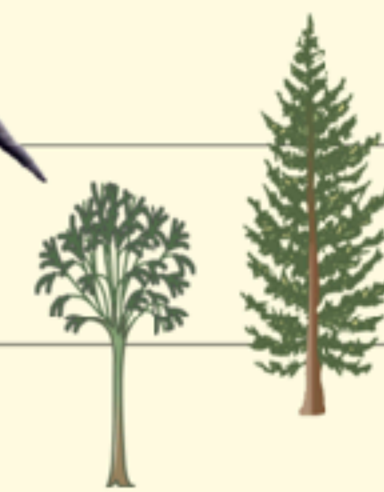
One line consisted of mostly small and mid-sized insectivorous (insect-eating) lizards;

this line later led to lizards, snakes, crocodiles, dinosaurs, and birds.

The other reptilian line led to a diverse group of **Permian and Early Mesozoic** mammal-like reptiles.

Two groups of winged insects, cockroaches and dragonflies, appeared in the Carboniferous period.

Eon	Era	Period	Epoch	Time*	Some Important Biological Events
Phanerozoic eon		Paleogene period	Eocene epoch	56 mya	Flowering plants dominant; modern mammalian orders appear and diversify; modern bird orders appear
			Paleocene epoch	66 mya	Semitropical vegetation (flowering plants and conifers) widespread; primitive mammals diversify
	Mesozoic era	Cretaceous period		146 mya	Rise of flowering plants; dinosaurs reach peak, then become extinct at end; toothed birds become extinct
		Jurassic period		200 mya	Gymnosperms common; large dinosaurs; first toothed birds
		Triassic period		251 mya	Gymnosperms dominant; ferns common; first dinosaurs; first mammals
		Permian period		299 mya	Conifers diversify; cycads appear; modern insects appear; mammal-like reptiles; extinction of many invertebrates and vertebrates at end of Permian
		Carboniferous period		359 mya	Forests of ferns, club mosses, horsetails, and gymnosperms; many insect forms; spread of ancient amphibians; first reptiles

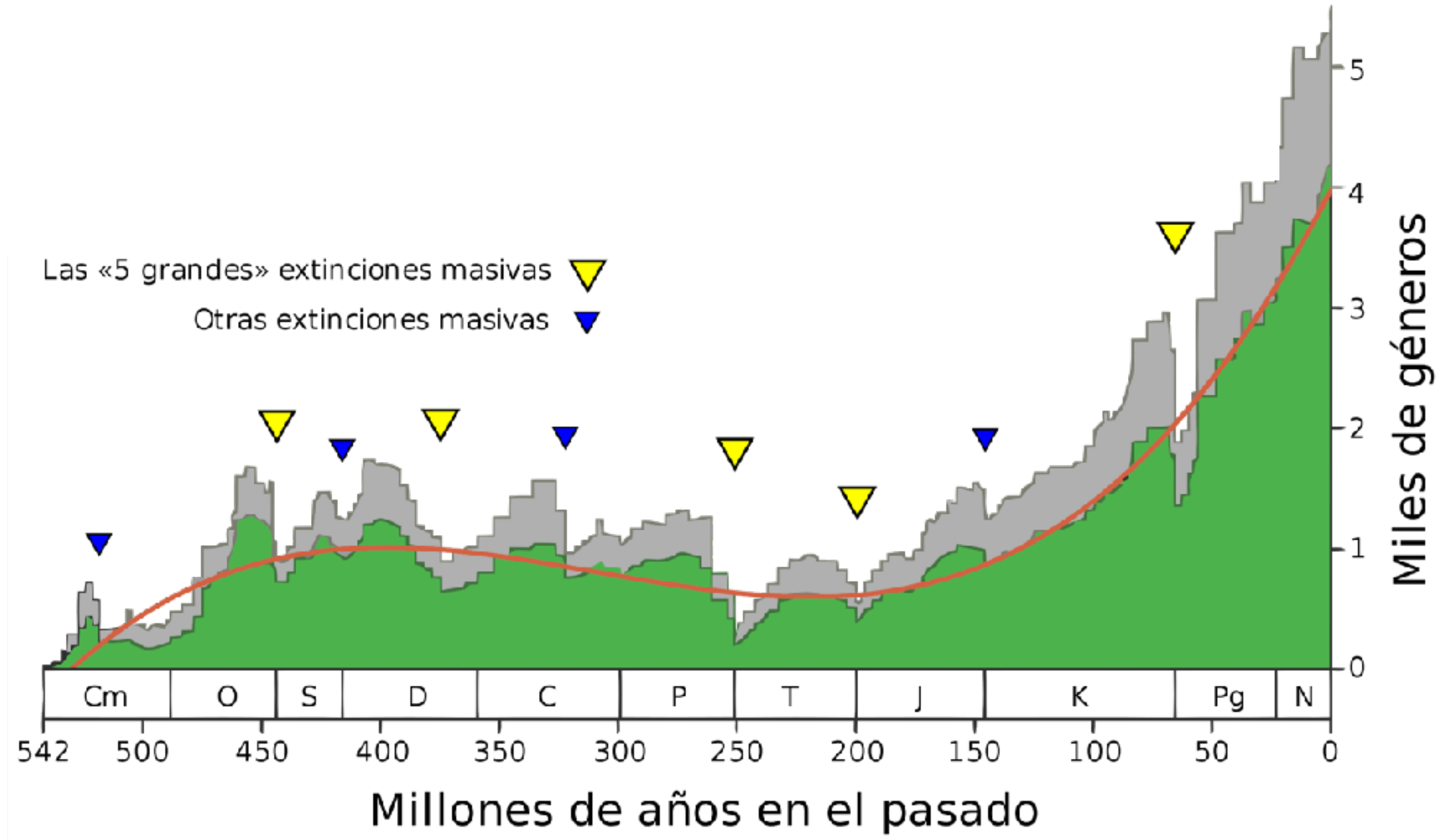


The greatest **mass extinction** of all time occurred at the end of the Paleozoic era**, between the Permian and Triassic periods** **251 mya**.

More than 90% of all existing marine species

70% of the vertebrate genera living on land.

Also evidence of a major extinction of plants.



Many causes have been suggested, from meteor impacts to global warming to changes in ocean chemistry.

Extinction occurred globally in a very compressed period, within a few hundred thousand years.

This is an extremely short period in the geologic time scale and suggests that some sort of catastrophic event caused the mass extinction.

Dinosaurs and other reptiles dominated the Mesozoic era

Age of Reptiles

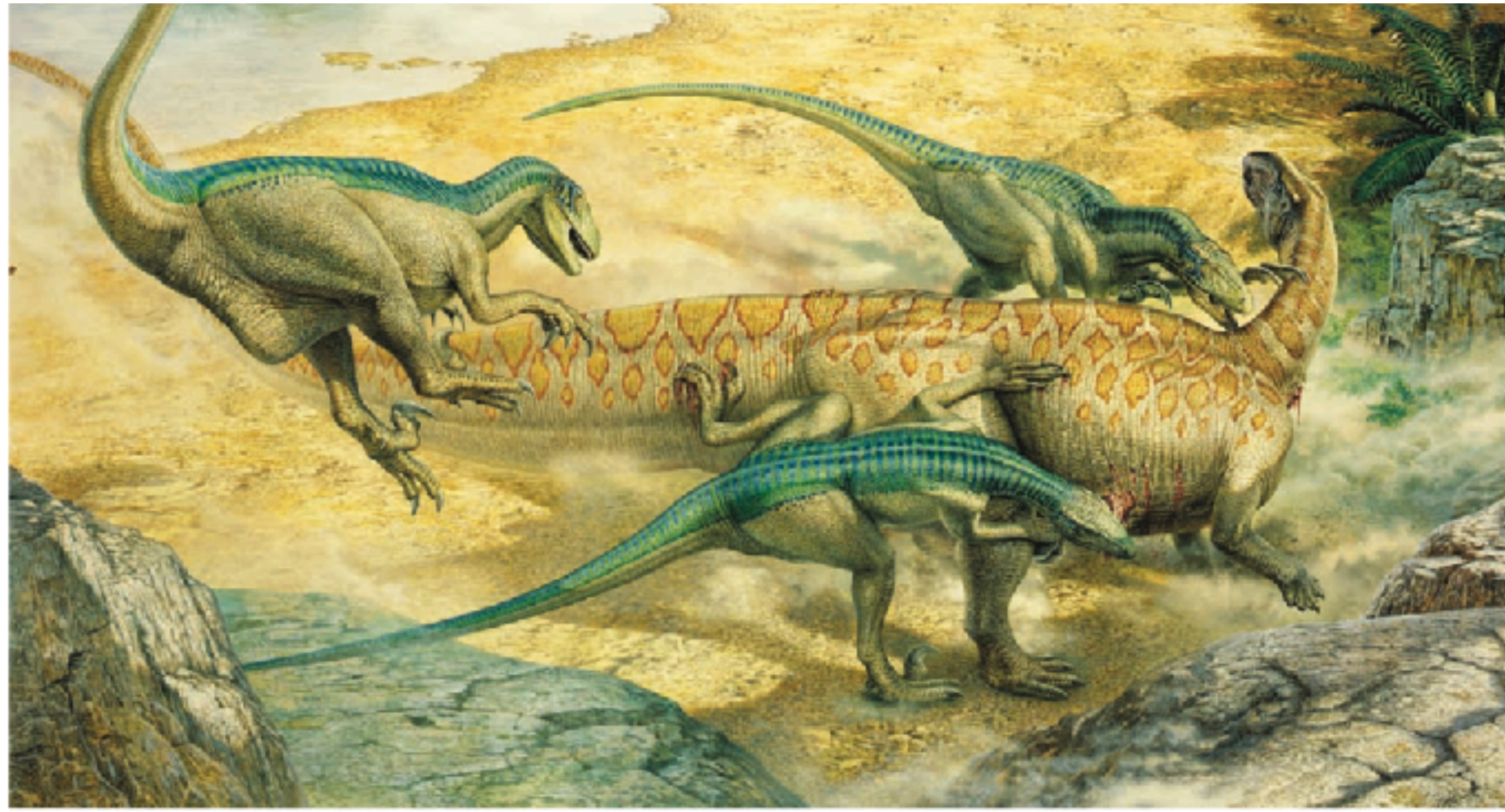


FIGURE 21-15 Dinosaurs

Three *Deinonychus* dinosaurs attack a larger *Tenontosaurus*. The name *Deinonychus* means "terrible claw" and refers to the enlarged, sharp claw on the second digit of its hind feet. *Deinonychus* dinosaurs were small (3 m, or 10 ft in length) but fearsome predators that hunted in packs. *Tenontosaurus* adults were as long as 7.5 m (24 ft).

Most of the modern orders of insects appeared during the Mesozoic era

Snails and bivalves (clams and their rela- tives) increased in number and diversity, and sea urchins reached their peak diversity.

From a botanical viewpoint, the Mesozoic era was dominated by gymnosperms until the Mid-Cretaceous period, when the flowering plants first diversified

During the **Triassic period,** reptiles underwent an adaptive radiation leading to the formation of many groups.

On land, the dominant Triassic groups were

the mammal-like therapsids,

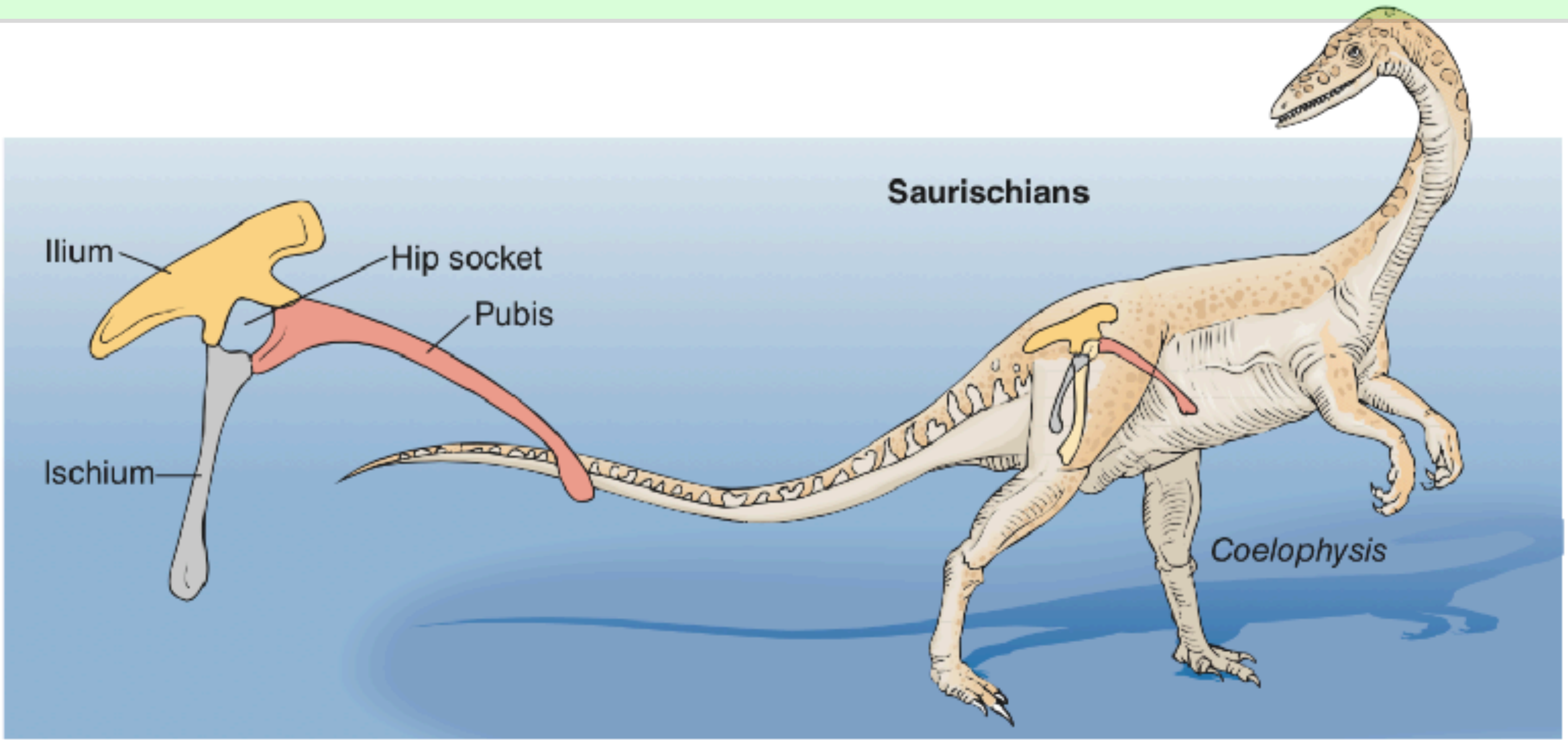
which ranged from small-sized insectivores (insect-eating reptiles) to moderately large herbivores (plant-eating reptiles),

and a diverse group of *thecodonts,* early "ruling reptiles," that were primarily carnivores.

Thecodonts are the ancestral reptiles that gave rise to crocodilians, flying reptiles, dinosaurs, and birds.

Evolutionary radiation of the dinosaurs expanded from one lineage to several dozen that ecologically filled a variety of adaptive zones.

Dinosaurs are placed in two main groups based on their pelvic bone structure: the *saurischians* and the *ornithischians*

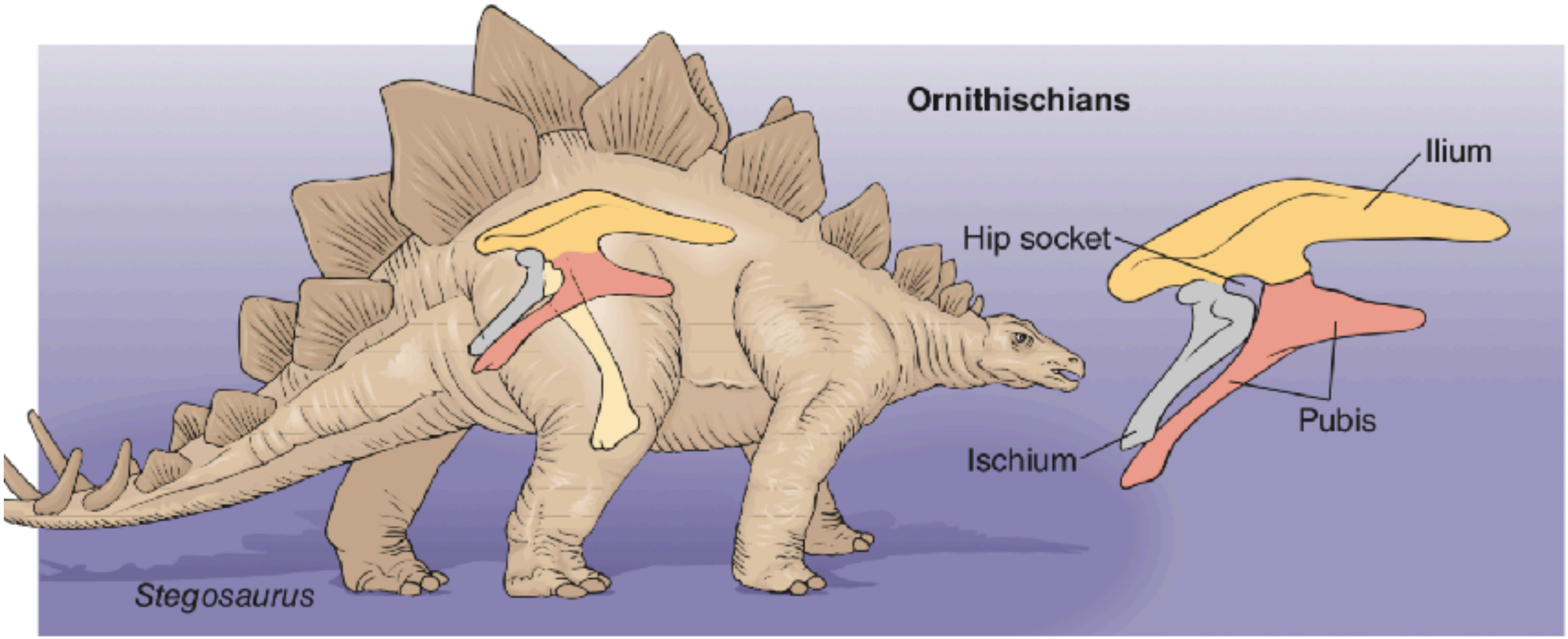


(a) The saurischian pelvis. Note the opening (hip socket), a trait possessed by no quadrupedal vertebrates other than dinosaurs.

Some **saurischians** were fast, bipedal forms ranging from those the size of a dog to the the gigantic carnivores of the Cretaceous period —*Tyrannosaurus*, *Giganotosaurus*, and *Carcharodontosaurus*.

Other **saurischians** were huge, quadrupedal dinosaurs that ate plants. Some were the largest terrestrial animals that have ever lived, including *Argentinosaurus*, with an estimated length of 30 m (98 ft) and an estimated weight of 72 to 90 metric tons (80 to 100 tons).

The other group of dinosaurs, the **ornithischians**, was entirely herbivorous. Although some ornithischians were bipedal, most were quadrupedal.



(b) The ornithischian pelvis. Note that it has the hole in the hip socket but differs from the saurischian pelvis in that it has a backward-directed extension of the pubis.

Some dinosaurs were warm-blooded, agile, and able to move extremely fast

Birds appeared by the **Late Jurassic period**

Fossil evidence indicates they evolved directly from saurischian dinosaurs

Archaeopteryx, the oldest known bird in the fossil record,

lived about 150 mya

Beginning in 1997, paleontologists made several discoveries of fossil dinosaurs with feathers, indicating that feathers appeared before birds.

Archaeopteryx is considered a bird, it had many reptilian features, including a mouthful of teeth and a long, bony tail.

Birds appeared by the **Late Jurassic period**

In 1915, William Beebe hypothesized that the ancestors of birds were probably tree-dwelling gliders that had feathers on all four limbs.

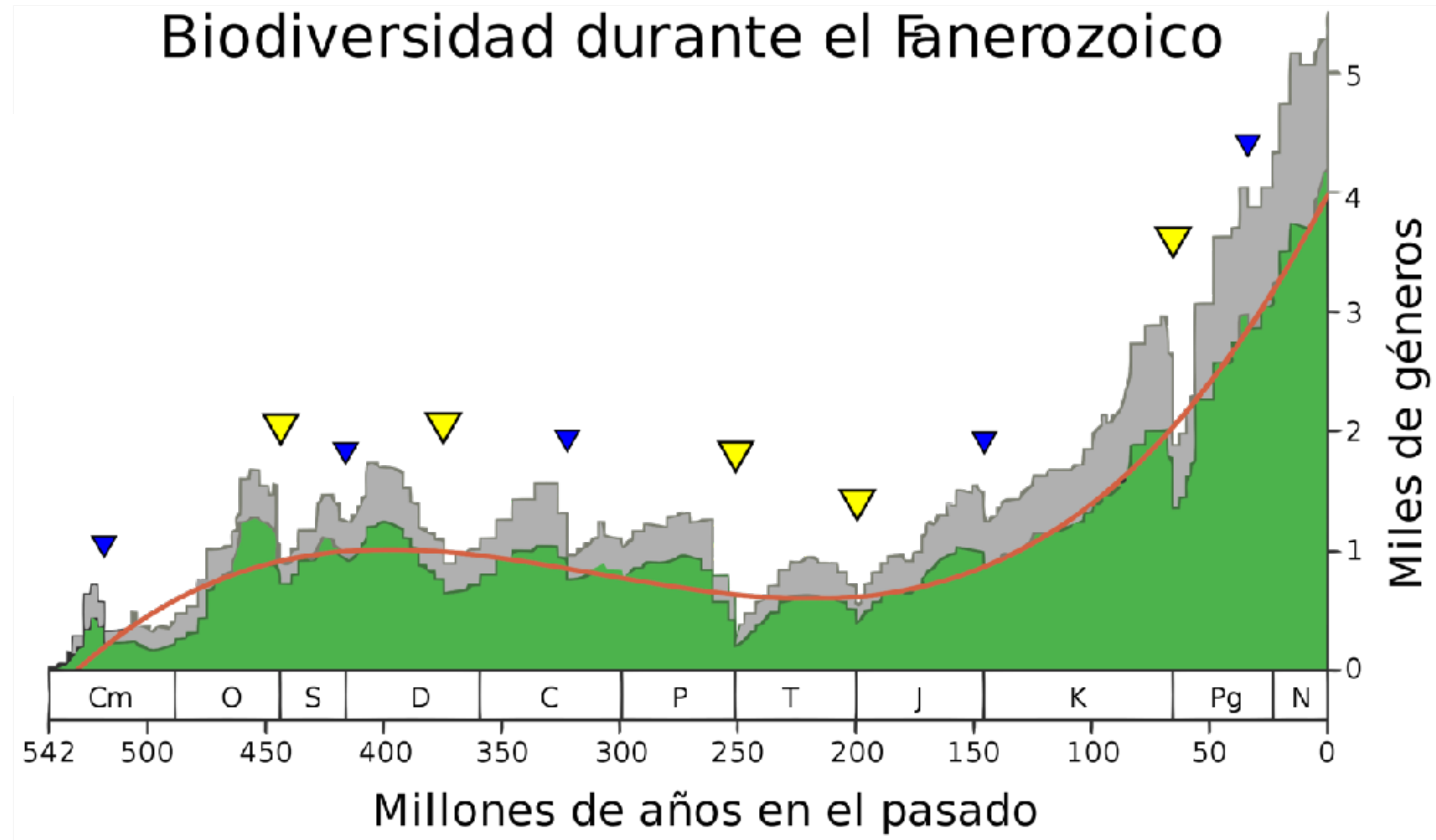
A century later, in 2003,

Chinese paleontologists announced the discovery complete fossils of the organisms that Beebe had hypothesized.

The earliest known bird, *Archaeopteryx,* lived about 150 mya and therefore predates *M. gui* by about 25 mil- lion years

preadaptations The first feathers may have provided thermal insulation but were subsequently modified for flight.

At the end of the Cretaceous period, 66 mya, dinosaurs, pterosaurs, and many other animals abruptly became **extinct**.



Many gymnosperms, with the exception of conifers, also perished.

Evidence suggests that a catastrophic collision of a large extraterrestrial body with Earth dramatically changed the climate at the end of the Cretaceous period

Part of the evidence is a thin band of dark clay, with a high concentration of iridium, located between Mesozoic and Cenozoic sediments at more than 200 sites around the world

The Cenozoic era is the age of mammals

the **Cenozoic era** could be called the Age of Mammals, the Age of Birds, the Age of Insects, or the Age of Flowering Plants.

This era is marked by the appearance of all these forms in great variety and numbers of species.

Flowering plants, which arose during the Cretaceous period, continued to diversify during the Cenozoic era.

FIGURE 21-17 A bird from the Eocene epoch
The flightless bird *Diatryma*, which stood 2.1 m (7 ft) tall and weighed 175 kg (385 lb), may have been an herbivore or a formidable predator. picture, *Diatryma* has captured a small, horselike perissodactyl.

During the Eocene epoch, there was an explosive radiation of birds, which acquired adaptations for different habitats.

Paleontologists hypothesize that the jaws and beak of the flightless giant bird *Diatryma,* for example, may have been adapted primarily for crushing and slicing vegetation in Eocene forests, marshes, and grasslands. Other paleontologists hypothesize that these giant birds were carnivores that killed or scavenged mammals and other vertebrate.

Eon	Era	Period	Epoch	Time*	Some Important Biological Events
	Cenozoic era	Quaternary period	Holocene epoch	0.01 (10,000 years ago)	Decline of some woody plants; rise of herbaceous plants; age of *Homo sapiens*
			Pleistocene epoch	2.6 mya	Extinction of some plant species; extinction of many large mammals at end
		Neogene period	Pliocene epoch	5 mya	Expansion of grasslands and deserts; many grazing animals
			Miocene epoch	23 mya	Flowering plants continue to diversify; diversity of songbirds and grazing mammals
		Paleogene period	Oligocene epoch	34 mya	Spread of forests; apes appear; present mammalian families are represented
			Eocene epoch	56 mya	Flowering plants dominant; modern mammalian orders appear and diversify; modern bird orders appear
			Paleocene epoch	66 mya	Semitropical vegetation (flowering plants and conifers) widespread; primitive mammals diversify

During the **Paleocene and Eocene epochs**, semi-tropical plant communities extended to relatively high latitudes

Later in the **Cenozoic era**, there is evidence of more open habitats

Grasslands and savannas spread throughout much of North America during the Miocene epoch, deserts developing later in the Pliocene and Pleistocene epochs

During the Pleistocene epoch, plant communities changed dynamically in response to the fluctuating climates associated with the multiple advances and re- treats of continental glaciers

During the **Paleocene epoch**, an explosive radiation of primitive mammals occurred.

Most are forest dwellers that are not closely related to modern mammals.

During the **Eocene epoch**, mammals continued to diverge,

and all the modern orders first appeared.

Many of the mammals were small,

but there were also some larger herbivores.

During the **Oligocene epoch,**

many modern families of mammals evolved,

including the first apes in Africa.

Many lineages showed adaptations that suggest a

more open type of habitat, such as grassland or savanna.

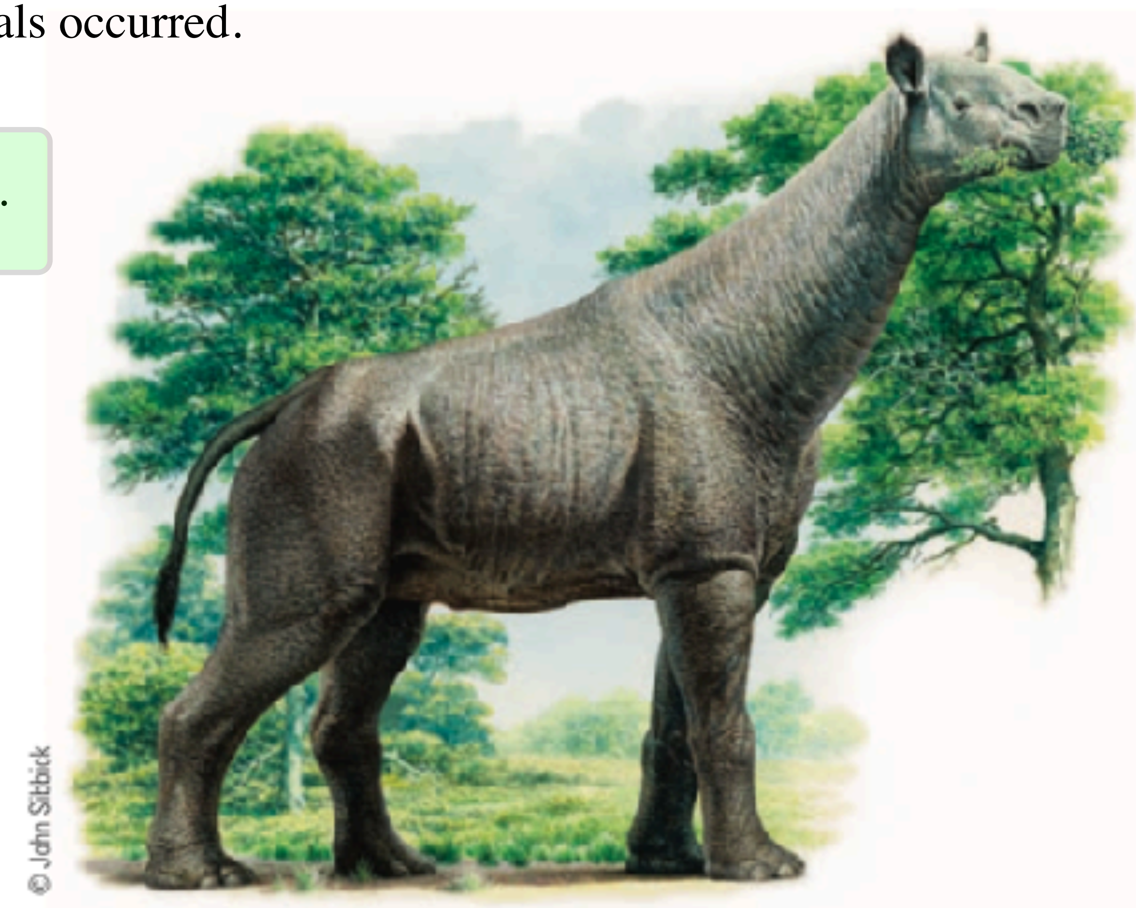


FIGURE 21-18 A mammal from the Oligocene epoch
Paraceratherium was an indricothere, a hornless relative of the rhinoceros. This huge land mammal was about 8 m (26 ft) long and weighed about 15 to 20 tons. It probably ate leaves and branches of deciduous trees, much as a modern-day giraffe does.

The *indricotheres,* are extinct relatives of the rhinoceros which lived on the grassless plains of Eurasia and became progressively larger during the Oligocene epoch.

Human ancestors appeared in Africa during the Late **Miocene** and Early **Pliocene** epochs.

Homo, the genus to which humans belong, appeared approximately 2.5 mya.

The **Pliocene** and **Pleistocene epochs** witnessed the introduction of spectacular North and South American large-mammal fauna, including mastodons, saber-toothed cats, camels, giant ground sloths, and giant armadillos.

However, many of the large mammals became **extinct** at the **end of the Pleistocene epoch**.

This extinction was possibly due to climate change—

the Pleistocene epoch was marked by several ice ages—

or to the influence of humans,
which had spread from Africa to Europe and Asia,
and later to North and South America.

Archaeological evidence indicates that this mass extinction event was concurrent with the appearance of human hunters.

Biologists use a binomial system for naming organisms

Taxonomic classification is hierarchical

The tree of life includes three domains and several kingdoms

TABLE 1-1 Classification of the Cat, Human, and White Oak Tree

Category	Cat	Human	White Oak
Domain	Eukarya	Eukarya	Eukarya
Kingdom	Animalia	Animalia	Plantae
Phylum	Chordata	Chordata	Anthophyta
Subphylum	Vertebrata	Vertebrata	None
Class	Mammalia	Mammalia	Eudicotyledones
Order	Carnivora	Primates	Fagales
Family	Felidae	Hominidae	Fagaceae
Genus	*Felis*	*Homo*	*Quercus*
Species	*Felis catus*	*Homo sapiens*	*Quercus alba*

The tree of life is a work in progress, but most biologists now assign organisms to **three** domains and to **several kingdoms** or clades

Molecular approaches to systematics

Woese selected a molecule known as small subunit ribosomal RNA (rRNA)

Because its molecular structure differs somewhat in various organisms,

hypothesized that the molecular composition of rRNA in closely related organisms

would be more similar than in distantly related organisms.

He established the ***domain*** level of taxonomy and assigned the prokaryotes to two domains: **Bacteria** and **Archaea**

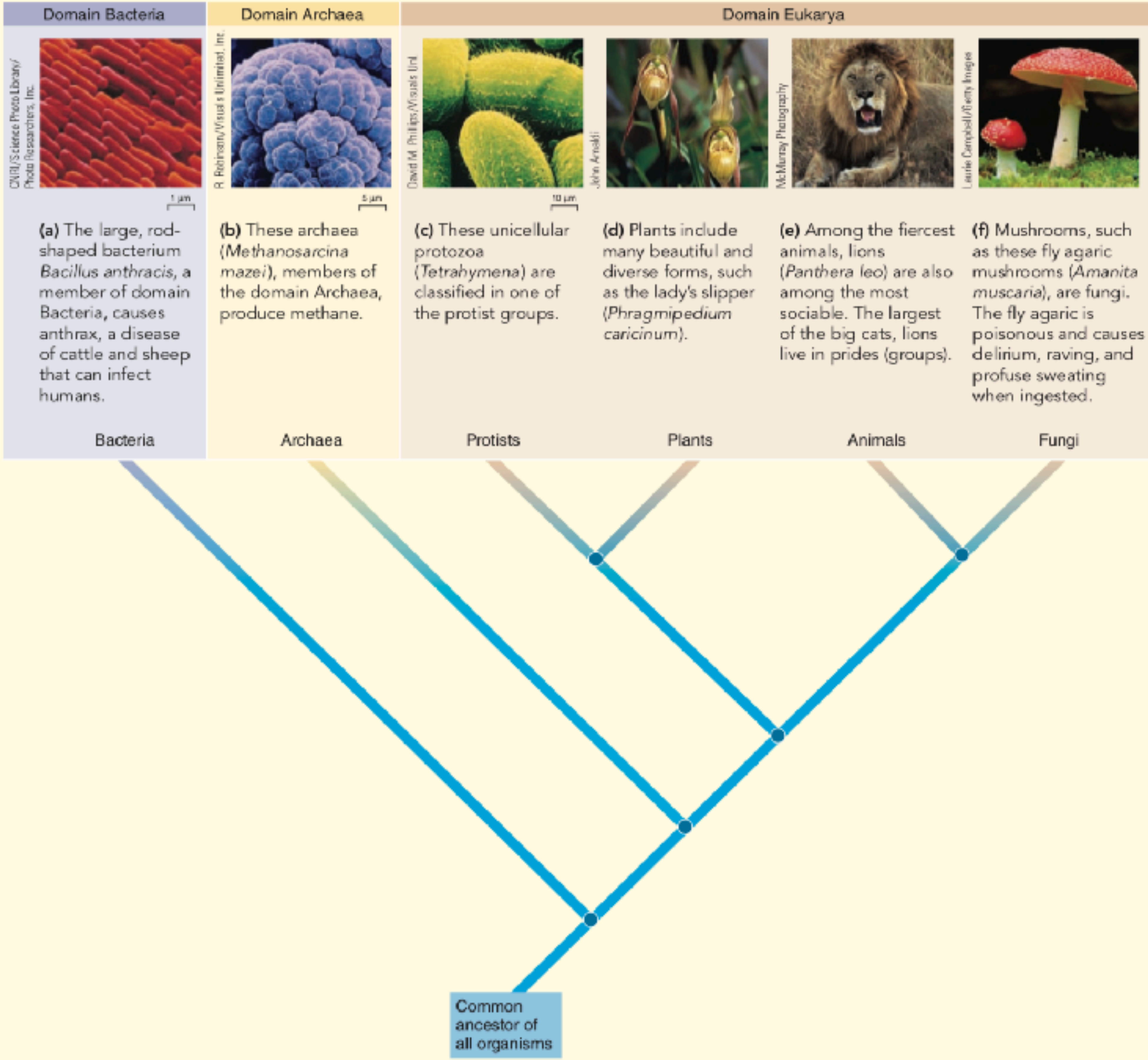


FIGURE 1-11 *Animated* **A survey of the three domains of life**

Biologists assign organisms to three domains and to several kingdoms and other groups. The protists do not form a clade and are no longer considered a kingdom. They are assigned to five "supergroups" (not shown).

Each taxonomic level is more general than the one below it

Hierarchy of increasingly broader groups.

As you move up the hierarchy, each group is more inclusive

When he set up his system,

Linnaeus did not have a theory of evolution in mind.

Nor did he have any idea of the vast number of extant (living)

and extinct organisms that would later be discovered.

Yet his system has proved remarkably flexible and adaptable

to new biological knowledge and theory.

Very few other 18th-century inventions survive today

in a form that would still be recognizable to their originators.

TABLE 23-1 Classification of Corn

Domain	Eukarya Organisms that have nuclei and other membrane-enclosed organelles
Kingdom	Plantae Terrestrial, multicellular, photosynthetic organisms
Phylum	Anthophyta Vascular plants with flowers, fruits, and seeds
Class	Monocotyledones Monocots: Flowering plants with one seed leaf (cotyledon) and flower parts in threes
Order	Commelinales Monocots with reduced flower parts, elongated leaves, and dry 1-seeded fruits
Family	Poaceae Grasses with hollow stems; fruit is a grain; and abundant endosperm in seed
Genus	*Zea* Tall annual grass with separate female and male flowers
Species	*Zea mays* Corn

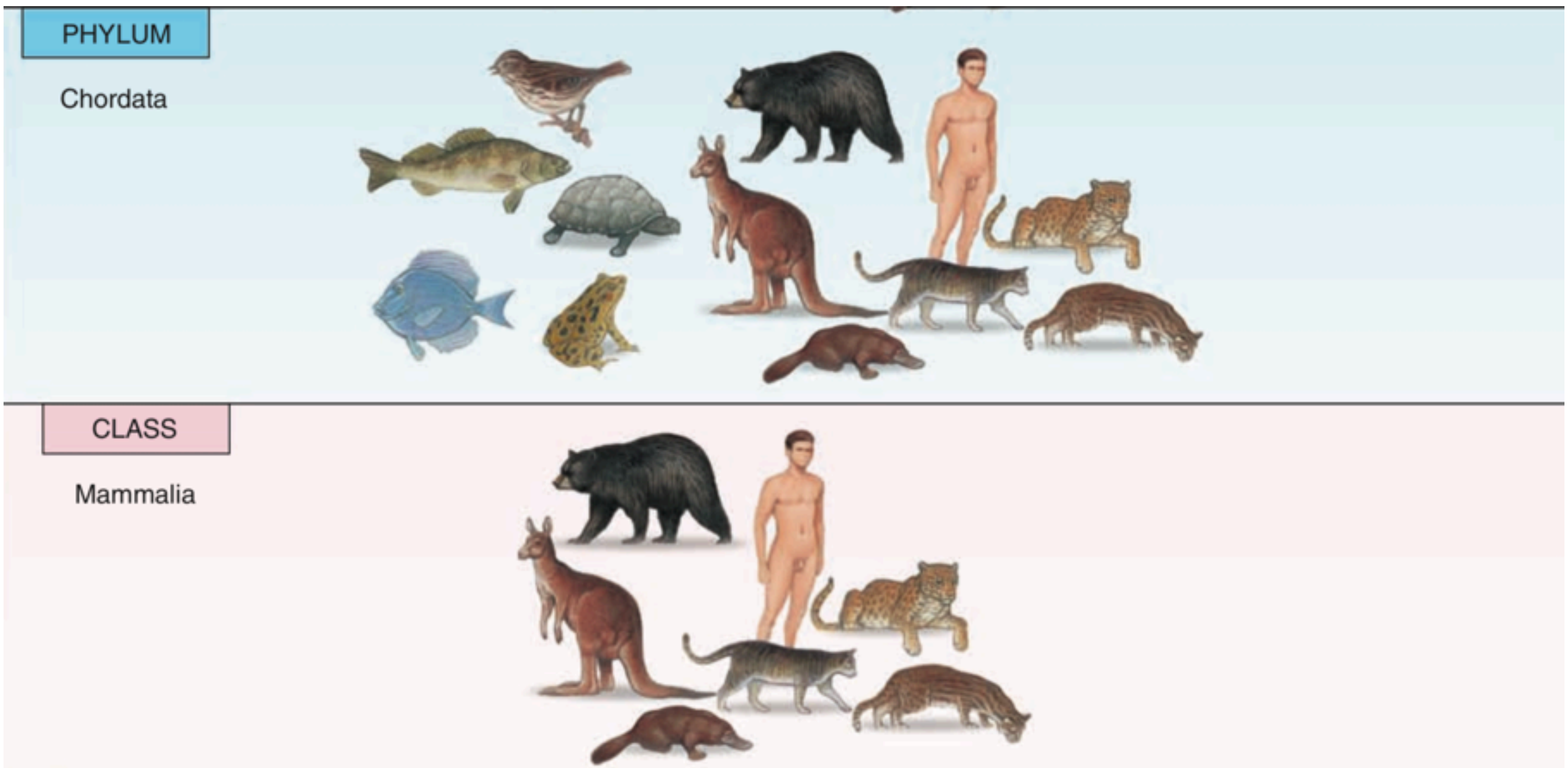
23.2 DETERMINING THE MAJOR BRANCHES IN THE TREE OF LIFE

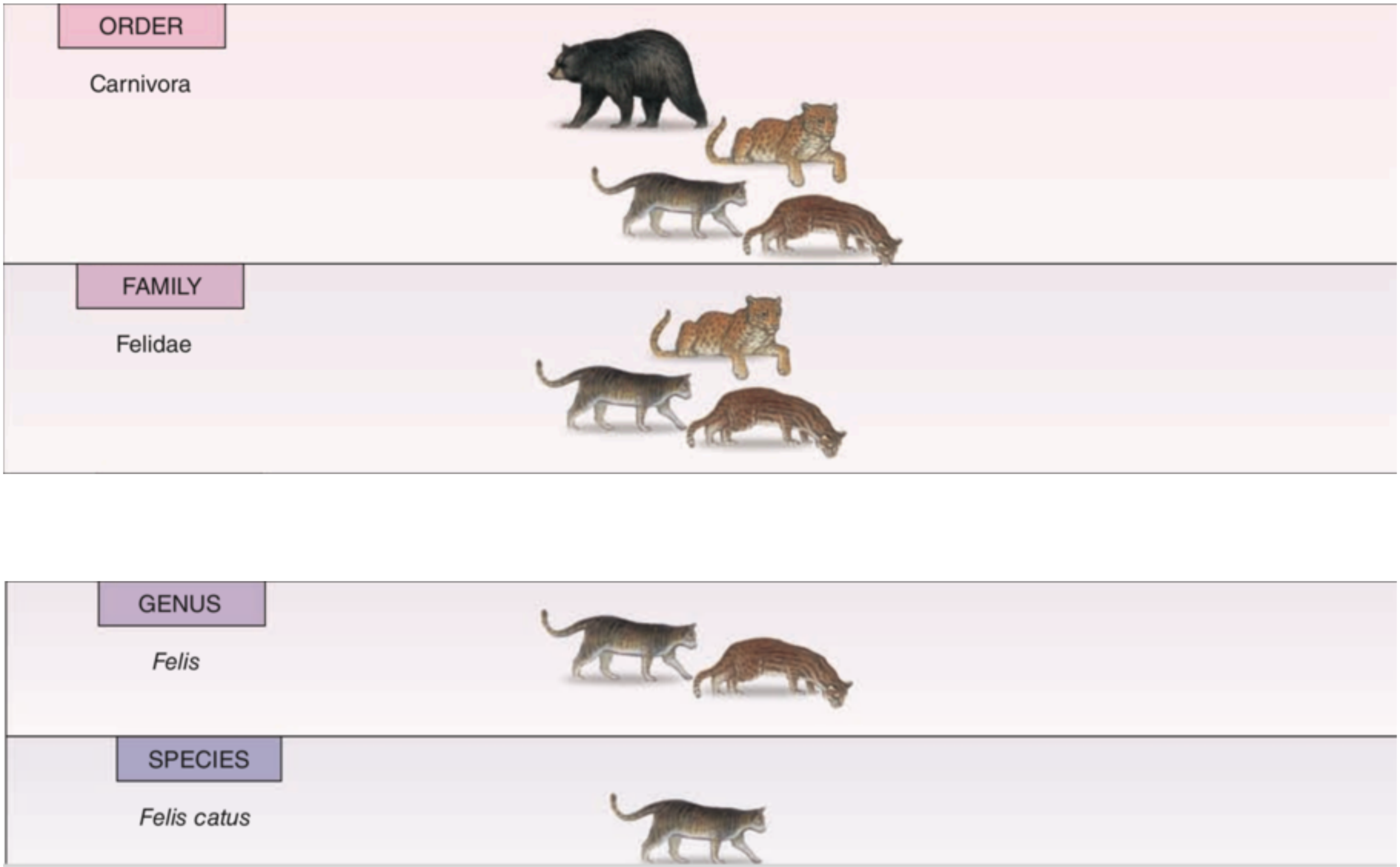
LEARNING OBJECTIVES

3 Describe the three domains and argue for and against classifying organisms in the domains. (Compare this approach with using kingdoms as the main rank of classification.)

4 Interpret a cladogram, describing the meaning of its specific nodes and branches.

Systematics is an evolving science




ORDER
Carnivora
FAMILY
Felidae
GENUS
Felis
SPECIES
Felis catus

The three domains form the three main branches of the tree of life

late 1970s, Carl Woese **16S rRNA**

Gene sequencing indicates that the **archaea** have a combination of bacteria-like and eukaryote-like genes.

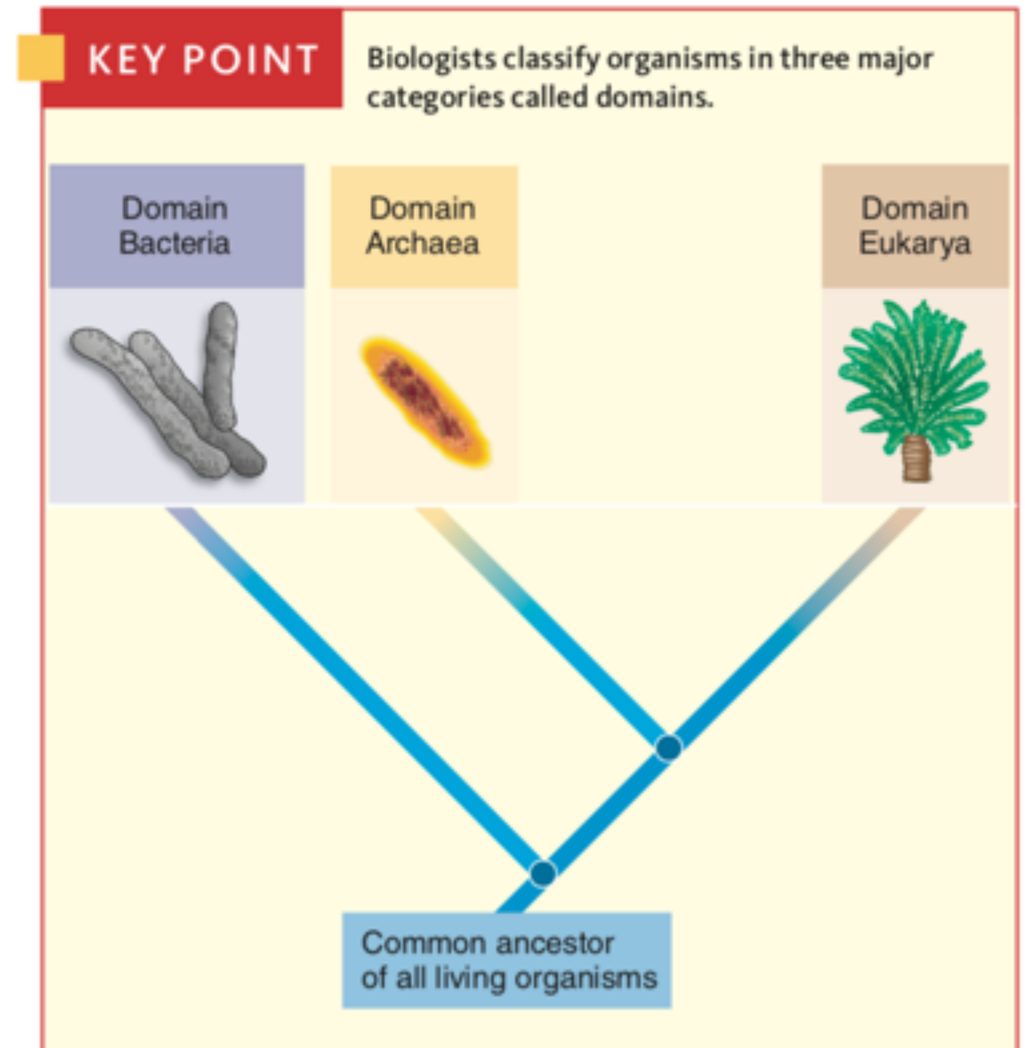


FIGURE 23-2 *Animated* The three domains

TABLE 23-2 Domains and Kingdoms

Domain	Kingdom	Characteristics	Ecological Role and Comments
Bacteria 	Bacteria	Prokaryotes (lack distinct nuclei and other membranous organelles); unicellular; microscopic; cell walls generally composed of peptidoglycan.	Most are decomposers; some parasitic (and pathogenic); some chemosynthetic autotrophs; some pho-tosynthetic; important in recycling nitrogen and oth elements; some used in industrial processes.
Archaea 	Archaea	Prokaryotes; unicellular; microscopic; peptidoglycan absent in cell walls; differ biochemically from bacteria.	Methanogens are anaerobes that inhabit sewage, swamps, and animal digestive tracts; extreme halophiles inhabit salty environments; extreme thermophiles inhabit hot, sometimes acidic environments.
	Protists formerly classified in kingdom Protista; now assigned to a number of "supergroups"	Eukaryotes; mainly unicellular or simple multicellular.	Protozoa are an important part of zooplankton. Alga are important producers, especially in marine and freshwater ecosystems; important oxygen source. Some protists cause diseases, for example, malaria.
	Plantae	Eukaryotes; multicellular; photosynthetic; possess multicellular reproductive organs; alternation of generations; cell walls of cellulose.	Terrestrial biosphere depends on plants in their role as primary producers; important source of oxygen in Earth's atmosphere.
Eukarya* 	Fungi	Eukaryotes; heterotrophic; absorb nutrients; do not photosynthesize; body composed of threadlike hyphae that form tangled masses that infiltrate food or habitat; cell walls of chitin.	Decomposers; some parasitic (and pathogenic); som form important symbiotic relationships with plant roots (mycorrhizae) or algae (lichens); some used as food; yeast used in making bread and alcoholic beve ages; some used to make industrial chemicals or anti biotics; responsible for much spoilage and crop loss.
	Animalia	Eukaryotes; multicellular heterotrophs; many exhibit tissue differentiation and complex organ systems; most able to move about by muscular contraction; nervous tissue coordinates responses to stimuli.	Consumers; some specialized as herbivores, carnivores, or detritus feeders.

Cladogram Each **branch** in a cladogram represents a clade, a group of organisms with a common ancestor.

Each branching point,
referred to as a **node** (depicted by a circle),
represents the divergence, or splitting,
of two or more new groups
from a common ancestor.

Thus, the node represents
the *most recent common ancestor* of each clade
depicted by the branches.

In this way, a cladogram uses the positions of branch points
to illustrate the hypothesized evolutionary relationships among taxa

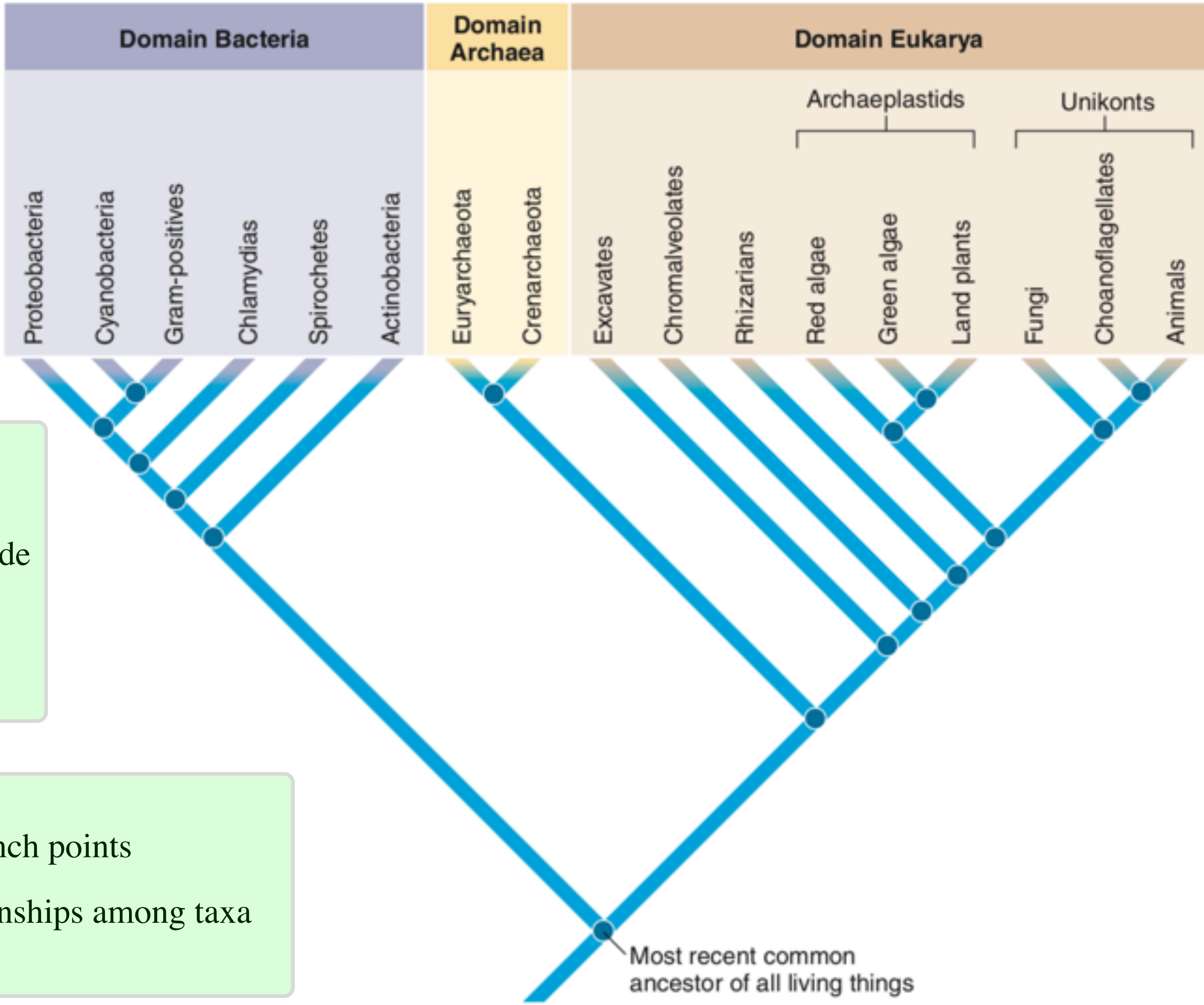
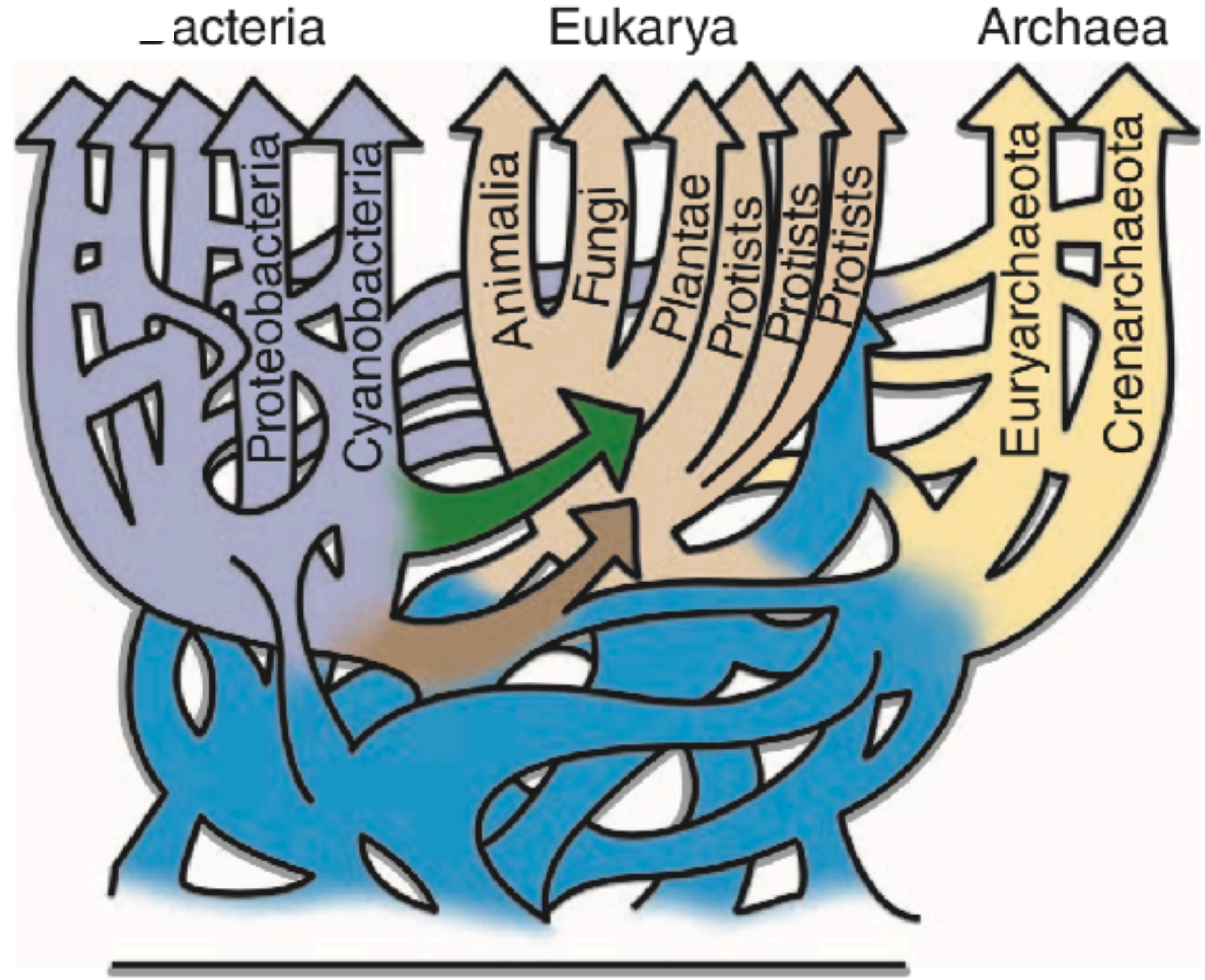


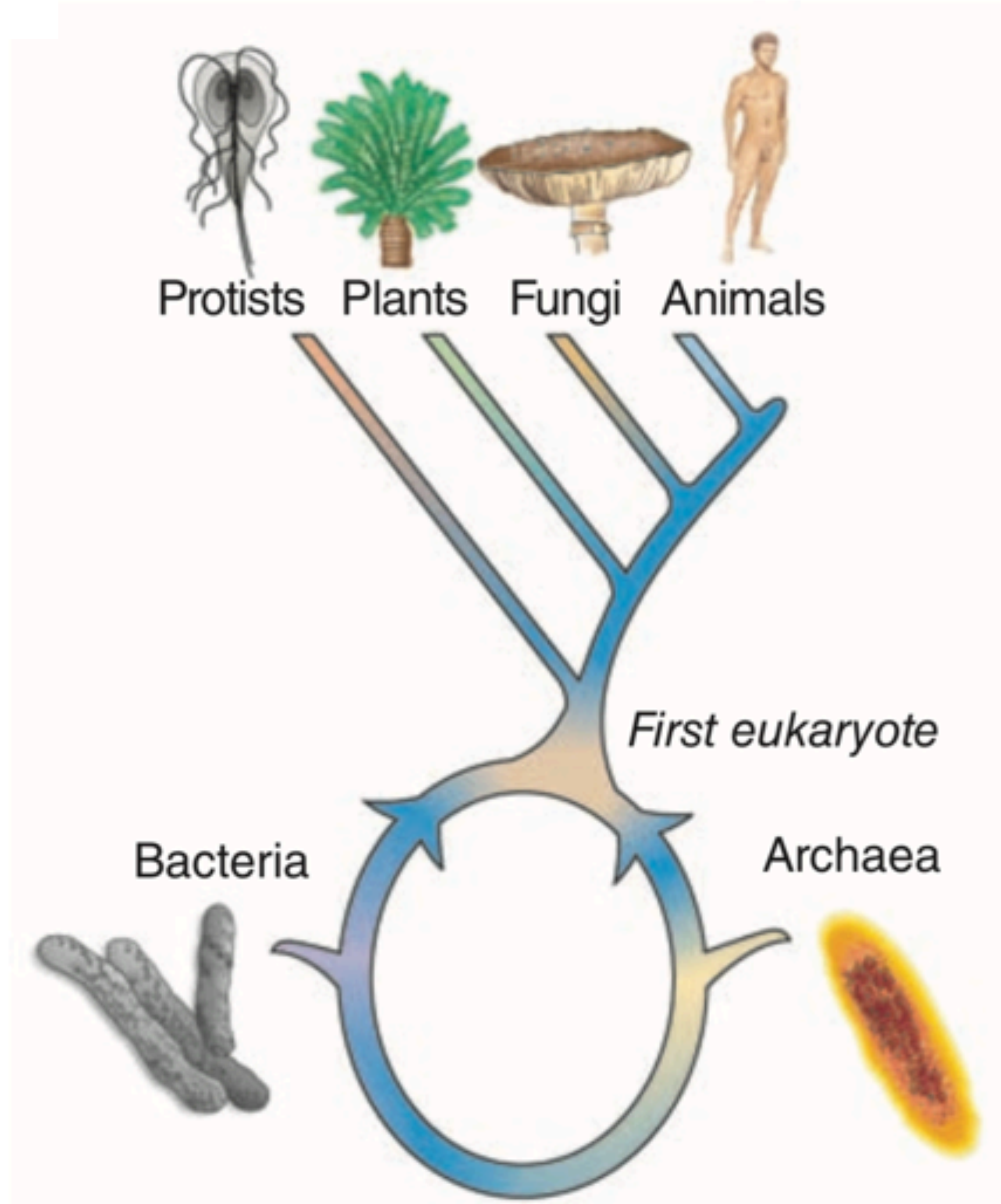
FIGURE 23-3 The tree of life, a work in progress
Some major branches of each of the three domains are shown. As new data are analyzed, the relationships of some of the branches will change.

Systematists continue to consider other hypotheses



(a) The three-domain approach drawn to show horizontal gene transfer as a continuous process between domains and also among groups within each domain. Only some of the branches are labeled. The diagonal brown arrow represents mitochondrial endosymbiosis; the diagonal green arrow represents chloroplast endosymbiosis.

Systematists continue to consider other hypotheses



(b) The ring of life is based on the hypothesis that lateral gene transfer between bacteria and archaea gave rise to the eukaryotes.

23.3 RECONSTRUCTING EVOLUTIONARY HISTORY

LEARNING OBJECTIVES

5 Critically review the difficulties encountered in choosing taxonomic criteria.

6 Apply the concept of shared derived characters to the classification of organisms.

7 Describe how analyses of molecular homologies contribute to the science of systematics.

8 Contrast monophyletic, paraphyletic, and polyphyletic taxa.

Modern taxonomy is based on evolution.

The goal is to reconstruct **phylogeny** (literally, "production of phyla"),

the evolutionary history of a group of organisms from a common ancestor.

As systematists determine evolutionary relationships among species and between species and higher taxa,

they build classifications based on common ancestry.

Homologous structures are important in determining evolutionary relationships

FIGURE 23-5 Is this animal a bird?
A few mammals, such as the duck-billed platypus, lay eggs, have beaks, and lack teeth. However, the platypus does not have feathers, and it nourishes its young with milk secreted from mammary glands.

Shared derived characters provide clues about phylogeny

Determining which traits best illustrate evolutionary relationships can be challenging.

Biologists carefully choose taxonomic criteria

What are the most important taxonomic characteristics of a bird?

feathers, beak, wings, absence of teeth, egg laying, and *endothermy*.

No mammal, however, has feathers.

The presence or absence of feathers determines what is and is not a bird.

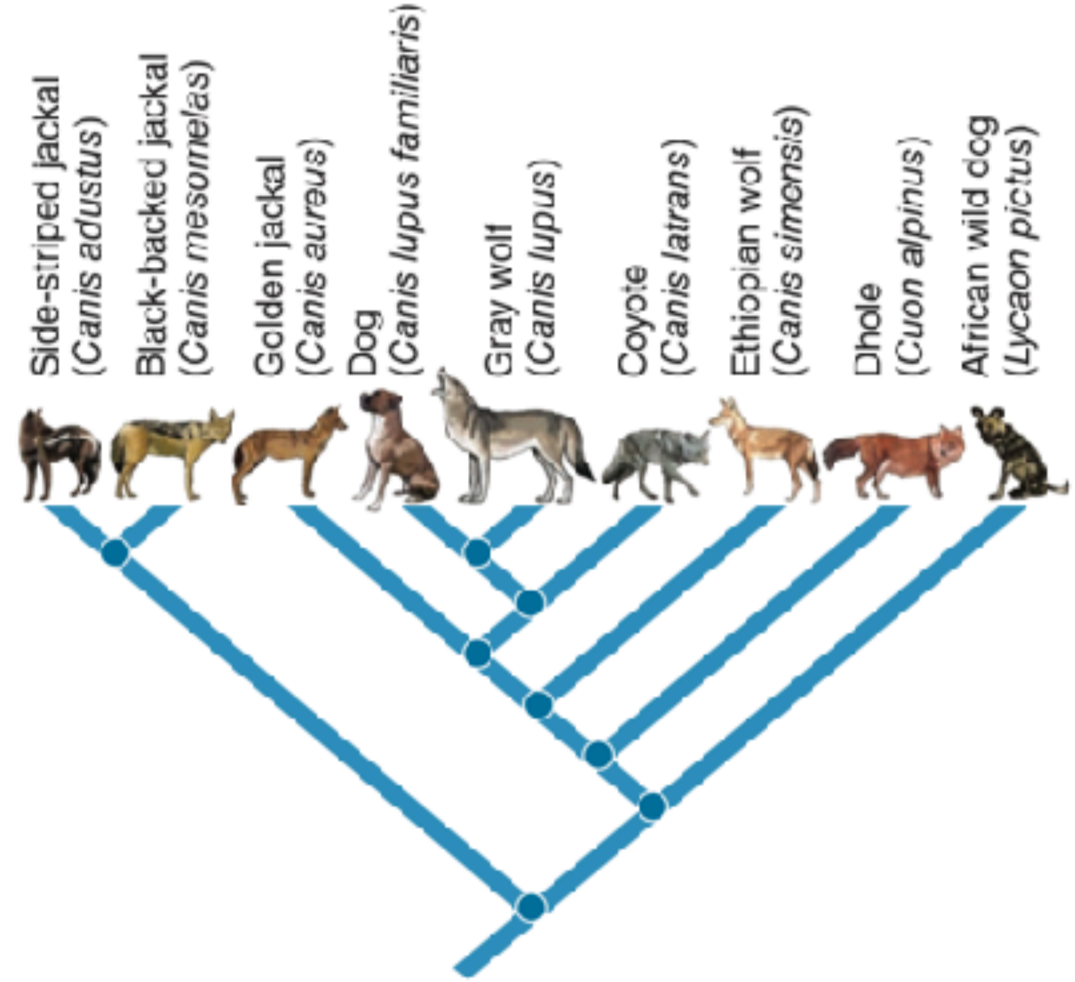
The science of **molecular systematics** focuses on molecular structure to clarify evolutionary relationships.

In 2003, scientists at the University of Guelph in Canada proposed :

we identify all living things by

their unique sequences of DNA or RNA,

rather than by their physical structure.



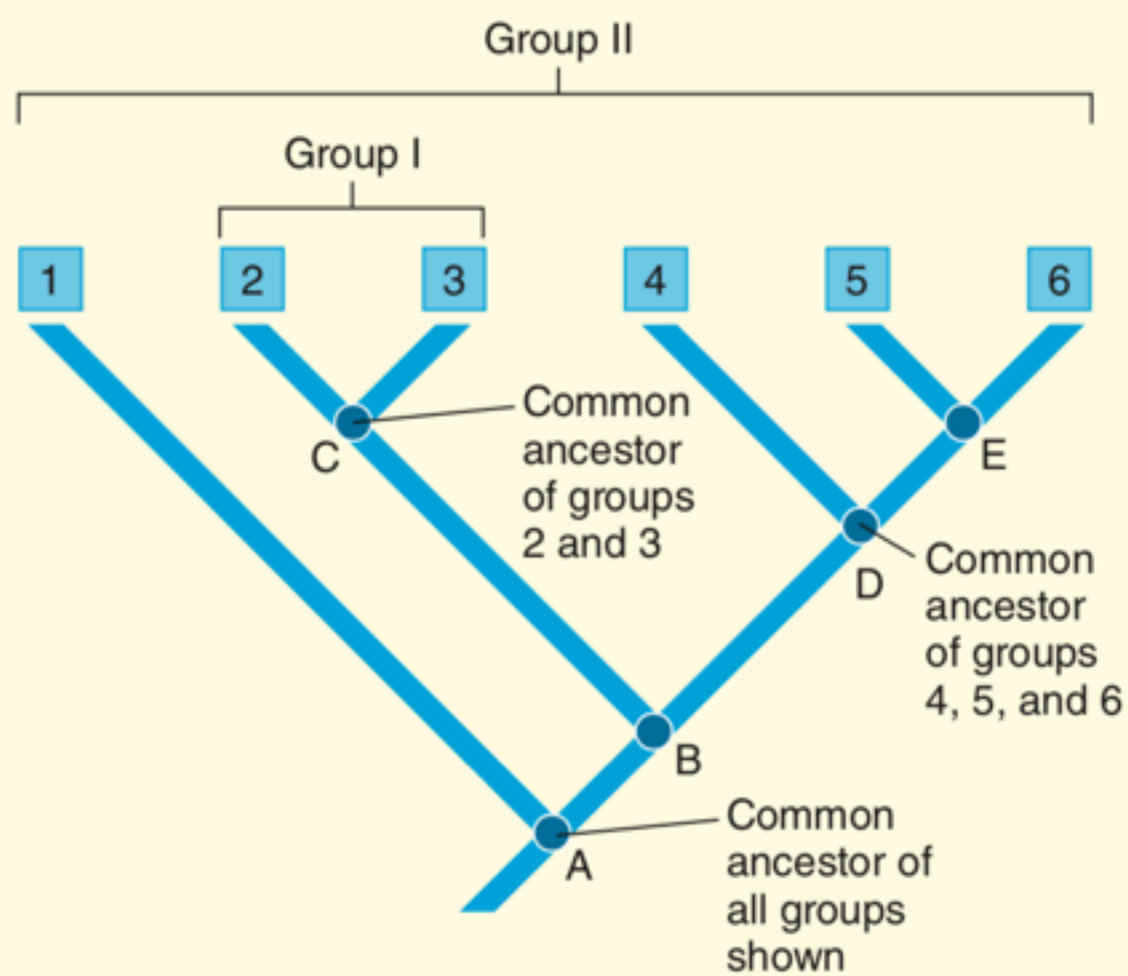
RESULTS AND CONCLUSION: Analysis of the comparisons of exon and intron nucleotide sequences allowed these researchers to build a cladogram of Canidae species. The data indicated that the dog is most closely related to the gray wolf. (Sequence divergence of nuclear exon and intron sequences is 0.04% and 0.21, respectively.) The two African jackals (branch at left) are the sister group of this clade, suggesting an African origin for the canids.

Lindblad-Toh, K., et al. "Genome Sequence, Comparative Analysis and Haplotype Structure of the Domestic Dog." *Nature*, Vol. 438, Dec. 8, 2005.

FIGURE 23-6 Molecular phylogeny

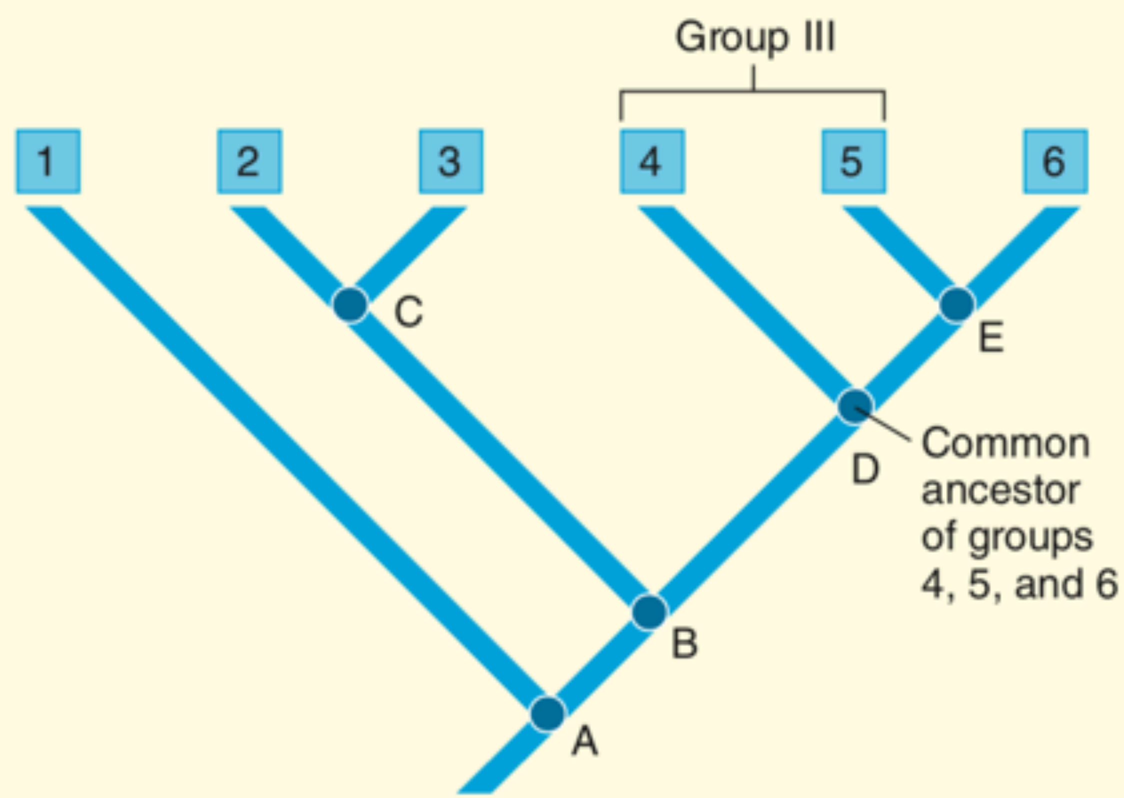
The molecular sequence selected can be used as a genetic marker, or **barcode,** to identify organisms,

Groups of organisms can be described as monophyletic, paraphyletic, or polyphyletic. Only monophyletic groups are considered clades.



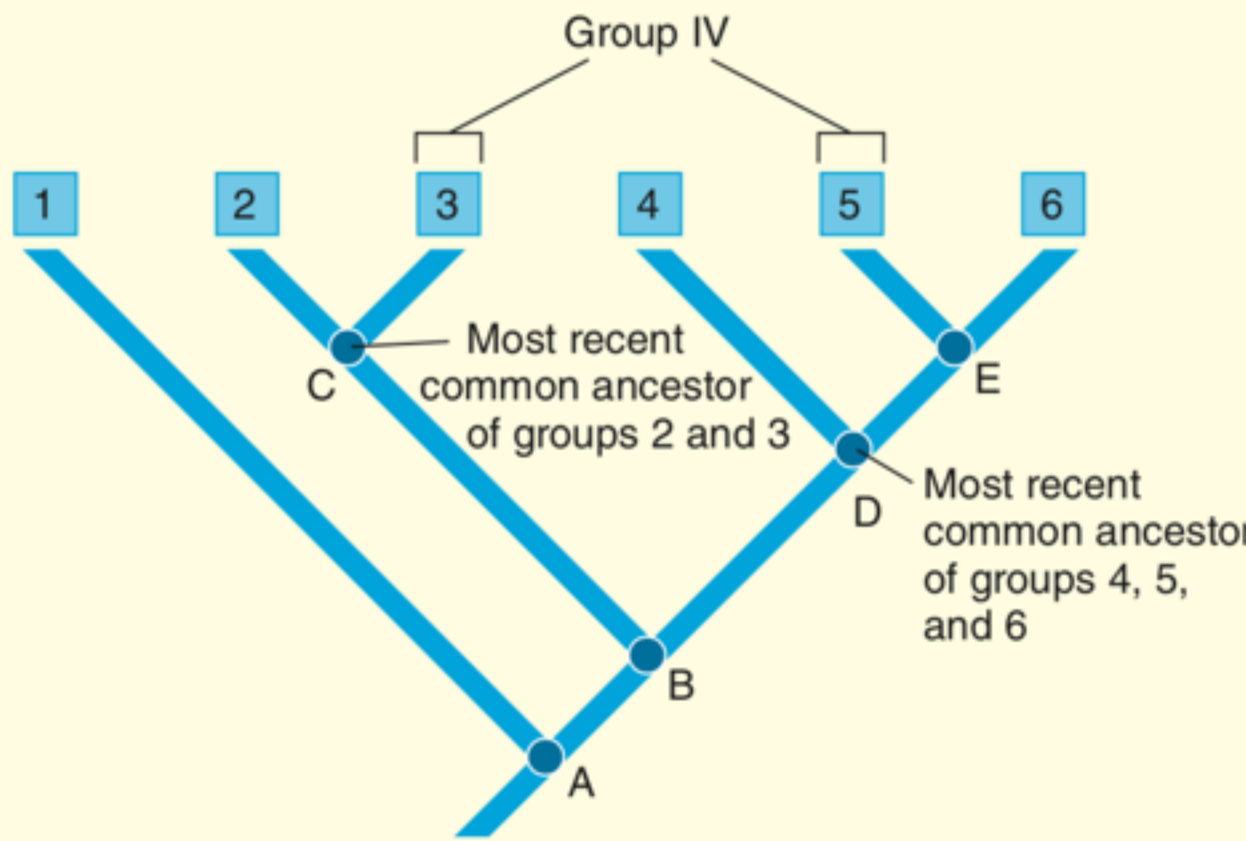
(a) Group I and group II are monophyletic groups, or clades. Each includes a common ancestor and all its descendants.

Groups of organisms can be described as monophyletic, paraphyletic, or polyphyletic. Only monophyletic groups are considered clades.



(b) Group III is paraphyletic. It includes some, but not all of the descendants of the recent common ancestor indicated at node D.

Groups of organisms can be described as monophyletic, paraphyletic, or polyphyletic. Only monophyletic groups are considered clades.



(c) Group IV is polyphyletic. Members of this group do not share the same recent common ancestor.

23.4 CONSTRUCTING PHYLOGENETIC TREES

Cladistics (also known as *phylogenetic systematics*)

is an approach in which organisms are classified based on recent common ancestry

The first step in constructing a cladogram

select the taxa,

The next step is to select the homologous characters to be analyzed.

The last, and often the most difficult,

step in preparing the data is to organize the character states into their correct evolutionary order.

outgroup analysis

Outgroup analysis is used in constructing and interpreting cladograms

In our example, the **lancelet**, a small marine chordate with a fishlike appearance, is **the chosen outgroup**.

A = Absent

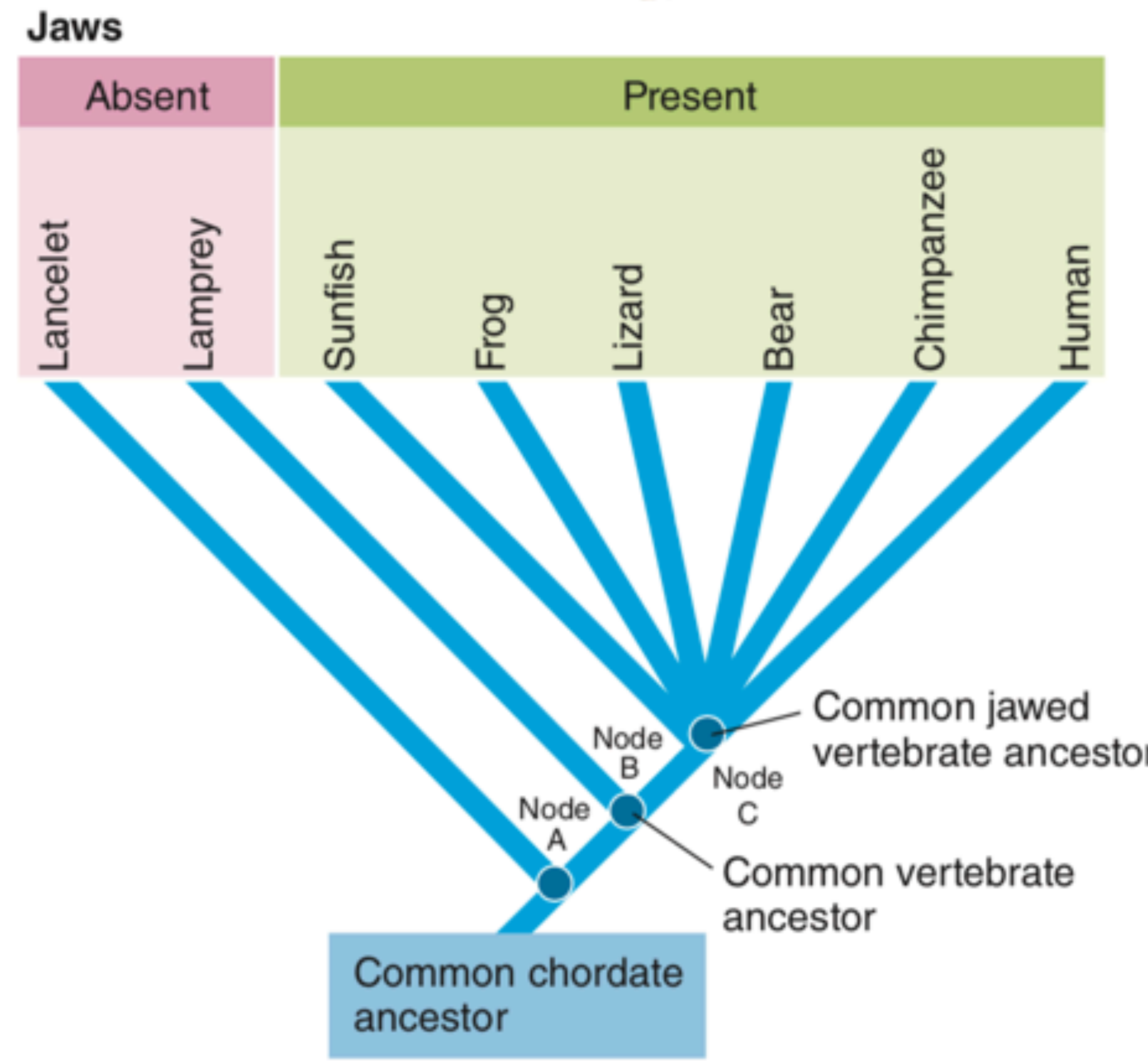
P = Present

TAXA	Vertebrae (backbones)	Jaws	Tetrapod (4 limbs)	Amniotic egg	Mammary glands	Opposable thumb	Upright posture
Lancelet (outgroup)	A	A	A	A	A	A	A
Lamprey	P	A	A	A	A	A	A
Sunfish	P	P	A	A	A	A	A
Frog	P	P	P	A	A	A	A
Lizard	P	P	P	P	A	A	A
Bear	P	P	P	P	P	A	A
Chimpanzee	P	P	P	P	P	P	A
Human	P	P	P	P	P	P	P

A = Absent

P = Present

TAXA	Vertebrae (backbones)	Jaws	Tetrapod (4 limbs)	Amniotic egg	Mammary glands	Opposable thumb	Upright posture
Lancelet (outgroup)	A	A	A	A	A	A	A
Lamprey	P	A	A	A	A	A	A
Sunfish	P	P	A	A	A	A	A
Frog	P	P	P	A	A	A	A
Lizard	P	P	P	P	A	A	A
Bear	P	P	P	P	P	A	A
Chimpanzee	P	P	P	P	P	P	A
Human	P	P	P	P	P	P	P

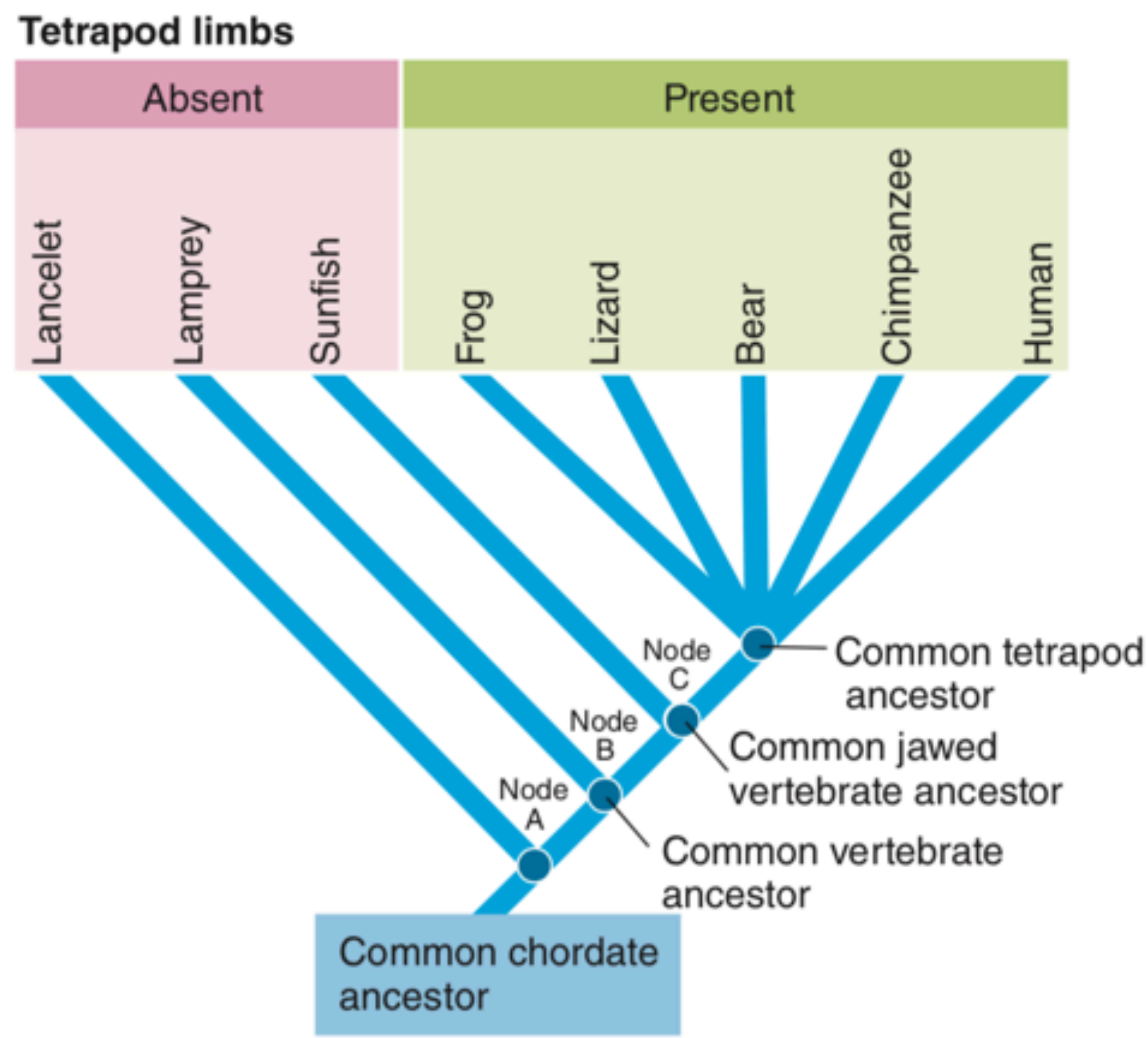


(a) All of the seven vertebrate taxa shown here have jaws, except the lamprey. Jaws are a shared derived character for these six taxa.

A = Absent

P = Present

TAXA	CHARACTERS						
	Vertebrae (backbones)	Jaws	Tetrapod (4 limbs)	Amniotic egg	Mammary glands	Opposable thumb	Upright posture
Lancelet (outgroup)	A	A	A	A	A	A	A
Lamprey	P	A	A	A	A	A	A
Sunfish	P	P	A	A	A	A	A
Frog	P	P	P	A	A	A	A
Lizard	P	P	P	P	A	A	A
Bear	P	P	P	P	P	A	A
Chimpanzee	P	P	P	P	P	P	A
Human	P	P	P	P	P	P	P



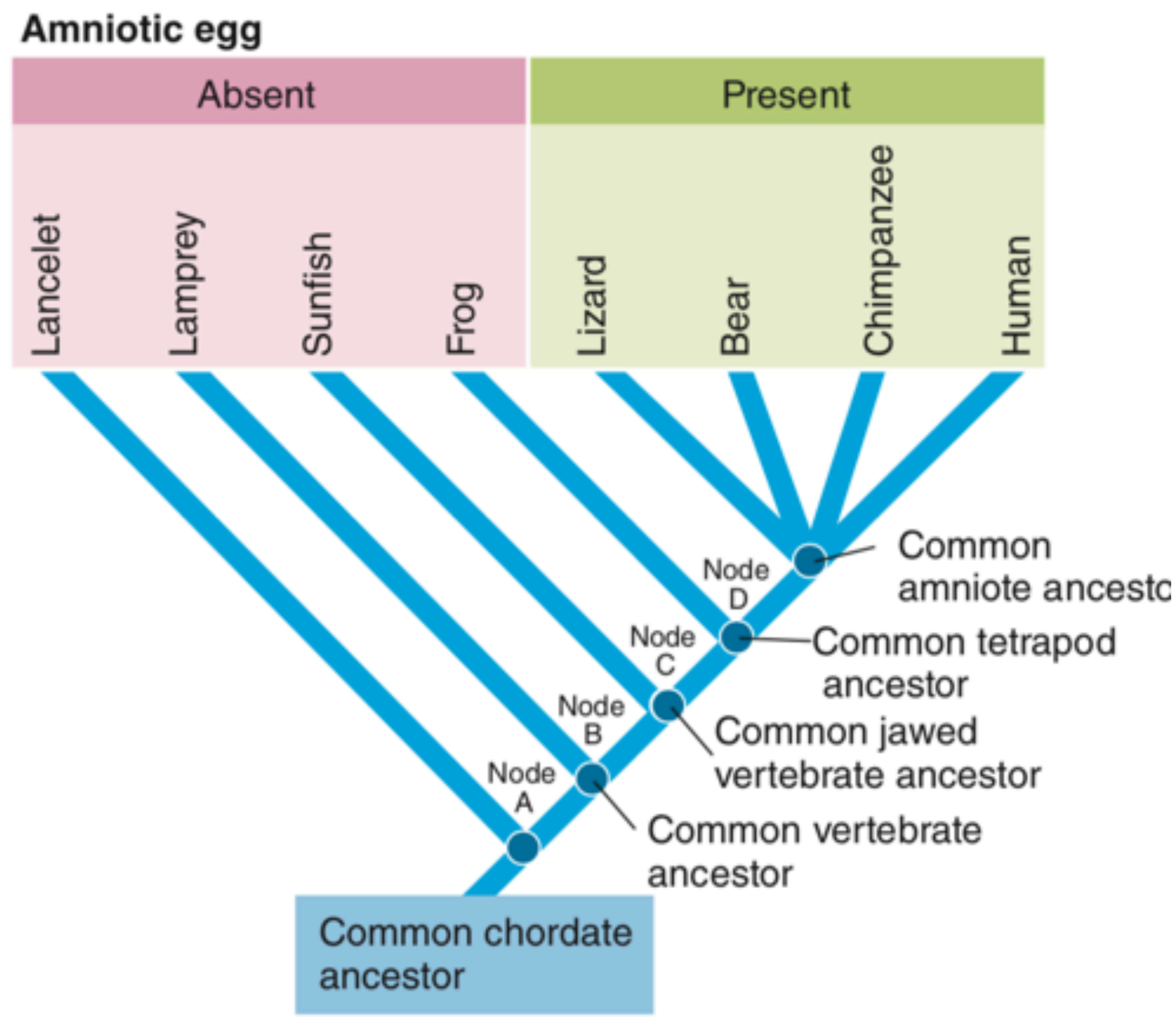
(b) Tetrapod limbs are a shared derived character for all vertebrate taxa shown here except the lamprey and sunfish.

A = Absent

P = Present

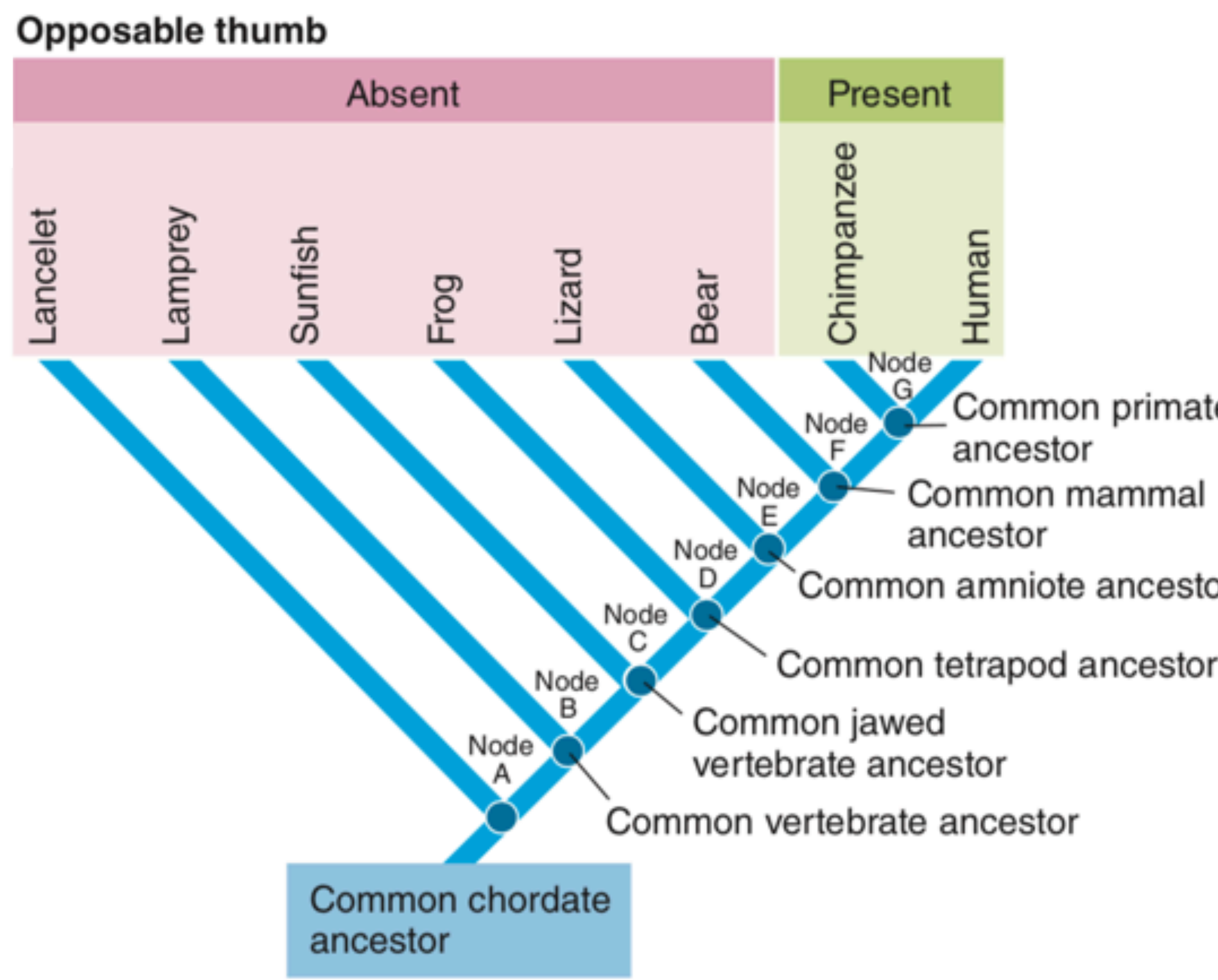
TAXA	Vertebrae (backbones)	Jaws	Tetrapod (4 limbs)	Amniotic egg	Mammary glands	Opposable thumb	Upright posture
Lancelet (outgroup)	A	A	A	A	A	A	A
Lamprey	P	A	A	A	A	A	A
Sunfish	P	P	A	A	A	A	A
Frog	P	P	P	A	A	A	A
Lizard	P	P	P	P	A	A	A
Bear	P	P	P	P	P	A	A
Chimpanzee	P	P	P	P	P	P	A
Human	P	P	P	P	P	P	P

CHARACTERS



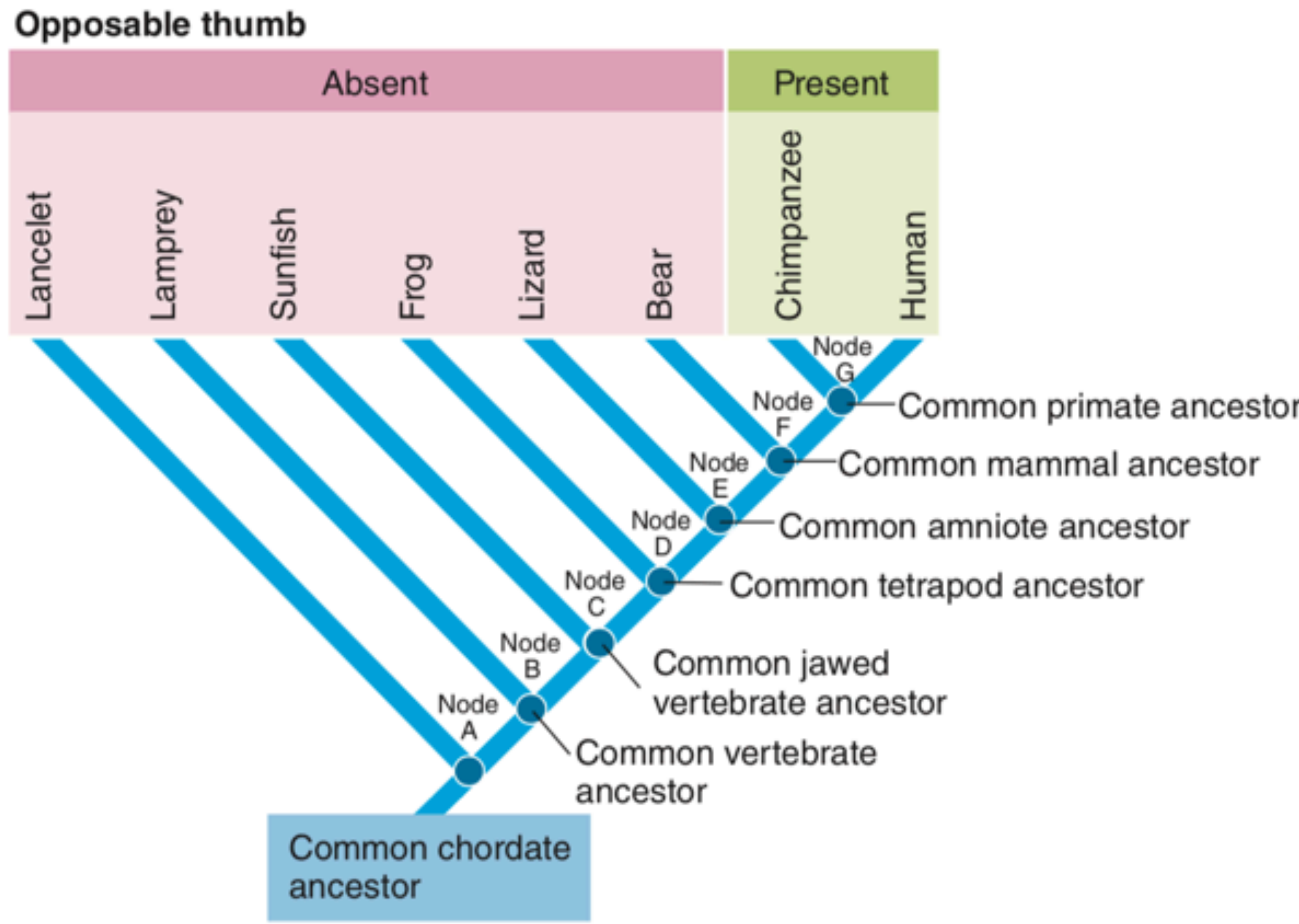
(c) The taxa represented by lizard, bear, chimpanzee, and human are amniotes. They share the derived character amniotic egg.

A = Absent; P = Present — TAXA	Vertebrae (backbones)	Jaws	Tetrapod (4 limbs)	Amniotic egg	Mammary glands	Opposable thumb	Upright posture
	CHARACTERS						
Lancelet (outgroup)	A	A	A	A	A	A	A
Lamprey	P	A	A	A	A	A	A
Sunfish	P	P	A	A	A	A	A
Frog	P	P	P	A	A	A	A
Lizard	P	P	P	P	A	A	A
Bear	P	P	P	P	P	A	A
Chimpanzee	P	P	P	P	P	P	A
Human	P	P	P	P	P	P	P



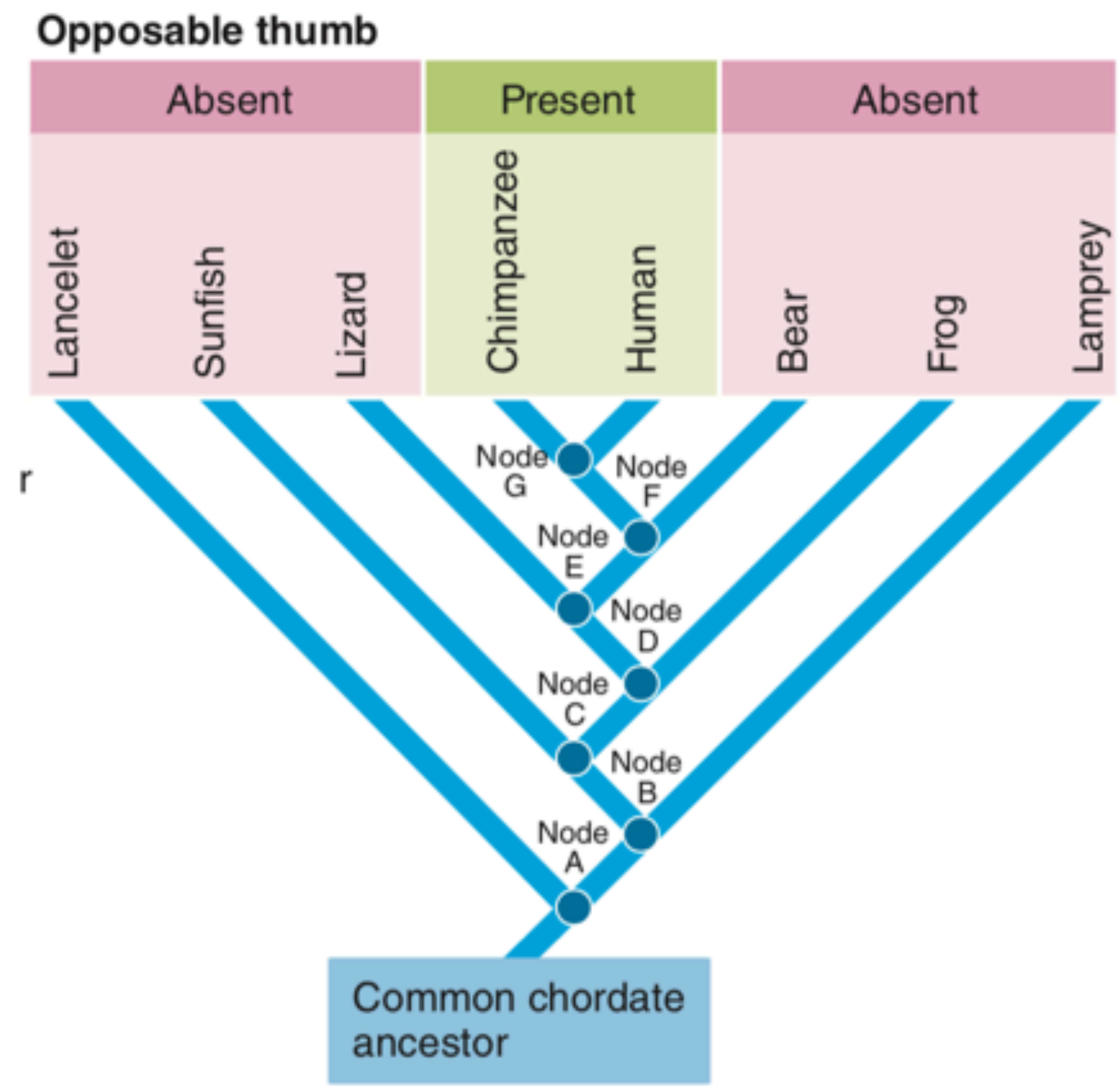
(d) Of the vertebrate taxa shown here, only the chimpanzee and human share the derived character opposable thumb.

FIGURE 23-10 Cladogram styles



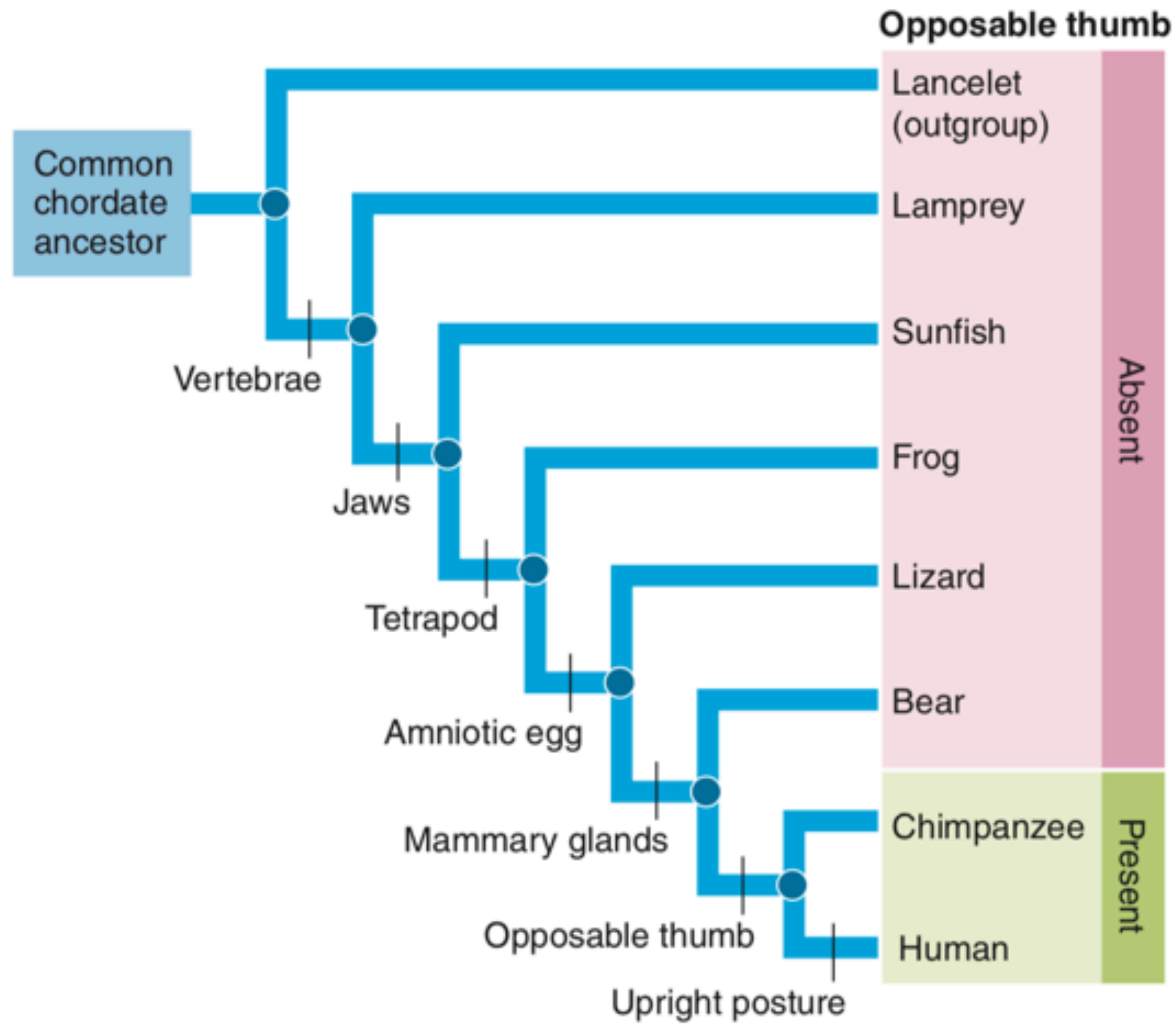
(a) This cladogram, the style used in this book, has diagonal branches.

FIGURE 23-10 Cladogram styles



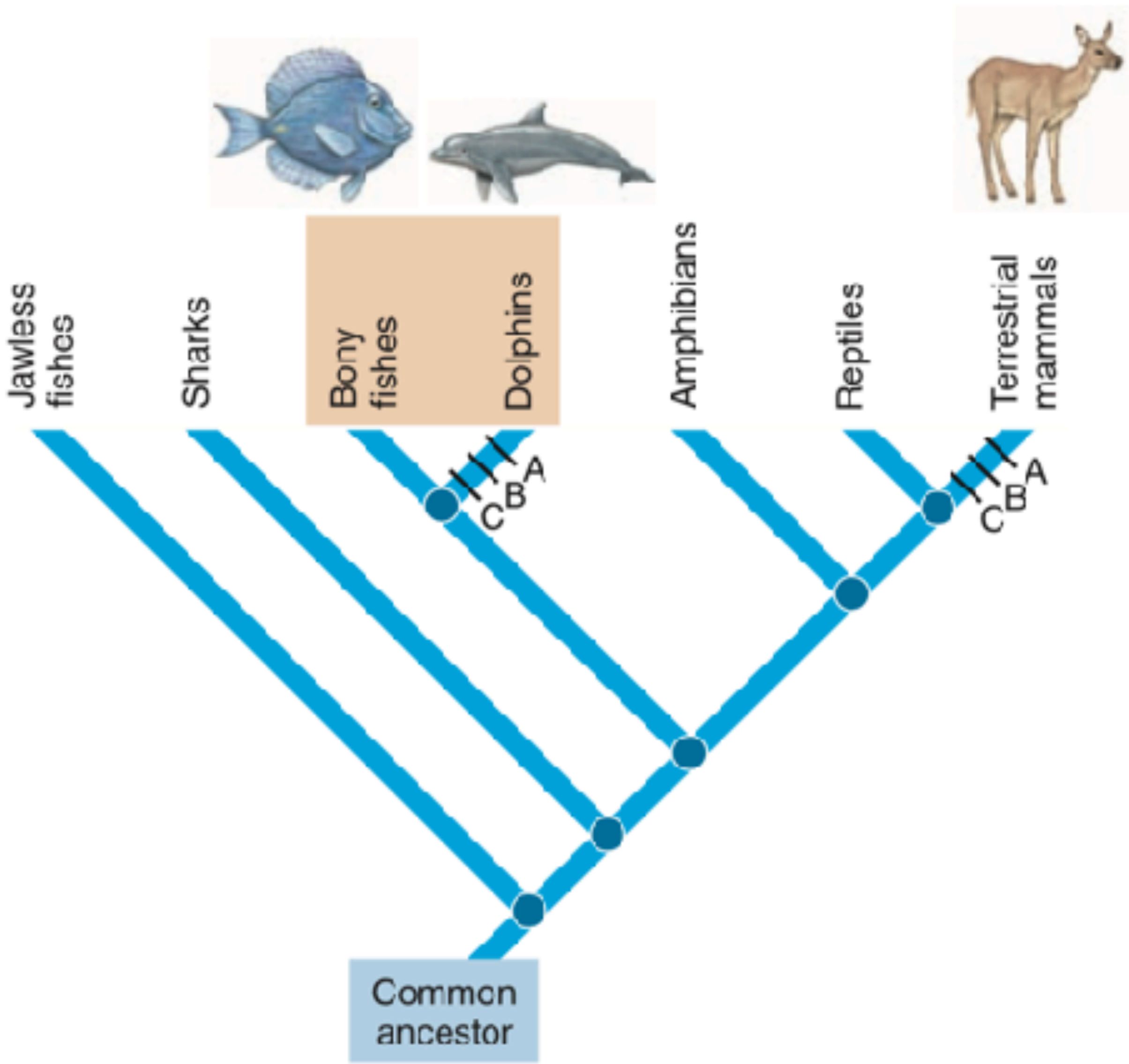
(b) This is another way to depict the same relationships shown in (a).

FIGURE 23-10 Cladogram styles

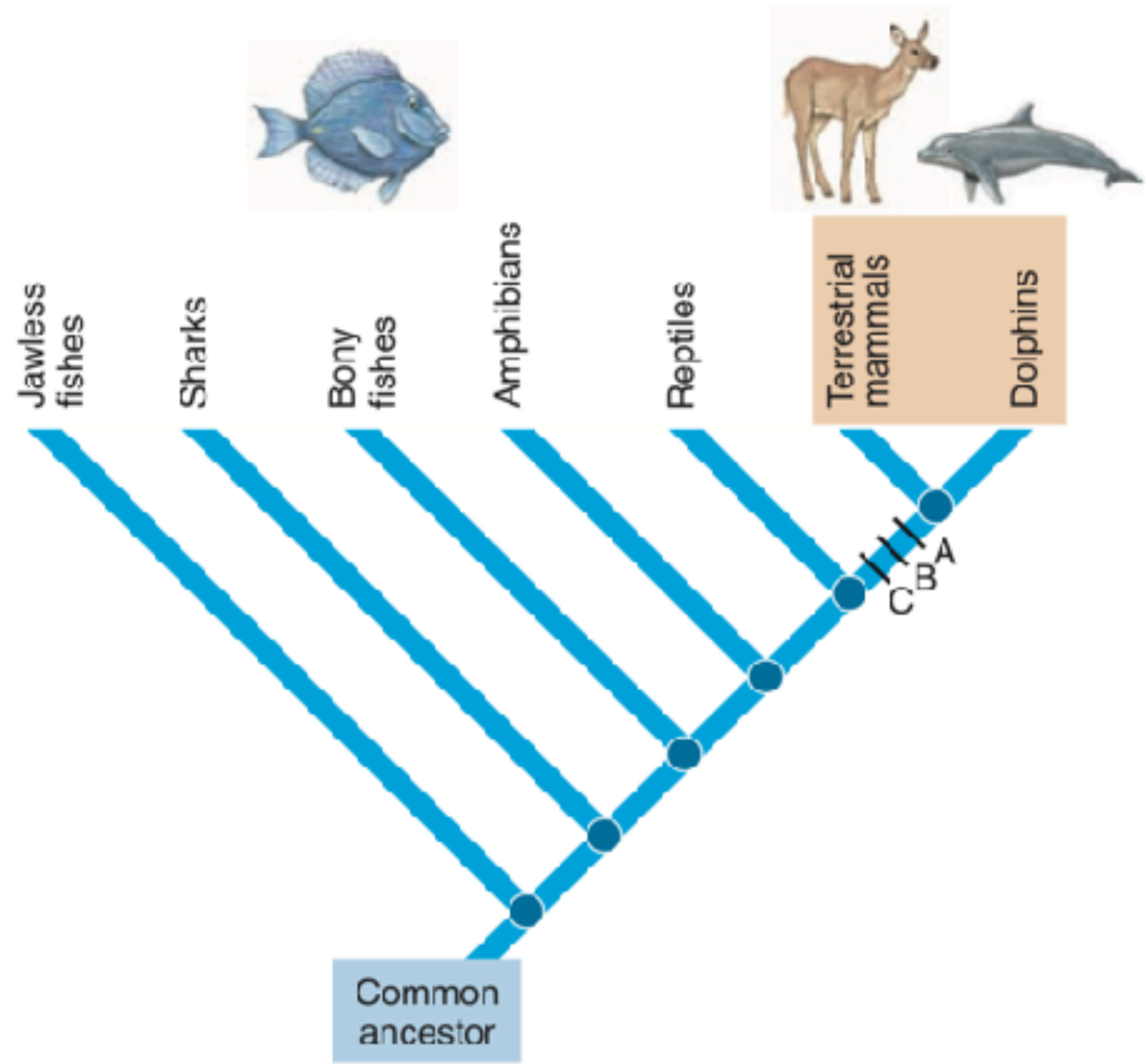


(c) This cladogram has rectangular branches and is rotated 90 degrees. However, it illustrates the same relationships as the cladograms in (a) and (b).

Systematists use the principles of parsimony and maximum likelihood to make decisions



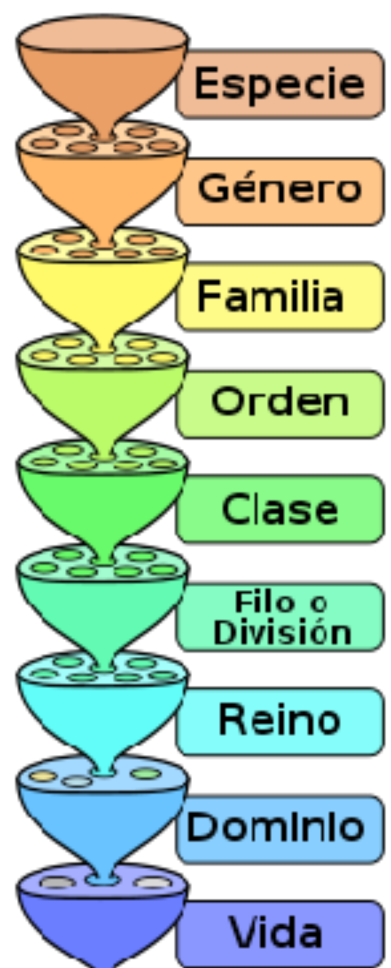
(a) Hypothesis 1: Dolphins and bony fishes are close relatives.



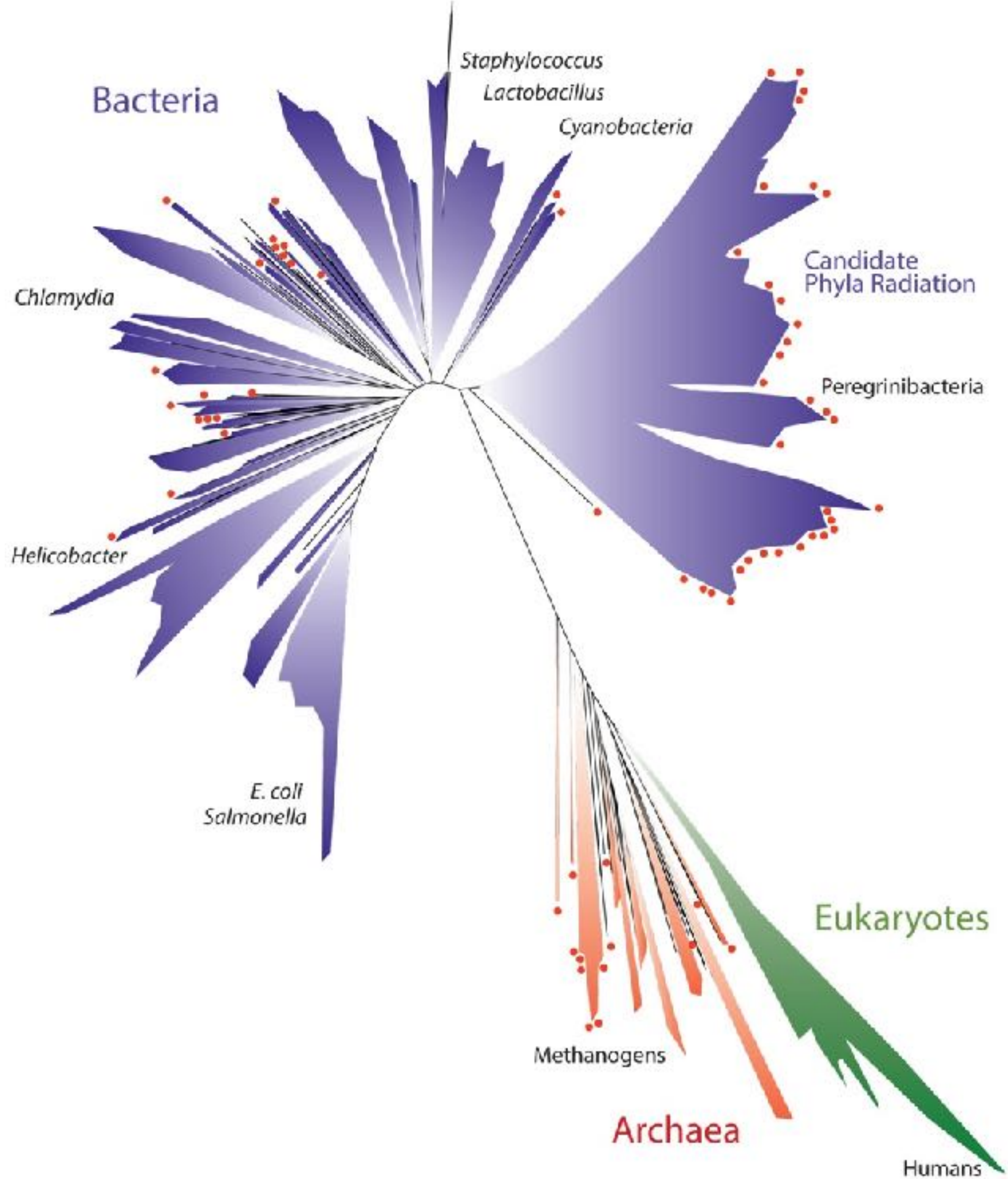
(b) Hypothesis 2: Dolphins and terrestrial mammals are close relatives.

La taxonomía ha cambiado en el tiempo...

Linnaeus 1735[27]	Haeckel 1866[28]	Chatton 1925[29][30]	Copeland 1938[31][32]	Whittaker 1969[33]	Woese *et al.* 1977[34][35]	Woese *et al.* 1990[36]	Cavalier-Smith 1993[37][38][39]	Cavalier-Smith 1998[40][41][42]	Ruggiero *et al.* 2015[43]
2 kingdoms	3 kingdoms	2 empires	4 kingdoms	5 kingdoms	6 kingdoms	3 domains	8 kingdoms	6 kingdoms	7 kingdoms
(not treated)	Protista	Prokaryota	Monera	Monera	Eubacteria	Bacteria	Eubacteria	Bacteria	Bacteria
					Archaebacteria	Archaea	Archaebacteria		Archaea
		Eukaryota	Protista	Protista	Protista	Eucarya	Archezoa	Protozoa	Protozoa
							Protozoa		
							Chromista	Chromista	Chromista
Vegetabilia	Plantae		Plantae	Plantae	Plantae		Plantae	Plantae	Plantae
				Fungi	Fungi		Fungi	Fungi	Fungi
Animalia	Animalia		Animalia	Animalia	Animalia		Animalia	Animalia	Animalia



Candidate Phyla



Gracias