CH 15: Tracing evolutionary history

李承叡
生態學與演化生物學研究所
生命科學館 1129

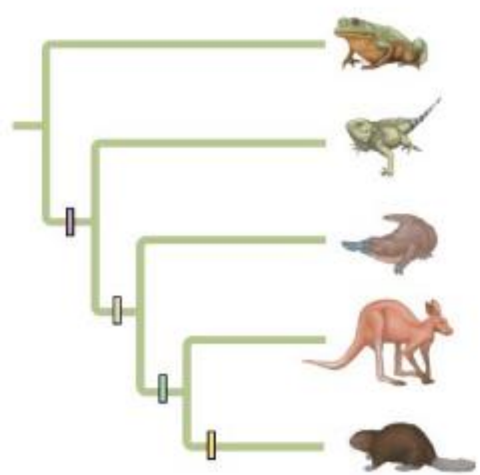
Figure 15.0-2

Chapter 15: Big Ideas

Early Earth and the Origin of Life

Major Events in the History of Life

Mechanisms of Macroevolution



Phylogeny and the Tree of Life

Early Earth and the Origin of Life

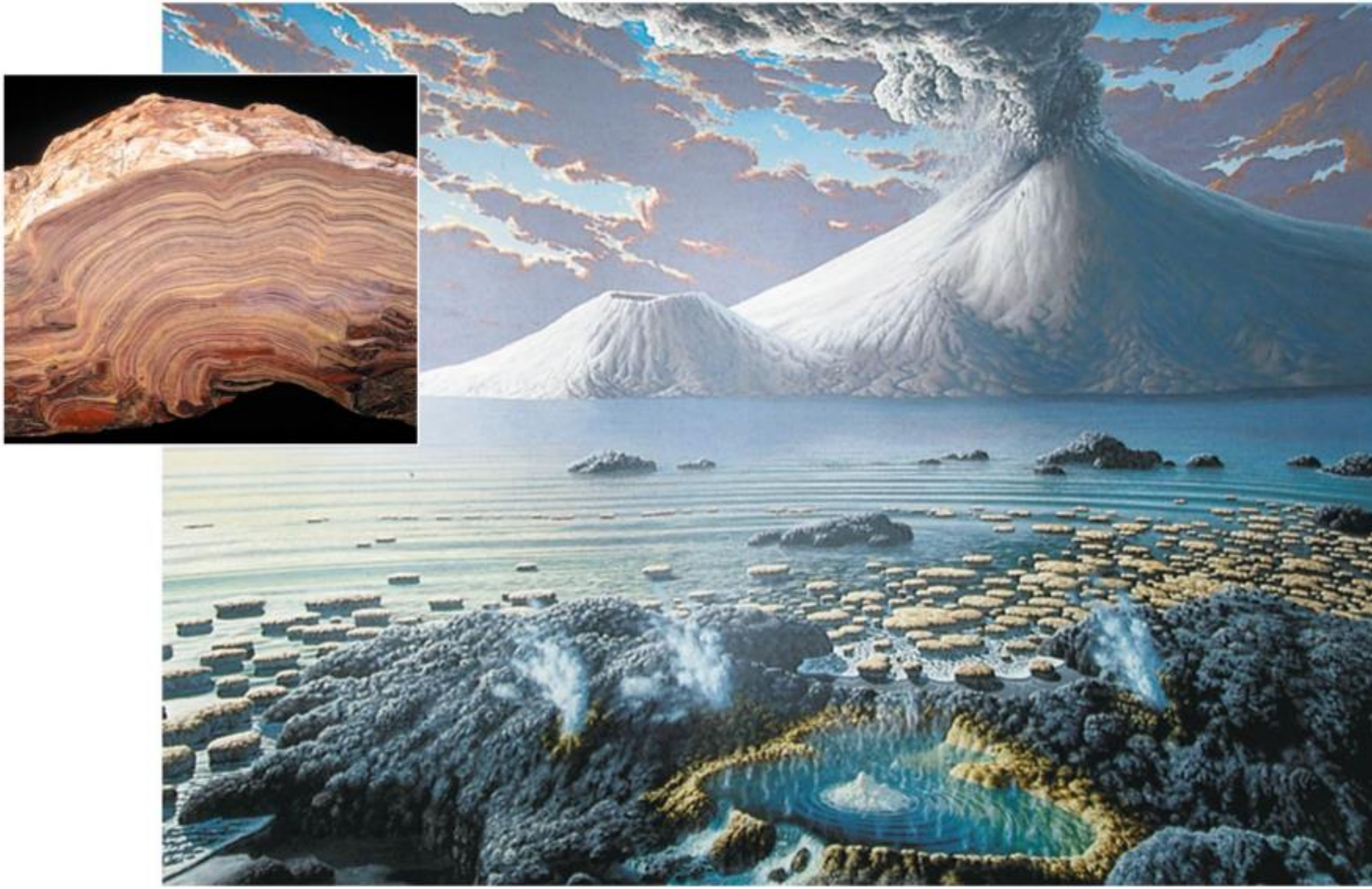
15.1 Conditions on early Earth made the origin of life possible

- The earliest evidence for life on Earth comes from 3.5-billion-year-old fossils

- **Stromatolites (疊層石)**, built by ancient photosynthetic prokaryotes still alive today.

- https://www.youtube.com/watch?v=N-G7IJCkyvg

Figure 15.1-0



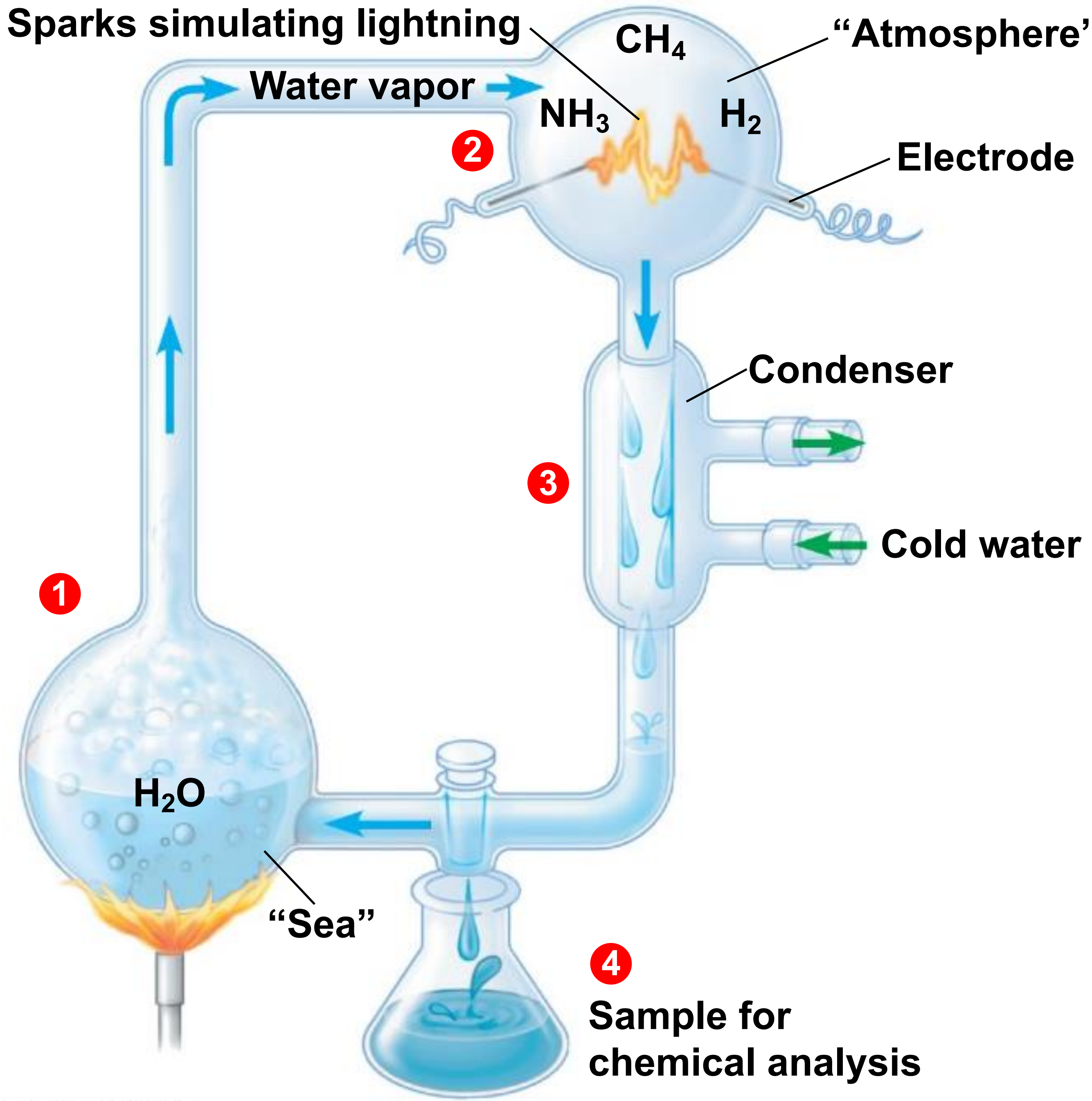
What is life?

- Organic compound that replicates themselves
- Protein
- Polysaccharide
- Lipid
- DNA, RNA
- Polymers, monomers, simple organic compounds

15.1 Conditions on early Earth made the origin of life possible

- The first life may have evolved through four stages.
  1. The abiotic (nonliving) synthesis of small organic molecules, such as amino acids and nitrogenous bases.
  2. The joining of these small molecules into polymers, such as proteins and nucleic acids.
  3. The packaging of these molecules into "protocells," membrane-enclosed droplets that maintained an internal chemistry different from that of their surroundings.
  4. The origin of self-replicating molecules that eventually made inheritance possible.

Figure 15.2



Sparks simulating lightning
CH4
"Atmosphere"
Water vapor
NH3
H2
Electrode
2
Condenser
3
Cold water
1
H2O
"Sea"
4
Sample for chemical analysis

15.2 SCIENTIFIC THINKING: Experiments show that the abiotic synthesis of organic molecules is possible

Hydrothermal vents? From Ed Yong:

https://www.youtube.com/watch?v=8W_ywzhkR90

- Hypotheses about the origins of life include
  - deep-sea environments near submerged volcanoes or hydrothermal vents or
  - meteorites as sources of organic molecules.

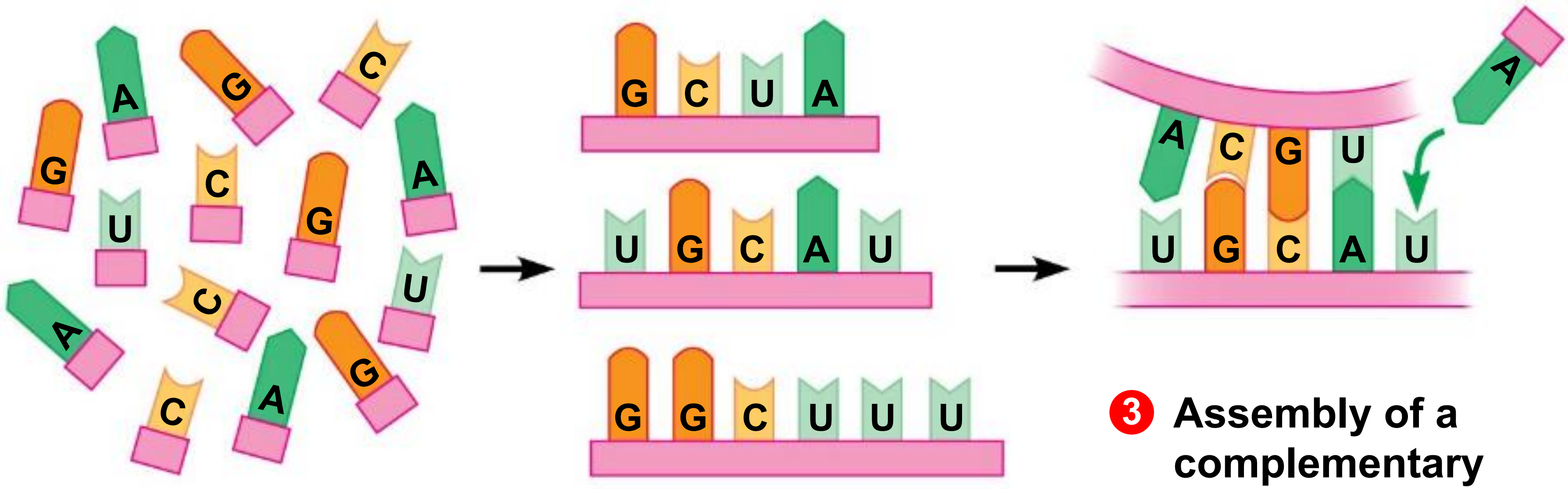
15.3 Stages in the origin of the first cells probably included the formation of polymers, protocells, and self-replicating RNA

- Then what? The isolation of organic molecules within a membrane-enclosed compartment.
  - Laboratory experiments demonstrate that small membrane-bounded sacs or vesicles form when lipids are mixed with water.
  - These abiotically created vesicles are able to grow and divide (reproduce).

15.3 Stages in the origin of the first cells probably included the formation of polymers, protocells, and self-replicating RNA

- The final step? Self-replicating molecules
  - Today's cells transfer genetic information from DNA to RNA to protein assembly. However, RNA molecules can assemble spontaneously from RNA monomers.
  - Furthermore, when RNA is added to a solution containing a supply of RNA monomers, new RNA molecules complementary to parts of the starting RNA sometimes assemble.
  - Some RNA molecules, called **ribozymes**, can carry out enzyme-like functions, supporting this hypothesis.

Figure 15.3b-3



1 Collection of monomers

2 Formation of short RNA polymers: simple "genes"

3 Assembly of a complementary RNA chain, the first step in the replication of the original "gene"

Mechanisms of Macroevolution

Figure 15.7b

15.7 Continental drift has played a major role in macroevolution

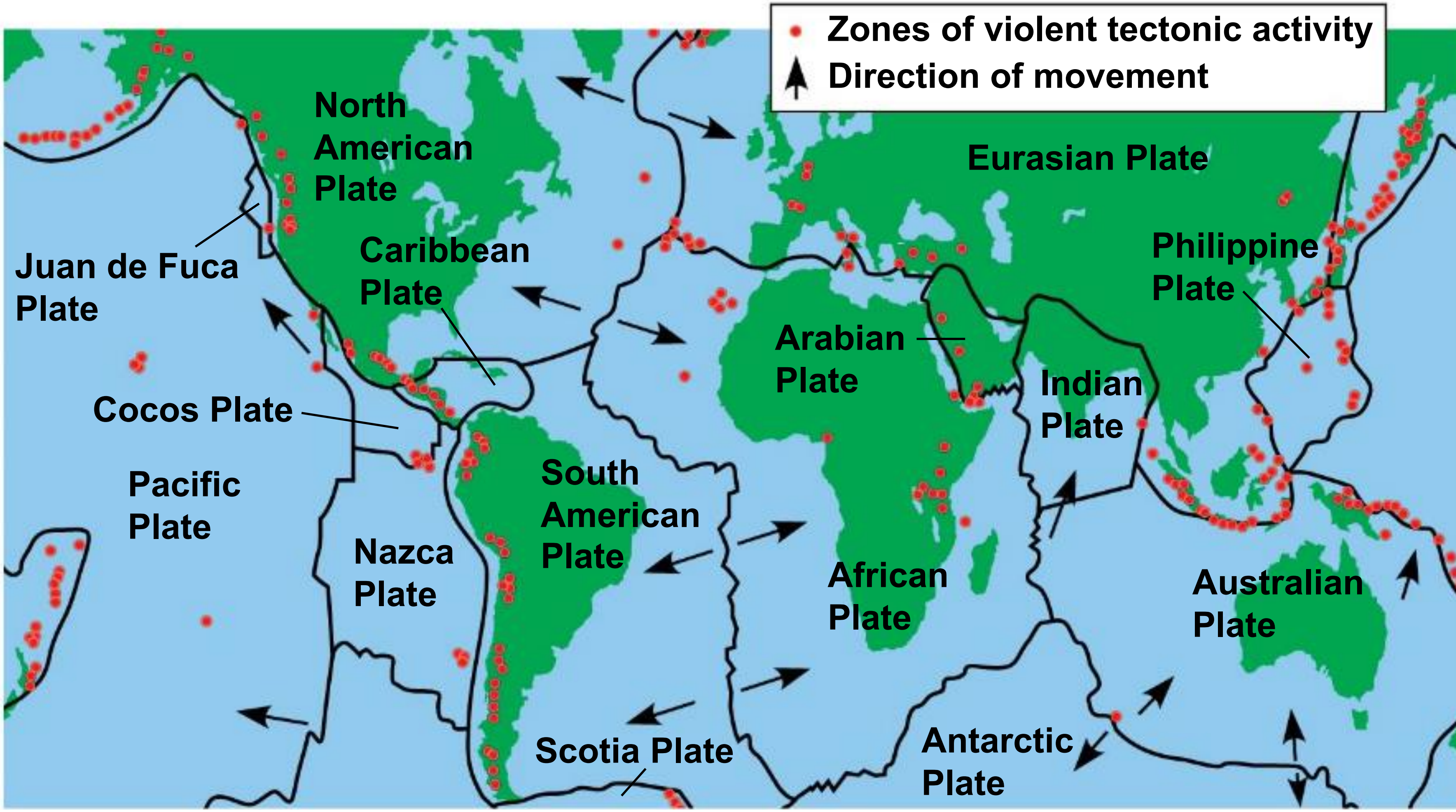
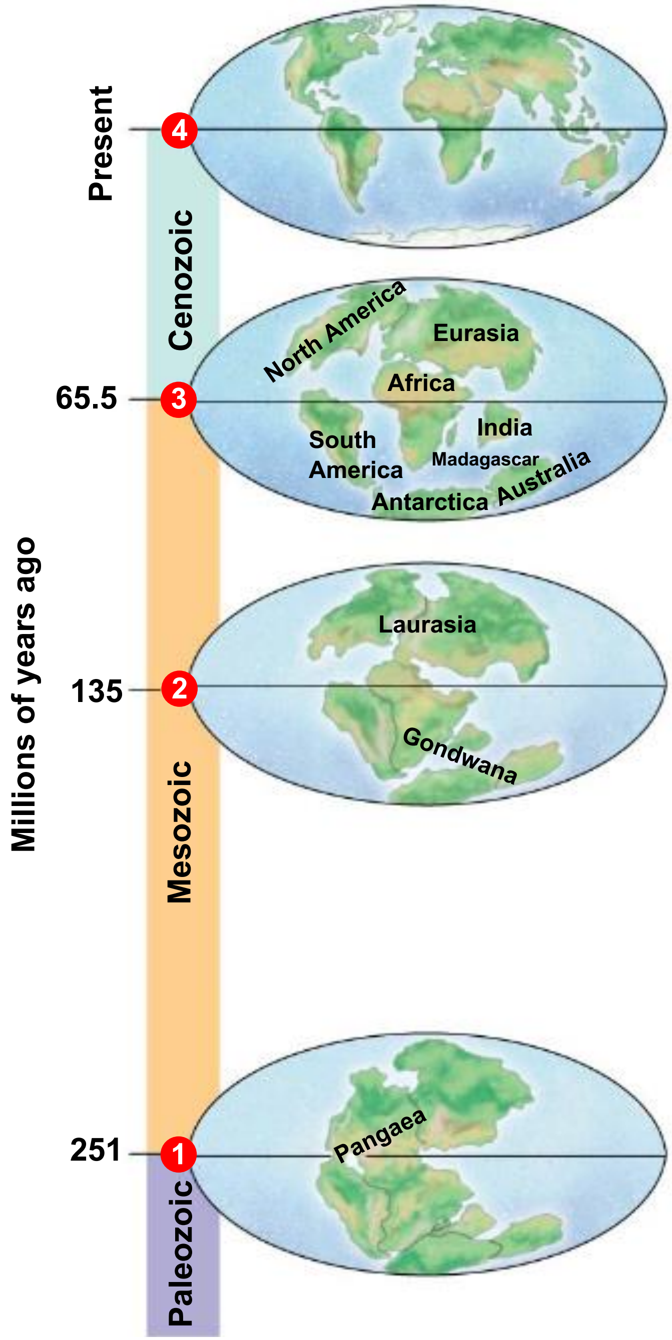


Figure 15.7c-4



15.7 Continental drift has played a major role in macroevolution

- Continental drift solves the mystery of marsupials, mammals whose young complete their embryonic development in a pouch outside the mother's body, such as kangaroos, koalas, and wombats.
- Australia and its neighboring islands are home to more than 200 species of marsupials, most of which are found nowhere else in the world.

Except opossums in South America

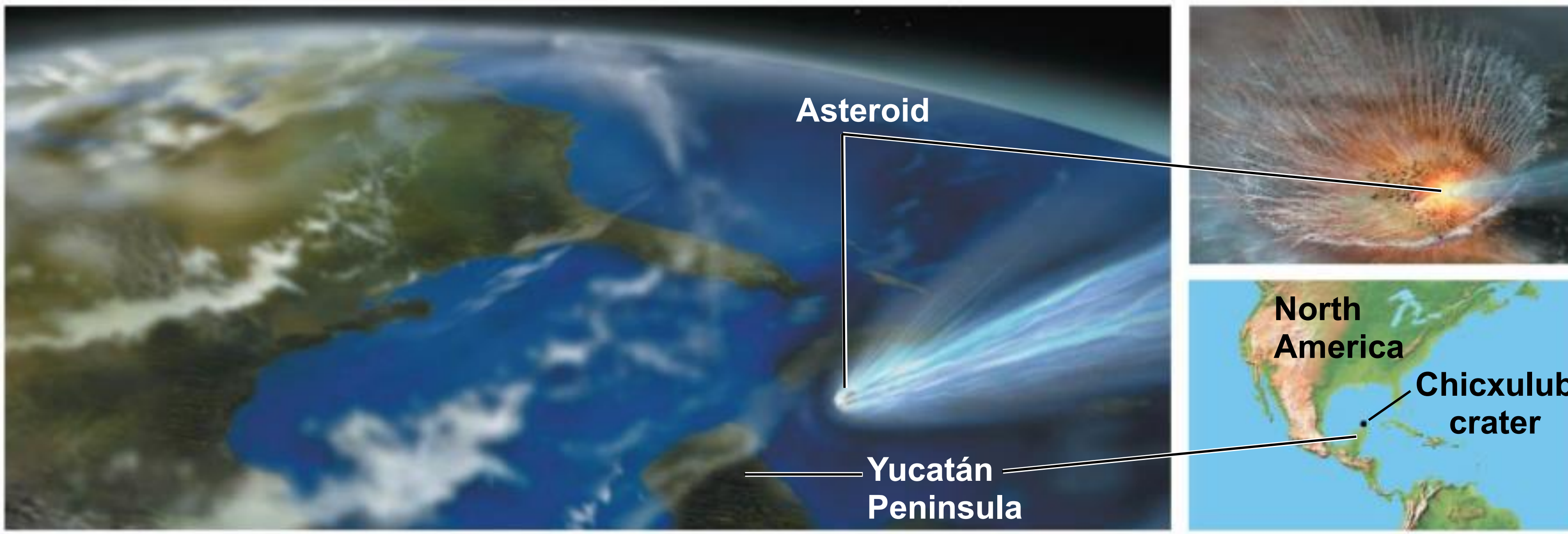
15.9 During mass extinctions, large numbers of species are lost

- The Permian (二疊紀) mass extinction
  - occurred about 251 million years ago,
  - defines the boundary between the Paleozoic and Mesozoic eras,
  - claimed 96% of marine animal species, and
  - took a tremendous toll on terrestrial life.

15.9 During mass extinctions, large numbers of species are lost

- The Cretaceous (白堊紀) mass extinction, about 65 million years ago,
  - caused the loss of more than half of all marine species and many lineages of terrestrial plants and animals,
  - resulted in the extinction of almost all of the dinosaurs except birds, and
  - was likely caused by a large asteroid that struck the Earth, which would have blocked light and severely disturbed the global climate for months.

Figure 15.9-0

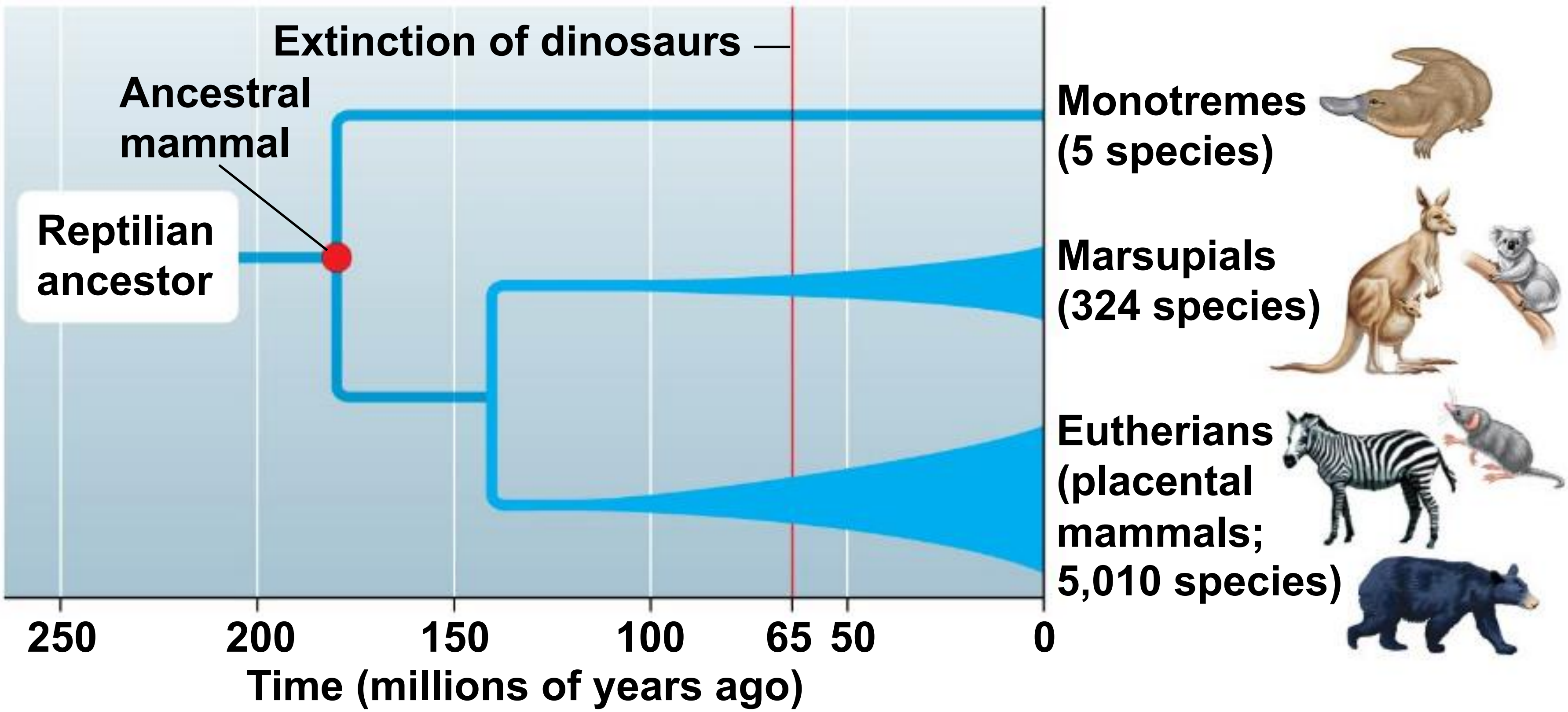


Asteroid
Yucatán Peninsula
North America
Chicxulub crater

15.10 Adaptive radiations have increased the diversity of life

- Adaptive radiations are periods of evolutionary change in which many new species evolve from a common ancestor, often following the colonization of new, unexploited areas.
- Also followed each mass extinction
- Mammals 65 million years ago

Figure 15.10


Extinction of dinosaurs
Ancestral mammal
Reptilian ancestor
Monotremes (5 species)
Marsupials (324 species)
Eutherians (placental mammals; 5,010 species)
250
200
150
100
65
50
0
Time (millions of years ago)

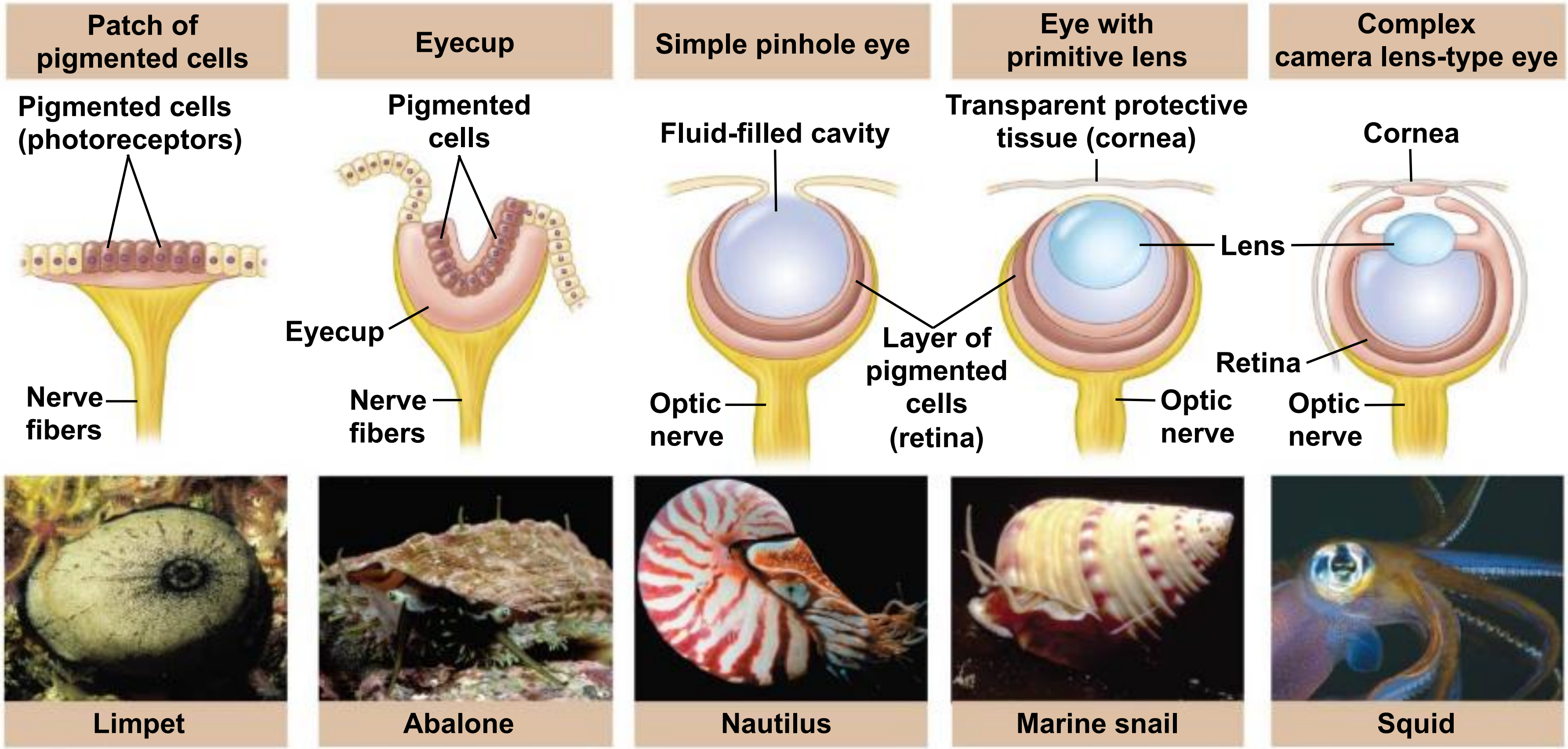
15.11 Genes that control development play a major role in evolution

- Stickleback fish in the ocean have bony plates that make up a kind of body armor and a large set of pelvic spines that help deter predatory fish.
- Stickleback fish in lakes have reduced or absent bony plates and pelvic spines, resulting from a change in the expression of a developmental gene in the pelvic region.

15.12 EVOLUTION CONNECTION: Novel traits may arise in several ways

- Most complex structures have evolved in increments from simpler versions having the same basic function—a process of refinement.
- But sometimes we can trace the origin of evolutionary novelties to the gradual adaptation of existing structures to new functions.
- As an example of the process of gradual refinement, consider the amazing camera-like eyes of vertebrates and squids.

Figure 15.12-0



PHYLOGENY AND THE TREE OF LIFE

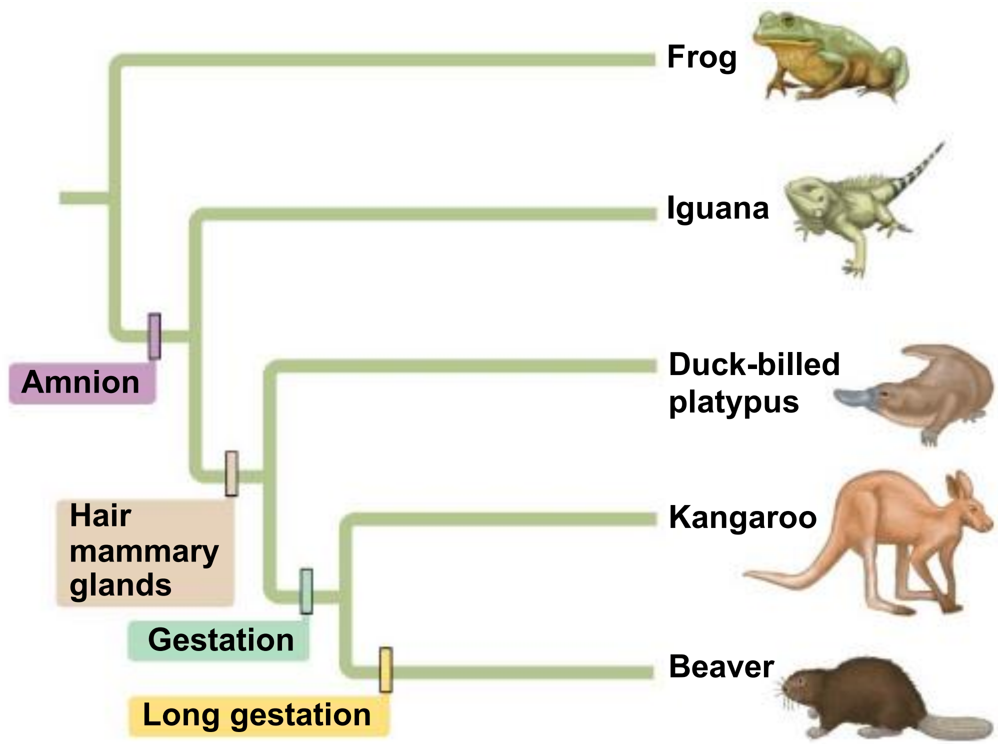
15.14 Phylogenies based on homologies reflect evolutionary history

- Homologies are similarities due to shared ancestry, evolving from the same structure in a common ancestor.
- Generally, organisms that share similar morphologies are closely related.
  - However, some similarities are due to similar adaptations favored by a common environment, a process called **convergent evolution**.
  - A similarity due to convergent evolution is called **analogy**.

Figure 15.16a-0

CHARACTERS \ TAXA	Frog	Iguana	Duck-billed platypus	Kangaroo	Beaver
Amnion	0	1	1	1	1
Hair, mammary glands	0	0	1	1	1
Gestation	0	0	0	1	1
Long gestation	0	0	0	0	1

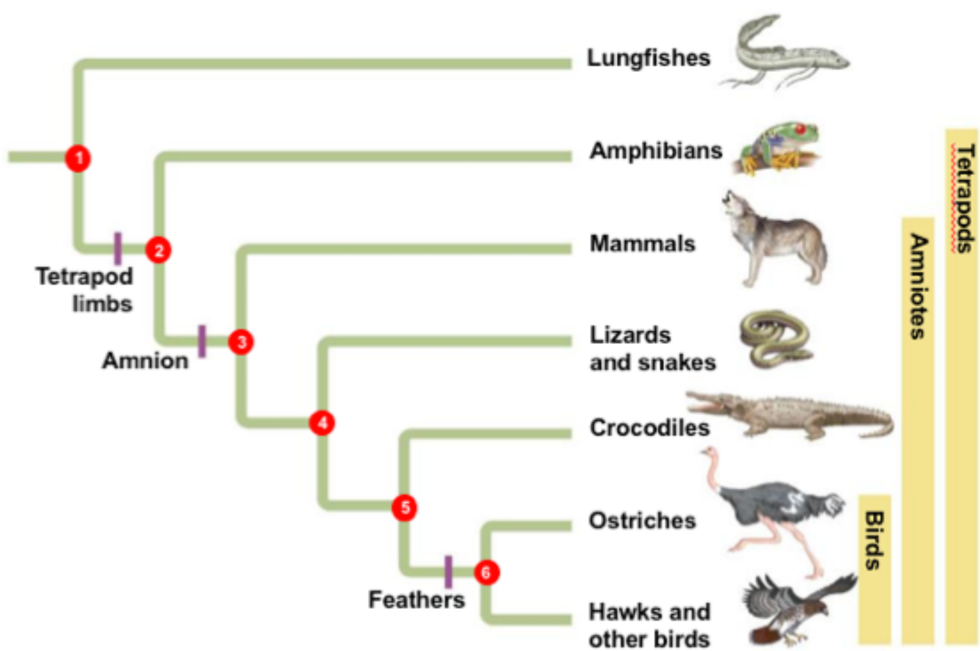
Character Table



Phylogenetic Tree

Monophyletic

- Monophyletic
  - A group of organisms who form a “clade” and consists of ALL descendants of the a common ancestor
- Which is monophyletic, which is not?
  - Bird
  - Reptile



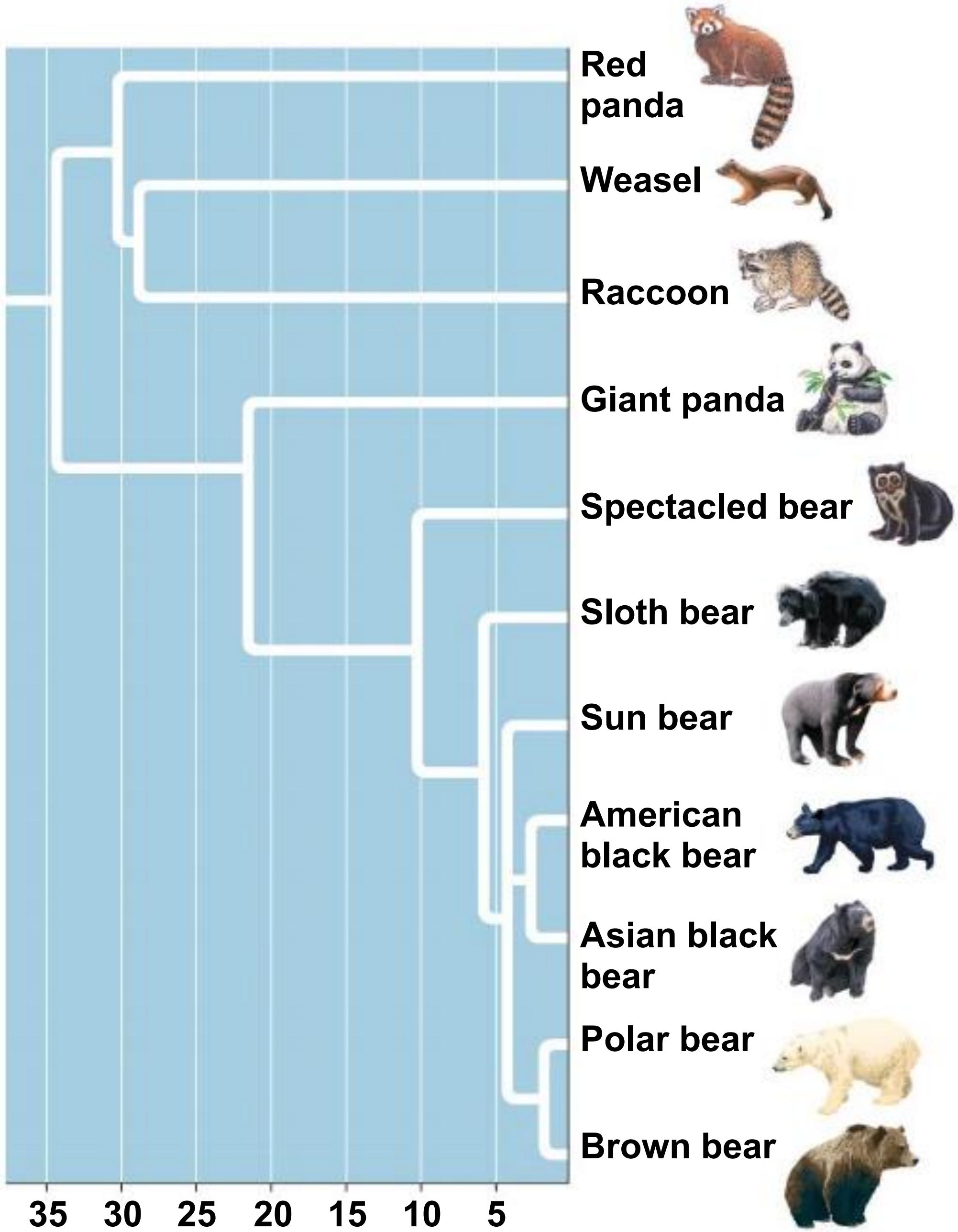
15.17 An organism's evolutionary history is documented in its genome

- **Molecular systematics** uses DNA and other molecules to infer relatedness.
  - Scientists have sequenced more than 110 billion bases of DNA from thousands of species.
  - This enormous database has fueled a boom in the study of phylogeny and clarified many evolutionary relationships.

15.17 An organism's evolutionary history is documented in its genome

- The longer two species have been on separate evolutionary paths, the more their DNA is expected to have diverged.
- Molecular evidence has also begun to sort out the relationships among the species of bears.

Figure 15.17-0



15.18 Molecular clocks help track evolutionary time

- **Molecular clocks**
  - genes that have a reliable average rate of change,
  - can be calibrated in real time by graphing the number of nucleotide differences against the dates of evolutionary branch points known from the fossil record, and
  - can be used to estimate the dates of other evolutionary episodes not documented in the fossil record.

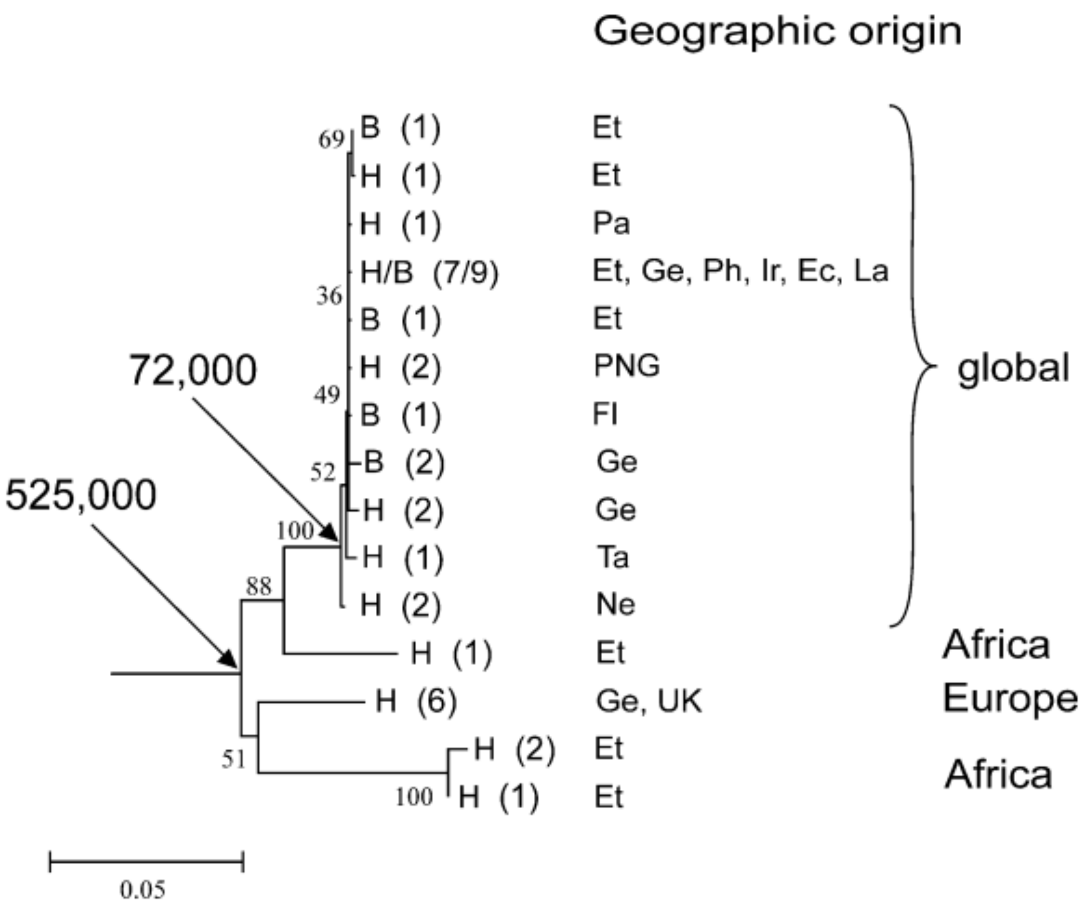
15.18 Molecular clocks help track evolutionary time

- Molecular clocks have been used to date a wide variety of events.
- In one fascinating example published in 2011, researchers studied the divergence of human body lice from head lice and estimated that people began to wear clothing between 83,000 and 170,000 years ago.
- I cannot find any citation…

Current Biology, Vol. 13, 1414–1417, August 19, 2003, DOI 10.1016/S0960-9822(03)00507-4

Molecular Evolution of *Pediculus humanus* and the Origin of Clothing

Ralf Kittler,[1] Manfred Kayser, and Mark Stoneking*
Max Planck Institute for Evolutionary Anthropology
Deutscher Platz 6
D-04103 Leipzig
Germany



only by silent substitutions. B: body louse, H: head louse; the frequency of a haplotype is indicated in brackets. Geographic origin of lice: Et: Ethiopia, Pa: Panama, Ge: Germany, Ph: Philippines, Ir: Iran, Ec: Ecuador, La: Laos, PNG: Papua New Guinea, Fl: Florida (USA), Ta: Taiwan, Ne: Nepal, UK: United Kingdom.

15.18 Molecular clocks help track evolutionary time

- Some biologists are skeptical about the accuracy of molecular clocks because the rate of molecular change may vary
  - at different times,
  - in different genes, and
  - in different groups of organisms.