### Chapter 25: The History of Life on Earth

#### Overview

1. In the last chapter, you were asked about *macroevolution*. To begin this chapter, give some examples of *macroevolution*. Include at least one novel example not in your text.

Answers may vary, but possible examples in the text include change in the emergence of terrestrial vertebrates through a series of speciation events, the impact of mass extinctions on the diversity of life, and the origin of key adaptations such as flight in birds. A novel example would be the development of tetrapods, but answers would vary.

### Concept 25.1 Conditions on early Earth made the origin of life possible

- How old is the planet? 4.6 billion years old. How old is the earliest evidence of life on Earth?
  3.5 billion years old.
- 3. The current theory of the origin of life suggests a sequence of four main stages. Summarize them here.

1.	The abiotic synthesis of small organic molecules, such as amino acids and nitrogenous bases
2.	The joining of these small molecules into macromolecules, such as proteins and nucleic acids
3.	The packaging of these molecules in protocells, droplets with membranes that maintain an internal
	chemistry different from that of their surroundings
4.	The origin of self-replicating molecules that eventually made inheritance possible

4. In the previous chart, the first stage is the synthesis of organic molecules. Consider the early planet, probably thick with water vapor and stinky with methane, ammonia, and hydrogen sulfide. What gas was missing from this early mix? Why?

No significant levels of oxygen gas were a part of the Earth's early atmosphere. Oxygen would not accumulate in the atmosphere in significant quantities until after the evolution of modern photosynthesis.

5. A. I. Oparin and J. B. S. Haldane hypothesized that the early atmosphere was a *reducing environment*. What did they suggest was the source of energy for early organic synthesis?

Lightning and intense UV radiation

6. In 1953 at the University of Chicago, *Stanly Miller* and *Harold Urey* tested the *Oparin-Haldane hypothesis* with this apparatus. (It is shown in Chapter 4, Figure 4.2, so you have seen it before.) Explain the elements of this experiment, using arrows to indicate what occurs in various parts of the apparatus.

See page 59 of your text for the labeled figure and explanation.

7. What was collected in the sample for chemical analysis? What was concluded from the results of this experiment?

Organic compounds were collected for analysis.

Miller and Urey concluded that organic molecules, a first step in the origin of life, may have been synthesized abiotically on the early Earth.

8. What are *protocells*? What properties of life do they demonstrate?

Protocells are abiotic precursors of a living cell that had a membrane-like structure and that maintained an internal chemistry different from that of its surroundings. Protocells demonstrate properties of life, including simple reproduction and metabolism, as well as the maintenance of an internal chemical environment different from that of their surroundings.

- 9. What did *Thomas Cech* propose was the first genetic material, DNA or RNA? RNA
- 10. What are *ribozymes*?

A ribozyme is an RNA molecule that functions as an enzyme, such as an intron that catalyzes its own removal during RNA splicing.

11. Explain the evidence for an early "RNA world."

In short, RNA is capable of both replication as well as catalytic action. In a particular environment, RNA molecules with certain base sequences are more stable and replicate faster and with fewer errors than other sequences. The RNA molecule whose sequence is best suited to the surrounding environment and has the greatest ability to replicate itself will leave the most descendant molecules. Occasionally, a copying error will result in a molecule that folds into a shape that is even more stable or more adept at self-replication than the ancestral sequence. Similar selection events may have occurred on the early Earth.

### Concept 25.2 The fossil record documents the history of life

- 12. In what type of rock are fossils found? sedimentary rock
- 13. What do we *not* know from analyzing rock strata?

Through fossils we can know the relative order of the appearance of different organisms, but cannot determine their absolute age.

14. Rocks and fossils are dated in several ways. *Relative dating* uses the order of rock strata to determine the relative age of fossils. *Radiometric dating* uses the decay of radioactive isotopes to determine the age of the rocks or fossils. It is based on the rate of decay, or **half-life** of the isotope. To determine the *absolute* age of a fossil, *radiometric dating* is used. Use this figure to explain the concept of radiometric dating. Label key elements.

See page 512 of your text for the labeled figure and explanation.

In this diagram, each division of the clock face represents a half-life.

15. What is the age range for which carbon-14 dating may be used?

Fossils up to 75,000 years old

16. To date fossils outside the rage of carbon-14 dating, researchers use indirect methods of establishing absolute fossil age. Explain how this could be done using radioisotopes with longer half-lives.

An indirect method can be used to infer the age of fossils that are sandwiched between two layers of volcanic rocks. As lava cools into volcanic rock, radioisotopes from the surrounding environment become trapped in the newly formed rock. Some of the trapped radioisotopes have long half-lives, allowing geologists to estimate the ages of ancient volcanic rocks. If two volcanic layers surrounding fossils are determined to be 525 million and 535 million years old, for example, then the fossils are roughly 530 million years old.

17. What are three groups of *tetrapods*?

Amphibians, reptiles, and mammals

18. Cite three ways of distinguishing mammal fossils from the other two groups of tetrapods.

The lower jaw is composed of one bone in mammals but of several bones in other tetrapods.

Mammals have a unique set of three bones in the middle ear: the hammer, anvil, and stirrup; other tetrapods have only the stirrup.

Teeth in mammals are differentiated into incisors, canines, premolars, and molars, whereas other tetrapods have undifferentiated, single-pointed teeth.

# Concept 25.3 Key events in life's history include the origins of single-celled and multicelled organisms and the colonization of land

19. What was the earliest form of life on the planet? How long ago did this life-form first occur?

Single-celled prokaryotes found in fossilized stromatolites. If microbial communities complex enough to form stromatolites existed 3.5 billion years ago, it is a reasonable hypothesis that single-celled organisms originated much earlier, perhaps as early as 3.9 billion years ago.

20. What unique ability was originated with *cyanobacteria*? How did this alter life on Earth and lead to a wave of mass extinctions?

Cyanobacteria first evolved oxygenic photosynthesis. The accumulating oxygen gas (O<sub>2</sub>) probably doomed many prokaryotic groups by attacking chemical bonds and damaging cells.

21. The first *eukaryotes* did not appear until approximately 2.1 billion years ago. Using the figure, label and explain the evolution of eukaryotes by *endosymbiosis*.

See page 517 of your text for the labeled figure and explanation.

- 22. Summarize three lines of evidence that support the model of endosymbiosis.
  - 1. The inner membrane of both organelles have enzymes and transport systems that are homologous to those found in the plasma membranes of living prokaryotes.
  - 2. Mitochondria and plastids replicate by a splitting process that is similar to that of certain prokaryotes.
  - 3. Each of these organelles contains a single, circular DNA molecule that, like the chromosomes of bacteria, is not associated with histones or large amounts of other proteins.
- 23. Use the clock model to note the following events in the life of the planet: *origin of the Earth, appearance of prokaryotes, evolution of atmospheric oxygen, occurrence of eukaryotic cells, multicellularity,* and *life moves onto land.* For each event, also label the number of years ago it occurred.

See page 517 of your text for the labeled figure and explanation.

## Concept 25.4 The rise and fall of groups of organisms reflect differences in speciation and extinction rates

24. If you have not studied geology, you will find this concept introduces a fascinating look at the changes in our planet as explained by *continental drift*. Define *continental drift*. How can continents move?

According to the theory of plate tectonics, the continents are part of great plates of Earth's crust that essentially float on the hot, underlying portion of the mantle. Movements in the mantle cause the plates to move over time in a process called continental drift.

25. On the figure below complete the time line on the left then label Pangaea, Gondwana, and Laurasia. Where was India 65 million years ago?

See page 520 of your text for the labeled figure.

65 million years ago, India had not yet "crashed" into Eurasia, forming the Himalayan Mountains.

- 26. See if you can answer each of these short questions:
  - a. What is the *San Andreas* Fault?

It marks the boundary between the Pacific and North American plates. Note that they are moving in two different directions

b. What caused the uplift of the Himalayas?

India "crashed" into Eurasia, forming the Himalayan Mountains.

c. How can a fossil freshwater reptile be found in both Brazil and West Africa, areas separated today by a wide expanse of ocean?

This is an indication that at the time this reptile flourished, the South American and African plates had not yet spread apart. This would have been true when Gondwana still existed, for example.

d. Why are no eutherians (placental) mammals indigenous to Australia?

The rise of placental mammals must have occurred after Australia broke away from the southern land mass. At the time of this separation, only marsupial mammals were found.

27. A *mass extinction* is the loss of large numbers of species in a short period, caused by global environmental changes. What caused the *Permian mass extinction* 250 million years ago (mya)? Summarize the species that were lost.

The Permian mass extinction occurred at the time of enormous volcanic eruptions in what is now Siberia. Besides spewing enormous amounts of lava and ash, the eruptions may have produced enough carbon dioxide to warm the global climate by an estimated 6°C. This slowed the mixing of ocean water, which would have led to widespread drop in oxygen concentration, suffocating oxygen-breathers, and promoting the growth of anaerobic bacteria. The poisonous gas emitted from these bacteria would have killed remaining land plants and animals.

28. A second important mass extinction is the *Cretaceous mass extinction* that happened about 65 mya. Everyone's favorite group, the dinosaurs, was lost, along with more than half of all marine species. What caused it?

The Cretaceous mass extinction is believed to have been caused by a large asteroid or comet colliding with Earth. The impact from this extraterrestrial object would have resulted in a cloud of debris that would have blocked sunlight and severely disturbed the global climate for several months.

29. What are *adaptive radiations*?

Adaptive radiations are periods of evolutionary change in which groups of organisms form many new species whose adaptations allow them to fill different ecological roles in their communities.

30. Why did a large-scale adaptive radiation occur after each mass extinction?

Each of the big five mass extinctions left many vacant ecological niches.

## Concept 25.5 Major changes in body form can result from changes in the sequences and regulation of developmental genes

31. What two areas of biology are merged in the field of study commonly called evo-devo?

Evolutionary biology and developmental biology

32. What is an evolutionary change in the rate or timing of developmental events?

#### Heterochrony

33. *Homeotic genes* are master regulatory genes that determine the location and organization of body parts. Mutations in a *homeotic gene* can have a profound effect on morphology. Homeotic gene mutations can contribute to the potential for evolutionary change. The *Hox* genes are one class of homeotic genes. What do they control?

Hox genes provide positional information in an animal embryo. This information prompts cells to develop into structures appropriate for a particular location.

### Concept 25.6 Evolution is not goal oriented

34. When a structure that has evolved in one context becomes co-opted for another purpose, this event is called exaptation. Does exaptation imply that organisms are anticipating future needs? No . Explain.

Natural selection cannot predict the future; it can only improve a structure in the context of its current utility.

### Test Your Understand Answers

Now you should be ready to test your knowledge. Place your answers here:

1. c 2. a 3. e 4. b 5. d 6. See page A-25 (Appendix) 7. c 8. c