Chapter 25: The History of Life on Earth

25.1 Describe steps by which simple cells may have originated from nonliving materials.

25.2 Explain what fossils are, how they are dated, and what the fossil record can reveal about life's history.

25.3 Identify when the origin of single and multicelled organisms and the colonization of land occurred, and explain the significance of these events.

25.4 Explain how plate tectonics, mass extinctions, and adaptive radiations have affected Earth's life.

25.5 Describe how changes in the sequence or regulation of genes can result in major changes in body form.

25.6 Use examples to show how novel and complex structures can arise by descent with modification.

How could the first organic molecules have formed? What were the earliest life-forms? How did eukaryotic cells evolve? How did life move from the water to land? This chapter looks at evidence to support hypotheses about the origins and development of life on Earth. Pay attention to the many ways the history of life on our planet is explained by natural processes.

Study Tip: At the very end of this chapter we have placed a timeline to complete as you work through this chapter, *The History of Life on Earth*. Follow the instructions under the Study Tip on p. 525 of your text but add additional significant events as they are explained.

1. The fossils of a whale in the Sahara Desert shown in Figure 25.1 in your text are an incredible find. The fossil record shows a pattern of how life changes on Earth much like the phylogenetic tree in the figure. Use the figure to answer the following:

   a. How many lineages from the phylogenetic tree end in extinction?

   b. What is the relationship between where a fossil is found in rock strata and its position on the phylogenetic tree?

   c. What are three large-scale processes that cause changes in the organisms on Earth over time?

   d. What happens during an *adaptive radiation*?

2. At the end of 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.

a.	
b.	
c.	
d.	

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

LO 25.1: Describe steps by which simple cells may have originated from nonliving materials.

3. The current theory of the origin of life suggests that chemical and physical processes could have produced simple cells through a sequence of four main stages. Summarize them here.

a.	
b.	
c.	
d.	

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

5. How old is the planet? _____ How old is the earliest evidence of life on Earth? _____. (*Reminder: Place these events on your timeline.)*

6. Recall that oxidation strips electrons from molecules. A. I. Oparin and J. B. S. Haldane hypothesized that the early atmosphere was a *reducing environment*. Why is that important?

   What did they suggest was the source of energy for early organic synthesis?

7. In 1953 at the University of Chicago, Stanley Miller and Harold Urey tested the *Oparin-Haldane hypothesis* with the apparatus you saw in Chapter 4, Figure 4.2. What was collected in the sample for chemical analysis? What was concluded from the results of this experiment?

8. The Miller-Urey-type experiments demonstrate one way organic compounds may have been generated. What are some other hypotheses that show alternative situations?

9. What properties of life do *protocell vesicles* demonstrate? What volcanic condition contributes to their formation? (Notice the difference in the graph in Figure 25.4 in your text.)

10. What was most likely the first genetic material, DNA or RNA? _____

11. What are *ribozymes*?

12. Explain the evidence for an early "*RNA world*."

Concept 25.2 The fossil record documents the history of life

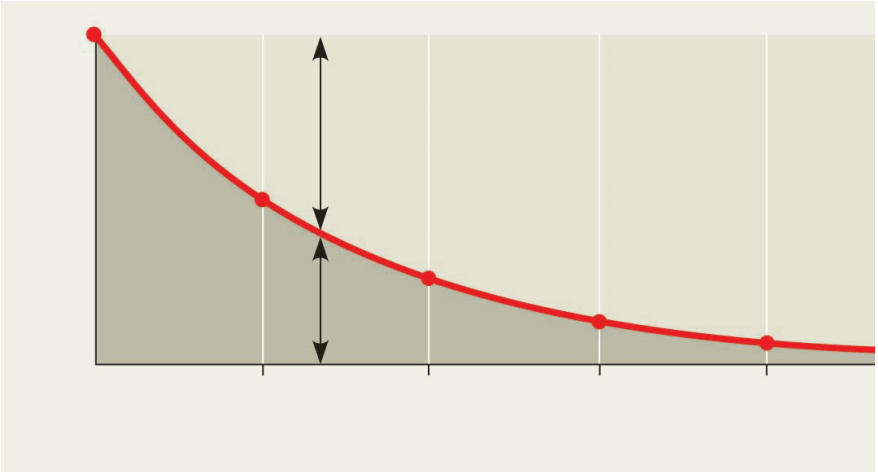
LO 25.2: Explain what fossils are, how they are dated, and what the fossil record can reveal about life's history.

13. Figure 25.5 in your text illustrates four different types of fossils. List them here and give an example of an organism that has been preserved in each way.

14. Which type of rock is the richest source of fossils?

15. The order of fossils deposited in *rock strata* tell us the sequence in which the fossils were deposited, but what do we *not* know from analyzing rock strata?

16. 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 the key elements including the axes.



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

18. Carbon-14 was used to establish the age of an ancient skeleton. The results showed that only 1/8 of the original carbon-14 isotope remained. Approximately how old is the skeleton? (Figure 25.6 in your text may help.)

19. To date fossils outside the range of carbon-14 dating, researchers use other methods of establishing absolute fossil age. Explain how this can be done using radioisotopes with longer half-lives.

End this concept by spending a few moments with Figures 25.7 and 25.8 in your text. Darwin's phrasing of evolution as descent with modification is on display in Figure 25.7, *Exploring the Origin of Mammals*. This is an excellent example of how fossils help us to understand the origin of new types of life. Figure 25.8 in your text shows a few tips about preparing and evaluating timelines. You may be able to use some of these ideas in your own timeline. Update it now.

Concept 25.3 Key events in life's history include the origins of unicellular and multicellular organisms and the colonization of land

LO 25.3: Identify when the origin of single and multicelled organisms and the colonization of land occurred, and explain the significance of these events.

20. Note the timeline represented as a circle in Figure 25.8 on pp. 532–533.

    a. Using the 1-hour timer analogy, when did prokaryotes originate? _____

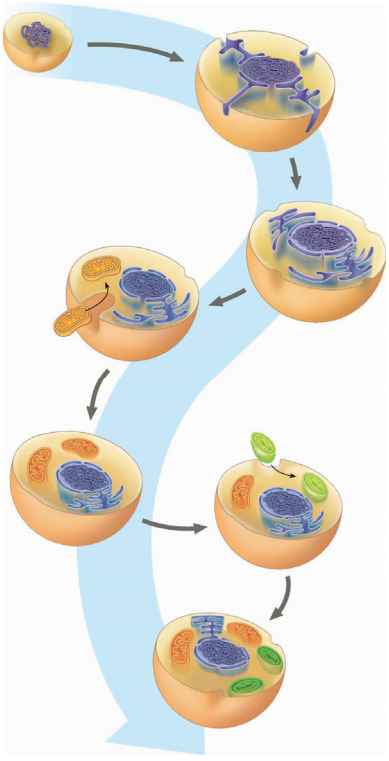
    b. How many years ago did prokaryotes originate on the geologic timescale?
    _____

    c. When did the colonization of land occur on the timer scale? _____

    d. How many years ago was the colonization of land on the geologic timescale?
    _____

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

22. The first *eukaryotes* did not appear until approximately 1.8 billion years ago. Using Figure 25.10 in your text, label and explain the evolution of eukaryotes by *endosymbiosis*.



23. Summarize three lines of evidence that support the model of endosymbiosis.

1.	
2.	
3.	

24. What effect did the *Cambrian explosion* have on changing the ways animals obtained their food? How did this affect the number of animal species?

25. What were some challenges both plants and animals had to overcome in order to colonize land?

26. What other life form appears to have colonized land associated with plants?

27. What group of animals colonized land about 450 million years ago?

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

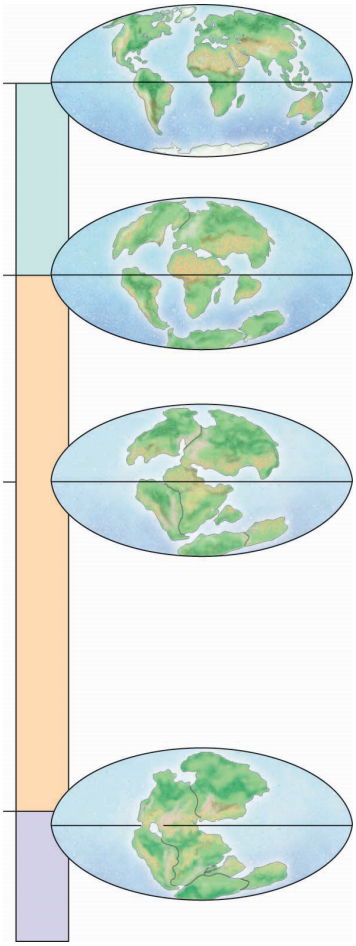
LO 25.4: Explain how plate tectonics, mass extinctions, and adaptive radiations have affected Earth's life.

28. The most abundant and dominant groups of organisms have changed over time. Some groups rise and others fall. If a group is rising (such as the mammals after extinction of the dinosaurs) what can you say about its extinction rate compared to its speciation rate?

29. Use Figure 25.14 in your text to determine how many millions of years ago lineages A and B had the greatest diversity? (Hint: Draw a line straight up on the graph to find the point at which there are the most branches.)

30. If you have not studied geology, you will find this concept introduces a fascinating look at the changes in our planet. *Continental drift* is occurring today as in the past. This is a result of *plate tectonics.* Explain how these land masses are being moved.

31. On the following figure, complete the timeline on the left including the eras, then label *Pangaea*, *Gondwana*, and *Laurasia*. Describe what is occurring with each part of this figure.



32. Based on the movement of the continents over time, answer the following:

    a. What is the San Andreas Fault?

    b. Where was India 65 million years ago?

    c. What caused the uplift of the Himalayas?

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

    e. Why are no *eutherian* (placental) mammals native to Australia?

33. A *mass extinction* is the loss of large numbers of species in a short period, caused by global environmental changes. There have been five mass extinctions over the past 500 million years. What caused the *Permian mass extinction* 250 million years ago (mya)?

34. Everyone's favorite group, the dinosaurs, was lost, along with more than half of all marine species, in a second important mass extinction, the *Cretaceous mass extinction,* which occurred about 65 mya. What caused it?

35. What environmental factors have scientists worried about the potential for a sixth mass extinction?

36. What are adaptive radiations?

37. Why did large-scale adaptive radiations occur after each mass extinction?

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

LO 25.5: Describe how changes in the sequence or regulation of genes can result in major changes in body form.

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

39. Explain how *heterochrony*, an evolutionary change in the rate or timing of developmental events, can lead to new forms on which evolution can act. Give a human example of this phenomenon.

40. *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?

41. Explain evidence that changes in gene regulation may result in evolutionary changes rather than changes in a gene's sequence. Why is this significant?

Concept 25.6 Evolution is not goal oriented

LO 25.6: Use examples to show how novel and complex structures can arise by descent with modification.

42. Could an eye be functional for a species if it could only determine light from dark?

    If you could not have a vertebrate eye, what animal's eye would you choose to have? Why?

43. Figure 25.29 in your text shows five different types of eyes. How does this support the concept heading that "*evolution is not goal oriented*?"

44. When a structure that has evolved in one context becomes co-opted for another purpose, this event is called _____. Does this imply that organisms are anticipating future needs? _____ Explain.

45. How does *species selection* explain that not all evolutionary trends are linear?

46. Does an evolutionary trend imply that there is an intrinsic drive toward a particular phenotype? _____ Explain.

Test Your Understanding, pp. 550–551

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

1. _____ 2. _____ 3. _____ 4. _____ 5. _____ 6. _____

7. _____