Chapter 14: Principles of Evolution

OVERVIEW

In this chapter, you will learn about the concept of **evolution**. The authors present an historical account of pre-Darwinian thought, followed by the Darwin-Wallace theory of evolution by natural selection. In the final part of this chapter, you will learn about various proofs of evolution. Recently in China, the preserved remains of some previously undiscovered types of dinosaurs with feathers were found. This provided evidence that non-flying dinosaurs are the ancestors of today's birds. How does the discovery of feathered dinosaur fossils support the proposition that modern organisms arose by descent with modification from earlier organisms?

1) How Did Evolutionary Thought Evolve?

Pre-Darwinian science, heavily influenced by theology, held that all organisms were simultaneously created by God and that each distinct life form remained unchanged from the moment of creation. Plato said that each object on Earth is an imperfect and temporary reflection of an "ideal form" and Aristotle categorized all organisms into a linear hierarchy (the "ladder of Nature"). These ideas went unchallenged for nearly 2,000 years. However, as European explorers noted in the 1700s, the numbers of **species** (different kinds of organisms) in newly discovered lands was greater than expected and led to thoughts that similar species might have developed from a common ancestor.

Fossils are the preserved remains of organisms that lived long ago. Fossils found in rocks resembled parts of living organisms. The organization of fossils is consistent: (1) older fossils are found in rock layers beneath younger fossils; (2) the resemblance to modern forms of life gradually increased as increasingly younger fossils are examined, like a ladder of nature stretching back in time; and (3) many fossils are of species now extinct. Scientists concluded that different types of organisms have lived at various times in the past.

Geology provided evidence that the Earth is exceedingly old. Biblical calculations suggest the Earth is 4,000 to 6,000 years old. Georges Cuvier's theory of **catastrophism** claims that successive catastrophes on Earth, like the biblical Great Flood, produced layers of rock and caused many species to become extinct in short time periods, perhaps (as proposed by Louis Agassiz) with the creation of more species after each event. Actually, Earth is very old, having been formed from the forces of wind, water, earthquakes, and volcanoes in much the same way then as now. This is the theory of **uniformitarianism**, proposed by James Hutton and Charles Lyell. Modern geologists estimate the Earth to be about 4.5 billion years old.

The French biologist Jean Baptiste Lamarck proposed in 1801 that organisms evolved through the **inheritance of acquired characteristics**: through an innate drive for perfection (never scientifically demonstrated), living organisms can modify their bodies through the use or disuse of parts (actually true) and these modifications can be inherited by their offspring (actually false). Though Lamarck's theory was abandoned, by the mid-1800s biologists began to realize that the fossil record suggested that present-day species had evolved from preexisting ones. But how?

Both Charles Darwin and Alfred Russel Wallace proposed, in 1858, that evolution occurs by natural selection. In 1859, Darwin published his book *On the Origin of Species by Means of Natural Selection*, which attracted much attention to his new theory. The box below summarizes the Darwin-Wallace theory of evolution by means of natural selection.

SUMMARY OF THE DARWIN-WALLACE THEORY OF EVOLUTION

Observation 1: All natural **populations** have the potential to increase geometrically in size due to reproductive abilities. A population consists of all individuals of one species in a particular area

Observation 2: Most natural populations maintain a relatively constant size.

Conclusion 1: Thus, many organisms must die young, producing few or no offspring each generation.

Observation 3: Individuals in a population differ in many abilities that affect survival and reproduction (some are "better adapted").

Conclusion 2: The most well adapted organisms probably reproduce the most, since they survive the best. This differential reproduction is due to **natural selection**, the process in which individuals whose traits best adapt them to their environment leave a larger number of offspring.

Observation 4: Some of the variation in adaptiveness among individuals is genetic and is passed on to the offspring.

Conclusion 3: Over many generations, differential reproduction among individuals with different genotypes changes the overall frequencies of genes in populations, resulting in evolution.

NOTES:
(1) Darwin did not know the mechanism of heredity (to explain Observation 4) and could not prove Conclusion 3.
(2) In desperation, Darwin resorted to a version of Lamarck's inheritance of acquired characteristics and this nearly destroyed his entire theory.

2) How Do We Know That Evolution Has Occurred?

Although scientists may still debate the relative importance of different mechanisms of evolutionary change, exceedingly few biologists dispute that evolution occurs. The fossil record provides evidence of evolutionary change over time. Giraffes, elephants, horses, and other types of organisms show a progressive series of fossils leading from ancient primitive organisms, through several intermediary stages, to the modern forms.

Comparative anatomy provides structural evidence of evolution. Through **convergent evolution**, unrelated species in similar environments evolve similar body functions from dissimilar underlying structures, called **analogous structures** (for example, wings of birds and butterflies). Also, closely related species in dissimilar environments evolve dissimilar body functions from similar underlying structures, called **homologous structures** (for example, among mammals, the forelimbs of apes, seals, dogs, and bats). Some species of organisms have **vestigial structures** (structures with no apparent purpose), which are homologous to functional structures in other species.

Embryological stages of animals can provide evidence of common ancestry. All vertebrate embryos look similar to one another early in their development (all have gill slits and tails, even humans), indicating that all vertebrate species have similar genes.

Modern biochemical and genetic analyses reveal relatedness among diverse organisms. All cells have DNA, RNA, ribosomes, similar genetic codes, similar amino acids in proteins, and similar chromosome structures.

3) What Is the Evidence That Populations Evolve by Natural Selection?

Artificial selection, the breeding of domestic organisms such as dogs to produce specific desired features, demonstrates that organisms may be modified by controlled breeding. Also, evolution by natural selection occurs today, as illustrated by the evolution of populations of roaches in Florida for which the poison roach bait called "Combat®" is ineffective.

Studies of evolution in natural and domestic populations of plants and animals have demonstrated that: (1) the variations on which natural selection works are produced by chance mutations, and (2) evolution by natural selection selects for organisms that are best adapted to a particular environment. Natural selection does not select for the "best" in any absolute sense, but only in the context of a particular environment. A trait that is advantageous under one set of circumstances may become disadvantageous if conditions change.

Case study revisited. In 2000, a new fossil of a feathered dinosaur turned out to be a fake. Skeptics of the original findings supporting feathered dinosaurs evolving into birds point out that the Chinese fossils of feathered dinosaurs are younger (120 million years old) than the fossils of actual flying birds (150 million years old). Perhaps the feathered "dinosaur" fossils are really ancient birds. But the Chinese fossils have dinosaurian skeletons that lack any birdlike feathers. Perhaps some lines of feathered dinosaurs persisted after the line leading to birds had branched off.

KEY TERMS AND CONCEPTS

Fill-In: From the following list of key terms, fill in the blanks in the following statements.

analogous	convergent	inheritance of acquired characteristics
artificial	fossils	uniformitarianism
catastrophism	homologous	vestigial

1. _____, the preserved remains of organisms that lived long ago, are often found in rocks and typically resemble parts of living organisms.

2. The theory of _____ claims that successive worldwide events, like the biblical Great Flood, produced layers of rock and caused many species to become extinct in short periods of time.

3. According to the theory of _____, Earth is very old, having been formed from the forces of wind, water, earthquakes, and volcanoes in much the same way then as now.

4. In 1801, the French biologist Lamarck proposed that organisms evolved through the _____.

5. Through _____ evolution, unrelated species in similar environments evolve similar body functions from dissimilar underlying structures, called _____ structures. Conversely, closely related species living in dissimilar environments, evolve dissimilar body functions from similar underlying structures, called _____ structures.

6. Some species of organisms have _____ structures with no apparent purpose, which are homologous to functional structures in other species.

7. The wing of a butterfly and the wing of a bird are _____ structures, while the forelimb of a human and the forelimb of a whale are _____ structures.

8. _____ selection, the breeding of domestic organisms such as dogs to produce specific desired features, demonstrates that organisms may be modified by controlled breeding.

Key Terms and Definitions

analogous structures: structures that have similar functions and superficially similar appearance but very different anatomies, such as the wings of insects and birds. The similarities are due to similar environmental pressures rather than to common ancestry.

artificial selection: a selective breeding procedure in which only those individuals with particular traits are chosen as breeders; used mainly to enhance desirable traits in domestic plants and animals; may also be used in evolutionary biology experiments.

catastrophism: the hypothesis that Earth has experienced a series of geological catastrophes, probably imposed by a supernatural being that accounts for the multitude of species, both extinct and modern, and preserves creationism.

convergent evolution: the independent evolution of similar structures among unrelated organisms as a result of similar environmental pressures; see *analogous structures.*

evolution: the descent of modern organisms with modification from preexisting life-forms; strictly speaking, any change in the proportions of different genotypes in a population from one generation to the next.

fossil: the remains of a dead organism, normally preserved in rock; may be petrified bones or wood; shells; impressions of body forms, such as feathers, skin, or leaves; or markings made by organisms, such as footprints.

homologous structures: structures that may differ in function but that have similar anatomy, presumably because the organisms that possess them have descended from common ancestors.

inheritance of acquired characteristics: the hypothesis that organisms' bodies change during their lifetimes by use and disuse and that these changes are inherited by their offspring.

natural selection: the unequal survival and reproduction of organisms due to environmental forces, resulting in the preservation of favorable adaptations. Usually, natural selection refers specifically to differential survival and reproduction on the basis of genetic differences among individuals.

population: all the members of a particular species within an ecosystem, found in the same time and place and actually or potentially interbreeding.

species (spē´-sēs): the basic unit of taxonomic classification, consisting of a population or series of populations of closely related and similar organisms. In sexually reproducing organisms, a species can be defined as a population or series of populations of organisms that interbreed freely with one another under natural conditions but that do not interbreed with members of other species.

uniformitarianism: the hypothesis that Earth developed gradually through natural processes, similar to those at work today, that occur over long periods of time.

vestigial structure (ves-tij´-ē-ul): a structure that serves no apparent purpose but is homologous to functional structures in related organisms and provides evidence of evolution.

THINKING THROUGH THE CONCEPTS

True or False: Determine if the statement given is true or false. If it is false, change the underlined word(s) so that the statement reads true.

9. _____ Before Darwin, most people thought species were capable of change.
10. _____ The idea that God created some new species after every catastrophe was proposed by Agassiz.
11. _____ The remains of organisms preserved in rock are called vestigial structures.
12. _____ Lamarck proposed that an internal drive toward complexity within cells is the driving force in evolution.
13. _____ The similarity in the bones making up a bird's wing and a horse's foot are due to convergent evolution.
14. _____ Amino acid sequences in proteins of different animals tend to support evolution.
15. _____ Aristotle's "ladder of Nature" was considered immutable.
16. _____ In convergent evolution, the two forms being modified are closely related.
17. _____ The many different varieties of dogs are the result of natural selection.
18. _____ Analogous structures arise due to convergent evolution.

Matching: Theories about life.

19. _____ uniformitarianism
20. _____ "ladder of Nature"
21. _____ "ideal forms"
22. _____ inheritance of acquired characteristics
23. _____ catastrophism
24. _____ multiple creations
25. _____ natural selection

Choices:

a. Lamarck
b. Aristotle
c. Wallace
d. Plato
e. Malthus
f. Agassiz
g. Cuvier
h. Lyell
i. Darwin

Multiple Choice: Pick the most correct choice for each question.

26. Which of the following proposes that living organisms inherited body parts modified through use or disuse?
    a. natural selection
    b. catastrophism
    c. inheritance of acquired characteristics
    d. evolution

27. Fossils resulted from a successive series of geological upheavals according to the theory of
    a. natural selection
    b. catastrophism
    c. uniformitarianism
    d. independent assortment

28. The evolution of adaptations between different species as a result of extensive interactions with each other is termed
    a. analogous evolution
    b. divergent evolution
    c. convergent evolution
    d. coevolution

29. Which of the following is homologous to the human arm?
    a. wing of insect
    b. wing of bird
    c. body of snake
    d. fin of fish
    e. tail of salamander

30. Supportive evidence for evolution is found in studies of
    a. biochemistry
    b. embryos
    c. comparative anatomy
    d. domestication of plants and animals
    e. all of the answers are correct

31. Fossils provide direct evidence for
    a. behavioral adaptations
    b. physiological characteristics
    c. habitat preference
    d. structural similarities and differences
    e. catastrophism

32. The fossil evidence seems to infer that
    a. birds gave rise to dinosaurs
    b. birds and dinosaurs have independent origins
    c. dinosaurs gave rise to birds
    d. birds gave rise to mammals
    e. mammals gave rise to birds

APPLYING THE CONCEPTS

These practice questions are intended to sharpen your ability to apply critical thinking and analysis to biological concepts covered in this chapter.

33. A species of moth has a very long proboscis (tubular mouth part) that is used to suck nectar from the inner base of a particular type of long, trumpet-shaped flower. Closely related moth species, however, have much shorter mouth parts and feed off nectar from plants with shorter tubular flowers. How would Darwin and Lamarck each explain the evolution of the species of moth with the exceptionally long proboscis?

34. The fossil record indicates that at progressively more recent levels of sediment (those progressively closer to the surface), fossils more closely resembling modern forms of plants and animals are found. How would you explain the changes in the fossil record if you believed in catastrophism or if you believed in uniformitarianism?

35. Fossils from China of feathered dinosaurs with distinct reptilian features are about 120 million years old, while the oldest fossils of birds are about 150 million years old. Are these fossils compatible with the theory that dinosaurs evolved into birds? What additional evidence would be needed to support this theory?

36. Over a 50 year period in the 1800s in England, in areas where industrial pollution covered the trees with soot, peppered moths evolved from having light colored wings to having dark colored wings. How would Lamarck (inheritance of acquired characteristics) and Darwin (evolution by natural selection) have explained the change?

Use the Case Study and the Web sites for this chapter to answer the following questions.

37. *Archaeopteryx* is considered the oldest known fossil bird. What features does it share with dinosaurs? Why is it considered a bird?

38. *Confuciusornis* is another fossil bird. It is almost as old as *Archaeopteryx* but shares one feature with birds that *Archaeopteryx* lacks. What is it?