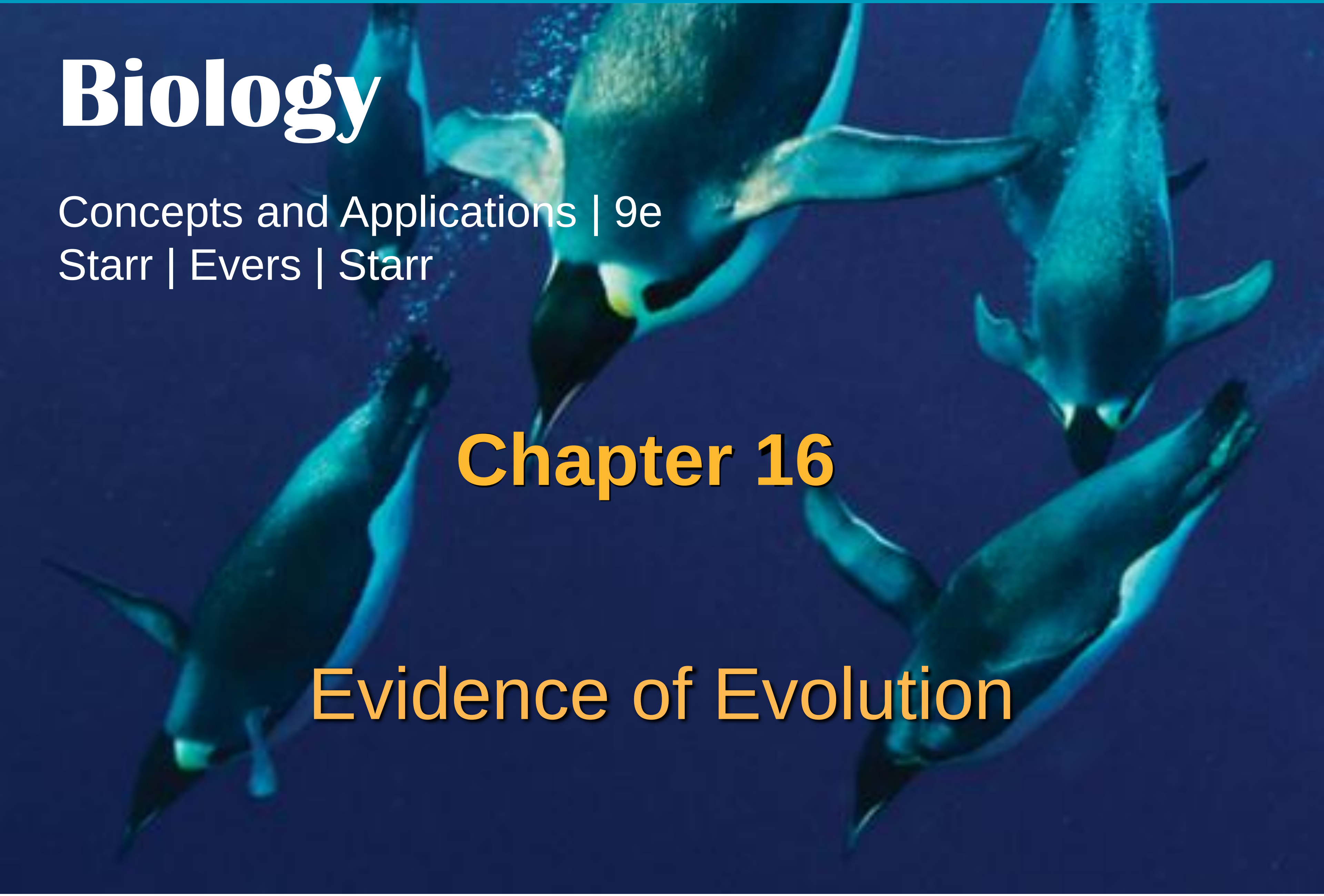

Biology

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Chapter 16

Evidence of Evolution

16.1 How Did Observations of Nature Change Our Thinking in the 19th Century?

- Expeditions by 19th century naturalists
  - Yielded increasingly detailed observations of nature
  - Collected thousands of plants and animals from around the world
  - Catalogued and described newly discovered species

How Did Observations of Nature Change Our Thinking in the 19th Century? (cont'd.)

- 19th century naturalists (cont'd.)
  - Pioneered the field of *biogeography*
    - The study of patterns in the geographic distribution of species
  - What are some patterns that emerged?

How Did Observations of Nature Change Our Thinking in the 19th Century? (cont’d.)

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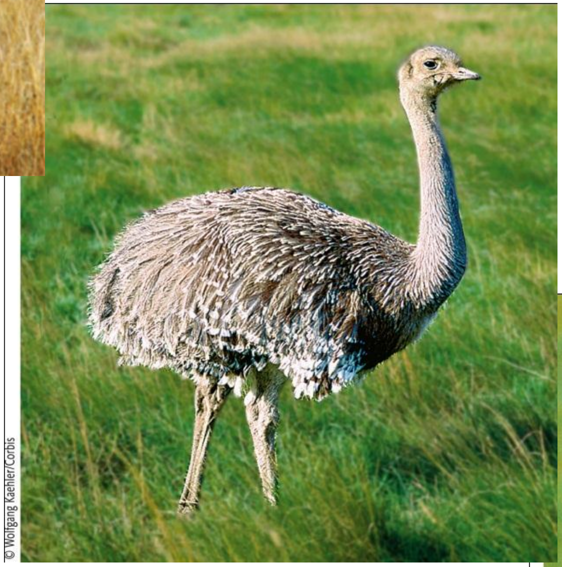

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How Did Observations of Nature Change Our Thinking in the 19th Century? (cont'd.)

- Comparative morphology
  - Study of anatomical patterns
  - The only way to distinguish differences in species at that time
  - Problematic in classifying organisms that are outwardly very similar, but quite different internally

How Did Observations of Nature Change Our Thinking in the 19th Century? (cont'd.)

- Example: the American spiny cactus and African spiny spurge
  - Live in similar environments
  - Native to different continents
  - Reproductive parts are very different, so they can't be as closely related they appear

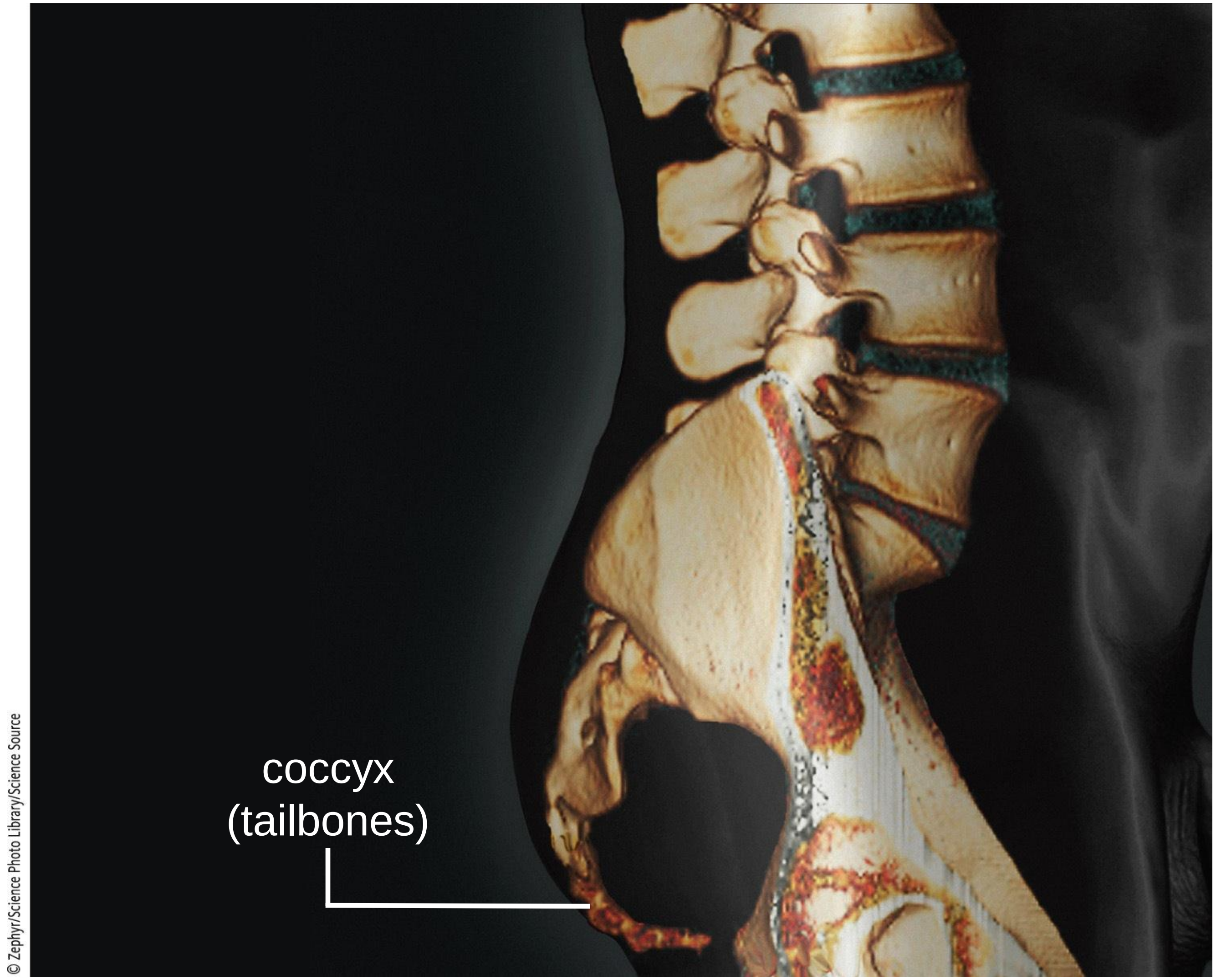
How Did Observations of Nature Change Our Thinking in the 19th Century? (cont'd.)

left, © Richard J. Hodgkiss, www.succulent-plant.com; right, © Marka/SuperStock.

How Did Observations of Nature Change Our Thinking in the 19th Century? (cont'd.)

- Vestigial structures
  - 19th century naturalists had difficulty explaining
  - Body parts that have no apparent function
  - Leg bones in snakes and tail bones in humans

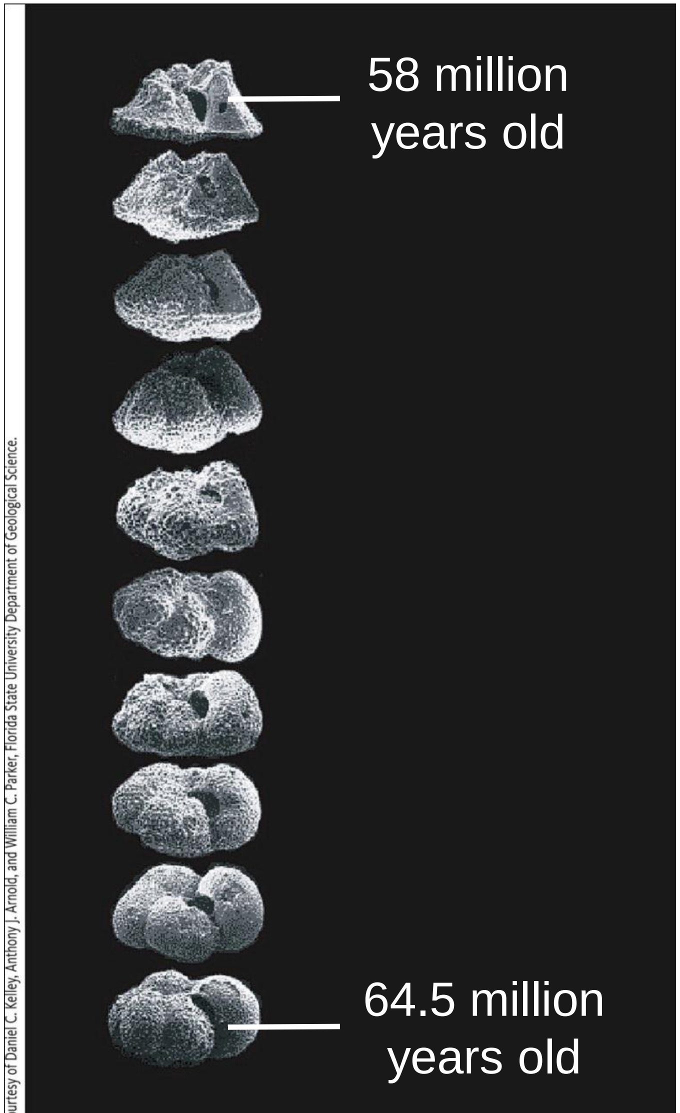
How Did Observations of Nature Change Our Thinking in the 19th Century? (cont'd.)



How Did Observations of Nature Change Our Thinking in the 19th Century? (cont'd.)

- Fossils
  - Physical evidence of an organism that lived in ancient past
  - Proved puzzling
    - Deeper layers held fossils of simple marine life
    - Layers above held similar but more complex fossils

How Did Observations of Nature Change Our Thinking in the 19th Century? (cont'd.)



Courtesy of Daniel C. Kelley, Anthony J. Arnold, and William C. Parker, Florida State University Department of Geological Science.

16.2 What Is Natural Selection?

- 19th century naturalists tried to explain evidence that life on Earth had changed over time
- George Cuvier
  - Assumed Earth to be in the thousands, not billions, of years
  - Proposed theory of catastrophism

What Is Natural Selection? (cont'd.)

- Jean-Baptiste Lamarck
  - Believed that a species gradually improved over generations due to a drive towards perfection
  - Proposed that environmental pressures cause an internal need for change
    - Resulting change is inherited by offspring
  - Thought about the processes that drive evolution

What Is Natural Selection? (cont'd.)

- Charles Lyell
  - Theory of uniformity
    - Over great spans of time, gradual, everyday geologic processes such as erosion could have sculpted Earth
  - Challenged idea that Earth is 6,000 years old
    - Calculated that Earth is millions of years old
  - Provided Darwin with insights

What Is Natural Selection? (cont'd.)

- Evolution
  - Lamarck was the first to think about lineage, a line of descent
  - Involves the idea that a species gradually improves over generations

What Is Natural Selection? (cont'd.)

- Charles Darwin
  - Naturalist aboard the *Beagle*
  - Circumnavigated the globe over a period of five years
  - Made detailed observations of geology, fossils, plants, and animals

What Is Natural Selection? (cont'd.)

- Charles Darwin (cont'd.)
  - Collected specimens like fossil glyptodonts
    - Noticed that Glyptodons and modern armadillos share traits, and therefore, that they possibly share an ancestor
  - Helped Darwin develop a theory of evolution by natural selection

What Is Natural Selection? (cont'd.)

- Thomas Malthus
  - Correlated increases in the size of human populations with episodes of disease, famine and war
  - Proposed idea that humans can run out of resources
    - Human reproduction can exceed capacity of environment to sustain them
  - Influenced Darwin's ideas of natural selection

What Is Natural Selection? (cont'd.)

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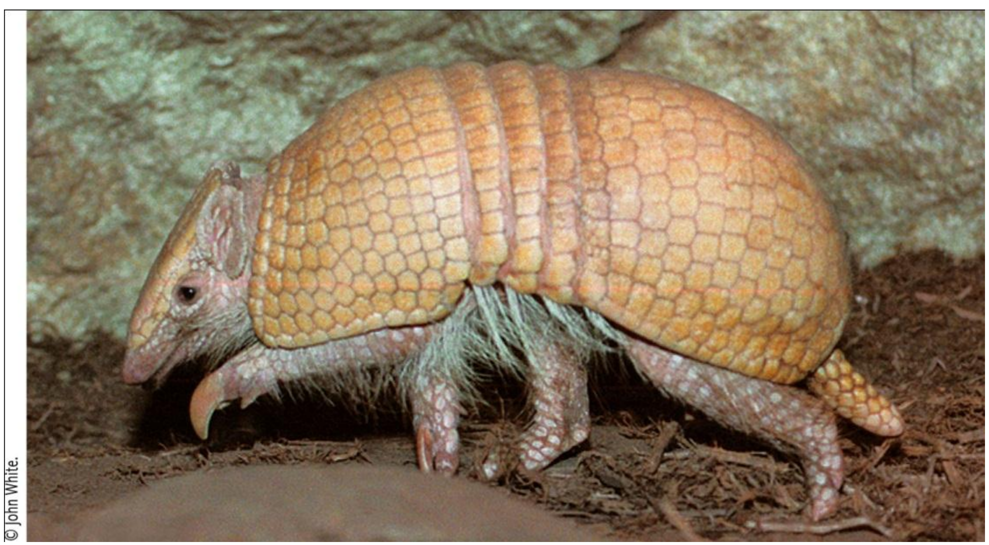

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What Is Natural Selection? (cont'd.)

- Darwin (cont'd.)
  - Realized some individuals have traits that make them better suited to their environment than others
    - Those traits might enhance the individual's fitness. or the ability to survive and reproduce
    - Adaptations – a trait that imparts greater fitness to an individual would become more common in a population over generations, compared with less competitive forms

What Is Natural Selection? (cont'd.)

- Darwin (cont'd.)
  - Called the process in which environmental pressures result in the differential survival and reproduction of individuals of a population *natural selection*
  - Published *On the Origin of Species*
    - Laid out the theory of evolution by natural selection

What Is Natural Selection? (cont'd.)

TABLE 16.1

Principles of Natural Selection, in Modern Terms

Observations About Populations

- Natural populations have an inherent capacity to increase in size over time.
- As population size increases, resources that are used by its individuals (such as food and living space) eventually become limited.
- When resources are limited, individuals of a population compete for them.

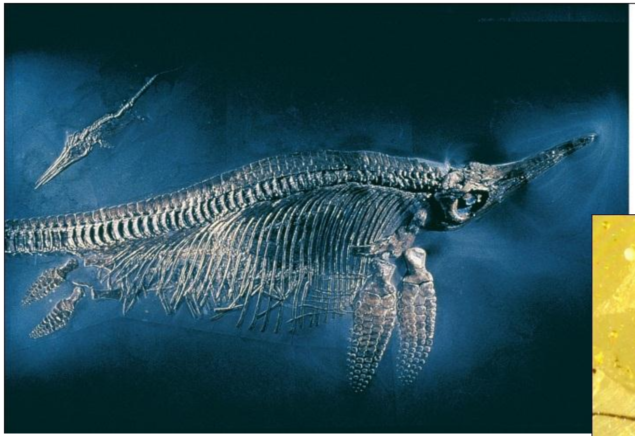
Observations About Genetics

- Individuals of a species share certain traits.
- Individuals of a natural population vary in the details of those shared traits.
- Shared traits have a heritable basis, in genes. Slightly different forms of those genes (alleles) give rise to variation in shared traits.

Inferences

- A certain form of a shared trait may make its bearer better able to survive.
- Individuals of a population that are better able to survive tend to leave more offspring.
- Thus, an allele associated with an adaptive trait tends to become more common in a population over time.

16.3 Why Do Biologists Study Rocks and Fossils?



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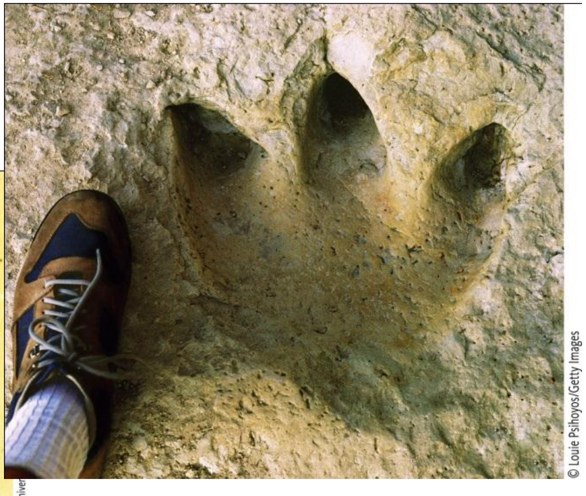

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Why Do Biologists Study Rocks and Fossils? (cont'd.)

- Most fossils are mineralized
  - Bones
  - Teeth
  - Shells
  - Seeds
  - Spores

Why Do Biologists Study Rocks and Fossils? (cont'd.)

- Trace fossils can be:
  - Footprints and other impressions
  - Nests
  - Burrows
  - Trails
  - Eggshells
  - Feces

Why Do Biologists Study Rocks and Fossils? (cont'd.)

- Fossilization
  - Begins when an organism or its traces become covered by sediments/volcanic ash
  - After a very long time, pressure and mineralization transform the remains into rock
  - Fossils are found in stacked layers of sedimentary rock
  - Younger fossils occur in more recent layers, on top of older fossils in older layers

Why Do Biologists Study Rocks and Fossils? (cont'd.)

- The fossil record
  - We have fossils for more that 250,000 species
  - Fossils are relatively rare, so the fossil record will always be incomplete
  - Most ancient species had no hard parts to fossilize
  - Burial site had to escape destructive geologic events

16.4 How Is The Age of Rocks and Fossils Measured?

- Radiometric dating
  - The time it takes for half of the atoms in a sample of radioisotope to decay is called half-life
  - Can determine the age of rocks and fossils

ANIMATION: Radioisotope decay

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How Is The Age of Rocks and Fossils Measured? (Cont'd.)

- Carbon dating
  - Recent fossils that still contain carbon can be dated (carbon 14)
    - The half-life of ^{14}C is 5,370 years
    - Most ^{14}C in a fossil will have decayed after about 60,000 years
    - ^{14}C in CO_2 enters food chains through photosynthesis
    - Ratio of ^{14}C to ^{12}C is used to calculate how many half-lives passed since the organism died

ANIMATION: Radiometric dating

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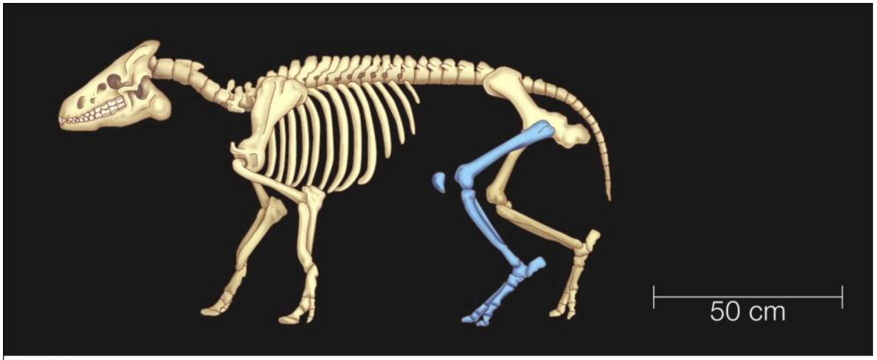
How Is The Age of Rocks and Fossils Measured? (Cont’d.)

- Finding a missing link
  - Fossil records holds clues to evolution:
    - Ancestors of whales probably walked on land
    - The skull and lower jaw have characteristics similar to those of ancient carnivorous land animals
    - With their artiodactyl-like ankle bones, *Rodhocetus* and *Dorudon* were probably offshoots of the artiodactyl-to-modern-whale lineage

How Is The Age of Rocks and Fossils Measured? (Cont'd.)



W. B. Scott (1894)

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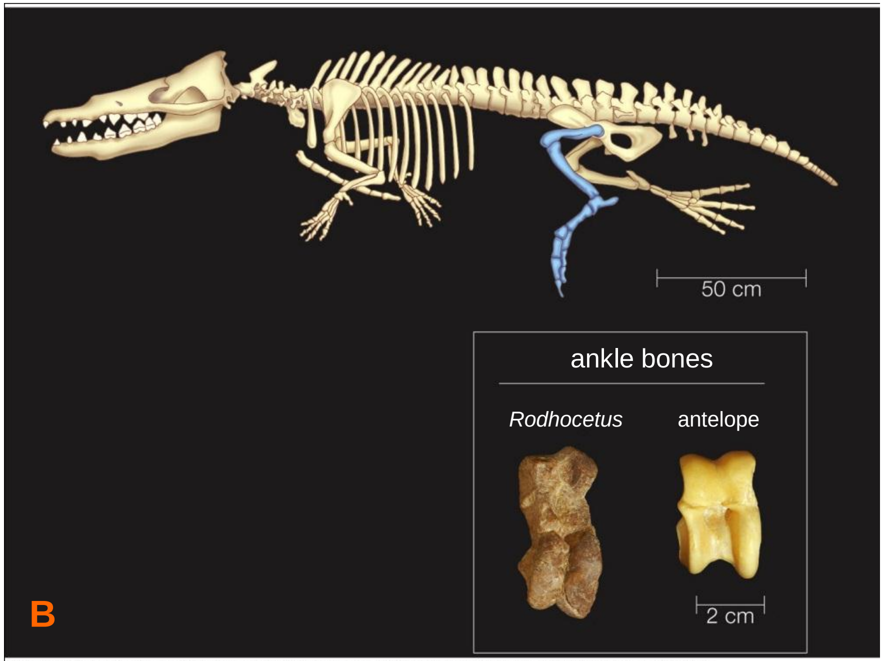

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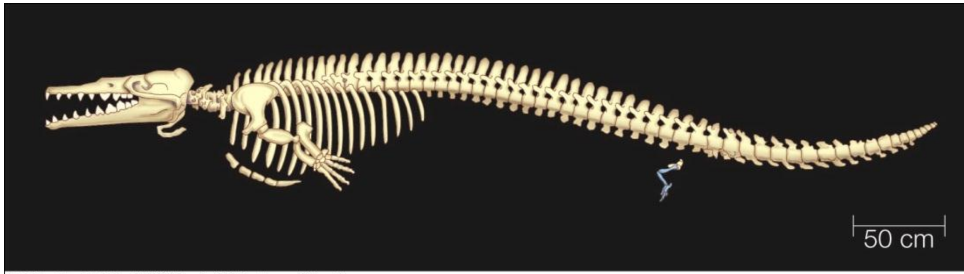

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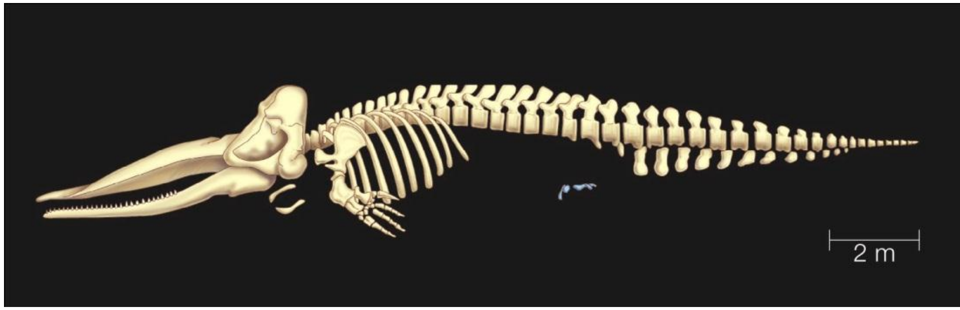

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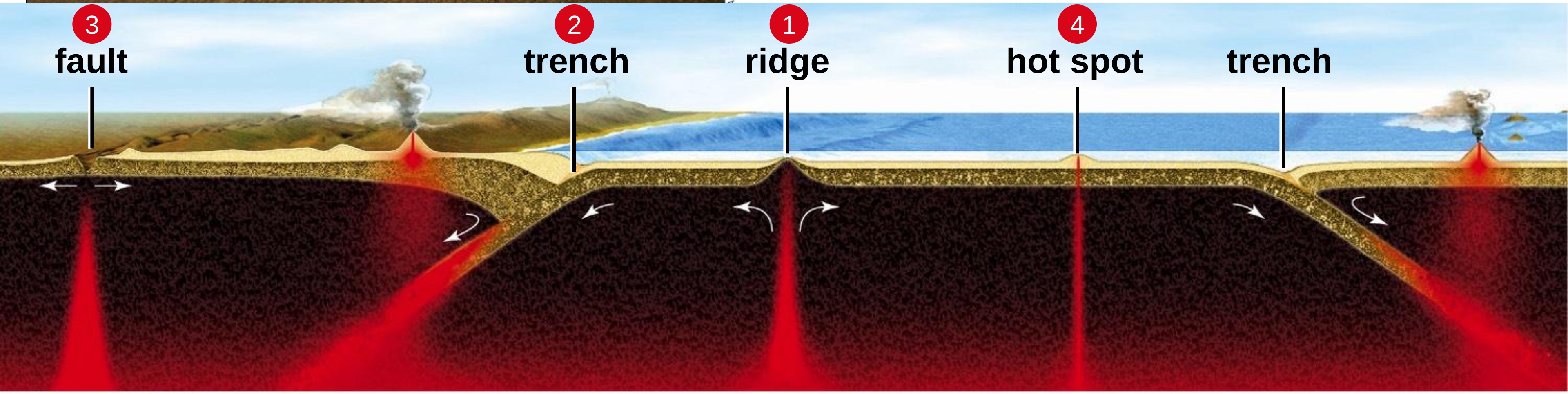
16.5 How Has Earth Changed Over Geologic Time?

- Theory of Plate Tectonics
  - Continents were one big supercontinent called Pangea
    - Formed about 237 mya (Triassic); broke up about 152 mya ago (Jurassic)
  - Continents drift over time
    - Continental plates move no more than 10 cm/year
    - New crust spreads outward from oceanic ridges, forcing tectonic plates away from the ridge and into trenches

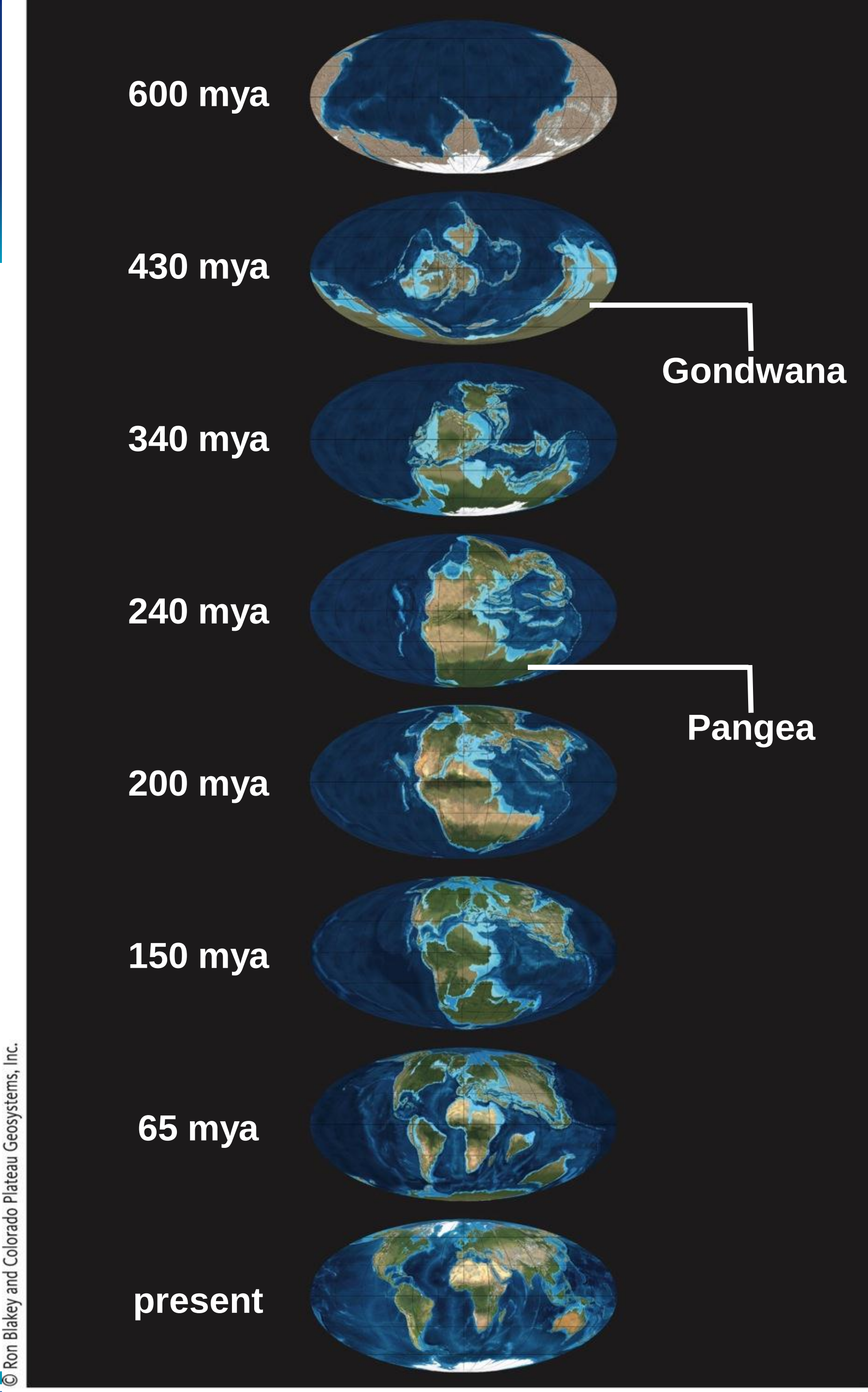
How Has Earth Changed Over Geologic Time? (cont'd.)



How Has Earth Changed Over Geologic Time? (cont'd.)

- Gondwana
  - Supercontinent that existed before Pangea, more than 500 mya
    - Identical layers of rock around the Southern Hemisphere hold matching fossils of organisms that were extinct millions of years before Pangea formed
  - Included most land masses that are now in the Southern Hemisphere, India and Arabia
  - Broke up in the Silurian

How Has Earth Changed Over Geologic Time? (cont'd.)



16.6 What Is The Geologic Time Scale?

- Geologic time scale
  - Chronology of Earth's history
  - Each layer offers clues about conditions on Earth at the time layer was deposited
  - Fossils in each layer are a record of life during that period of time
  - Correlates geologic and evolutionary events

ANIMATION: Geologic time scale

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16.7 What Evidence Does Evolution Leave In Body Form?

- Clues about the history of a lineage may be found
  - In body form, function, and biochemistry
- Comparative morphology
  - Shows similarities in structure of body parts
  - Reflects shared ancestry
  - Can be used to unravel evolutionary relationships

What Evidence Does Evolution Leave In Body Form?(cont'd.)

- *Morphological divergence*
  - Change from the body form of a common ancestor
- *Homologous structures*
  - Body parts that appear different in different lineages, but are similar in some aspect
    - Become modified to a different size, shape, or function in different lineages
  - Are evidence of a common ancestor

ANIMATION: Evolution of limb bones

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What Evidence Does Evolution Leave In Body Form?(cont'd.)

- *Morphological convergence*
  - Independent evolution of similar body parts in different lineages
- *Analogous structures*
  - Body parts that look alike in different lineages but did not evolve in a common ancestor

What Evidence Does Evolution Leave In Body Form?(cont'd.)

16.8 How Do Similarities In DNA and Protein Reflect Evolution?

- Similar patterns of embryonic development reflect shared ancestry
  - Master genes that control embryonic development patterns have changed very little or not at all over evolutionary time
  - Master genes with similar sequence and function in different lineages are strong evidence that those lineages are related

How Do Similarities In DNA and Protein Reflect Evolution? (cont'd.)

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How Do Similarities In DNA and Protein Reflect Evolution? (cont'd.)

- *Homeotic* genes
  - Master genes
  - Guide formation of specific body parts during development
  - Example: *Hox* genes
  - Similar genes give rise to similar proteins
  - Proteins are also commonly compared
    - The amino acid sequence of a protein is compared between several species

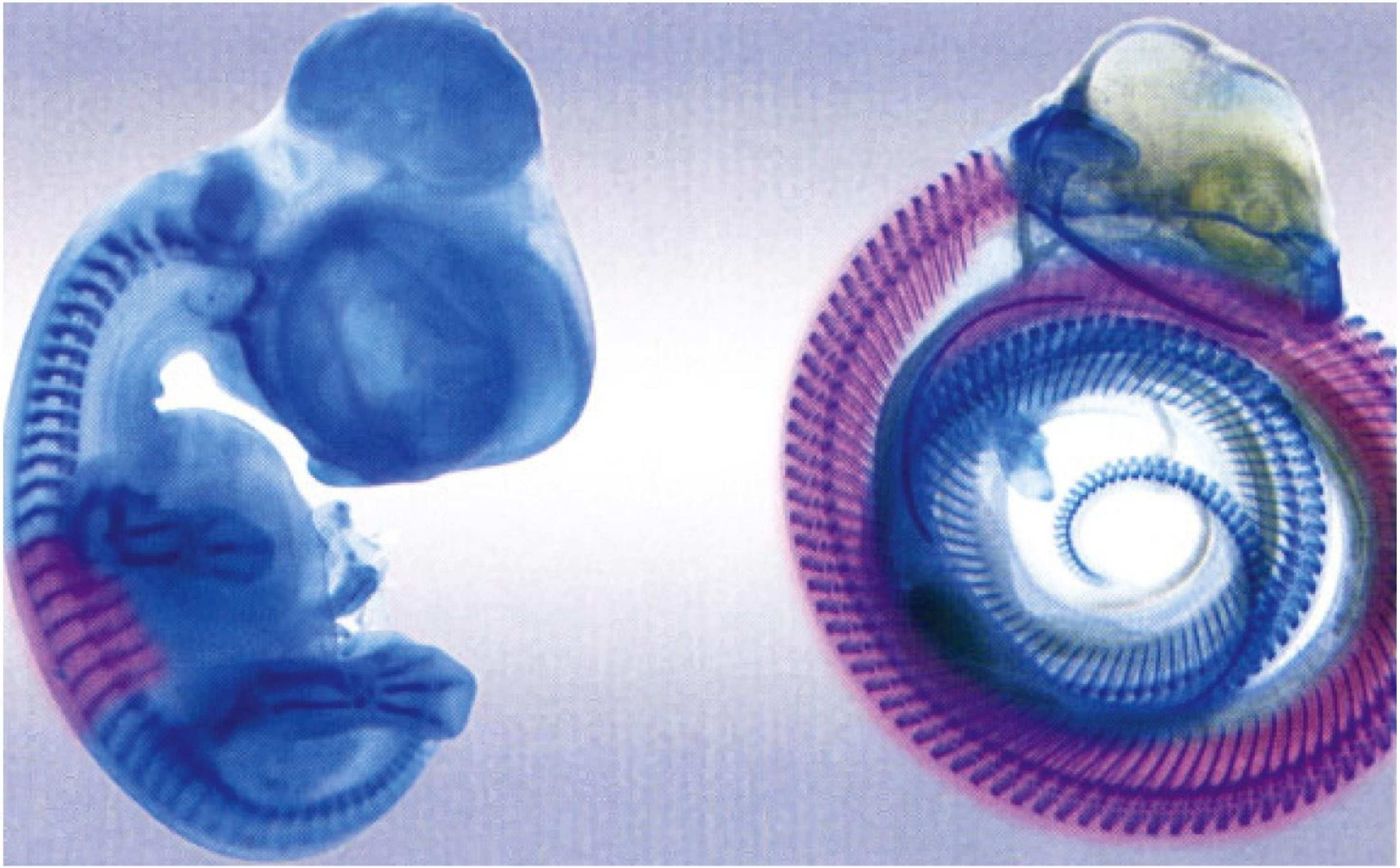
How Do Similarities In DNA and Protein Reflect Evolution? (cont'd.)

- Similarities in patterns of animal development occur because the same genes direct the process
  - Similar developmental patterns—and shared genes—are evidence of common ancestry, which can be ancient
- Mutations change the nucleotide sequence of each lineage's DNA over time

How Do Similarities In DNA and Protein Reflect Evolution? (cont'd.)

- There are generally fewer differences between the DNA of more closely related lineages
- Similar genes give rise to similar proteins
- Fewer differences occur among the proteins of more closely related lineages

How Do Similarities In DNA and Protein Reflect Evolution? (cont'd.)



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How Do Similarities In DNA and Protein Reflect Evolution? (cont'd.)

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song sparrow	...CRDVQFGWLIRNLHANGASFFFICIYLHIGRGIYYGSYLNK--ETWNVGIILLLALMATAFVGYVLPWGQMSFWG...
Gough Island finch	...CRDVQFGWLIRNIHANGASFFFICIYLHIGRGLYYGSYLYK--ETWNVGVILLLTLMATAFVGYVLPWGQMSFWG...
deer mouse	...CRDVNYGWLIRYMHANGASMFFICLFLHVGRGMYYGSYTFT--ETWNIGIVLLFAVMATAFMGYVLPWGQMSFWG...
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baker's yeast	...MRDVHNGYILRYLHANGASFFFMVMFMHMAKGLYYGSYRSPRVTLWNVGVIIFTLTIATAFLGYCCVYGQMSHWG...

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16.9 Reflections of a Distant Past

- An asteroid impact may have caused a mass extinction 65.5 million years ago
  - Resulted in a simultaneous loss of many lineages from Earth

Reflections of a Distant Past (cont'd.)

- K-Pg boundary sequence (formerly known as K-T boundary)
  - A unique rock layer
  - Formed worldwide 65.5 million years ago
  - Marks an abrupt transition in the fossil record
  - Implies a mass extinction

Reflections of a Distant Past (cont'd.)