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Objectives

- **Identify** several observations that led Darwin to conclude that species evolve.
- **Relate** the process of natural selection to its outcome.
- **Summarize** the main points of Darwin's theory of evolution by natural selection as it is stated today.
- **Contrast** the gradualism and punctuated equilibrium models of evolution.

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Darwin Proposed a Mechanism for Evolution

- In 1859, the English naturalist Charles Darwin published convincing evidence that species evolve, and he proposed a reasonable mechanism explaining how evolution occurs.
- Like all scientific theories, the theory of evolution has developed through decades of scientific observation and experimentation.
- The observations that Darwin made on a voyage of the HMS *Beagle* led to his ideas about evolution.

End of Slide

Darwin's Voyage

Darwin Proposed a Mechanism for Evolution, *continued*

Science Before Darwin's Voyage

- In Darwin's time, most people—including scientists—held the view that each species is a divine creation that exists, unchanging, as it was originally created.
- In 1809, the French scientist Jean Baptiste Lamarck (1744–1829) proposed a hypothesis for how organisms change over generations.
- Lamarck believed that over the lifetime of an individual, physical features increase in size because of use or reduce in size because of disuse.

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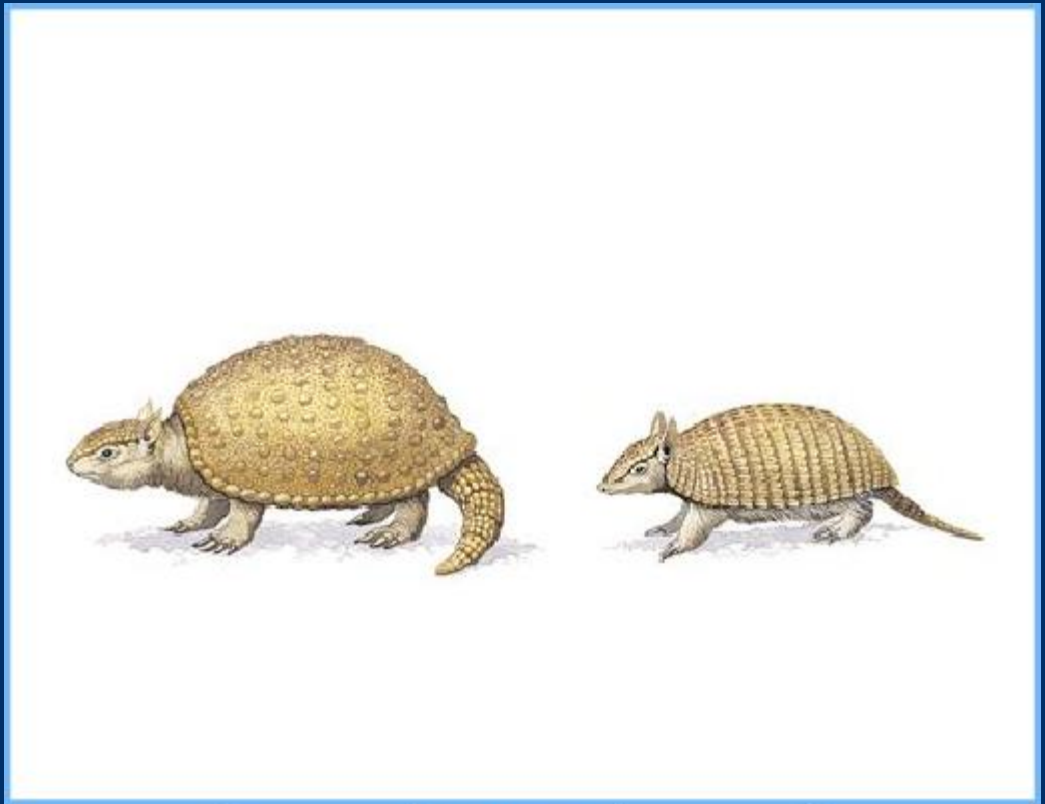
Lamarck's Theory of Evolution



Darwin Proposed a Mechanism for Evolution, *continued*

Darwin's Observations

- During his voyage on the *Beagle,* Darwin found evidence that challenged the traditional belief that species are unchanging.
- Darwin visited the Galápagos Islands, located about 1,000 km (620 mi) off the coast of Ecuador. Darwin was struck by the fact that many of the plants and animals of the Galápagos Islands resembled those of the nearby coast of South America.

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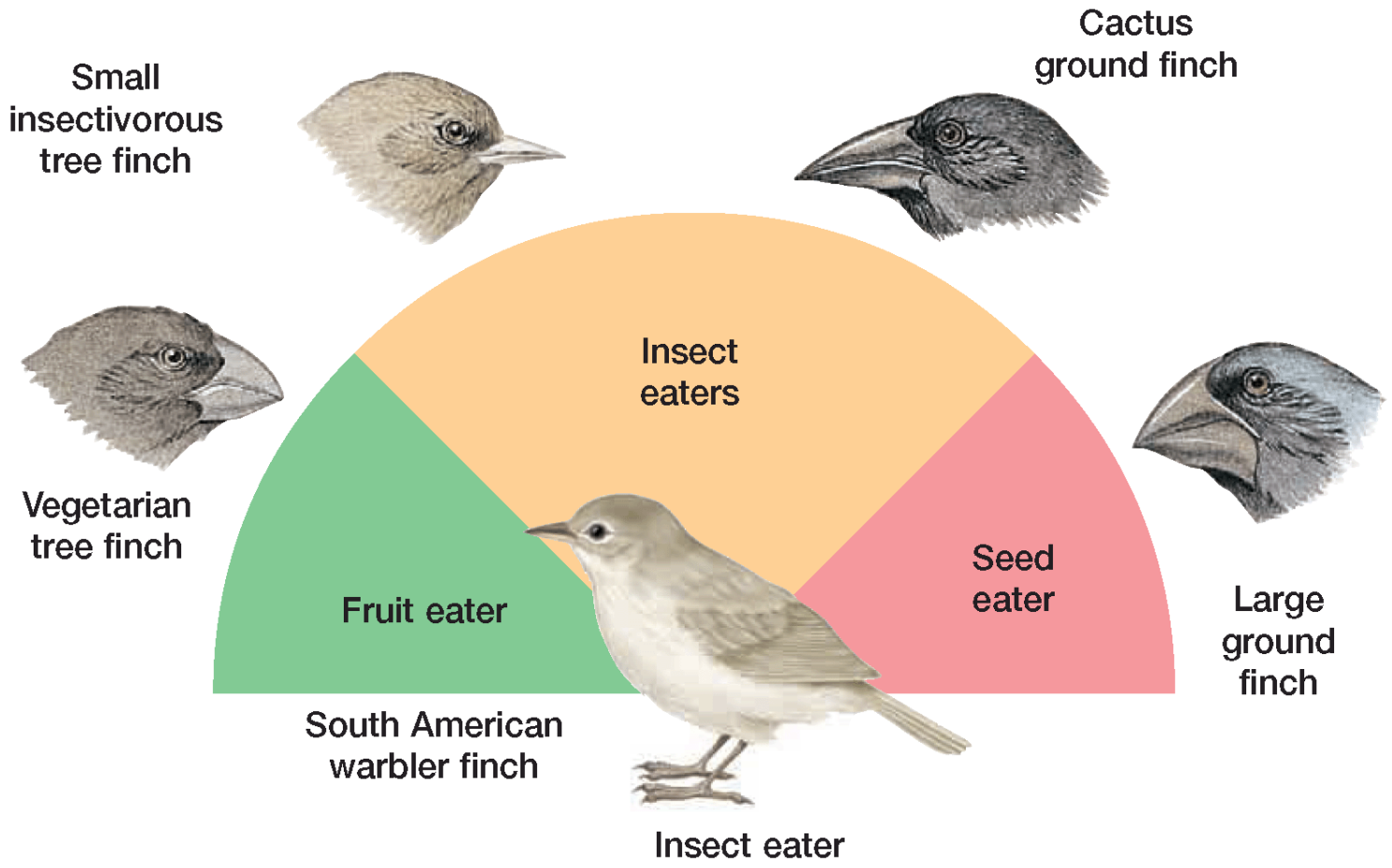
Darwin's Finches

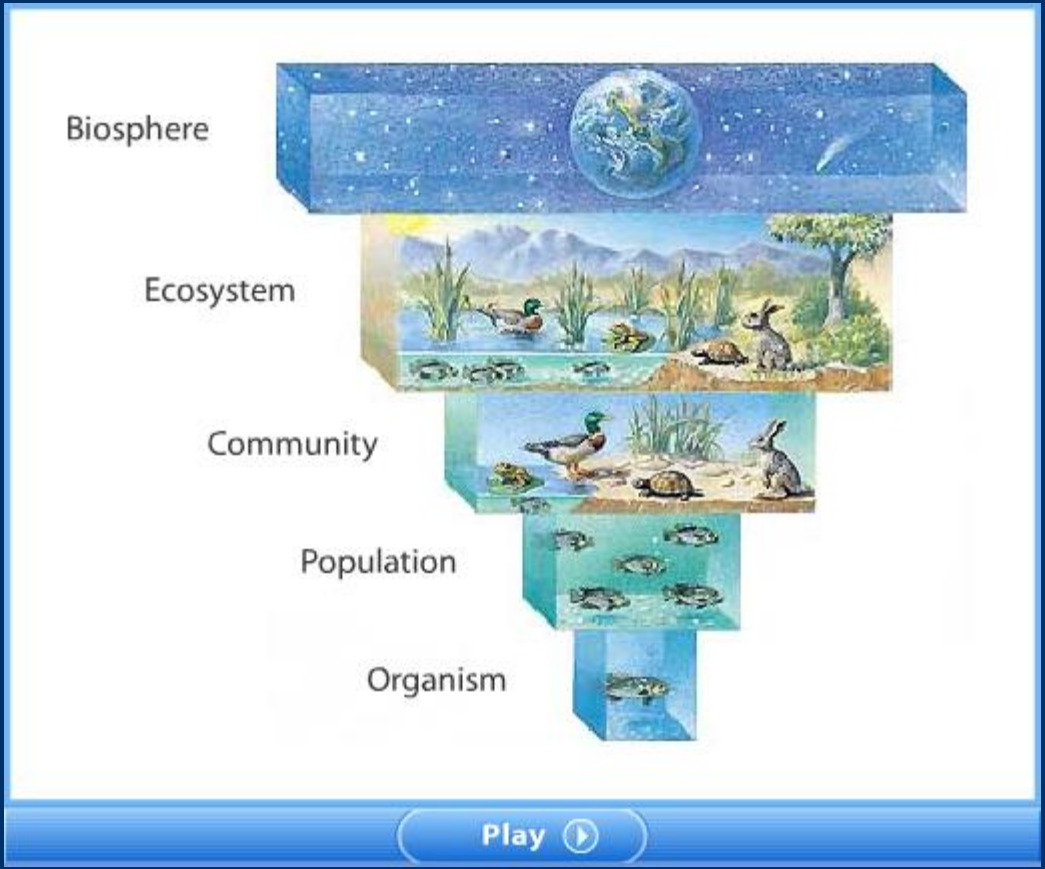


Darwin Proposed a Mechanism for Evolution, *continued*

Growth of Populations

- The key that unlocked Darwin's thinking about how evolution takes place was an essay written in 1798 by the English economist Thomas Malthus.
- Malthus suggested that human populations do not grow unchecked because death caused by disease, war, and famine slows population growth.
- In the study of biology, a **population** consists of all the individuals of a species that live in a specific geographical area and that can interbreed.

Population



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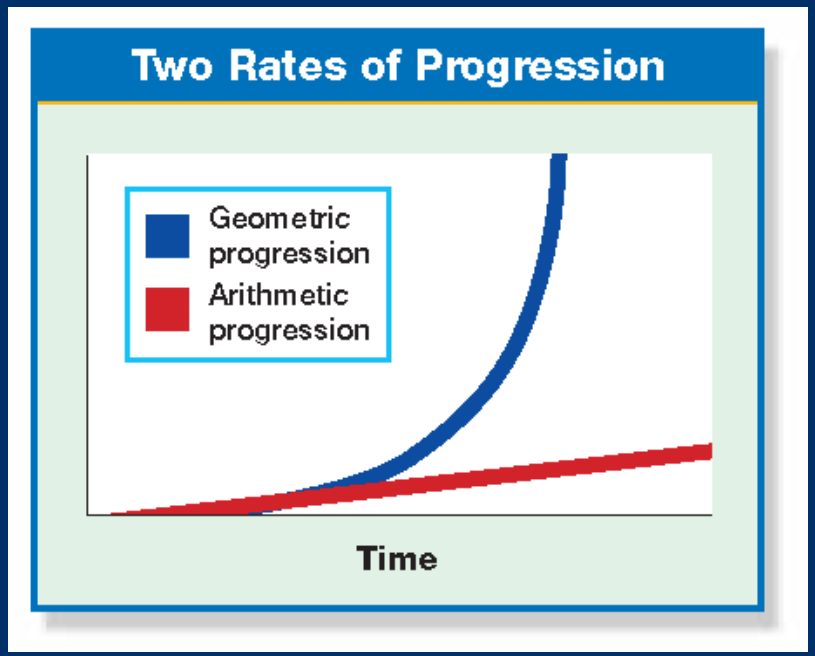
Darwin Proposed a Mechanism for Evolution, *continued*



Growth of Populations

- The blue graph line shows uncontrolled population growth, in which the numbers increase by a multiplied constant. The red graph line shows increased food supply, in which the numbers increase by an added constant.

End of Slide

Evolution by Natural Selection

- Individuals that have physical or behavioral traits that are better adapted to their environment are more likely to survive and will reproduce more successfully than those that do not have such traits.
- Darwin called this differential rate of reproduction **natural selection.**
- An **adaptation** is a feature that has become common in a population because the feature provides a selective advantage.

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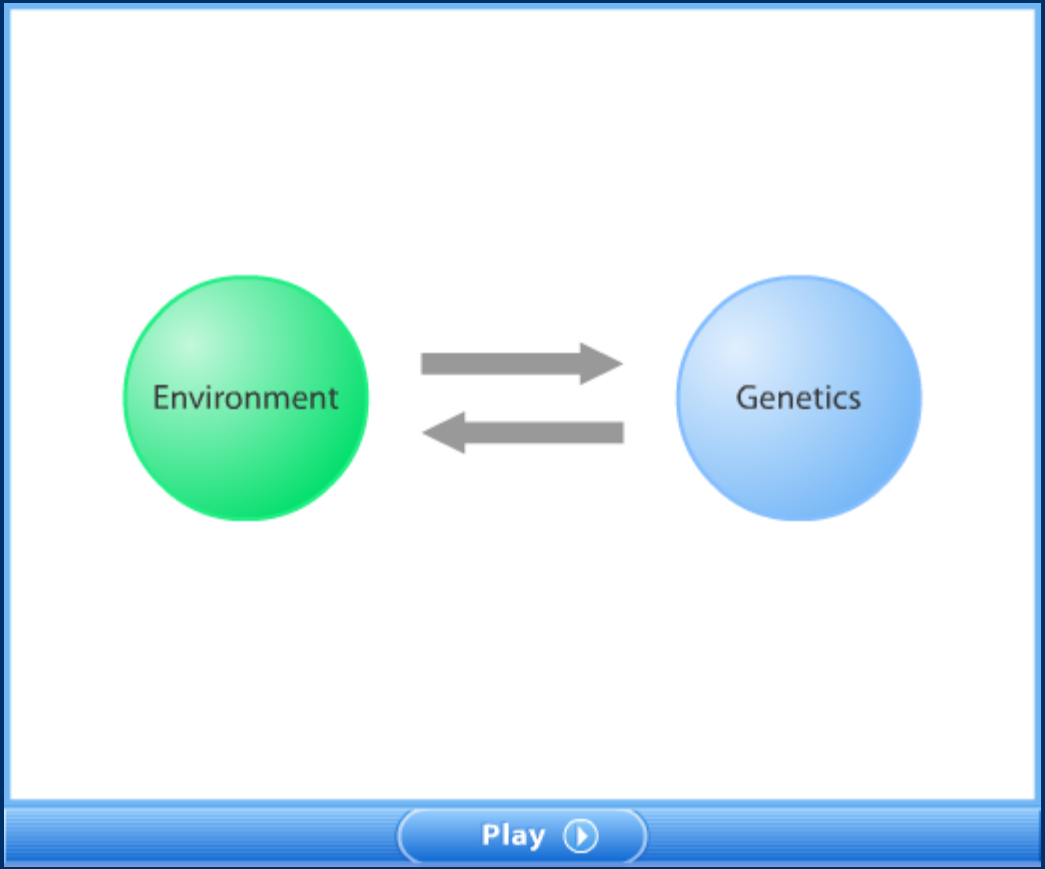
Natural Selection



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Adaptation

Evolution by Natural Selection, *continued*

- In 1844, Darwin finally wrote down his ideas about evolution and natural selection in an early outline that he showed to only a few scientists he knew and trusted.
- Darwin decided to publish after he received a letter and essay in June 1858 from the young English naturalist Alfred Russel Wallace (1823–1913), who was in Malaysia at the time. Wallace's essay described a hypothesis of evolution by natural selection.
- Darwin's friends arranged for a summary of Darwin's manuscript to be presented with Wallace's paper at a public scientific meeting.

End Of Slide

Evolution by Natural Selection, *continued*

Darwin's Theory

- Darwin's theory of evolution by natural selection is supported by four major points:

  1. Variation exists within the genes of every population or species.

  2. In a particular environment, some individuals of a population or species are better suited to survive and have more offspring.

  3. Over time, the traits that make certain individuals of a population able to survive and reproduce tend to spread in that population.

  4. There is overwhelming evidence from fossils and many other sources that living species evolved from organisms that are extinct.

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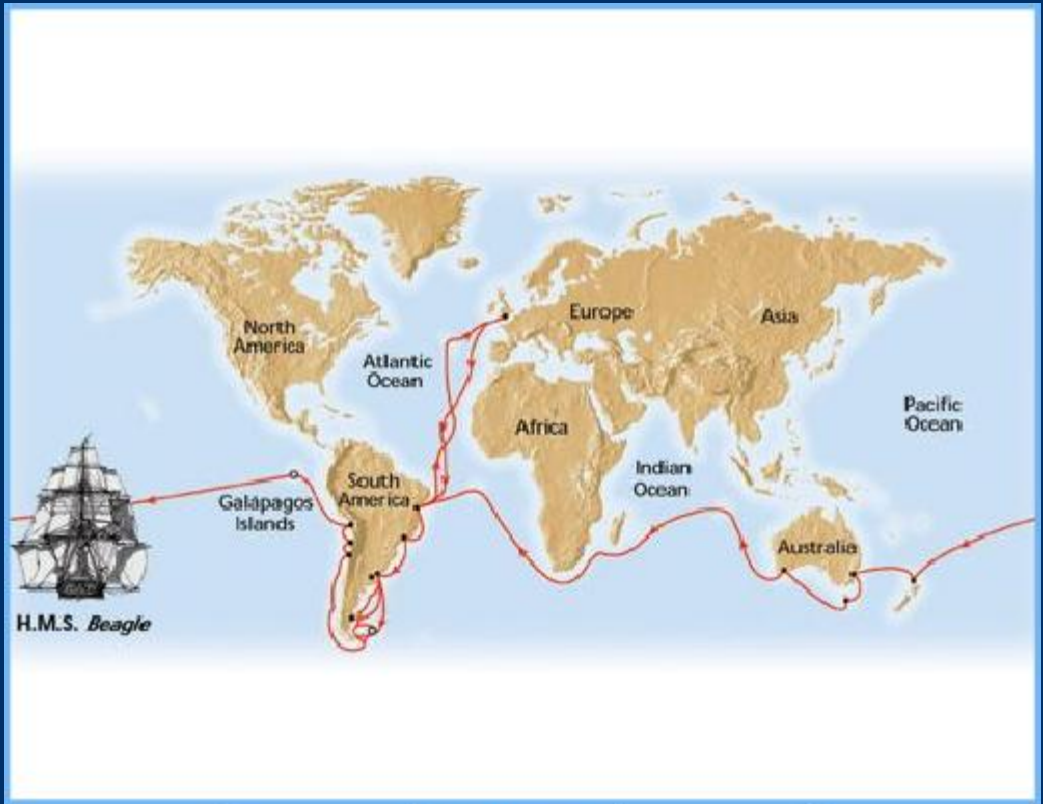
Darwin's Theories



Darwin's Ideas Updated

Change Within Populations

- Darwin's key inference was based on the idea that in any population, individuals that are best suited to survive and do well in their environment will produce the most offspring.
- Scientists now know that genes are responsible for inherited traits.
- Therefore, certain forms of a trait become more common in a population because more individuals in the population carry the alleles for those forms.

End of Slide

Darwin's Ideas Updated

Species Formation

- Populations of the same species living in different locations tend to evolve in different directions.
- **Reproductive isolation** is the condition in which two populations of the same species do not breed with one another because of their geographic separation.
- As two isolated populations of the same species become more different over time, they may eventually become unable to breed with one another.

End Of Slide

Reproductive Isolation

Wood frog

Leopard frog

Play

End Of Slide

Geographic Isolation

End Of Slide

Darwin's Ideas Updated

The Tempo of Evolution

- For decades, most biologists have understood evolution as a gradual process that occurs continuously.
- The model of evolution in which gradual change over a long period of time leads to species formation is called **gradualism.**
- Another model of evolution, in which periods of rapid change in species are separated by periods of little or no change, is called **punctuated equilibrium.**

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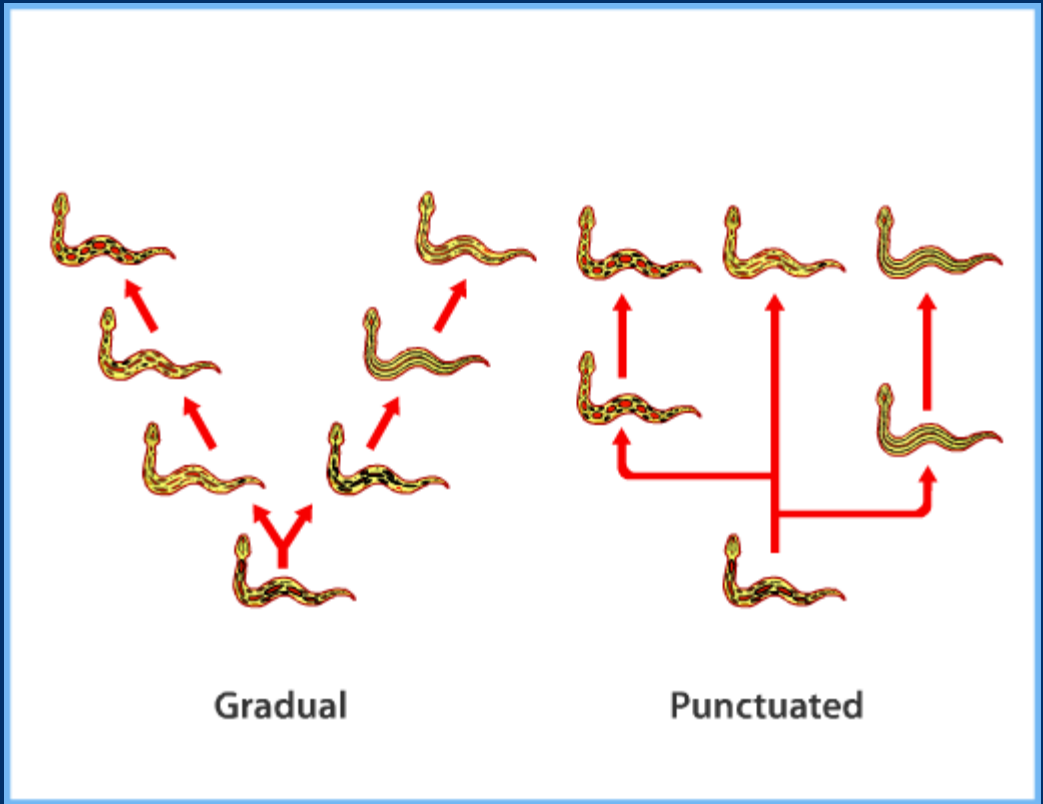
Gradualism

Comparing Punctuated Equilibrium and Gradualism



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Objectives

- **Describe** how the fossil record supports evolution.
- **Summarize** how biological molecules such as proteins and DNA are used as evidence of evolution.
- **Infer** how comparing the anatomy and development of living species provides evidence of evolution.

End Of Slide

The Fossil Record

- Fossils provide an actual record of Earth's past life-forms give evidence that:

  1. Earth is about 4.5 billion years old.

  2. Organisms have inhabited Earth for most of its history.

  3. All organisms living today share common ancestry with earlier, simpler life-forms.

End Of Slide

The Fossil Record

Formation of Fossils

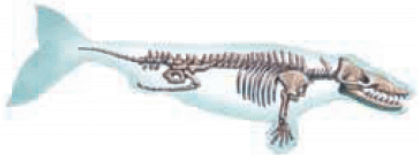
- The fossil record, and thus the record of the evolution of life, is not complete.
- **Paleontologists,** scientists who study fossils, can determine the age of fossils fairly accurately by using radiometric dating.
- Radiometric dating the sediments in which a fossil is found enables paleontologists to arrange fossils in sequence from oldest to youngest.

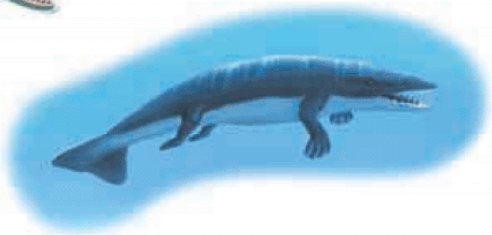
End Of Slide

Evidence of Whale Evolution

Whales are thought to have evolved from an ancestral line of four-legged mammals, which are represented here by their fossils and artistic reconstructions showing what scientists think they may have looked like.

Mesonychids are one hypothesized link between modern whales and certain hoofed mammals. They were about 2 m (6 ft) long. They are thought to have lived about 60 million years ago. Some scientists favor an alternative hypothesis linking whales to other ancestral hooved mammals. These hooved mammals are also ancestral to hippopotamuses or pigs.



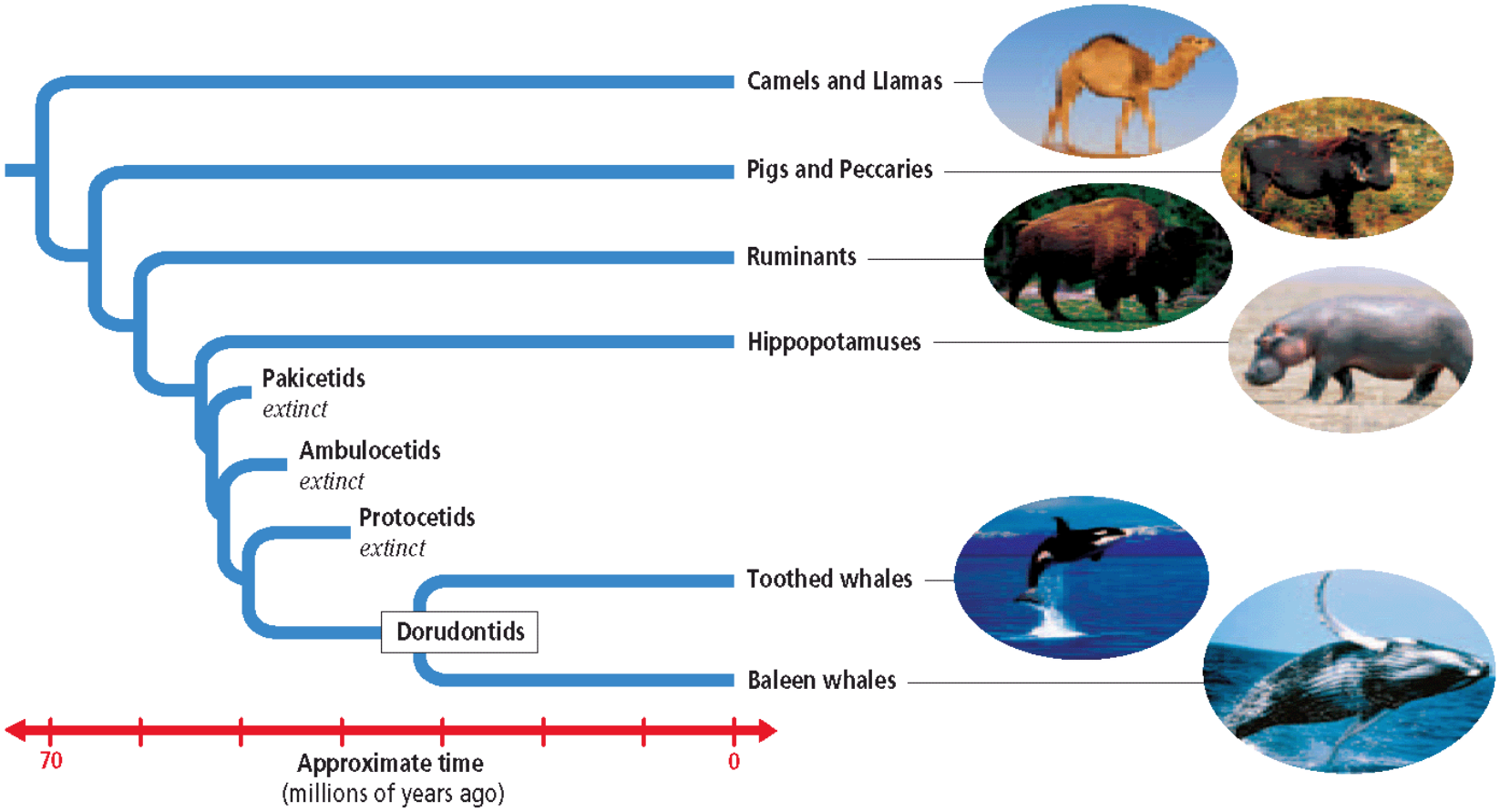


Rodhocetus kasrani, a more recent ancestor of modern whales, probably spent little time on land. Its reduced hind limbs could not have aided in walking or swimming. It is thought to have existed about 40 million years ago.

Ambulocetus natans apparently walked on land like modern sea lions and swam by flexing its backbone and paddling with its hind limbs (as do modern otters). They were about 3 m (10 ft) long. They existed about 50 million years ago.

Modern whales have forelimbs that are flippers and hind limbs that have been reduced to only a few internal functionless hind-limb bones.

Evolutionary Relationship Between Whales and Hoofed Mammals



Anatomy and Development

- Comparisons of the anatomy of different types of organisms often reveal basic similarities in body structures even though the structure's functions may differ between organisms.
- Sometimes bones are present in an organism but are reduced in size and either have no use or have a less important function than they do in other, related organisms. Such structures are called **vestigial structures.**
- **Homologous structures** are structures that share a common ancestry.

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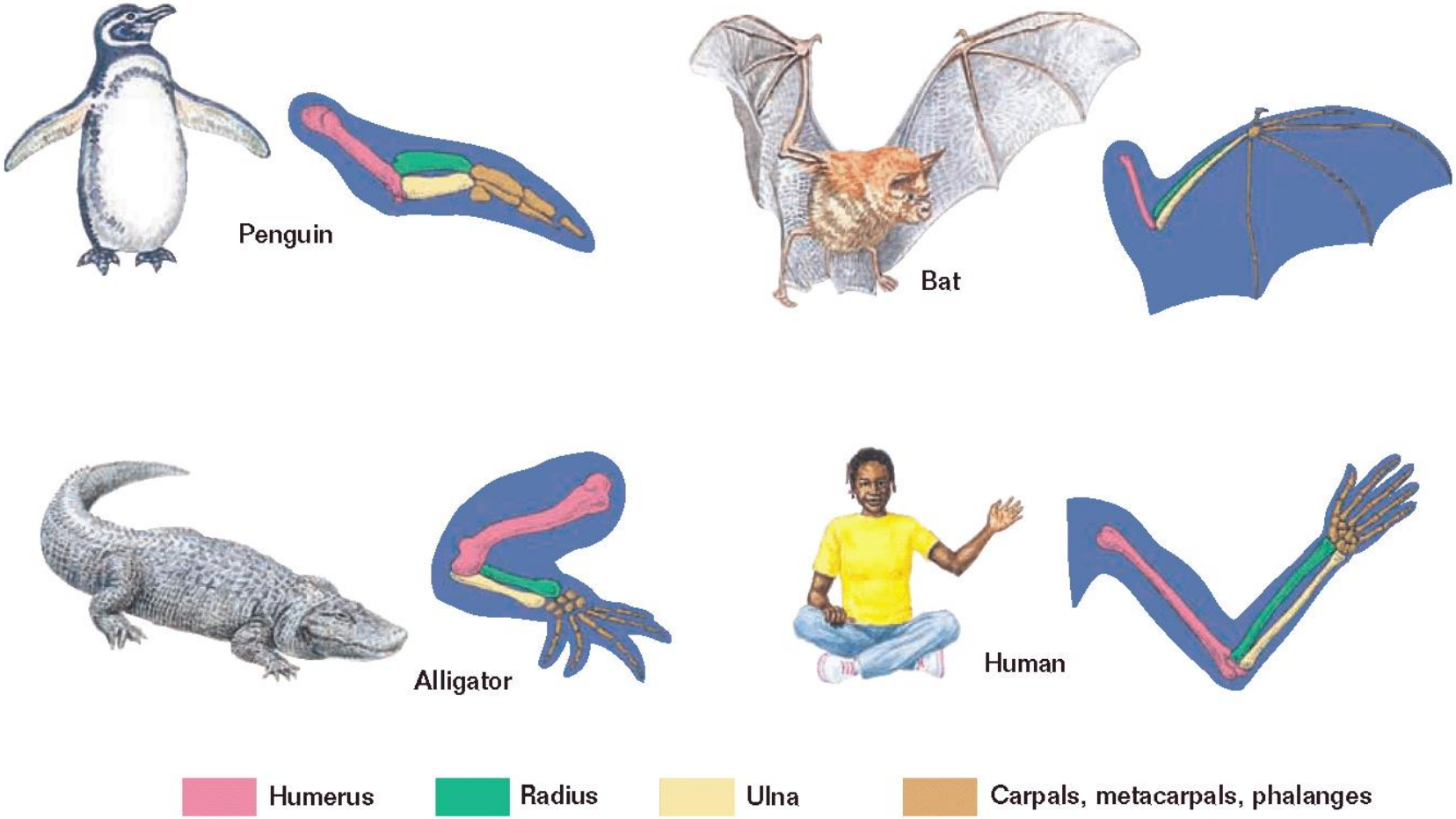
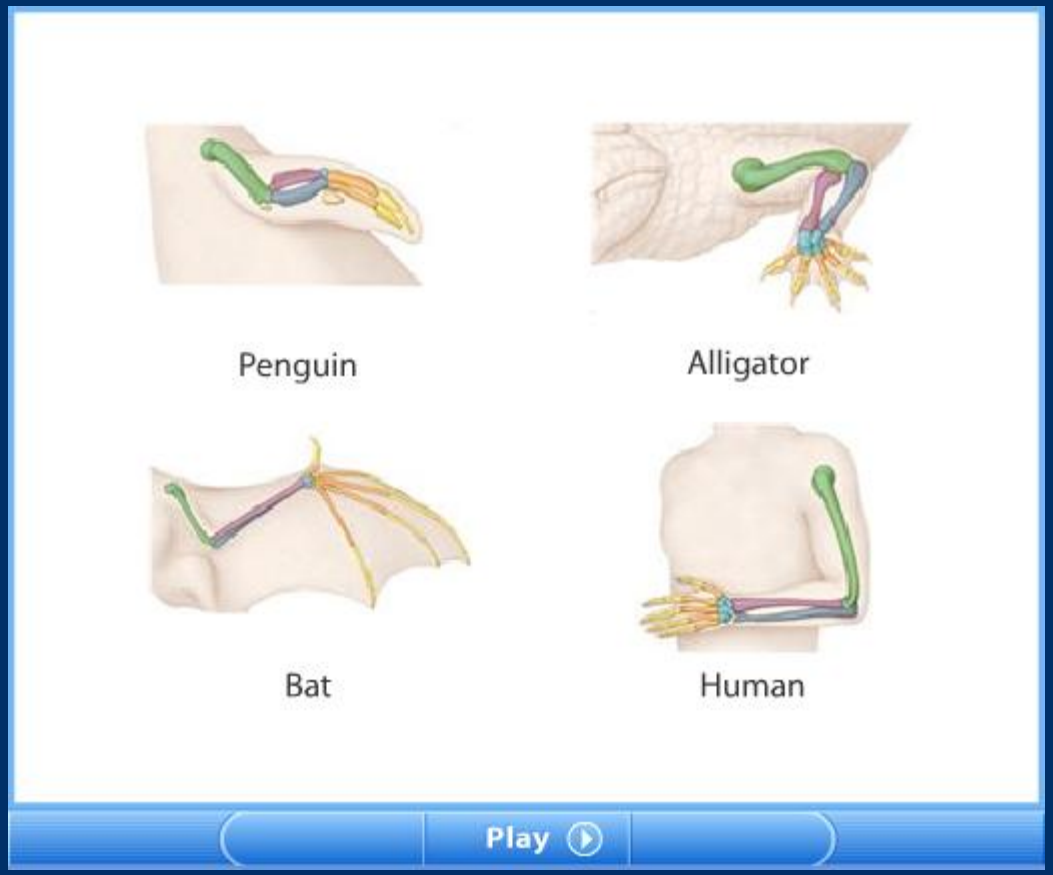
Vestigial Features

Forelimbs of Vertebrates



Homologous Features



Anatomy and Development, *continued*

- The evolutionary history of organisms is also seen in the development of embryos.
- At some time in their development, all vertebrate embryos have a tail, buds that become limbs, and pharyngeal pouches.
- The tail remains in most adult vertebrates. Only adult fish and immature amphibians retain pharyngeal pouches (which contain their gills).

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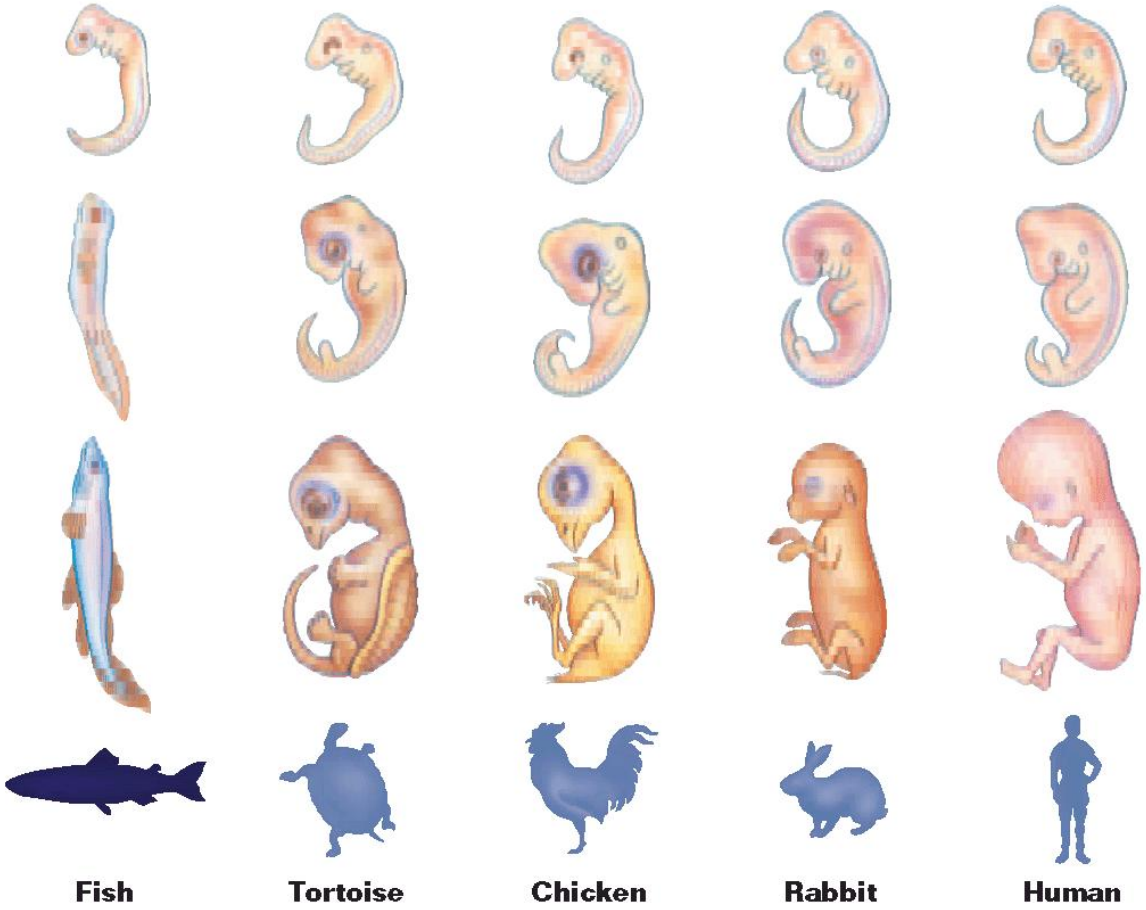
Comparing Vertebrate Embryo Development



Similarities in Embryology

Biological Molecules

Proteins

- As species evolved, one change after another should have become part of their genetic instructions. Therefore, more and more changes in a gene's nucleotide sequence should build up over time.
- If evolution has taken place, then species descended from a recent common ancestor should have fewer amino acid differences between their proteins than do species that shared a common ancestor in the distant past.
- In fact, species that share a common ancestor more recently have few amino acid sequence differences.

End Of Slide

Hemoglobin Comparison

Species	Amino Acid Differences from Human Hemoglobin Protein
Gorilla	1
Rhesus monkey	8
Mouse	27
Chicken	45
Frog	67
Lamprey	125

Biological Molecules, *continued*

DNA Sequences

- Scientists evaluate the number of nucleotide changes that have taken place in a gene since two species diverged from a common ancestor by comparing the nucleotide sequence of genes.
- Using the data obtained from proteins and nucleotides, scientists generate hypotheses about how organisms are related through evolution.
- The hypotheses, based on molecular data, tend to reflect the relationships indicated by the fossil record.

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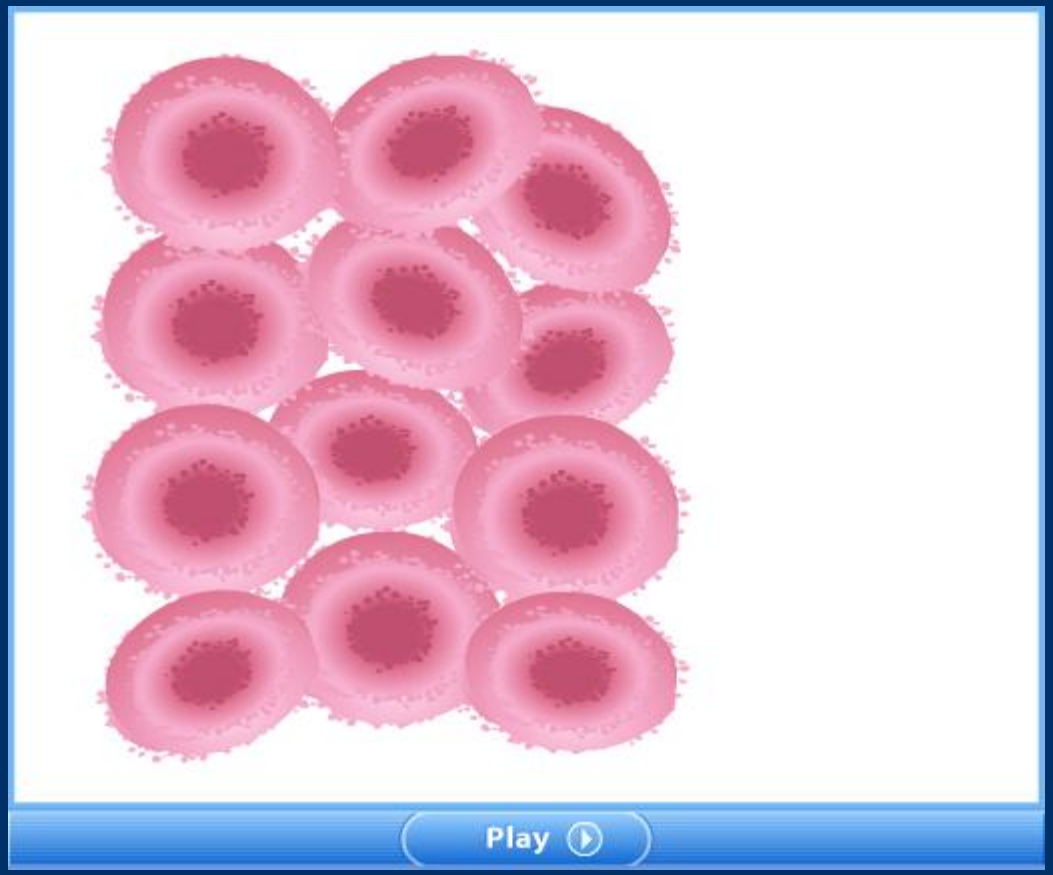
Similarities in Macromolecules



Objectives

- **Identify** four elements in the process of natural selection.
- **Describe** how natural selection has affected the bacteria that cause tuberculosis.
- **Relate** natural selection to the beak size of finches.
- **Summarize** the process of species formation.

End Of Slide

Natural Selection at Work

Factors in Natural Selection

- The process of natural selection is driven by four important points that are true for all real populations:

  1. All populations have genetic variation.

  2. The environment presents challenges to successful reproduction.

  3. Individuals tend to produce more offspring than the environment can support.

  4. Individuals that are better able to cope with the challenges presented by their environment tend to leave more offspring than those individuals less suited to the environment do.

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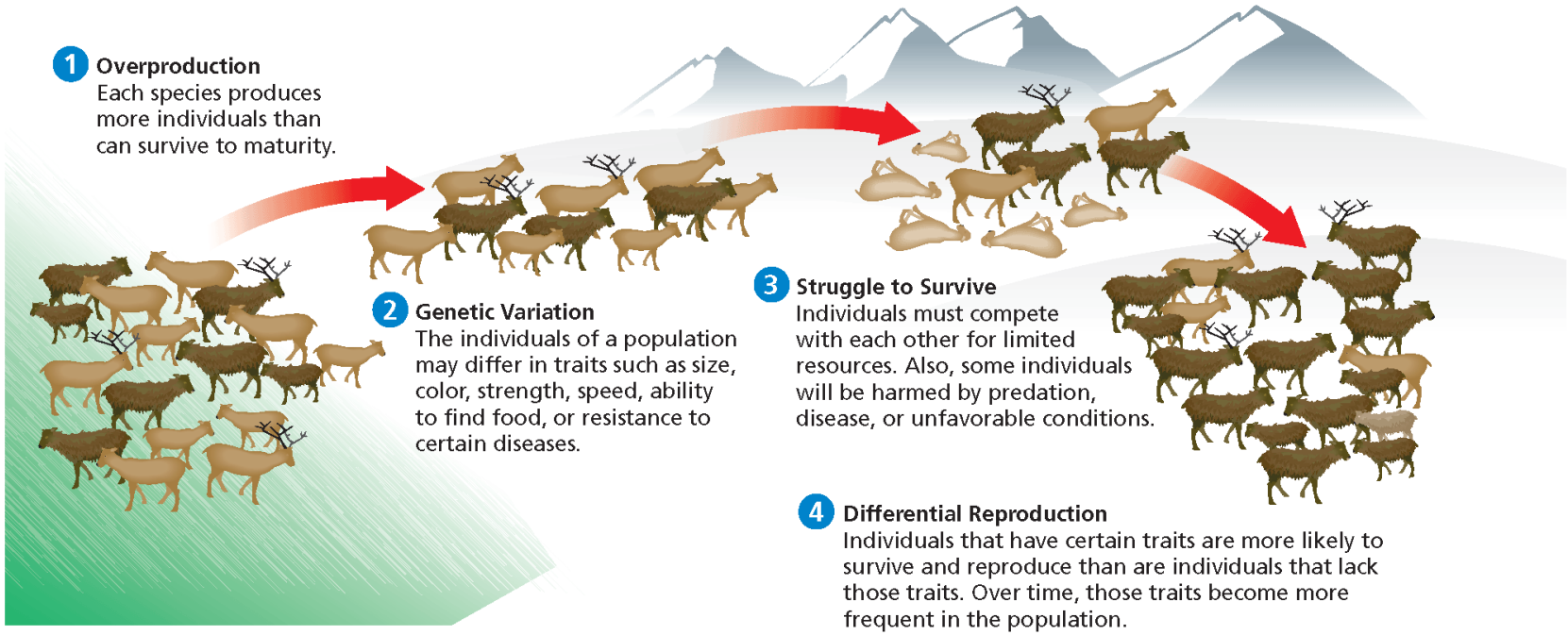
Natural Selection



Natural Selection at Work, *continued*

Example of Natural Selection

- The lung disease tuberculosis (TB) is usually caused by the bacterium *Mycobacterium tuberculosis*.
- In the 1950s, two effective antibiotics, isoniazid and rifampin, became available to treat TB.
- In the late 1980s, however, new strains of *M. tuberculosis* that are largely or completely resistant to isoniazid and rifampin appeared.

End Of Slide

Natural Selection at Work, *continued*

Evolution of Antibiotic Resistance

- Rifampin acts by binding to *M. tuberculosis* RNA polymerase, preventing transcription and so killing the bacterial cell.
- The mutation in the polymerase's *rpoB* gene prevents rifampin from binding to the polymerase.
- TB bacteria with the mutation were able to survive treatment with the antibiotic, so natural selection led to the evolution of rifampin resistance in *M. tuberculosis.*

End Of Slide

Natural Selection at Work, *continued*

Evolution in Darwin's Finches

- Darwin collected 31 specimens of finches from three islands when he visited the Galápagos Islands.
- Darwin suggested that the nine species of Galápagos finches evolved from an original ancestral species.
- Changes occurred as different populations accumulated adaptations to different food sources.

End Of Slide

Natural Selection at Work, *continued*

Evolution in Darwin's Finches

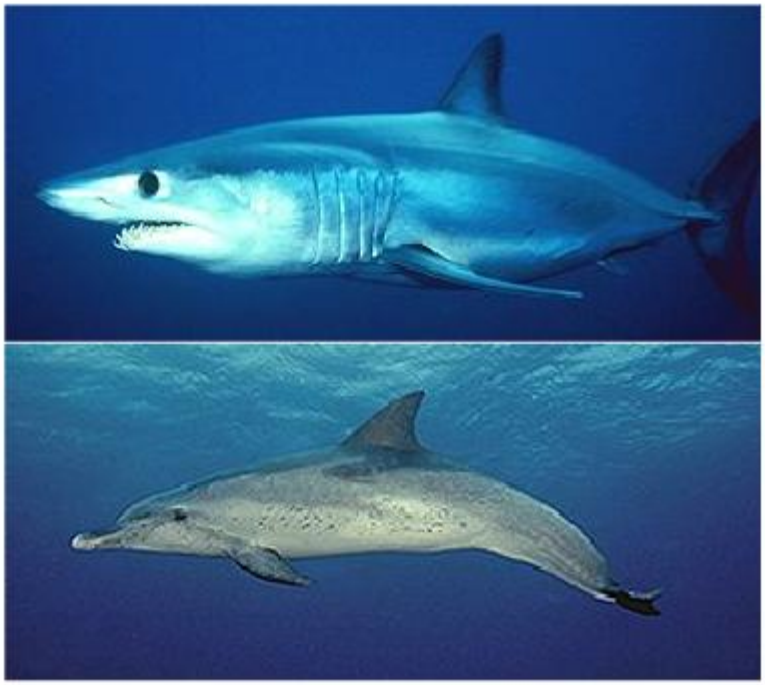
- A study of the finches was carried out over 25 years beginning in 1973 by Peter and Rosemary Grant of Princeton University.
- The Grants measured the beaks of many birds every year.
- The numbers of birds with different beak shapes are changed by natural selection in response to the available food supply, just as Darwin had suggested.

End Of Slide

Formation of New Species

- Species formation occurs in stages.
- The accumulation of differences between groups is called **divergence.**
- Biologists call the process by which new species form speciation.

Comparing Convergent and Divergent Evolution



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Formation of New Species, *continued*

Forming Subspecies

- Separate populations of a single species often live in several different kinds of environments.
- Over time, populations of the same species that differ genetically because of adaptations to different living conditions become what biologists call **subspecies.**
- The members of newly formed subspecies have taken the first step toward speciation.

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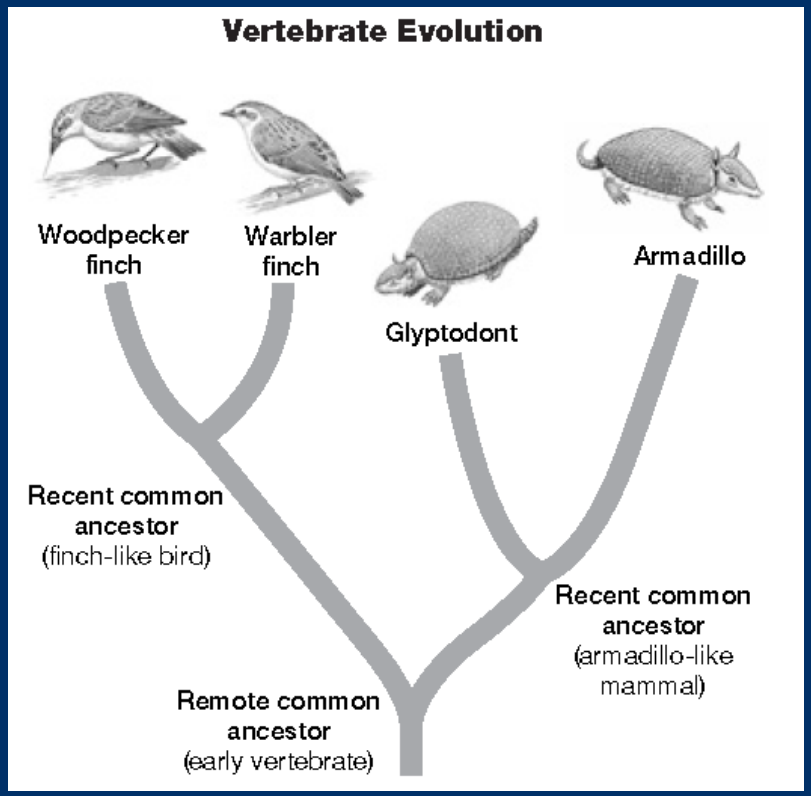
Multiple Choice

Use the figure below to answer questions 1–3.



Multiple Choice, *continued*

1. The diagram implies that warbler finches and armadillos

   A. are unrelated
   B. share a recent common ancestor.
   C. share a remote common ancestor.
   D. did not evolve from older forms of life.

Multiple Choice, *continued*

1. The diagram implies that warbler finches and armadillos

   A. are unrelated
   B. share a recent common ancestor.
   C. share a remote common ancestor.
   D. did not evolve from older forms of life.

Multiple Choice, *continued*

2. Which organism has DNA that is probably most similar to the glyptodont's DNA?

F. woodpecker finch
G. warbler finch
H. finch-like bird
J. armadillo

Multiple Choice, *continued*

2. Which organism has DNA that is probably most similar to the glyptodont's DNA?

F. woodpecker finch
G. warbler finch
H. finch-like bird
J. armadillo

Multiple Choice, *continued*

3. Because the woodpecker finch and the warbler finch are different species, they probably

   A. cannot interbreed.
   B. lack homologous structures.
   C. develop from very different embryos.
   D. are more similar to glyptodonts than to each other.

Multiple Choice, *continued*

3. Because the woodpecker finch and the warbler finch are different species, they probably

   A. cannot interbreed.
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