Descent With Modification: A Darwinian View of Life

Chapter 22

- Objectives
  - Describe the contributions to evolutionary theory made by Linnaeus, Cuvier, Lyell, Lamarck, Malthus, and Wallace
  - Describe Lamarck's theories, and explain why they have been rejected
  - Explain what Darwin meant by "descent with modification"
  - List and explain Darwin's four observations and two inferences
  - Explain why an individual organism cannot evolve
  - Describe at least four lines of evidence for evolution by natural selection

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Introduction

- Overview: Darwin Introduces a Revolutionary Theory
  - A new era of biology began on November 24, 1859, the day Charles Darwin published *On the Origin of Species by Means of Natural Selection*
- *The Origin of Species* focused biologists' attention on the great diversity of organisms

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- Darwin made two major points in his book
  - He presented evidence that the many species of organisms presently inhabiting the Earth are descendants of ancestral species
  - He proposed a mechanism for the evolutionary process, natural selection

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- The Darwinian revolution challenged traditional views of a young Earth inhabited by unchanging species
- In order to understand why Darwin's ideas were revolutionary we need to examine his views in the context of other Western ideas about Earth and its life

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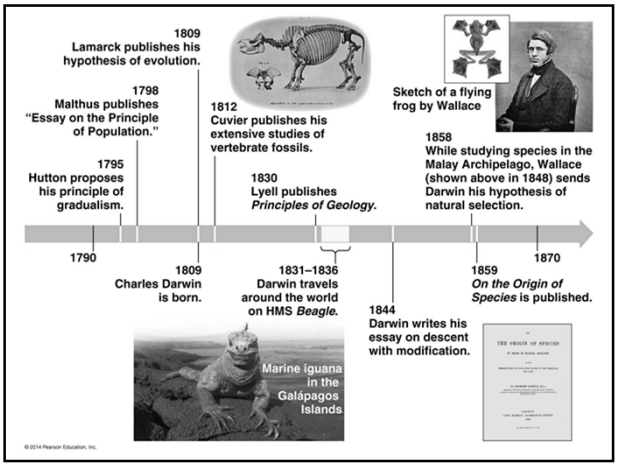

- The dominant philosophy in biology during the 1700's was natural theology
  - adaptations of organisms were seen as evidence of the designed purpose of each
  - derived from Aristotelian philosophy
    - while some early Greek philosophers proposed a gradual evolution of life, Plato and Aristotle opposed evolution
      - viewed living organisms as perfect and unchanging
      - every rung of the *scala naturae* was occupied
    - reinforced by Judeo-Christian tradition and culture

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- Carolus Linnaeus-developed hierarchical taxonomic system based on binomial naming system
  - attempted to bring order and classification to creation
- Georges Cuvier-studied fossils of the Paris Basin
  - developed the discipline of paleontology, the study of fossils

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Fossils, Cuvier, and Catastrophism

- Fossils and the fossil record
  - Fossil formation
    - hard parts, like skeletons, shells and teeth, remain after organic matter has decayed-fossilize easily
    - some fossils, like leaves, retain some organic material with molecular fragments that can be analyzed
      - insects trapped in tree resin, and protected from bacteria and fungi, are fossilized intact in amber
      - petrified fossils form when minerals slowly infiltrate organic matter
      - fossilized molds form when covered organisms decay and space is filled with other sediment

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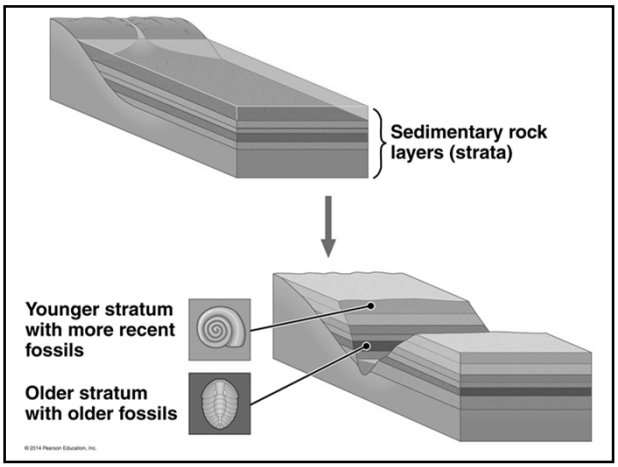

- Cuvier realized the importance of fossils as a history of life
  - recognized extinction as a common event but opposed the idea of gradual evolutionary change
    - proposed the principle of catastrophism as an explanation for changes in the fossil record between strata
    - periodic local catastrophes destroyed much of life in a region which was then repopulated by migration

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Theories of Gradualism

- James Hutton-proposed the theory of gradualism to explain the origin of geologic features
  - large scale changes are the cumulative product of slow, continuous processes

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- Charles Lyell-outlined the idea uniformitarianism as an extension of Hutton's gradualism
  - continual, consistent, gradual geological change responsible for shaping the earth
  - forces active today are the same as were active in the past and operate the same

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- Gradualism and uniformitarianism lead to two conclusions that influenced Darwin
  - the Earth must be very old for geologic changes to occur as a result of slow continuous actions
  - slow, imperceptible, processes occurring over a long period of time can result in substantial changes

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Lamarck's Theory of Evolution

- Jean Baptiste Lamarck developed the first comprehensive model of evolution
  - It is based on two ideas
    - use and disuse
      - often used parts of an organism become large, unused deteriorate

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- inheritance of acquired characteristics
  - traits acquired during lifetime passed onto offspring
  - first to propose evolution as the best explanation of the fossil record and the diversity of life
  - recognized adaptation to the environment as the product of evolution
- The mechanisms he proposed are unsupported by evidence

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Darwinian Evolution

- In *The Origin of Species*, Darwin proposed that species change through natural selection
- As the 19th century dawned it was generally believed that species had remained unchanged since their creation, but a major change would challenge this thinking

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Darwin's Research

- Darwin's views were shaped by his experiences on the voyage of the *Beagle*

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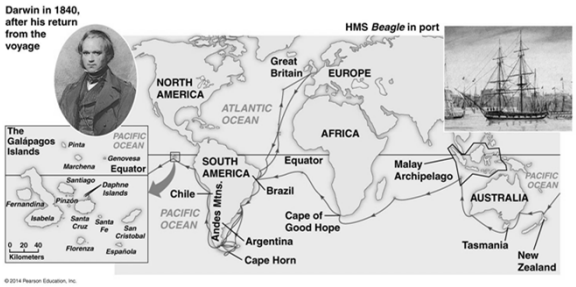

- During *Beagle* voyage (1831-1836), Darwin was influenced most by:
  - Comparisons of South American fossils with living species there and fossils elsewhere
    - fossils in South America, although different from living species, were distinctly South American
    - species living in temperate regions of South America were more closely related to species in the tropical regions of the continent rather than the temperate regions of Europe

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– Darwin's interest in the geographic distribution of species was kindled by the *Beagle*'s stop at the Galápagos Islands near the equator west of South America
  - Observations of organisms in Galapagos Islands and their distribution indicated that the species were unique to the islands
    – however, they resembled species living in South America

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Darwin's Focus on Adaptation

- After returning, Darwin began the development of the theory of evolution based on natural selection
  – He began to perceive adaptation to the environment and the origin of new species as closely related processes

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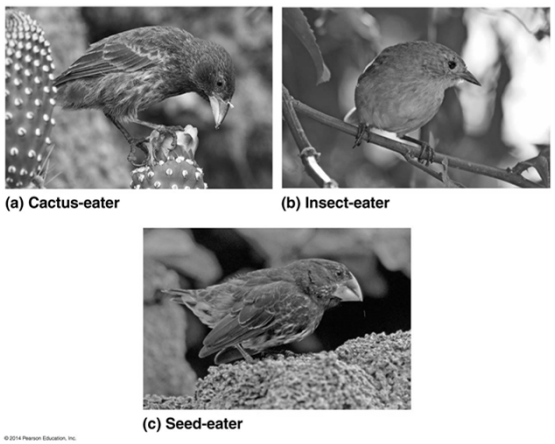
(a) Cactus-eater

(b) Insect-eater

(c) Seed-eater

- Darwin recognized that the origin of new species from ancestral forms by gradual accumulation of adaptations to new environments required an explanation
  - He developed the theory of natural selection as the mechanism of evolutionary change

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- In 1844, Darwin wrote a long essay on the origin of species and natural selection but he was reluctant to introduce his theory publicly, anticipating the uproar it would cause
  - In June 1858 Darwin received a manuscript from Alfred Russell Wallace who had developed a theory of natural selection similar to Darwin's
- Darwin quickly finished *The Origin of Species* and published it the next year

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The Origin of Species

- Darwin developed two main ideas
  - Evolution explains life's unity and diversity
  - Natural selection is a cause of adaptive evolution
- The phrase *descent with modification* summarized Darwin's perception of the unity of life
  - States that all organisms are related through descent from an ancestor that lived in the remote past

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- Darwinian evolution views the history of life like tree with multiple branches from base of trunk to tips of branches
  - Species on one branch more closely interrelated than to species on other branches
    - Linnaean hierarchy reflects the history of life
  - Many branches end in a dead end
    - 99% of all known species are extinct

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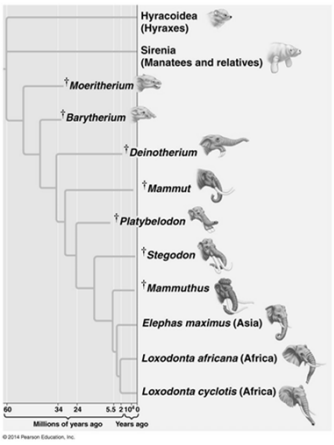

Natural Selection and Adaptation

- Darwin inferred natural selection from two observations
  - Individuals within a population of any species differ in many heritable traits

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– Any population produces more offspring than their environment can support
  - overpopulation causes a struggle for existence among members of the population

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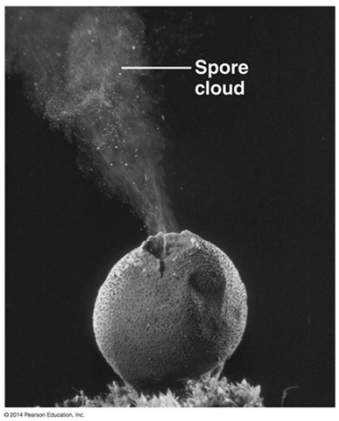

- Darwin concluded that individuals in the population will have differential reproductive success
  - individuals with the best combination of traits for the local environment will leave proportionally larger numbers of offspring
    - differential reproductive success means that some heritable traits are more likely to appear in successive generations

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- Differential reproductive success is natural selection
  - causes evolution of populations
    - the population is the unit of evolution
    - simple definition is a group of individuals of the same species living in the same geographic region

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Artificial Selection

- The power of natural selection can be illustrated by artificial breeding
  - In the process of artificial selection humans have modified other species over many generations by selecting and breeding individuals that possess desired traits

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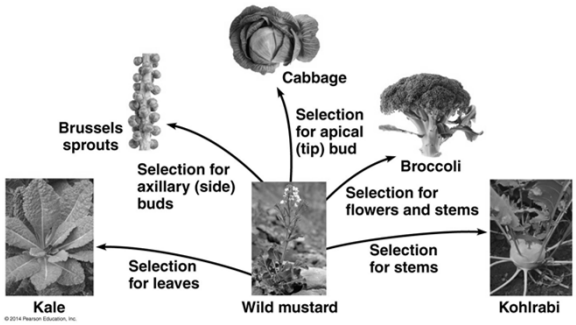

Summary of Natural Selection

- Natural selection is the mechanism of evolution
  - The essence of natural selection is differential reproduction
    - individuals in populations vary
    - individuals suited to environment reproduce easily and abundantly
    - favored characteristics are passed to next generation, unfavorable are not
    - over time, favorable characteristics accumulate in individuals in population

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- Natural selection is regional and timely
  - Populations adapt to local environment during one time period

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A flower mantid in Malaysia

A flower-eyed mantid in South Africa

A leaf mantid in Borneo

Natural Selection in Action

- Darwin's theory explains a wide range of observations
- Darwin's theory of evolution continues to be tested by how effectively it can account for additional observations and experimental outcomes
  - Evidence of natural selection in action provides evidence of evolution
  - Two examples provide evidence for natural selection

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Natural Selection in Response to Introduced Plant Species

- Soapberry bugs use their "beak" to feed on seeds within fruits
  - In southern Florida soapberry bugs feed on balloon vine with larger fruit; they have longer beaks
  - In central Florida they feed on goldenrain tree with smaller fruit; they have shorter beaks
    - Correlation between fruit size and beak size has also been observed in Louisiana, Oklahoma, and Australia

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- In all cases, beak size has evolved in populations that feed on introduced plants with fruits that are smaller or larger than the native fruits
  - These cases are examples of evolution by natural selection
  - In Florida this evolution in beak size occurred in less than 35 years

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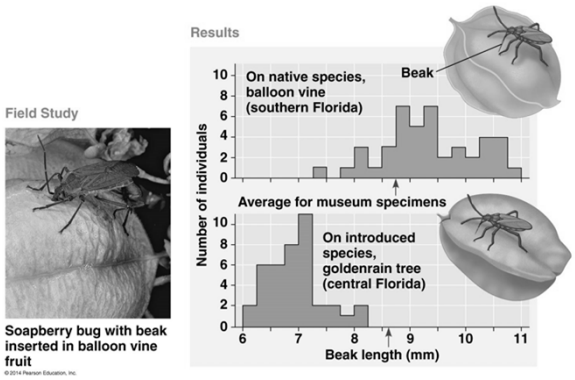

The Evolution of Drug-Resistant Bacteria

- The bacterium *Staphylococcus aureus* is commonly found on people
  - One strain, methicillin-resistant *S. aureus* (MRSA) is a dangerous pathogen
    - *S. aureus* became resistant to penicillin in 1945, two years after it was first widely used
    - *S. aureus* became resistant to methicillin in 1961, two years after it was first widely used
  - MRSA strains are now resistant to many antibiotics

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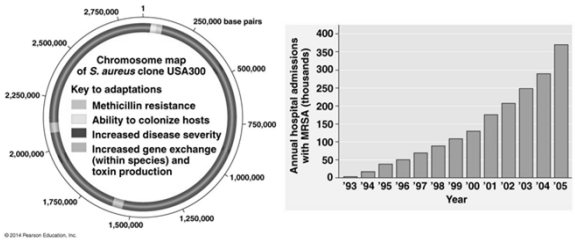

Homology, Biogeography, and the Fossil Record

- Darwinian view of life supported by several independent types of evidence
- Comparative anatomy
  - Comparison of homologous structures
    - structures that are similar in characteristics in species that share common ancestry
      - example-all mammals have same basic limb structure

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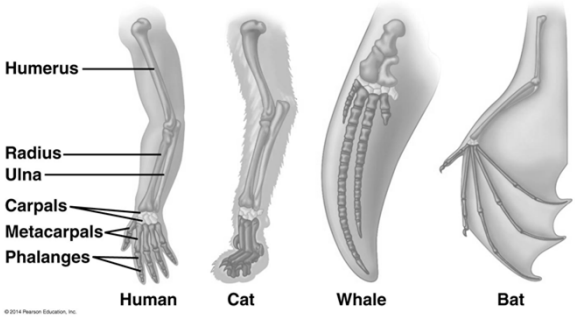

- Comparative embryology
  - Different organisms go through similar embryonic stages
  - All vertebrates have embryonic stages with gill pouches in throat, a notochord (cartilaginous supporting rod), dorsal hollow nerve chord (spinal chord) and post-anal tail.
    - gill pouches develop into different homologous structures with different functions
      - gills in fish
      - Eustachian tubes in mammals

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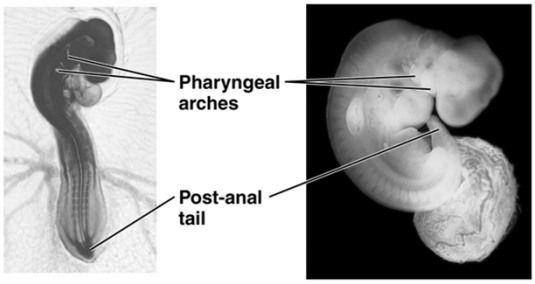

Chick embryo (LM)

Human embryo

- Vestigial organs and structures
  - remnants of structures important in ancestors but of little use to the new species
    - example-vestigial limb bones in primitive snakes such as boas

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Molecular Homologies

- Molecular biology
  - Shared molecular characteristics link distantly related organisms
    - the universality of the genetic code in essentially all organisms
      - evolved in early life forms and passed along through all branches of the tree of life
  - Many genes are shared among organisms and were inherited from a common ancestor

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- Molecular homologies can be used to reinforce the hierarchical pattern of the tree of life
  - Conservation of protein sequences
    - the evolutionary relationship among vertebrates, based on skeletal anatomy, is corroborated by protein sequence data

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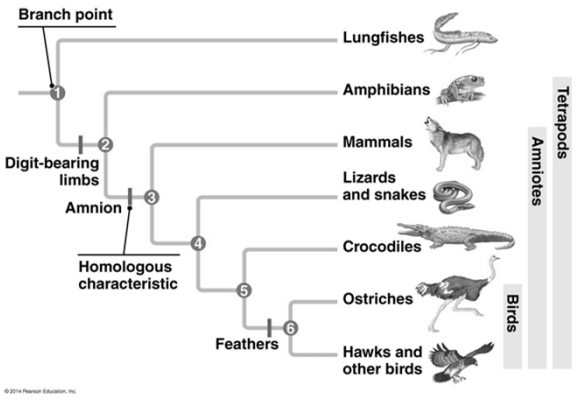

Biogeography

- Observations of the distribution of different but related life forms around the world and neighboring geographical regions
  - Species living in the same geographic region tend to be more closely related to each other than to species from other geographic regions
    - convergent evolution results in species from different geographic regions that resemble each other
    - similarity due to similar lifestyles not common evolutionary heritage

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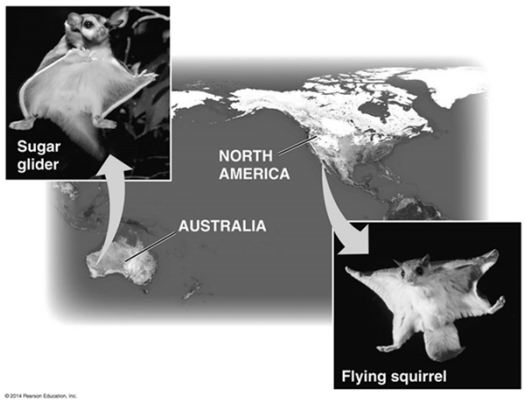

- Islands more similar to closest mainland than ecologically similar but more distant islands
  - many species are endemic
  - dispersal of the founding population through island archipelagos results in many new species

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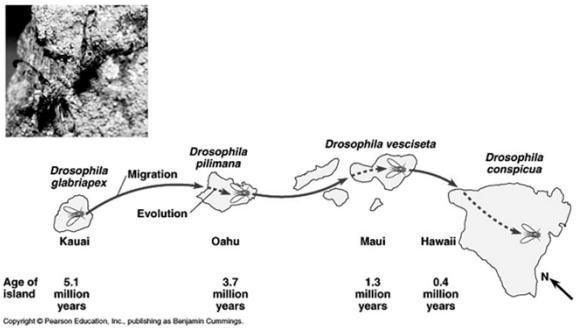

- Earth's continents are not fixed
  - Positioned in large crustal plates that float on underlying magma
    - plates drift over time
  - Currnet continents were formerly united in a single large continent called **Pangaea**, but have since separated by continental drift
  - An understanding of continent movement and modern distribution of species allows us to predict when and where different groups evolved

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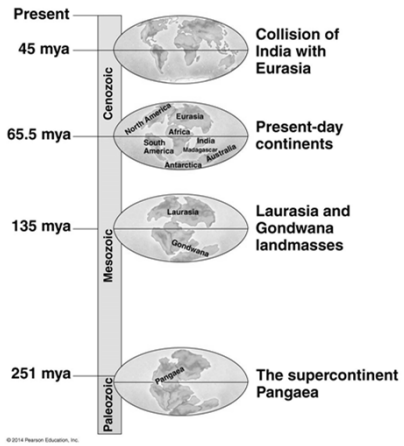

The Fossil Record

- The succession of forms observed in the fossil record is consistent with other inferences about the major branches of descent in the tree of life
  - The fossil record shows a sequence of fossils from the oldest known (prokaryotes ~3.5 billion years) through the appearance of eukaryotes to modern forms
    - the pattern is simple → complex and is consistent with other evidence for evolution

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- The fossil record provides evidence of the extinction of species, the origin of new groups, and changes within groups over time

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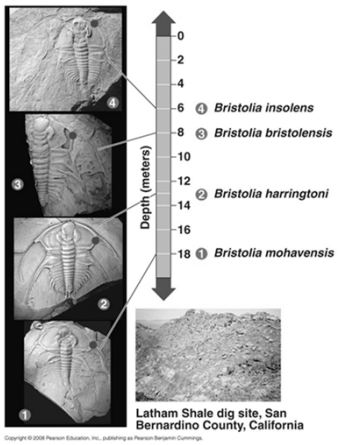

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- Comparing fossils and present-day species can add support to hypotheses based on other evidence
  - DNA sequence data suggests that modern cetaceans are descended from an early even-toed ungulate
    - Comparison of ankle bones from modern mammals and an early cetacean ancestor support this hypothesis

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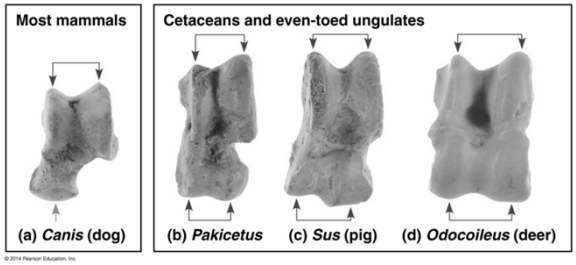

- The Darwinian view of life predicts that evolutionary transitions should leave signs in the fossil record
  - Paleontologists have recently discovered fossils that document the loss of limbs and the development of flippers and tail flukes during cetacean evolution

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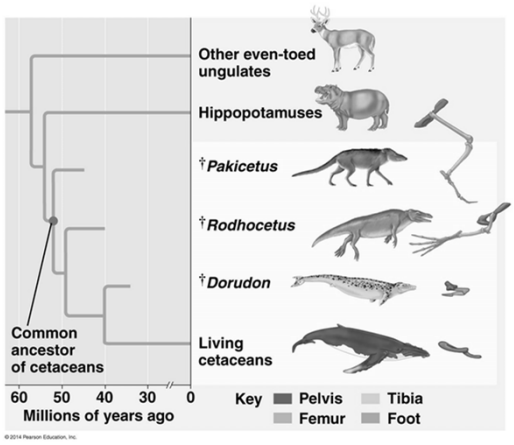

What Is Theoretical about the Darwinian View of Life?

- Theories are comprehensive explanations of accumulated observations and experimental results that previously appeared to be unrelated
  - They are much broader in scope than hypothesis and are not speculative or "hypothetical"
    - the colloquial use of theory is closer to a hypothesis
- Darwinian evolution is based on historical evidence
  - It integrates diverse areas of biological study and stimulates many new research questions

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