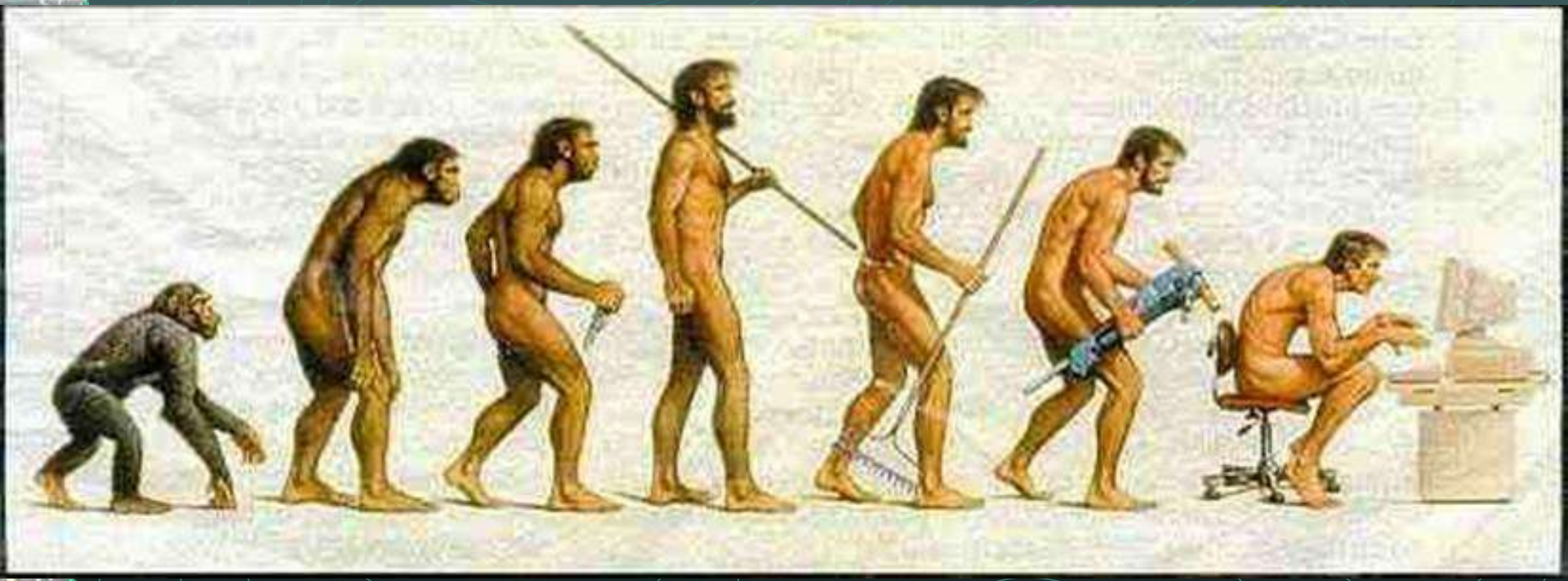
Chapter 13:
The Theory of Evolution



Biology II

Foundations of Evolution

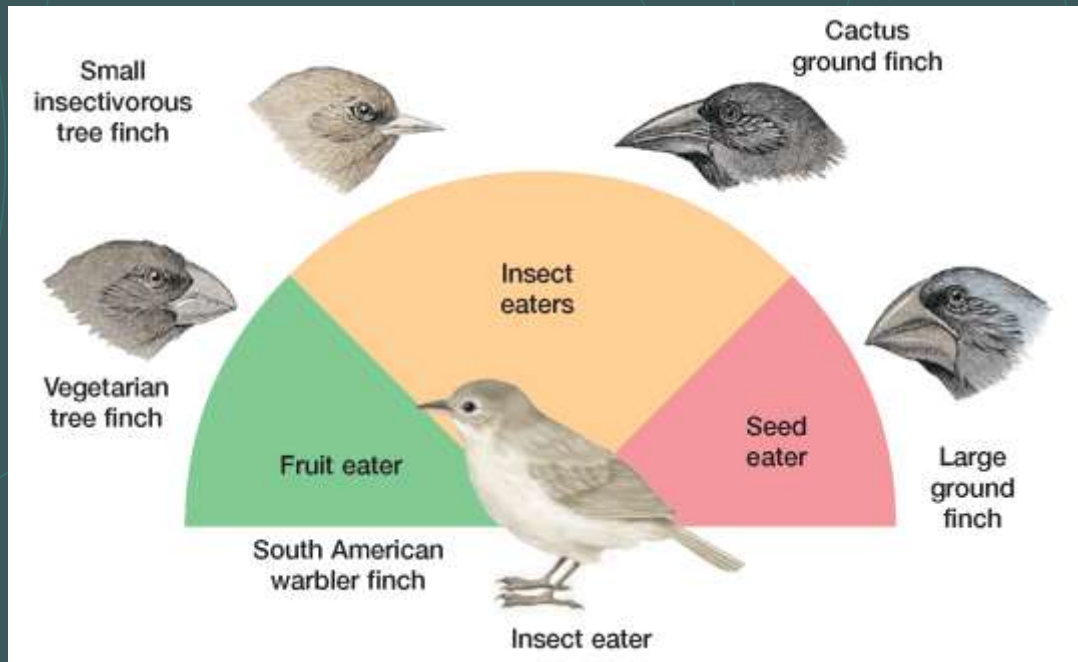
- Idea that life evolves proposed by Roman philosopher Lucretius 2,000 years ago
- Modern theory of evolution founded on work of English naturalist Charles Darwin (1859)
  - Urged by father to study medicine as well as theology
  - Set out as naturalist on HMS Beagle in 1831 at age 22

Science Before Darwin's Voyage

- In Darwin's time, it was believed that each species was a divine creation that remains unchanged by time
- In 1809, French scientist Lamarck proposed a hypothesis for how organisms change over generations
  - Believed that physical features increase or reduce in size, based on the amount of use of that feature
    - These changes then passed on to offspring
    - Though this hypothesis is now known to be incorrect, he correctly pointed out that change in species is linked to physical conditions of life

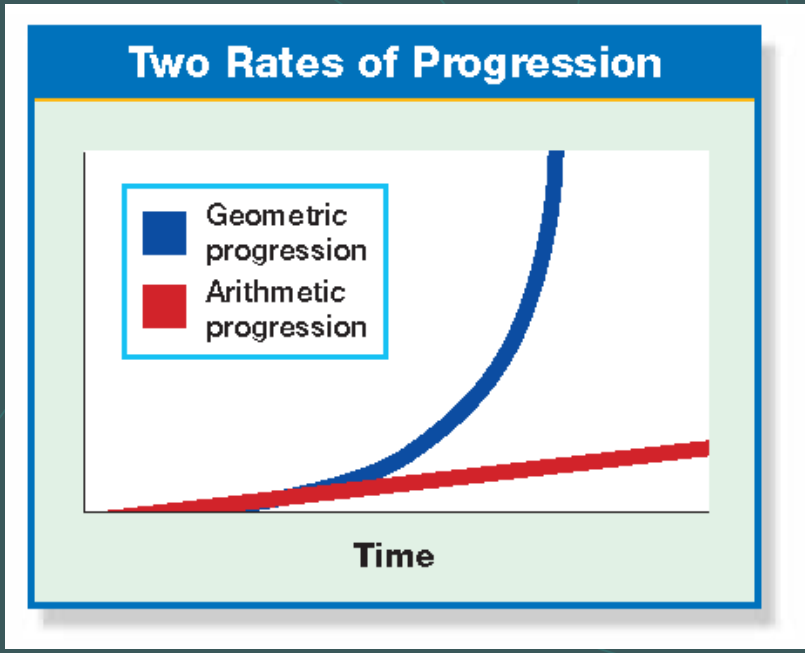
Darwin's Observations

- As Darwin traveled, he saw many fossils that could only be explained by a process of gradual change
  - Visited the Galapagos Islands and was struck by fact that many plants and animals there closely resembled those of nearby coast of South America
    - Suggested that these organisms migrated to islands from South America and changed after arrival
      - This change was called "descent with modification"



Growth of Populations

- Darwin's thoughts on evolution influenced by essay written in 1798 by English economist Thomas Malthus
  - Wrote that human populations are able to increase faster than food supply can, but human populations do not grow unchecked because death caused by disease, war, and famine
    - **Population** – consists of all the individuals of a species that live in a specific geographical area and that can interbreed



Natural Selection

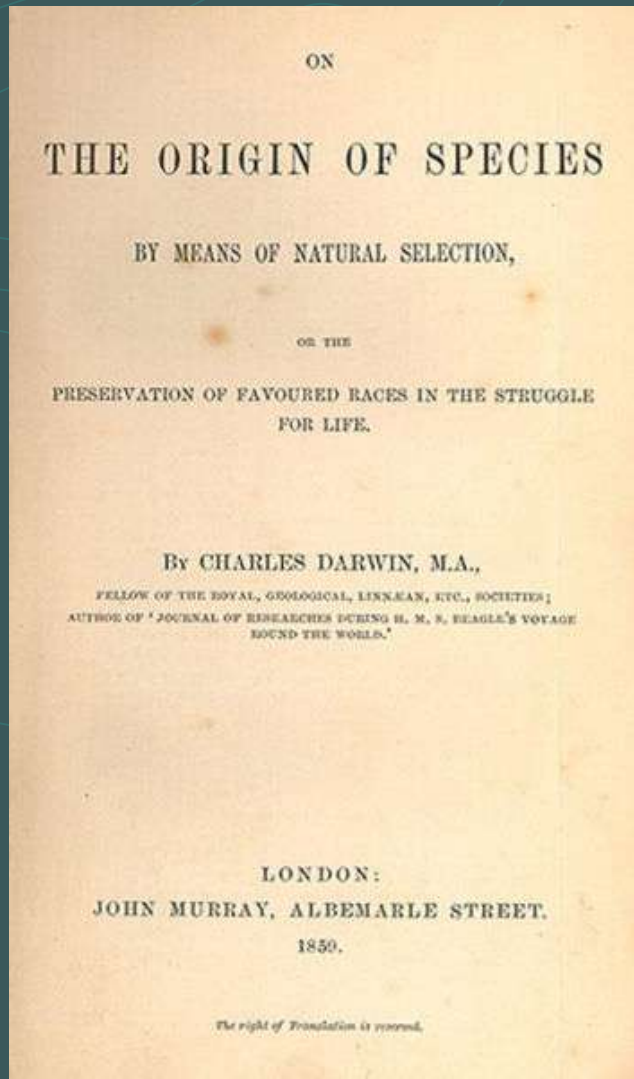
- Darwin realized that Malthus's hypotheses about human populations apply to all species
  - Every organism has potential to produce many offspring during lifetime, but in most cases, only a limited number of those offspring survive to reproduce
  - Based on Malthus's work and his own observation, Darwin made key association that individuals that have physical or behavioral traits that better suit their environment are more likely to survive and will reproduce more successfully than those that do not have those traits
    - Called this differential rate of reproduction **natural selection**
  - In time, number of individuals that carry favorable characteristics that are heritable will increase in a population, causing evolution, or a change in the nature of a population

Adaptation

- Darwin also suggested that organisms differ from place to place because their habitats present different challenges to, and opportunities for, survival and reproduction
  - Each species has evolved and accumulated adaptations in response to its particular environment
    - **Adaptation** – inherited trait that has become common in a population because the trait provides a selective advantage

Publication of Darwin's Work

- In 1844, Darwin finally wrote his ideas about evolution and natural selection in an early outline
  - Did not publish his manuscript until 1858, for fear of harsh criticism, until another naturalist, Alfred Russel Wallace sent him a letter describing these same hypotheses, asking for help to get his essay published



ON

THE ORIGIN OF SPECIES

BY MEANS OF NATURAL SELECTION,

OR THE

PRESERVATION OF FAVOURED RACES IN THE STRUGGLE FOR LIFE.

By CHARLES DARWIN, M.A.,

FELLOW OF THE ROYAL, GEOLOGICAL, LINNÆAN, ETC., SOCIETIES;
AUTHOR OF 'JOURNAL OF RESEARCHES DURING H. M. S. BEAGLE'S VOYAGE ROUND THE WORLD.'

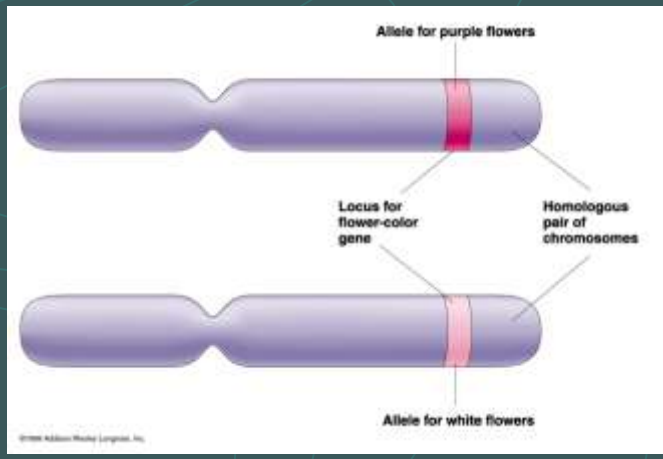
LONDON:
JOHN MURRAY, ALBEMARLE STREET.
1859.

Darwin's Theory

- Darwin's book, *On the Origin of Species by Means of Natural Selection* began circulation in November of 1859
  - Though many were deeply disturbed by his theory, it was supported by 4 major points
    - Inherited variation exists within the genes of every population or species, the result of random mutation and translation errors
    - In a particular environment, some individuals of a population or species are better suited to survive and have more offspring
    - Over time, the traits that make certain individuals of a population able to survive and reproduce tend to spread in that population
    - There is overwhelming evidence from fossils and many other sources that living species evolved from organisms that are extinct

Change Within Populations

- Darwin's key inference was based on 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
    - In other words, natural selection causes the frequency of certain alleles in a population to increase or decrease over time
    - Mutations and recombination of alleles during sexual reproduction provide new variations for natural selection to act upon

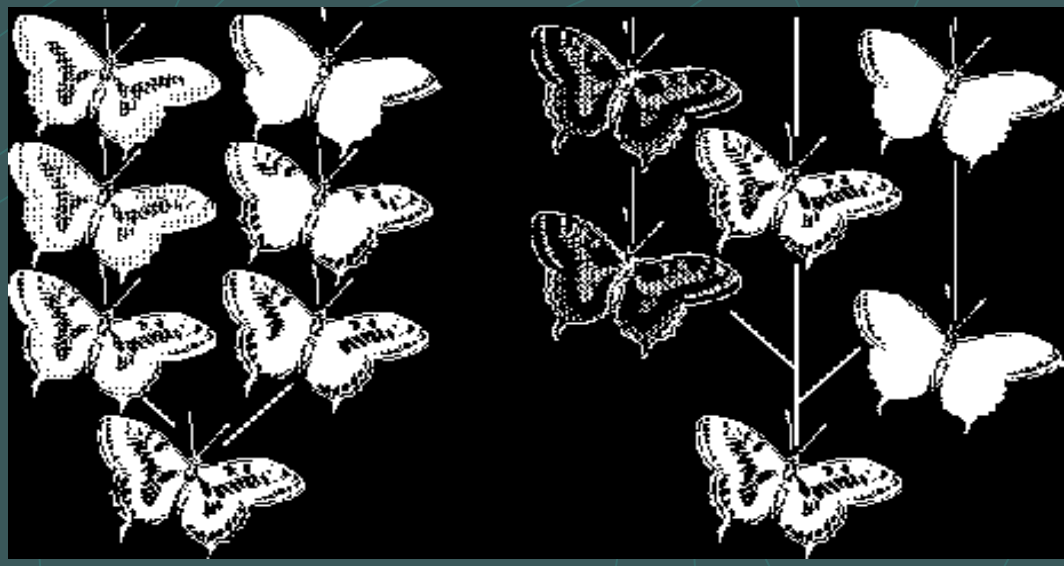


Species Formation

- Populations of the same species living in different locations tend to evolve in different ways
  - A result of **reproductive isolation**, or the condition in which two populations of the same species do not breed with one another because of geographic separation, difference in mating periods, or barriers to reproduction
    - As 2 isolated populations of same species become different over time, they may eventually become unable to breed with one another, creating 2 different species

The Tempo of Evolution

- **Gradualism** – model of evolution in which gradual change over a long period of time leads to species formation
- American biologists Gould and Eldredge have suggested that successful species may stay unchanged for long periods of time



  - Hypothesize that major environmental changes in past have caused evolution to occur in spurts
    - **Punctuated equilibrium** – model of evolution in which periods of rapid change in species are separated by periods of little to no change

The Fossil Record

- Fossils of animals show a pattern of development from early ancestors to modern descendents
  - Offer most direct evidence that evolution takes place
  - Provide an actual record of Earth's past life forms
  - Change over time can be seen in fossil record, since fossilized species found in older rocks are different from those found in newer rocks

Fossil Intermediates

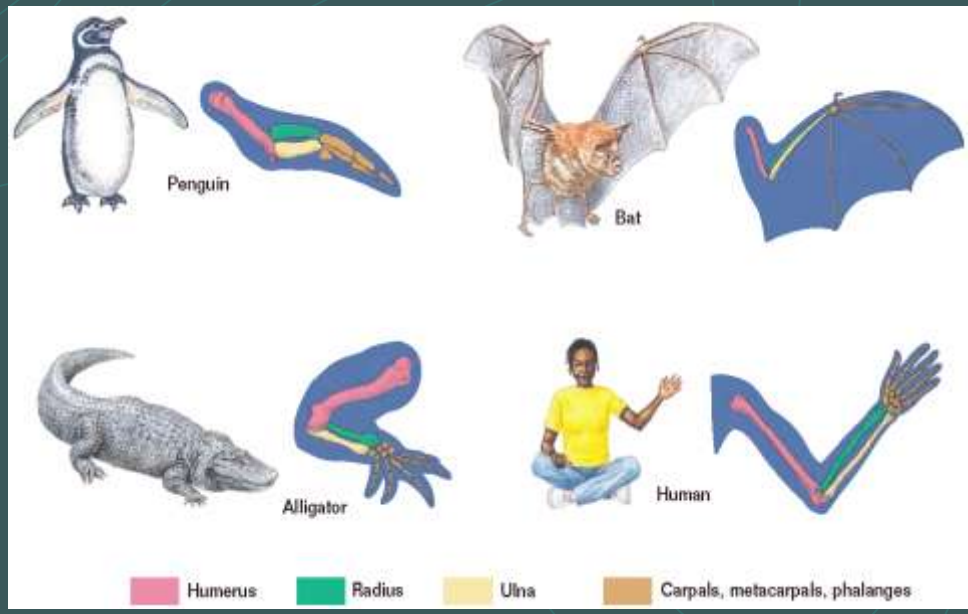
- After observing the differences between fossils, Darwin predicted that intermediate forms between the great groups of organisms would eventually be found
  - To this date, fossil intermediates have been found between fish and amphibians, reptiles and birds, and reptiles and mammals
- Today, Darwin's theory is almost universally accepted as best available explanation for biological diversity on Earth, with most scientists agreeing on 3 main points:
  - Earth is ~4.5 by old
  - Organisms have inhabited Earth for most of its history
  - All organisms living today share common ancestry with earlier, simpler life-forms

Formation of Fossils

- Fossil record, and thus the record of the evolution of life, is incomplete
  - Many species lived in environments where fossils do not form
    - Most fossils form when organisms and traces of organisms are rapidly buried in fine sediments deposited by water, wind, or volcanic eruptions
  - By radiometric dating certain rocks and mineral in the sediment around fossils, paleontologists can arrange fossils in order from oldest to youngest
    - **Paleontologist** – scientist who study fossils

Anatomy and Development

- Comparisons of anatomy of different types of organisms often reveal basic similarities in body structures even though that structure's function may differ between organisms



  - **Vestigial structures** – structure in an organism that is reduced in size and function and that may have been complete and functional in organism's ancestor
  - **Homologous structure** – structures that share a common ancestry

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.

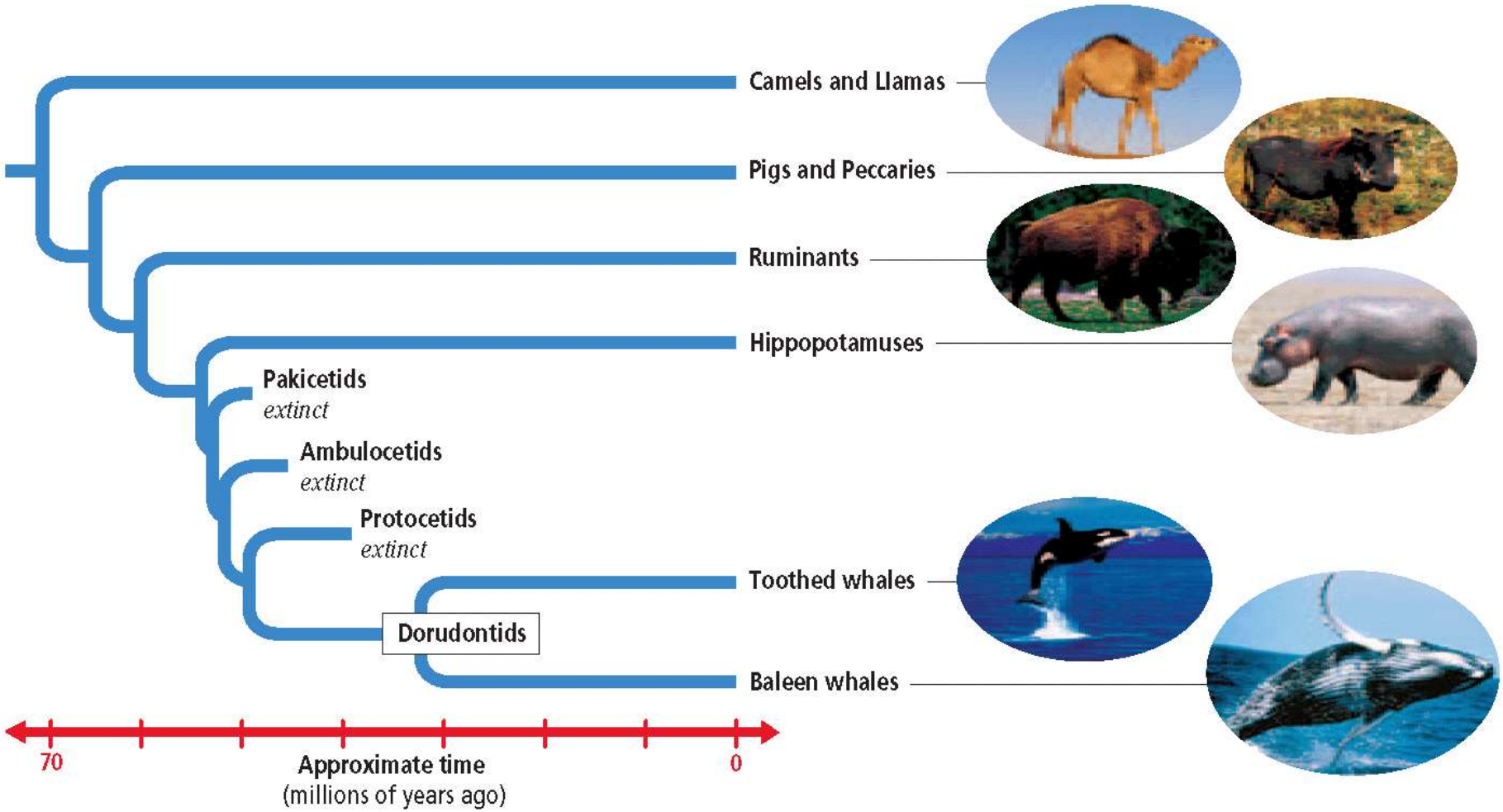
Mesonychids are one hypothesized link between modern whales and certain hoofed mammals. They were about 2 m (6 ft) long. They are thought to have lived about 60 million years ago. Some scientists favor an alternative hypothesis linking whales to other ancestral hooved mammals. These hooved mammals are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

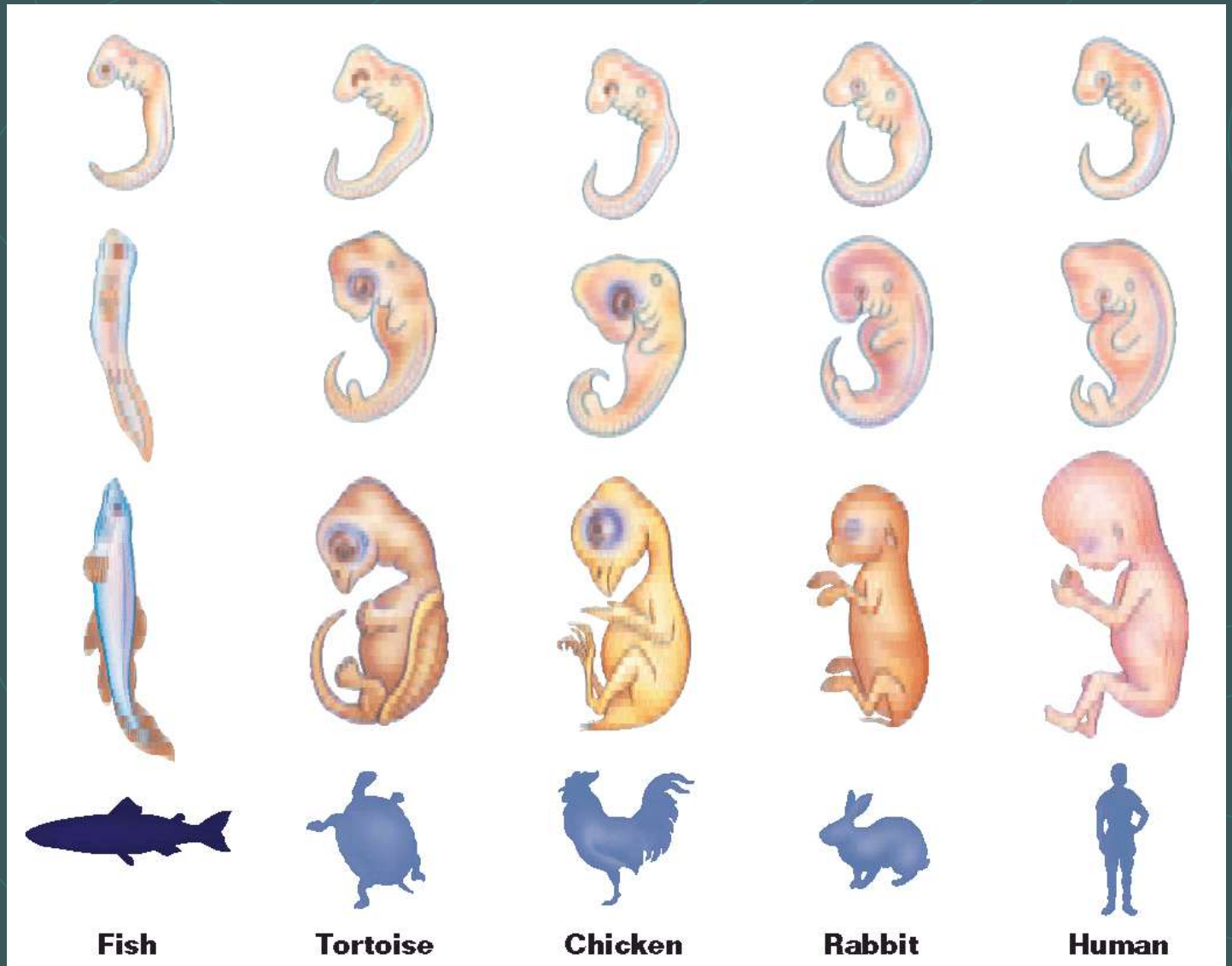
Relationships Between Whales and Hoofed Mammals



Embryonic Development as Evidence for Evolution

- Most scientist believe that the evolutionary history of organisms is also seen in the development of embryos
  - At some time in development, all vertebrate embryos have a tail, buds that become limbs, and pharyngeal pouches
    - Tail remains in most adult vertebrates (Disappears during fetal development in humans)
    - Only adult fish and immature amphibians retain pharyngeal pouches, which contain their gills (Pharyngeal pouches develop into structures in the throat in humans)

Comparative Embryonic Development



Proteins as Evidence for Evolution

- If species have changed over time as the fossil record indicates, then the genes that determine those species' characteristics should also have changed by either mutation or selection
  - It has been shown that species who are thought to have a more recent common ancestor share a more similar amino acid sequence than organisms more distantly related
    - This pattern does not always hold true, however, since certain proteins may evolve more rapidly in some groups than others

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

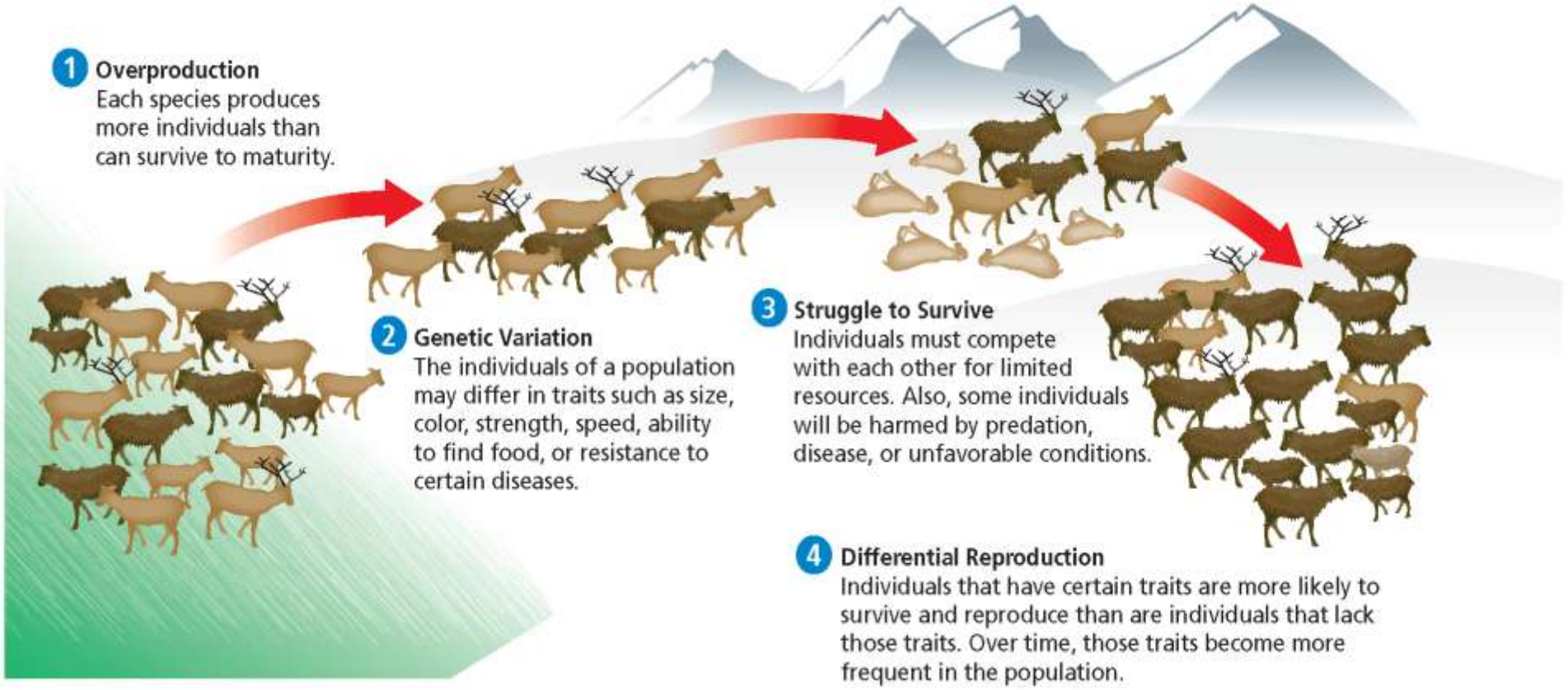
DNA Sequences as Evidence for Evolution

- More accurate hypotheses about evolutionary histories are based on large numbers of gene (DNA) sequences
  - Tend to be very similar to evolutionary histories inferred by biologists based on comparative anatomy and fossil evidence
  - Scientists evaluate number of nucleotide changes that have taken place in a gene since the 2 species diverged from a common ancestor by comparing the nucleotide sequence of genes

Factors in Natural Selection

- Process of natural selection is driven by 4 important points that are true for all real populations
  - All populations have genetic variation
    - Organisms of the same species differ slightly from one another in their genetic makeup
  - The environment presents challenges to successful reproduction
    - Those organisms that die before reproduction cannot pass on their genes
  - Individuals tend to produce more offspring than the environment can support
    - Individuals in a population often compete with one another to survive
  - 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

Factors in Natural Selection

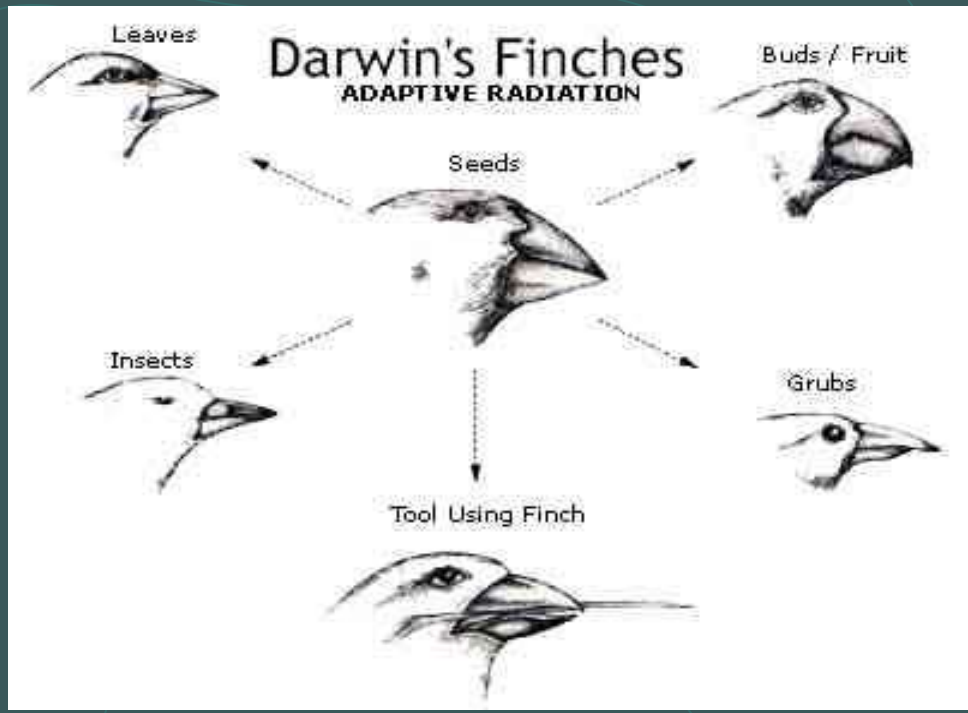


Antibiotic Resistance and Natural Selection

- The lung disease tuberculosis (TB) is usually caused by the bacterium *Mycobacterium tuberculosis*
  - In 1950s, 2 effective antibiotics, isoniazid and rifampin, became available, saving millions of lives
    - Rifampin works by binding to the bacterium's RNA polymerase, preventing transcription, killing the bacterial cell
  - In late 1980s, new strains of this bacteria appeared that were largely or completely resistant to both antibiotics
    - These new strains had mutations in the polymerase's rpoB gene that prevented rifampin from binding to the polymerase
    - TB bacteria with the mutation were able to survive treatment with the antibiotic, and so natural selection led to the evolution of rifampin resistance in the bacterial species

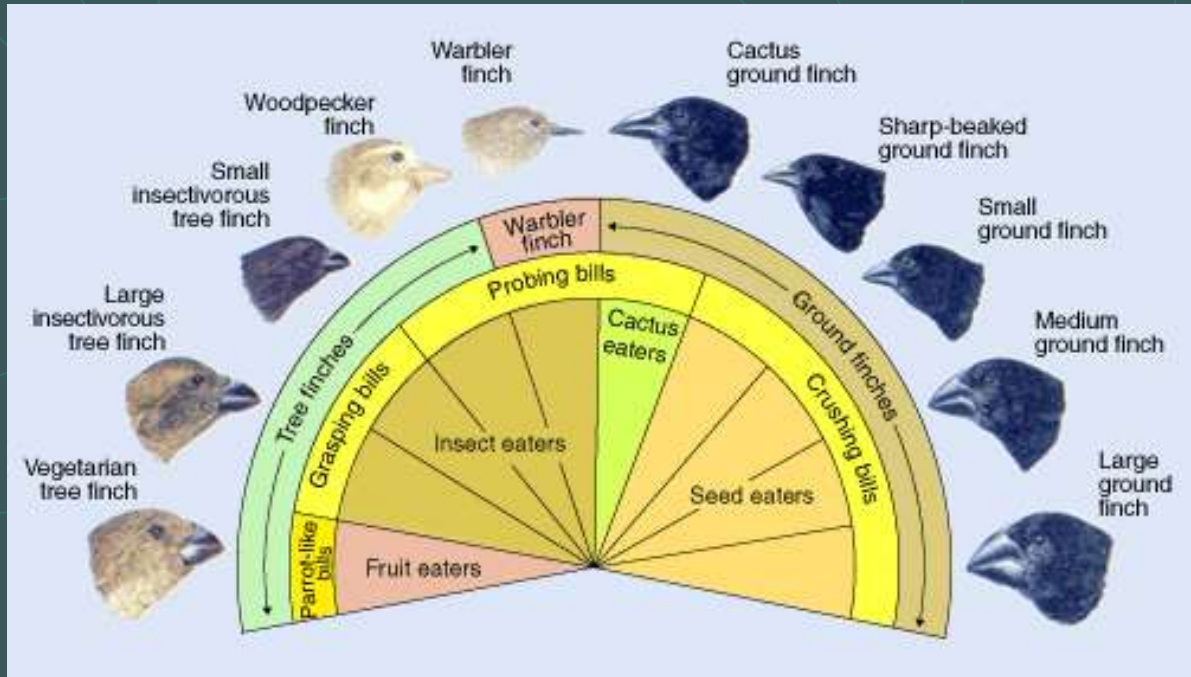
Evolution in Darwin's Finches

- Darwin collected 31 specimens of finches from 3 islands when he visited the Galapagos Islands
  - In all, he collected 9 distinct species, all very similar to one another except for their bills
  - Darwin suggested that these 9 species evolved from an original ancestral species
    - Changes occurred as different populations accumulated adaptations to different food sources



Testing Darwin's Hypotheses

- Darwin's ideas were first tested in 1938 by naturalist David Lack, who found little evidence to support Darwin's hypotheses
  - Lack watched finches closely for 5 months and found that stout-beaked finches and slender-beaked finches were feeding on the same sort of seeds

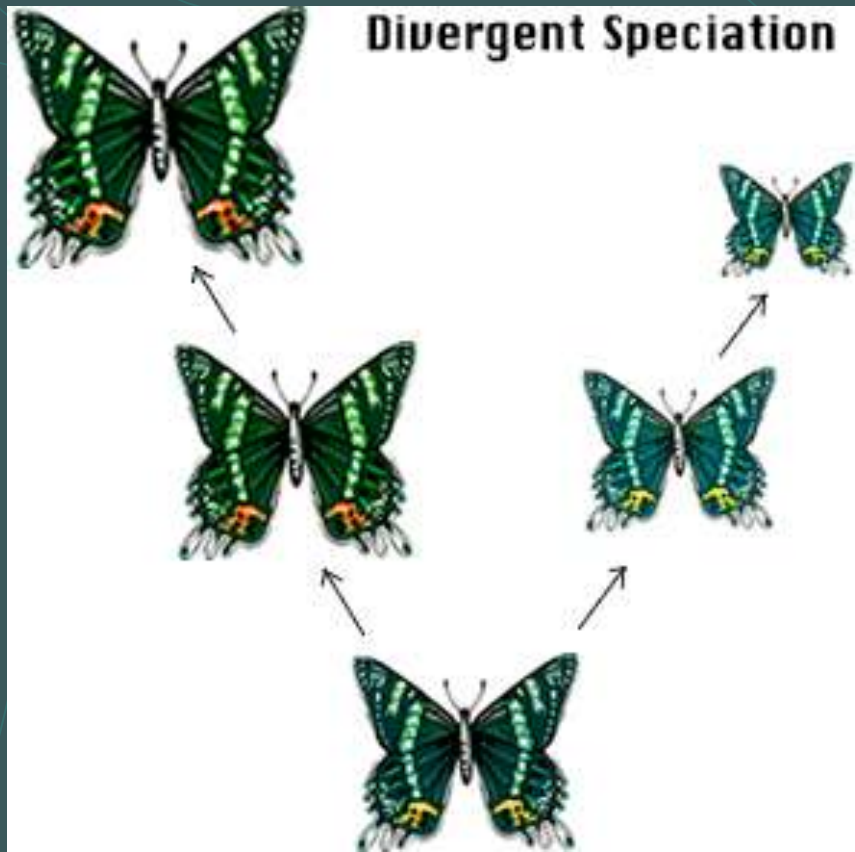


Darwin's Hypotheses Supported

- Beginning in 1973, a far more thorough 25 year study was conducted by Peter and Rosemary Grant
  - These scientists found that, only during dry years was the size of the beak important
    - During these years, few small, tender seeds were available, and the difference between survival and starvation is the ability to eat larger, tougher seeds
      - After several dry years, the birds that had longer, more massive beaks had better feeding success and produced more offspring
      - When wet season returned, birds tended to have smaller beaks again, proving that different beak shapes are changed by natural selection in response to the available food supply

Speciation

- Species formation occurs in stages
  - **Divergence** – accumulation of differences between groups
    - Divergence leads to the formation of a new species
  - **Speciation** – process by which new species form



Subspecies

- Separate populations of a single species often live in several different kinds of environments
  - Natural selection will act of these members of the same species in different ways, according to the selective pressures of their respective environments
  - If environments differ enough, separate populations of the same species can become very dissimilar
    - **Subspecies** – populations of the same species that differ genetically because of adaptations to different living conditions
  - If subspecies become so different that they can no longer interbreed successfully, they are then considered separate species

Maintaining New Species

- Why are even closely related species usually unable to interbreed?
  - Geographical isolation
  - Reproduction at different times
  - Physical differences
  - Sexual selection
  - Infertility of hybrid offspring