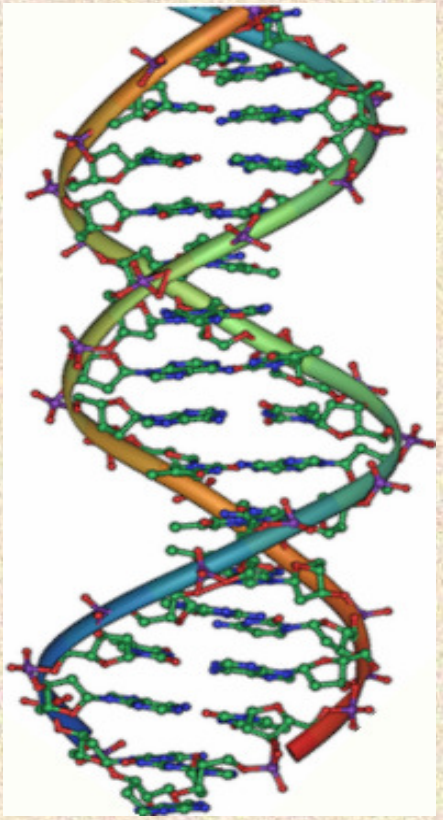
# Evolution



commons.wikimedia.org/wiki/Image:DNA_double_helix_vertikal.PNG

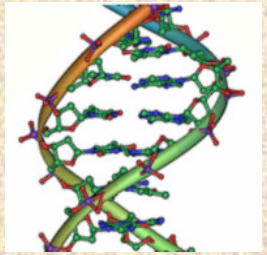
commons.wikimedia.org/wiki/Image:Charles_Darwin_1881.jpg

# Evolution as Theory and Fact

Rodin's "The Thinker"

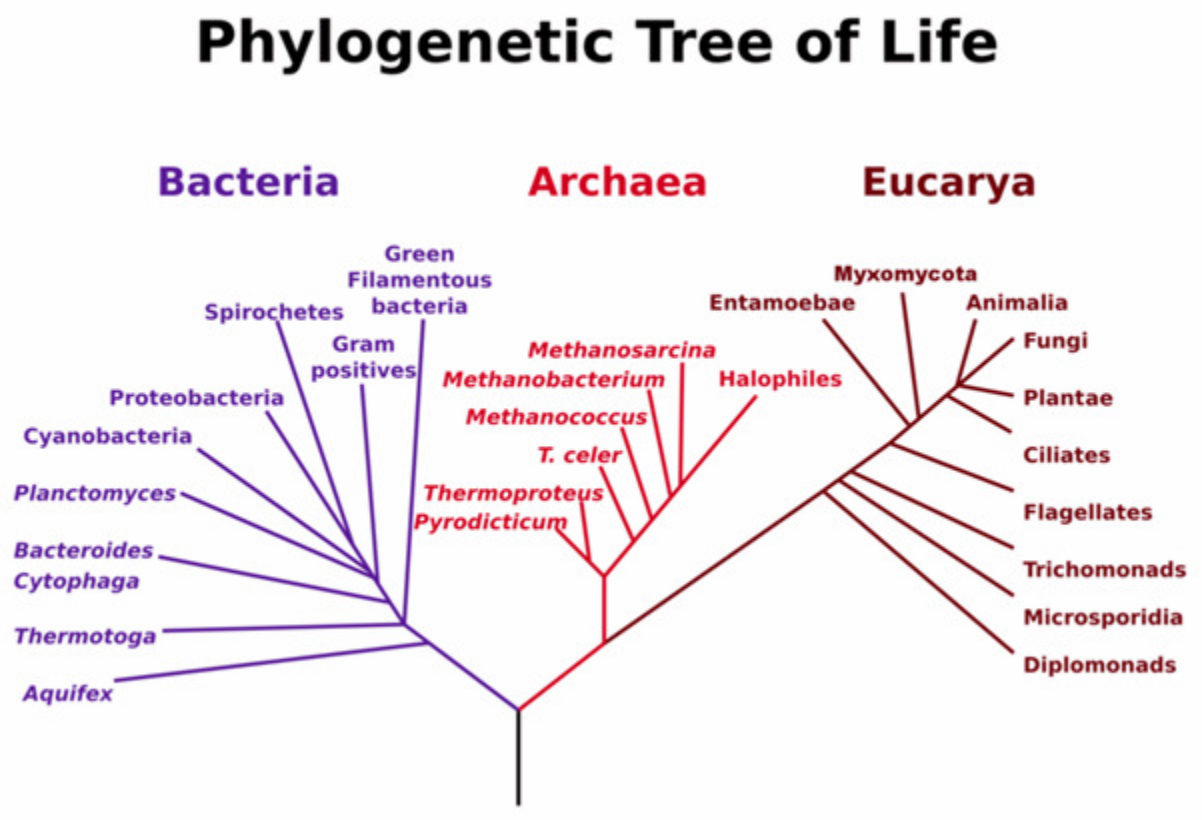
- Confusion sometimes arises as to whether Evolution is a theory or a fact. Actually it is both!
- The theory of Evolution deals with how Evolution happens. Our understanding of this process is always changing.
- Evolution is also a fact as there is a huge amount of indisputable evidence for its occurrence.

# Questions



1. Discussion: Should Creationism and Evolution be given “equal time” in science classes?
2. How does evolution work?
3. What is the evidence for evolution?
4. Why does the controversy still exist?

# The Tree of Life



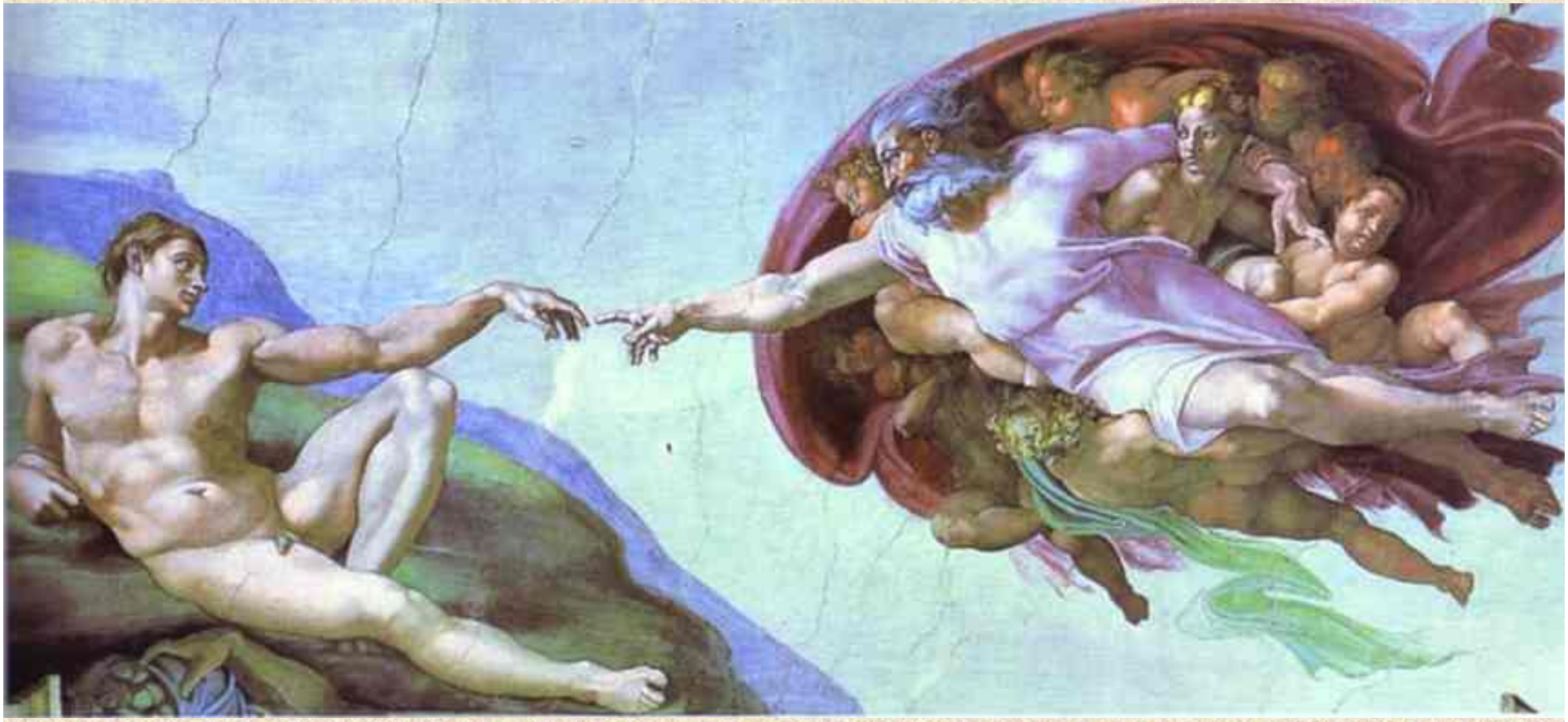

All living things share a common ancestor.

Based on rRNA coding.

We can draw a Tree of Life to show how every species is related.

Evolution is the process by which one species gives rise to another and the Tree of Life grows.

# Fixed species



Michelangelo's fresco on the ceiling of the Sistine Chapel

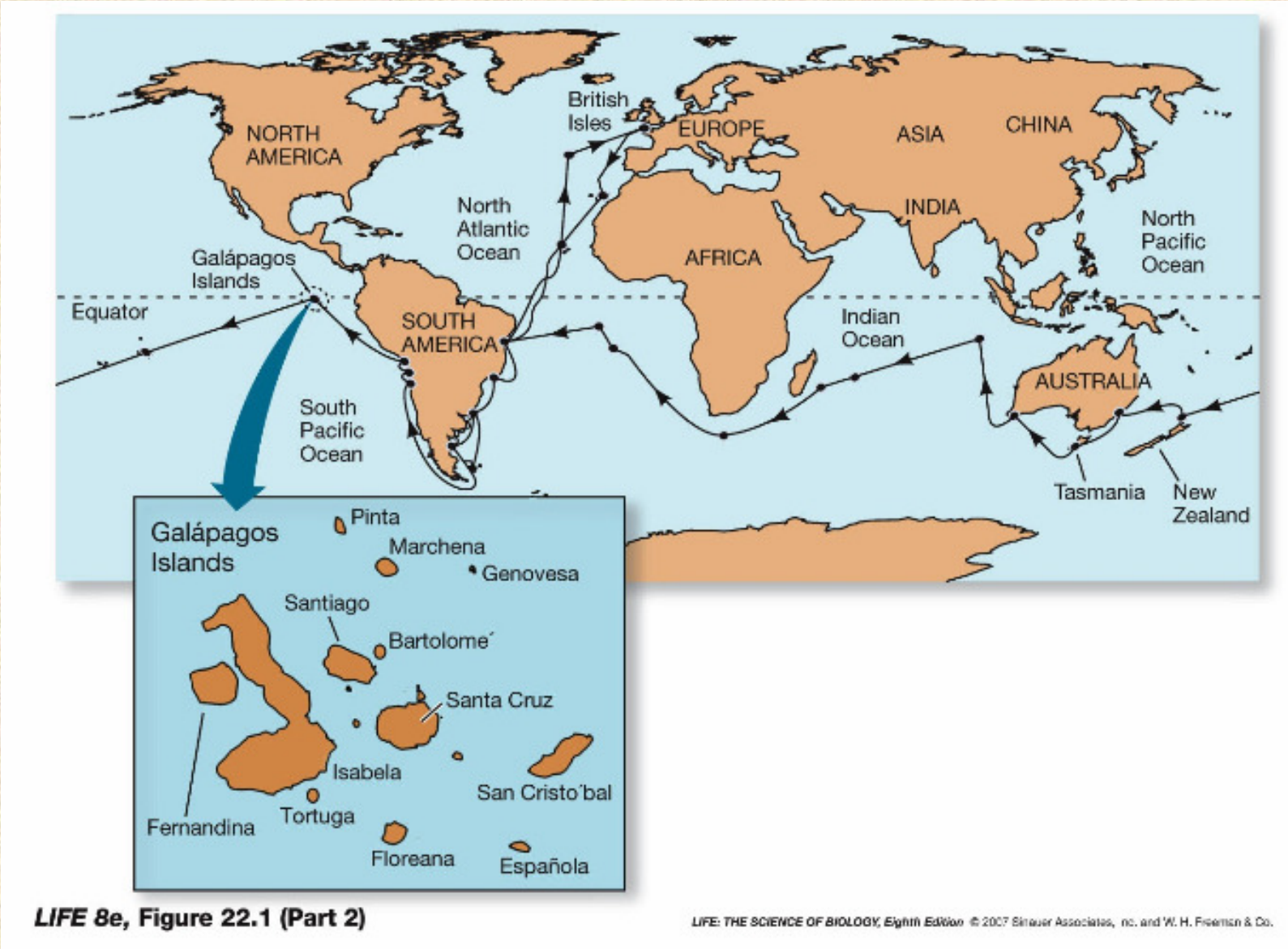
en.wikipedia.org/wiki/The_Creation_of_Adam

From Classical times until long after the Renaissance, species were considered to be special creations, fixed for all time.

# Darwin and the Galápagos

- During Charles Darwin's five-year voyage
  - (1831-1836) on the HMS Beagle,
  - he visited the Galápagos Islands
  - where he made important observations
  - that changed his ideas about
  - the then popular concept called the ***fixity of species***
    - an idea holding that all present-day species
    - had been created in their present form
    - and had changed little or not at all
- Darwin fully accepted
  - the Biblical account of creation before the voyage

# Route of HMS *Beagle*



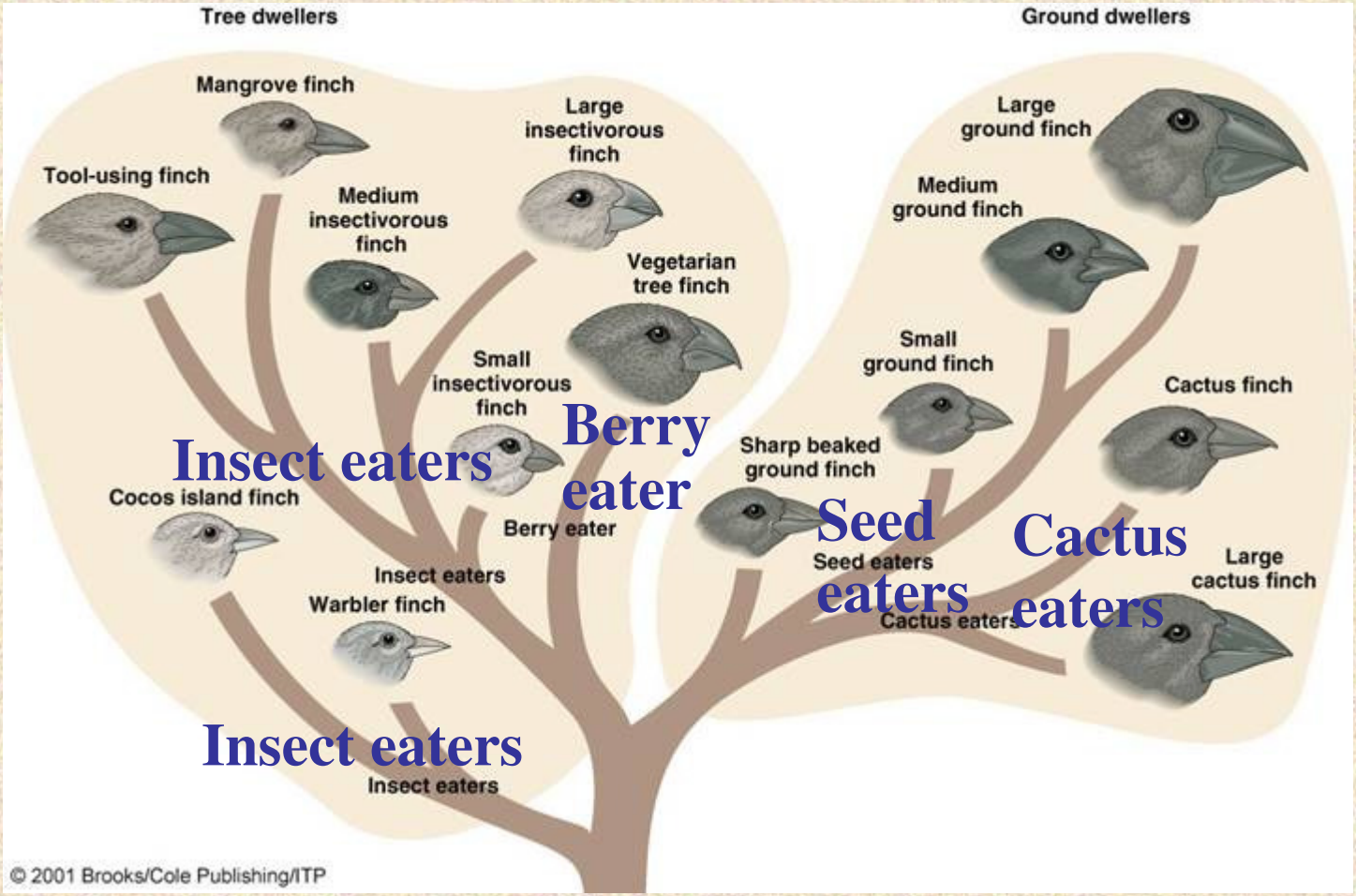

***LIFE 8e*, Figure 22.1 (Part 2)**

# Darwin Developed the Theory

- During the voyage Darwin observed
  - that fossil mammals in South America
  - are similar yet different from present-day
  - llamas, sloths, and armadillos
  - that the finches and giant tortoises living
  - on the Galápagos Islands vary from island to island
  - and still resemble ones from South America,
  - even though they differ in subtle ways
- These observations convinced Darwin
  - that organisms descended with modification
  - from ancestors that lived during the past
  - the central claim of the theory of evolution

# Galápagos Finches

- Darwin's finches from the Galápagos Islands
  - arranged to show evolutionary relationships




- Notice that beak shape
- varies depending on diet

# Why Study Evolution?

- Evolution
  - involving inheritable changes in organisms through time
- is fundamental to biology and paleontology
  - Paleontology is the study of life history as revealed by fossils
- Evolution is a ***unifying theory***
    - like plate tectonic theory
  - that explains an otherwise
  - encyclopedic collection of facts
- Evolution provides a framework
  - for discussion of life history

# Misconceptions about Evolution

- Many people have a poor understanding
  - of the theory of evolution
  - and hold a number of misconceptions,
  - which include:
    - evolution proceeds strictly by chance
    - nothing less than fully developed structures
      - such as eyes are of any use
    - there are no transitional fossils
      - so-called missing links
      - connecting ancestors and descendants
    - humans evolved from monkeys
      - so monkeys should no longer exist

# Evolution: Historical Background

- Evolution, the idea that today's organisms
  - have descended with modification
  - from ancestors that lived during the past,
- is usually attributed solely to Charles Darwin,
  - but it was seriously considered long before he was born,
  - even by some ancient Greeks
  - and by philosophers and theologians
    - during the Middle Ages
- Nevertheless, the prevailing belief
  - in the 1700s was that Genesis and the works of Aristotle
  - explained the origin of life
  - and contrary views were heresy

# Evolution: Historical Background

- During the 18th century,
  - naturalists were discovering evidence
  - that could not be reconciled
  - with literal reading of the Bible
- In this changing intellectual atmosphere,
  - scientists gradually accepted a number of ideas:
    - the principle of uniformitarianism,
    - Earth's great age,
    - that many types of plants and animals had become extinct,
    - and that change from one species to another occurred
- What was lacking, though,
  - was a theoretical framework to explain evolution

# Lamarck

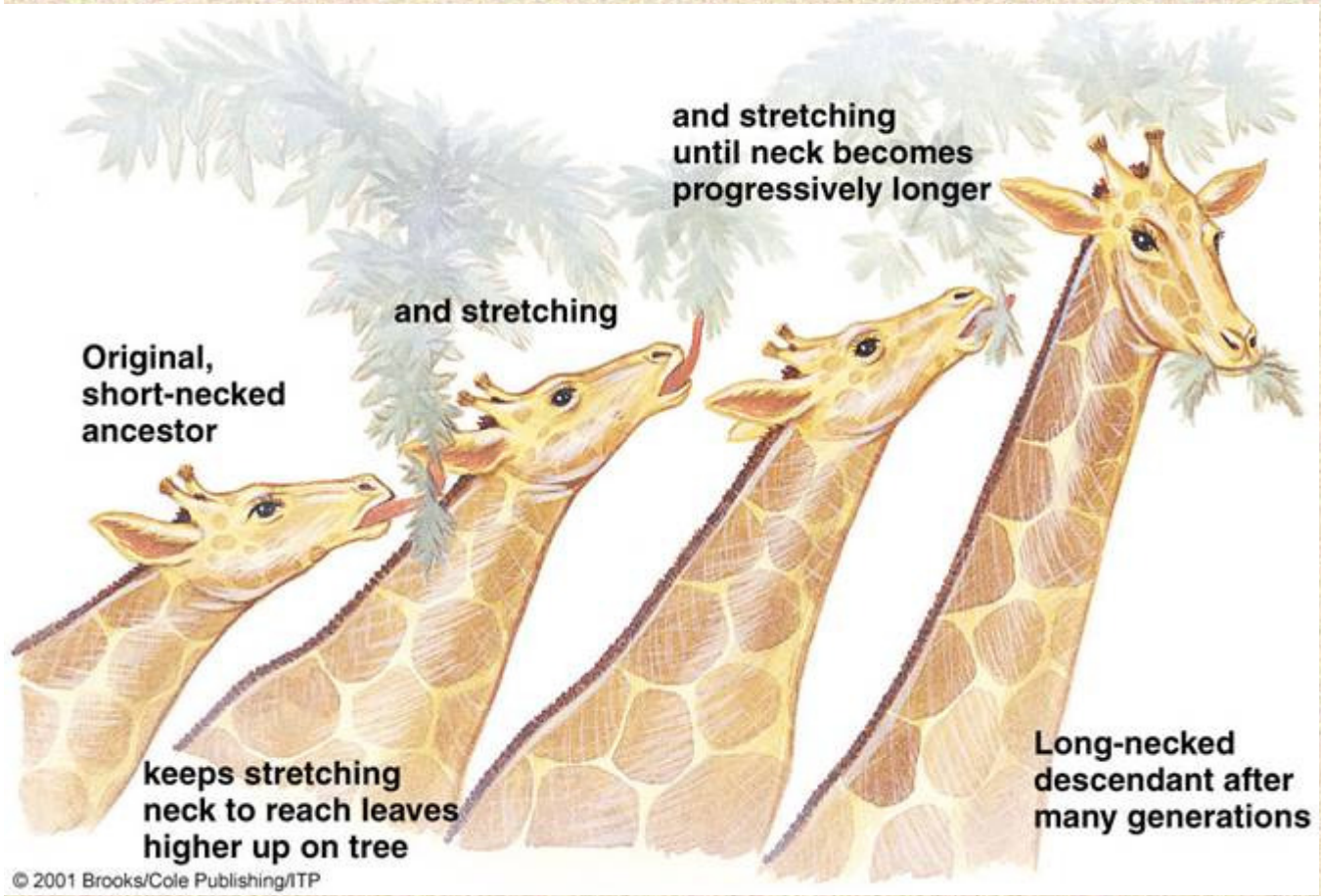
- Jean-Baptiste de Lamarck
  - (1744-1829) is best remembered for his theory
  - of inheritance of acquired characteristics,
  - even though he greatly contributed
  - to our understanding of the natural world
- According to this theory,
  - new traits arise in organisms because of their needs
  - and are somehow passed on to their descendants
- Lamarck's theory seemed logical at the time

# Lamarck's Theory

- Lamark's theory was not totally refuted
  - until decades later
  - with the discovery that ***genes***
    - units of heredity
  - cannot be altered by any effort by an organism during its lifetime

# Lamarck's Giraffes

- According to Lamarck's theory of inheritance of acquired characteristics



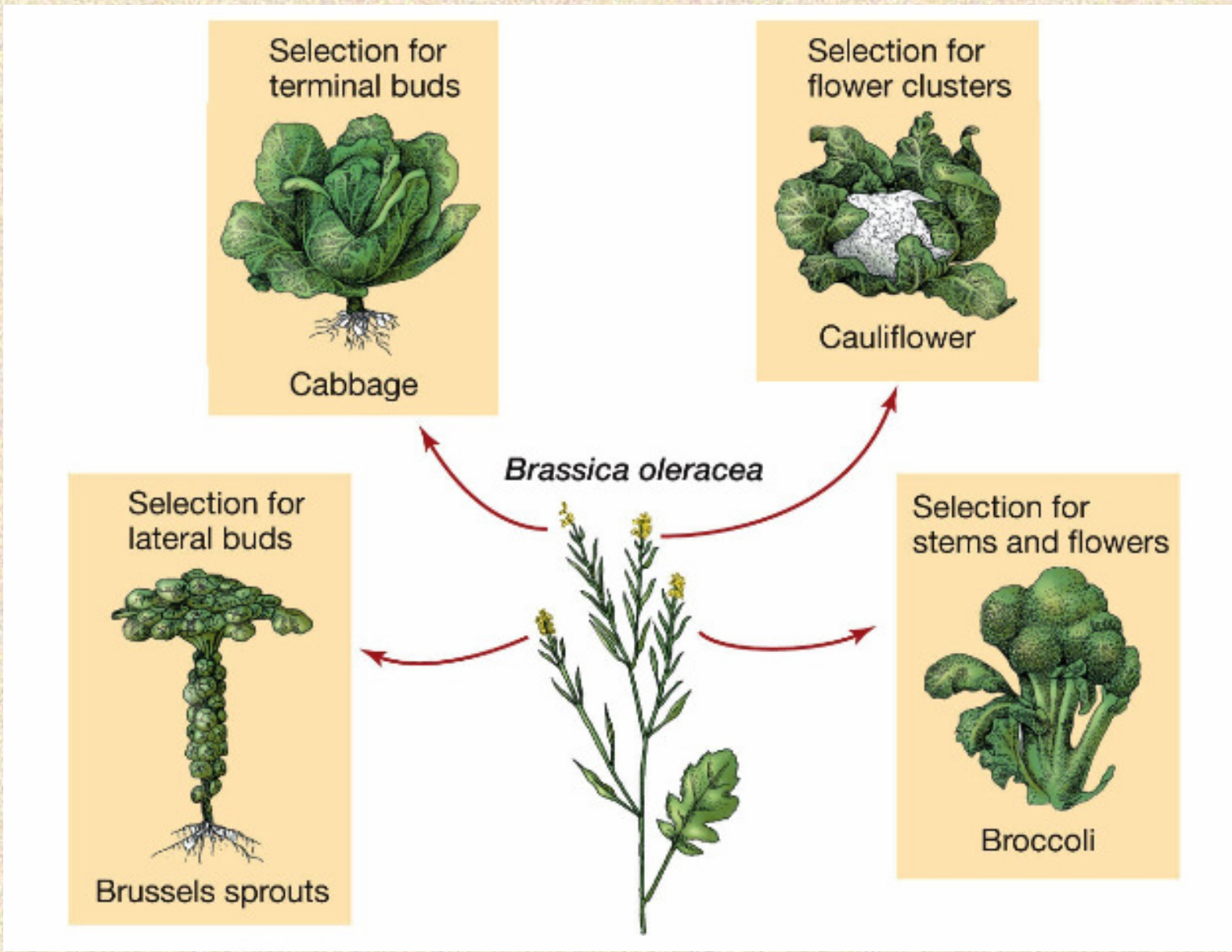

  - ancestral short-necked giraffes
  - stretched their necks
  - to reach leaves high on trees.
  - Their offspring were born
  - with longer necks

# Natural Selection

- Plant and animal breeders
  - practice artificial selection
  - by selecting those traits they deem desirable
  - and then breed plants and animals with those traits
  - thereby bringing about a great amount of change
- Observing artificial selection
  - gave Darwin the idea that
  - a process of selection among variant types
  - in nature could also bring about change
- Thomas Malthus' essay on population
  - suggested that competition for resources
  - and high infant mortality limited population size

# Artificial Selection

# Artificial Selection



# Darwin and Wallace

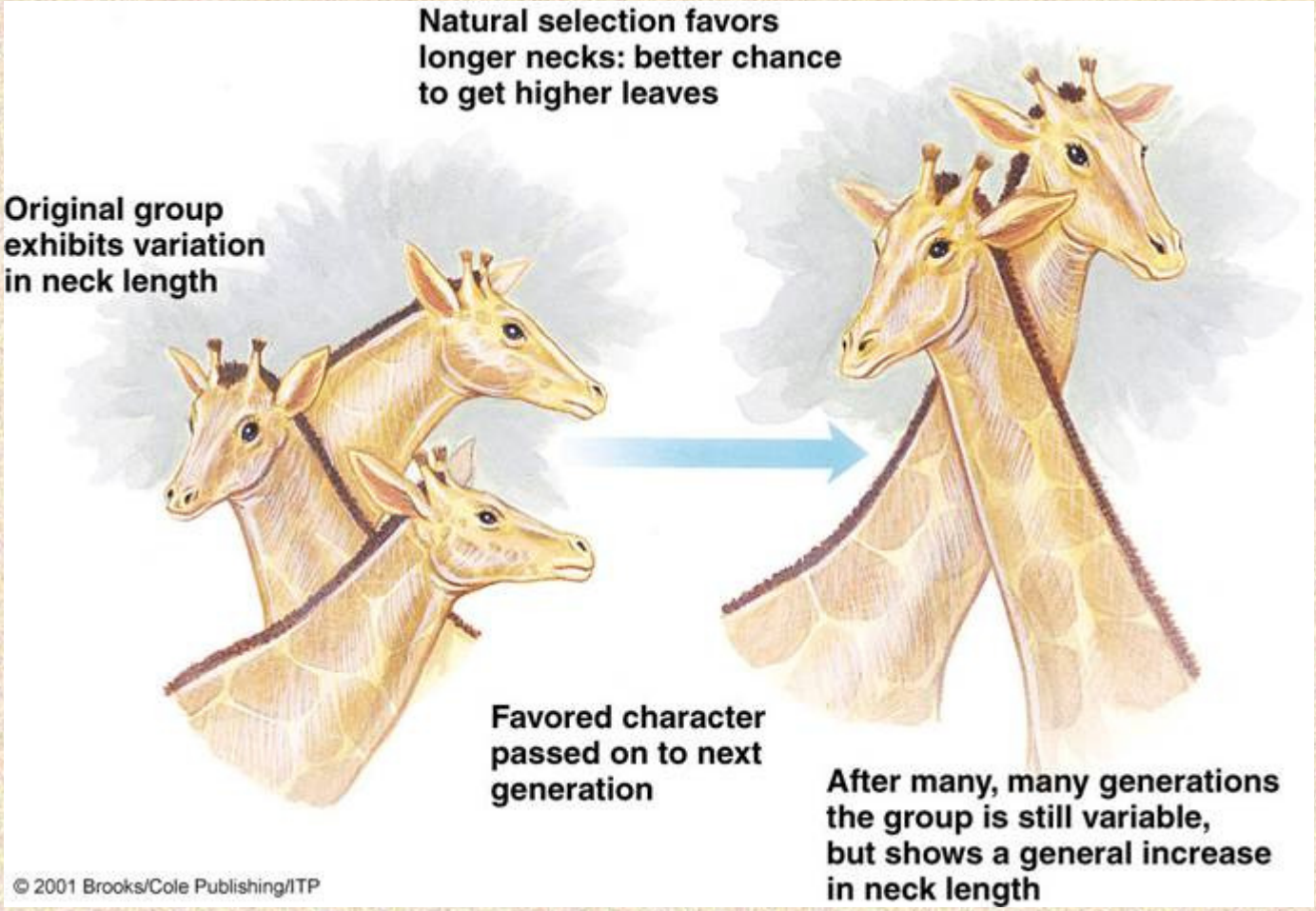
- Darwin and Alfred Russel Wallace (1823-1913)
  - read Malthus' book
  - and came to the same conclusion,
- that a natural process
  - was selecting only a few individuals for survival
- Darwin's and Wallace's idea
  - called natural selection
  - was presented simultaneously in 1859

# Natural Selection—Main Points

- Organisms in all populations
  - possess heritable variations such as
  - size, speed, agility, visual acuity,
  - digestive enzymes, color, and so forth
- Some variations are more favorable than others
  - some have a competitive edge
  - in acquiring resources and/or avoiding predators
- Not all young survive to reproductive maturity
  - Those with favorable variations
  - are *more likely* to survive
  - and pass on their favorable variations

# Naturally Selected Giraffes

- According to the Darwin-Wallace theory
  - of natural selection, giraffe's long neck evolved




  - because ancestors with longer necks
  - had an advantage
  - and reproduced more often

# “Survival of the Fittest”

- In colloquial usage,
  - natural selection is sometimes expressed as
  - “survival of the fittest”
- This is misleading because
  - natural selection is not simply a matter of survival
  - but involves differential rates
  - of survival *and* reproduction

# Not only Biggest, Strongest, Fastest

- One misconception about natural selection
  - is that among animals
  - only the biggest, strongest, and fastest
  - are likely to survive
  - These characteristics might provide an advantage
- but natural selection may favor
  - the smallest if resources are limited
  - the most easily concealed
  - those that adapt most readily to a new food source
  - those having the ability to detoxify some substance
  - and so on...

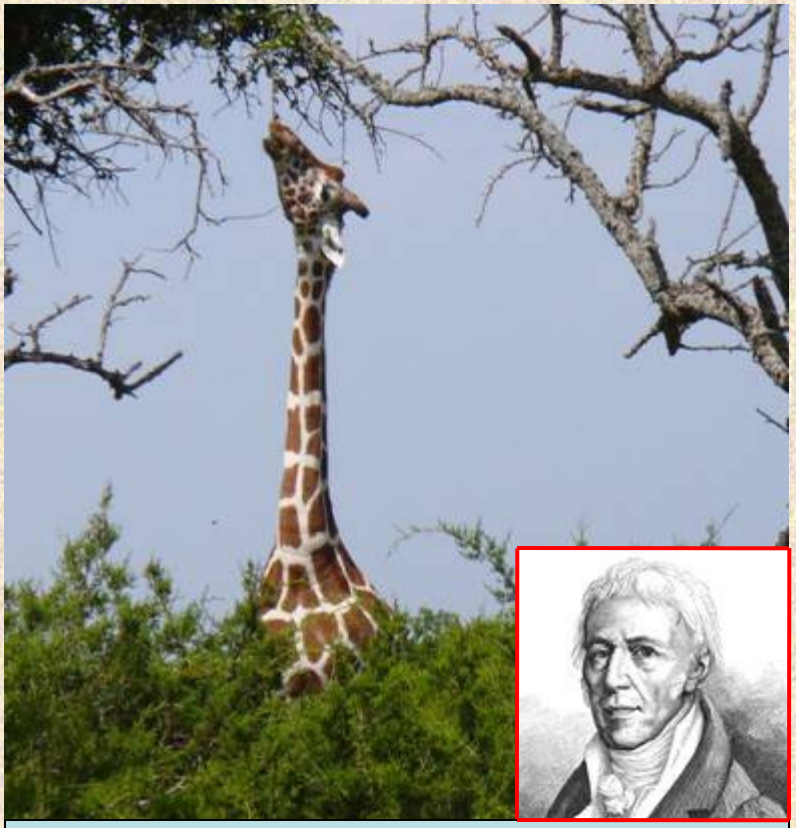
# Limits of Natural Selection

- Natural selection works
  - on existing variation in a population
- It could not account for the origin of variations
- Critics reasoned that should a variant trait arise,
  - it would blend with other traits and would be lost
- The answer to these criticisms
  - existed even then in the work of Gregor Mendel,
  - but remained obscure until 1900

# Sexual Selection

- Sexual selection is a special type of natural selection, which acts on characters that determine reproductive success.
- If an individual survives but does not reproduce, it makes no contribution to the next generation.
- Sexual selection favors traits that increase the chances of reproduction.

# Transmutation

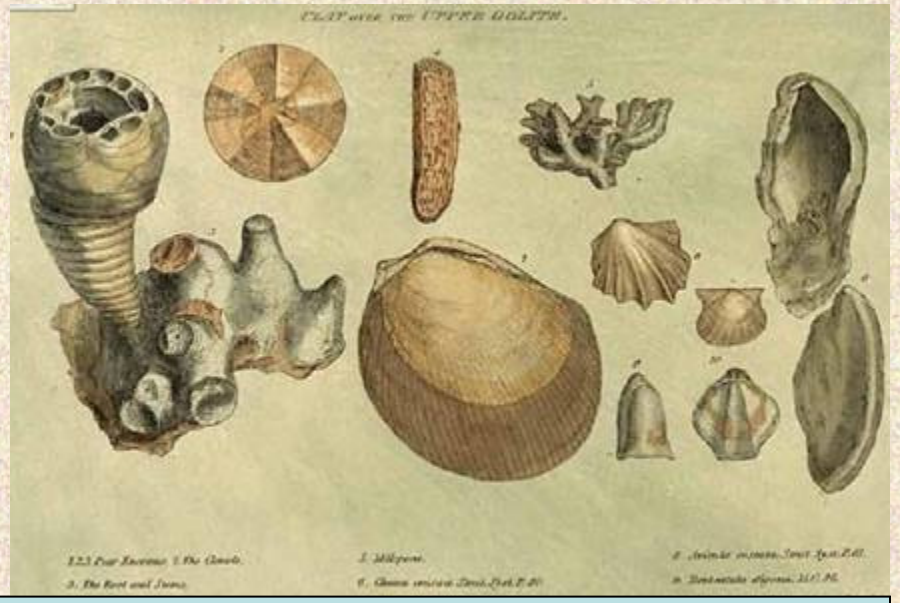


Jean Baptiste de Lamarck

- Around 1800, scientists began to wonder whether species could change or transmute.
- Lamarck thought that if an animal acquired a characteristic during its lifetime, it could pass it onto its offspring.
- Hence giraffes got their long necks through generations of straining to reach high branches.

commons.wikimedia.org/wiki/Image:Jean-baptiste_lamarck2.jpg
en.wikipedia.org/wiki/Image:Giraffe_standing.jpg

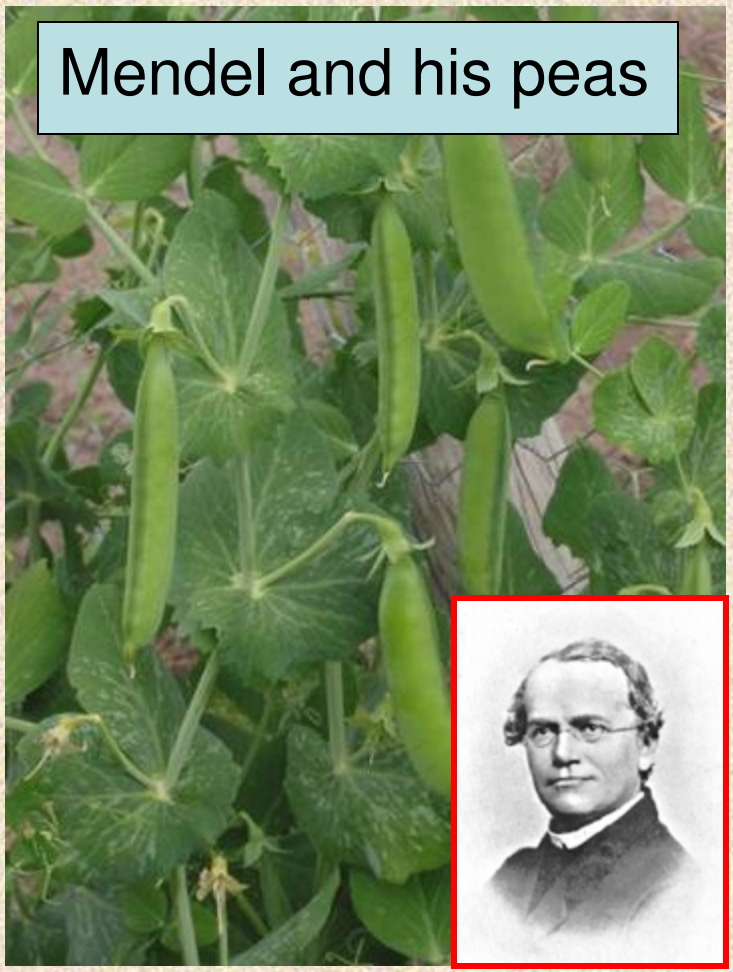
# Fossils and Strata



William Smith, his geology map & some of his fossil specimens

At about the same time, geologists like William Smith were mapping the rocks and fossils of Britain. He and others showed that different species existed in the past compared with today.

# Discovery Genetics




- From 1856-63, a monk called Gregor Mendel cultivated 29,000 pea plants to investigate how evolution worked i.e., how characteristics were passed down the generations.

- He figured out the basic principles of genetics. He showed that offspring received characteristics from both parents, but only the dominant characteristic trait was expressed. Mendel's work only came to light in 1900, long after his death

en.wikipedia.org/wiki/Image:Mendel.png
en.wikipedia.org/wiki/Image:Doperwt_rijserwt_peulen_Pisum_sativum.jpg

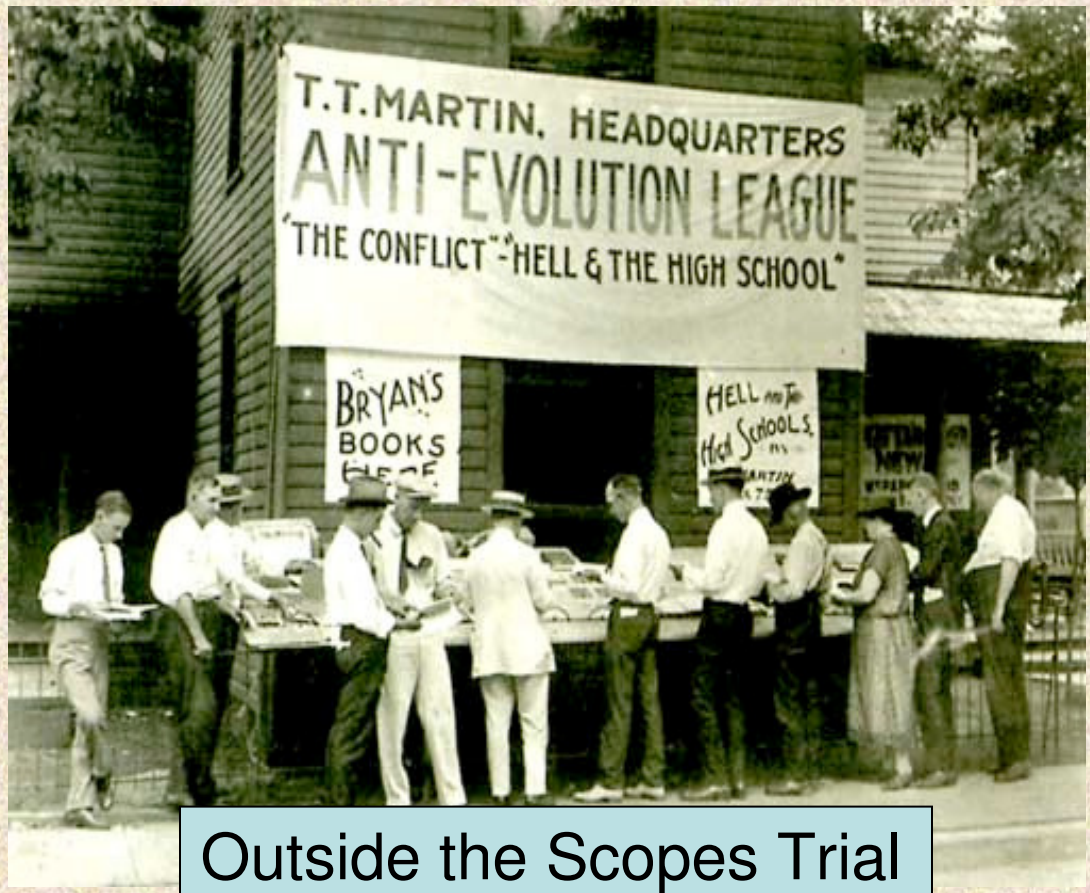
# Making Sense

Julian Huxley and the Modern Synthesis

- In the early 20th century, scientist started to make sense of how evolution worked.
- Building on Mendel's genetics, studies showed how characteristics in a population could be selected by environmental pressures.
- This Modern Synthesis, as Julian Huxley called it, brought Darwin's Natural Selection back to the centre of evolutionary theory.

en.wikipedia.org/wiki/Image:Hux-Oxon-72.jpg

# Opposition

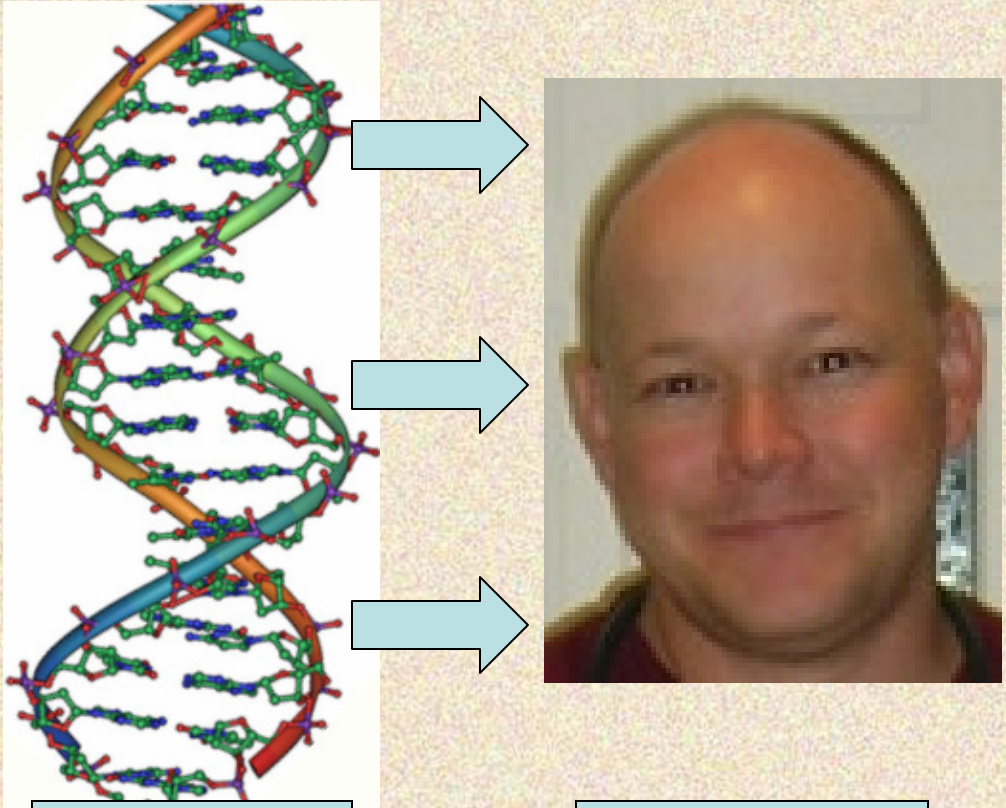



Outside the Scopes Trial

- Despite the achieval of scientific consensus on evolution, some Christian groups continued to oppose the concept.
- In 1925, the teaching of evolution was outlawed in Tennessee, USA, resulting in the infamous Scopes Monkey Trial

www.templeton-cambridge.org/fellows/vedantam/publications/2006.02.05/eden_and_evolution/

# All in the Genes



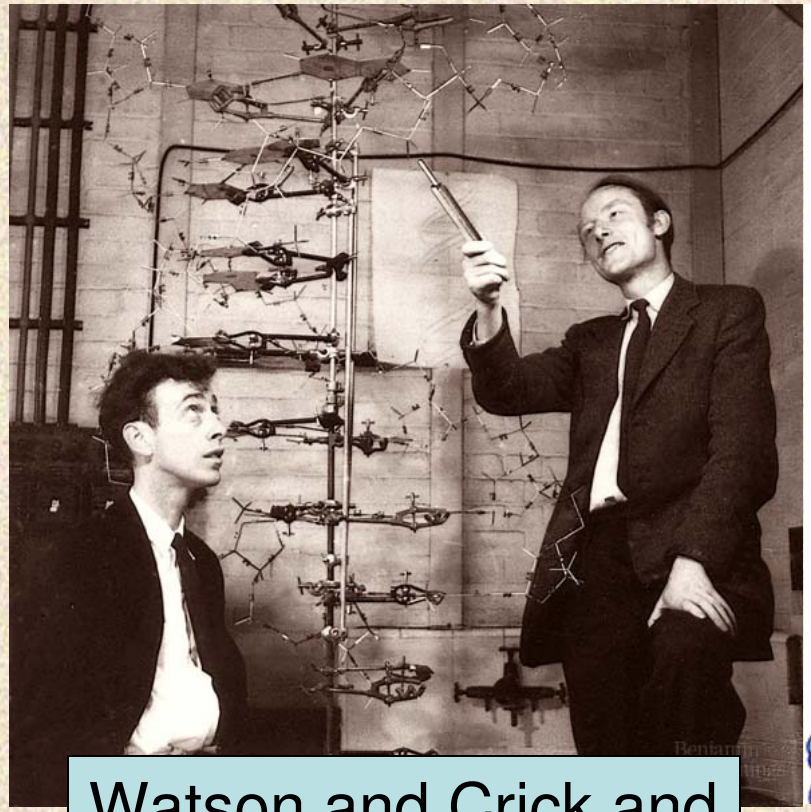
Genotype

Phenotype

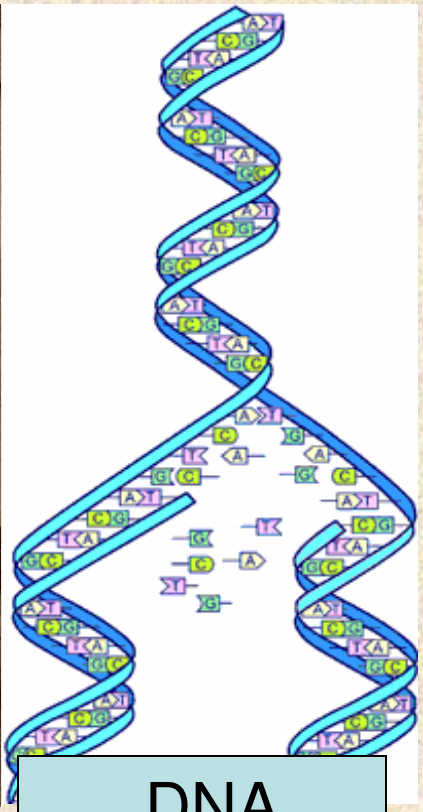
- The genetic make-up of an organism is known as its genotype.
- An organism's genotype and the environment in which it lives determines its total characteristic traits i.e. its phenotype.

commons.wikimedia.org/wiki/Image:DNA_double_helix_vertikal.PNG

# DNA



Watson and Crick and their model of DNA



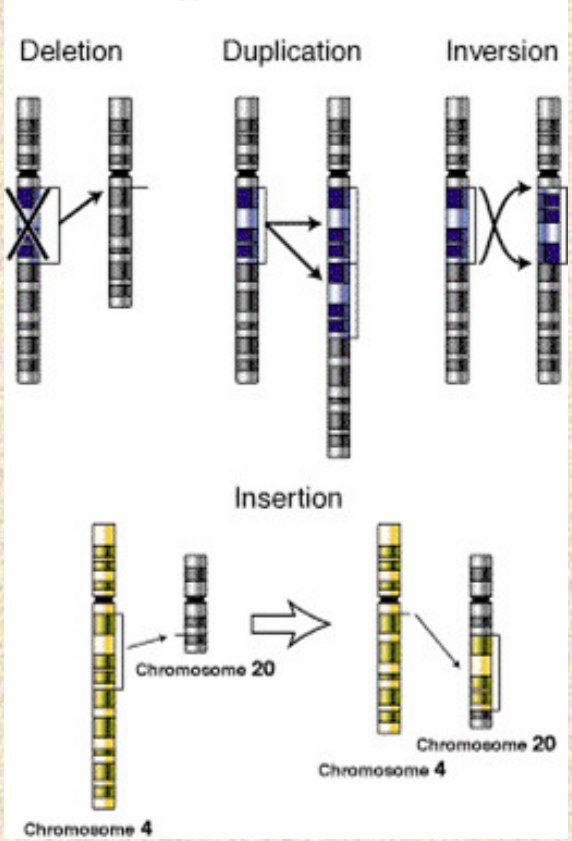
DNA replication

- The double-helix structure of DNA was discovered in 1953.
- This showed how genetic information is transferred from one cell to another almost without error.

www.chem.ucsb.edu/~kalju/chem110L/public/tutorial/images/WatsonCrick.jpg
en.wikipedia.org/wiki/DNA

# Mutation

Types of mutation




- However, occasional mutations or copying errors can and do occur when DNA is replicated.
- Mutations may be caused by radiation, viruses, or carcinogens.

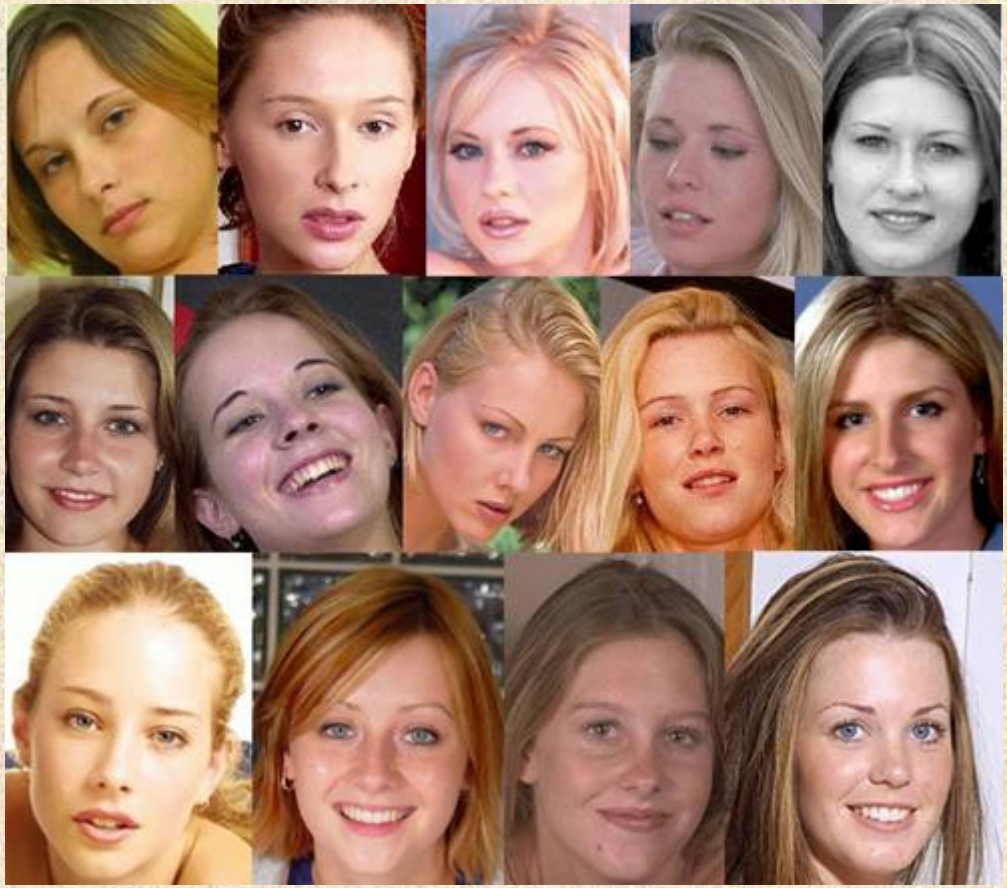

Mutant fruitfly

- Mutations are rare and often have damaging effects. Consequently organisms have special enzymes whose job it is to repair faulty DNA.

upload.wikimedia.org/wikipedia/commons/7/79/Types-of-mutation.png

humansystemstherapeutics.com/bb.htm

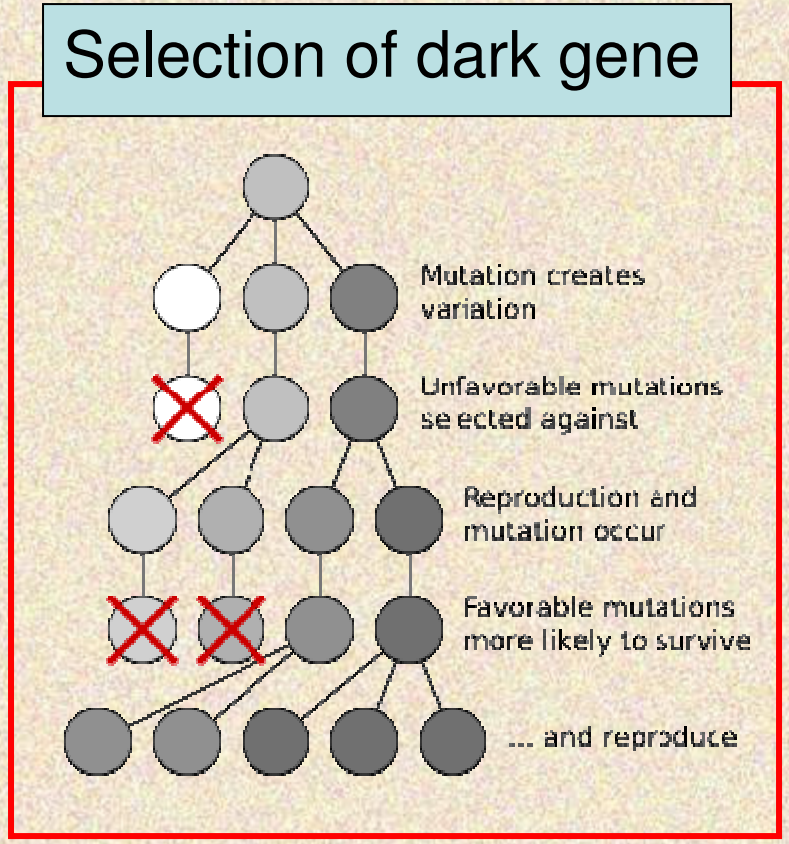
# Variation



- Nevertheless, some mutations will persist and increase genetic variation within a population.
- Variants of a particular gene are known as alleles. For example, the one of the genes for hair colour comprises brown/blonde alleles.

majorityrights.com/index.php/weblog/comments/racial_variation_in_some_parts_of_the_skull_involved_in_chewing/

# Natural Selection

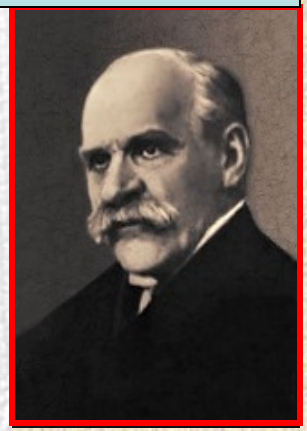



en.wikipedia.org/wiki/Image:Mutation_and_selection_diagram.svg

- Mutant alleles spread through a population by sexual reproduction.
- If an allele exerts a harmful effect, it will reduce the ability of the individual to reproduce and the allele will probably be removed from the population.
- In contrast, mutants with favorable effects are preferentially passed on

# Peppered Moth

Haldane and the peppered moth



- The Peppered Moth is an example of Natural Selection in action discovered by Haldane
- During the Industrial Revolution the trees on which the moth rested became soot-covered.
- This selected against the allele for pale colour in the population (which were poorly camouflaged from predators) and selected for the dark colour allele.

http://en.wikipedia.org/wiki/Image:Biston.betularia.7200.jpg
en.wikipedia.org/wiki/Image:Biston.betularia.f.carbonaria.7209.jpg
en.wikipedia.org/wiki/J._B._S._Haldane

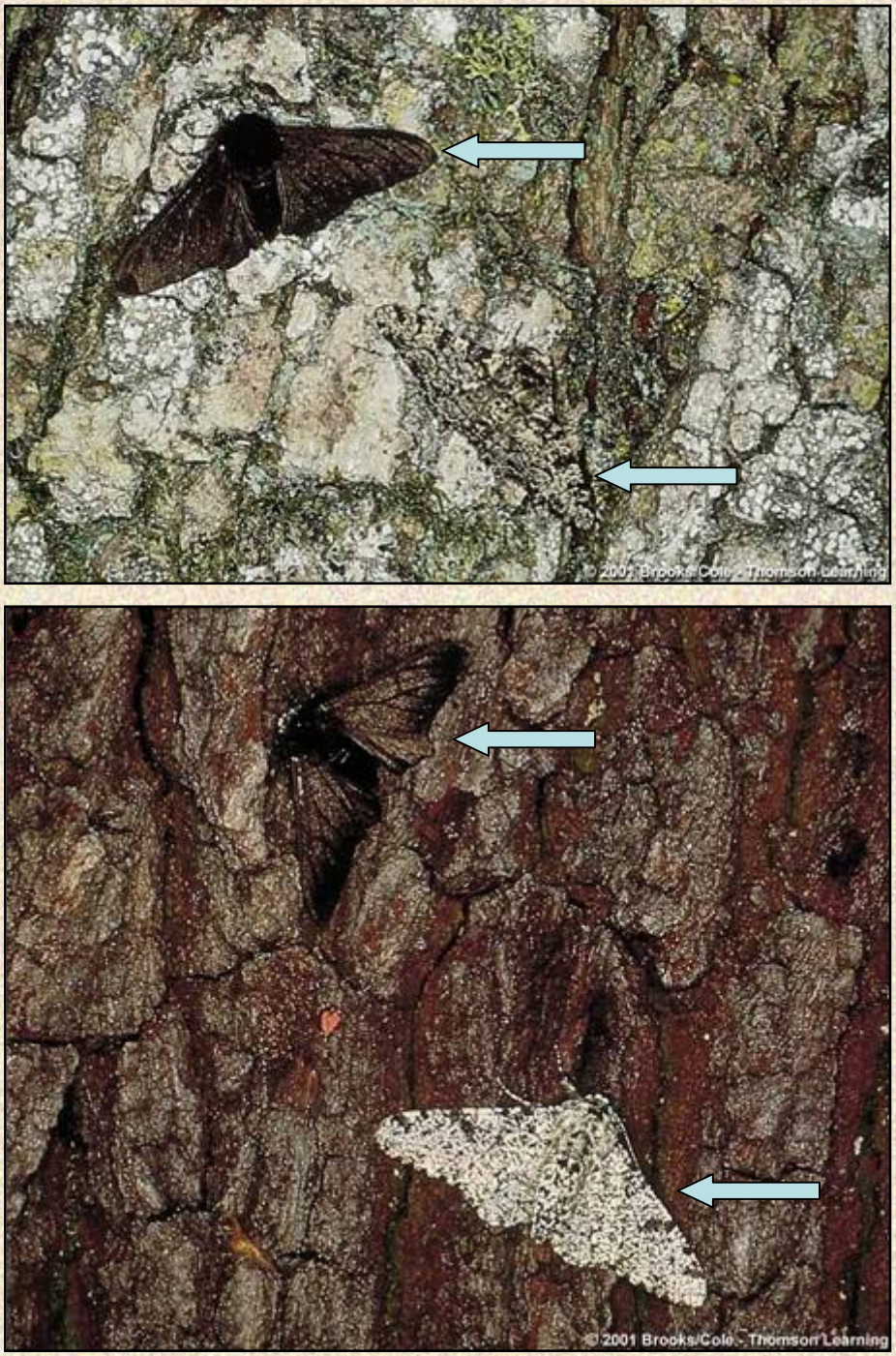



Fig. 18.5, p. 287

# Microevolution & Macroevolution

- The change in a POPULATION'S genetic makeup (gene pool) over time (successive generations)
  - Those with selective advantages (i.e., adaptations), survive and reproduce
  - All species descended from earlier ancestor species
- **Microevolution**
- Small genetic changes in a population such as the spread of a mutation or the change in the frequency of a single allele due to selection (changes to gene pool)
  - Not possible without genetic variability in a pop…
- **Macroevolution**
  - Long term, large scale evolutionary changes through which new species are formed and others are lost through extinction

# Microevolution

Dogs are wolves

- The dog is another example of how selection can change the frequency of alleles in a population.
- Dogs have been artificially selected for certain characteristics for many years, and different breeds have different alleles.
- All breeds of dog belong to the same species, *Canis lupus* (the wolf) so this is an example of Microevolution as no new species has resulted.

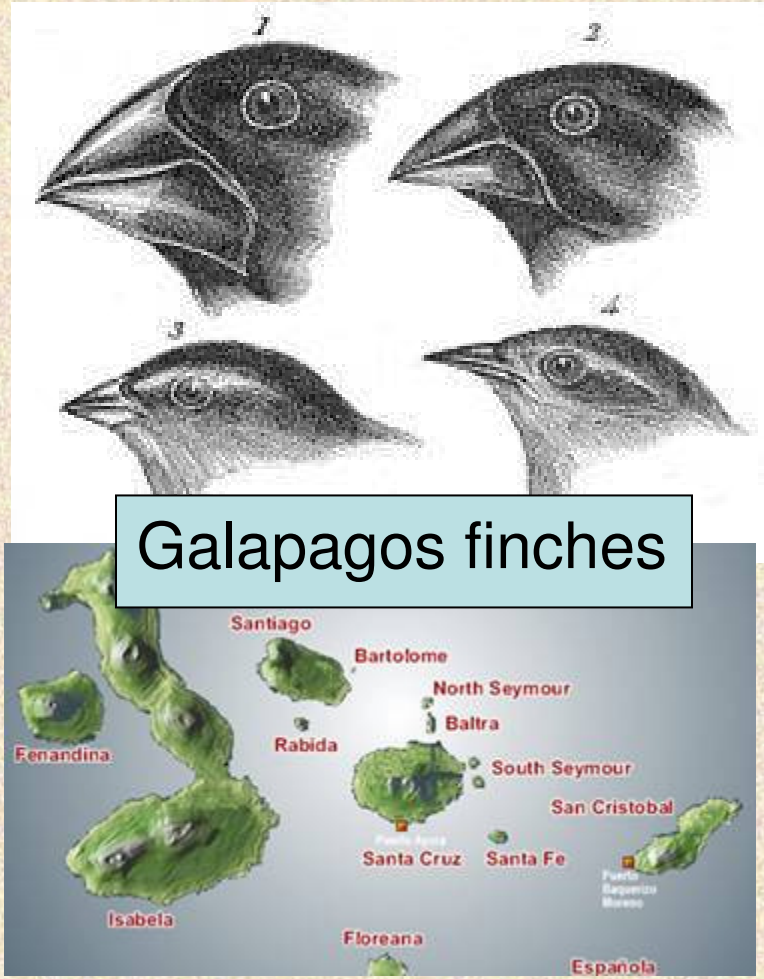
www.puppy-training-solutions.com/image-files/dog-breed-information.jpg

# Microevolution

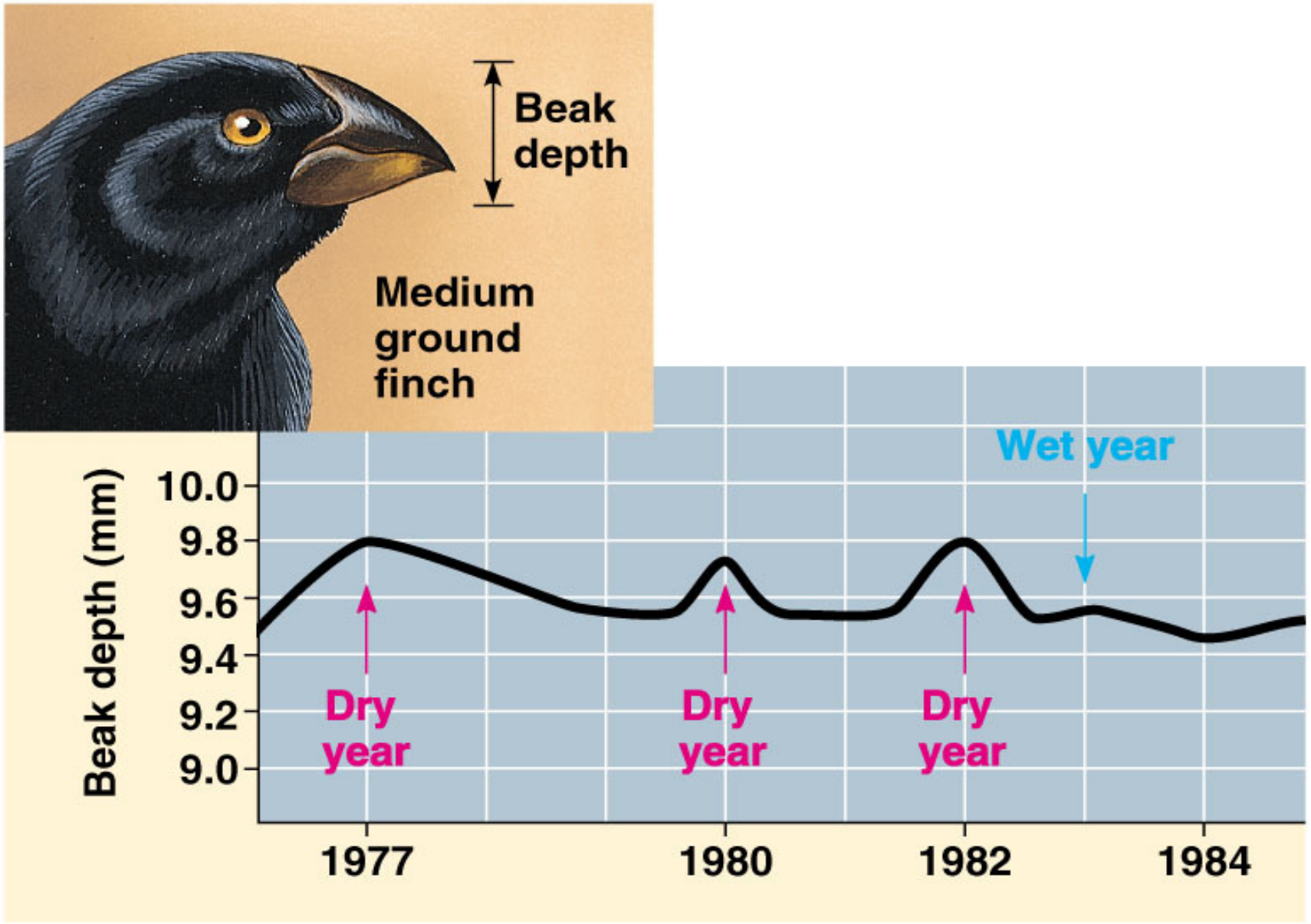
- Changes in a population's gene pool over time.
  - Genetic variability within a population is the catalyst
- **Four Processes cause Microevolution**
  - **Mutation** (random changes in DNA—ultimate source of new alleles) [stop little]
    - Exposure to mutagens or random mistakes in copying
    - Random/unpredictable relatively rare
  - **Natural Selection** (more fit = more offspring)
  - **Gene flow** (movement of genes between pop's)
  - **Genetic drift** (change in gene pool due to random/chance events)

# Macroevolution

- However, if two populations of a species become isolated from one another for tens of thousands of years, genetic difference may become marked.
- If the two populations can no-longer interbreed, new species are born. This is called Macroevolution.
- Darwin's Galapagos finches are an example of this process in action.




www.ingala.gov.ec/galapagosislands/images/stories/ingala_images/galapagos_take_a_tour/small_pics/galapagos_map_2.jpg



# Speciation

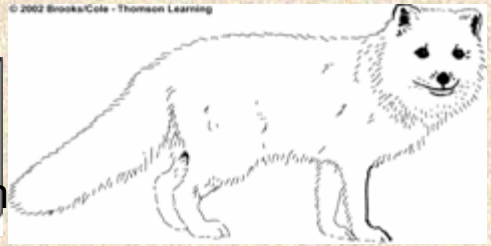
- Two species arise from one
  - Requires Reproductive isolation
    - Geographic: Physically separated
    - Temporal: Mate at different times
    - Behavioral: Bird calls / mating rituals
    - Anatomical: Picture a mouse and an elephant hooking up
    - Genetic Inviability: Mules
- Allopatric (Geographic)
  - Speciation that occurs when 2 or more populations of a species are geographically isolated from one another
  - The allele frequencies in these populations change
  - Members become so different that that can no no longer interbreed
  - See http://www.mhhe.com/biosci/esp/2001_gbio/folder_structure/ev/m3/s2/evm3s2_4.htm
  - Populations evolve with overlapping ranges
  - Behavioral barrier or hybridization or polyploidy

# Speciation

Early fox population

Spreads northward and southward and separates

Northern population



**Arctic Fox**

Adapted to cold through heavier fur, short ears, short legs, short nose. White fur matches snow for camouflage.

Different environmental conditions lead to different selective pressures and evolution into two different species.

Southern population

**Gray Fox**

Adapted to heat through lightweight fur and long ears, legs, and nose, which give off more heat.

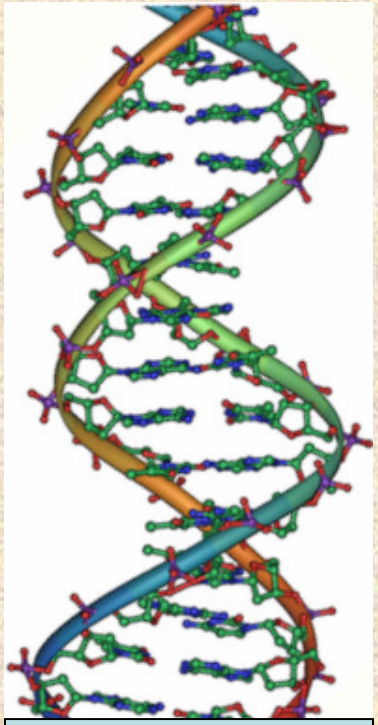
# Speciation Today?

London Underground Mosquito

en.wikipedia.org/wiki/Image:Gb-lu-Angel-southbound.jpg
en.wikipedia.org/wiki/Culex

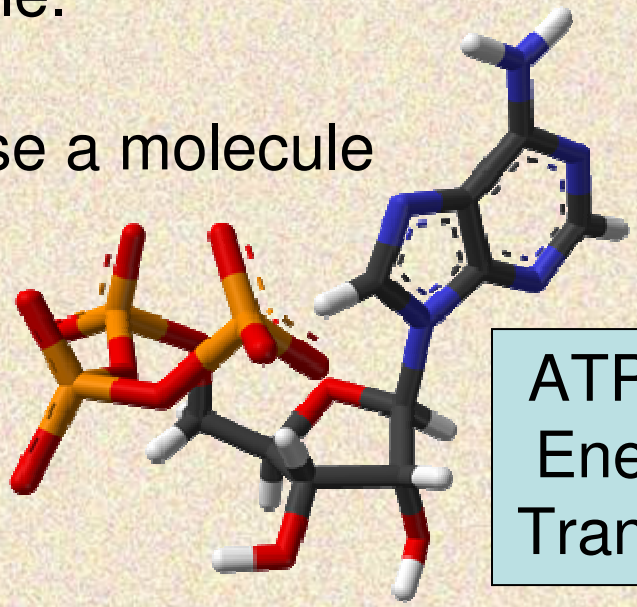
- The mosquito was introduced to the London Underground during its construction around 1900.
- It became infamous in the War for attacking people sheltering from the Blitz.
- Studies indicate several genetic differences from its above-ground ancestors. Interbreeding between populations is difficult suggesting that speciation may be occurring.

# Biochemistry



DNA for Information Transfer

- The basic similarity of all living things suggests that they evolved from a single common ancestor.
- As we have already seen, all living things pass on information from generation to generation using the DNA molecule.
- All living things also use a molecule called ATP to carry energy around the organism.



ATP for Energy Transfer

en.wikipedia.org/wiki/Image:ATP-xtal-3D-sticks.png

# Similar Genes

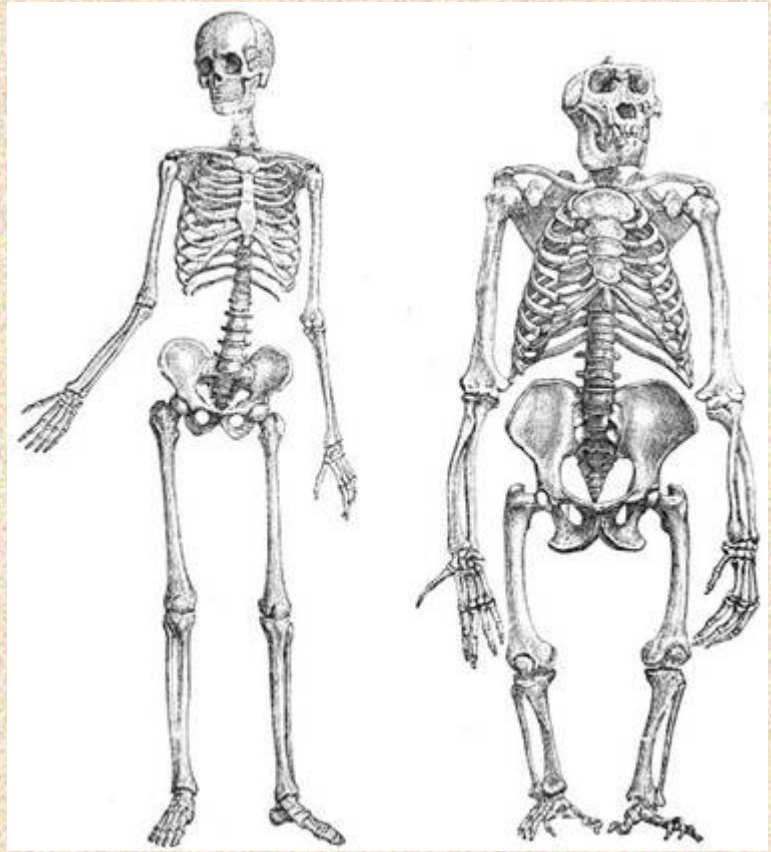
```
HUMAN          CCAAGGTCACGACTACTCCAATTGTCACAACTGTTCCAACCGTCACGACTGTTGAACGA
CHIMPANZEE     CCAAGGTCACGACTACTCCAATTGTCACAACTGTTCCAACCGTCATGACTGTTGAACGA
GORILLA        CCAAGGTCACAACTACTCCAATTGTCACAACTGTTCCAACCGTCACGACTGTTGAACGA
```

Genetic code of chimps and gorillas is almost identical to humans

- If evolution is true then we might also expect that closely related organisms will be more similar to one another than more distantly related organisms.

- Comparison of the human genetic code with that of other organisms show that chimpanzees are nearly genetically identical (differ by less than 1.2%) whereas the mouse differs by ≈15%.

# Comparative Anatomy



Human and Gorilla

- Similar comparisons can be made based on anatomical evidence.
- The skeleton of humans and gorillas are very similar suggesting they shared a recent common ancestor, but very different from the more distantly related woodlouse…

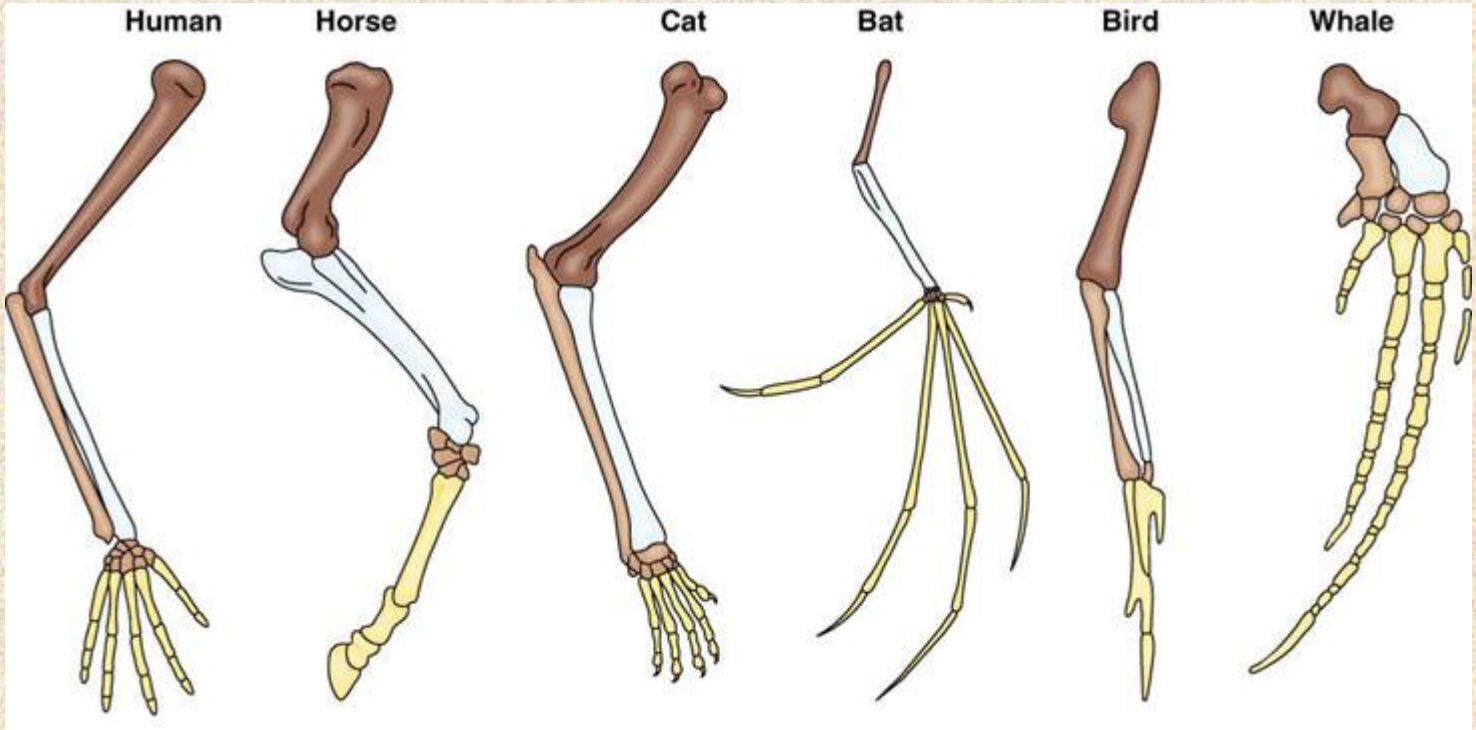
yet all have a common shared characteristic: bilateral symmetry

Woodlouse

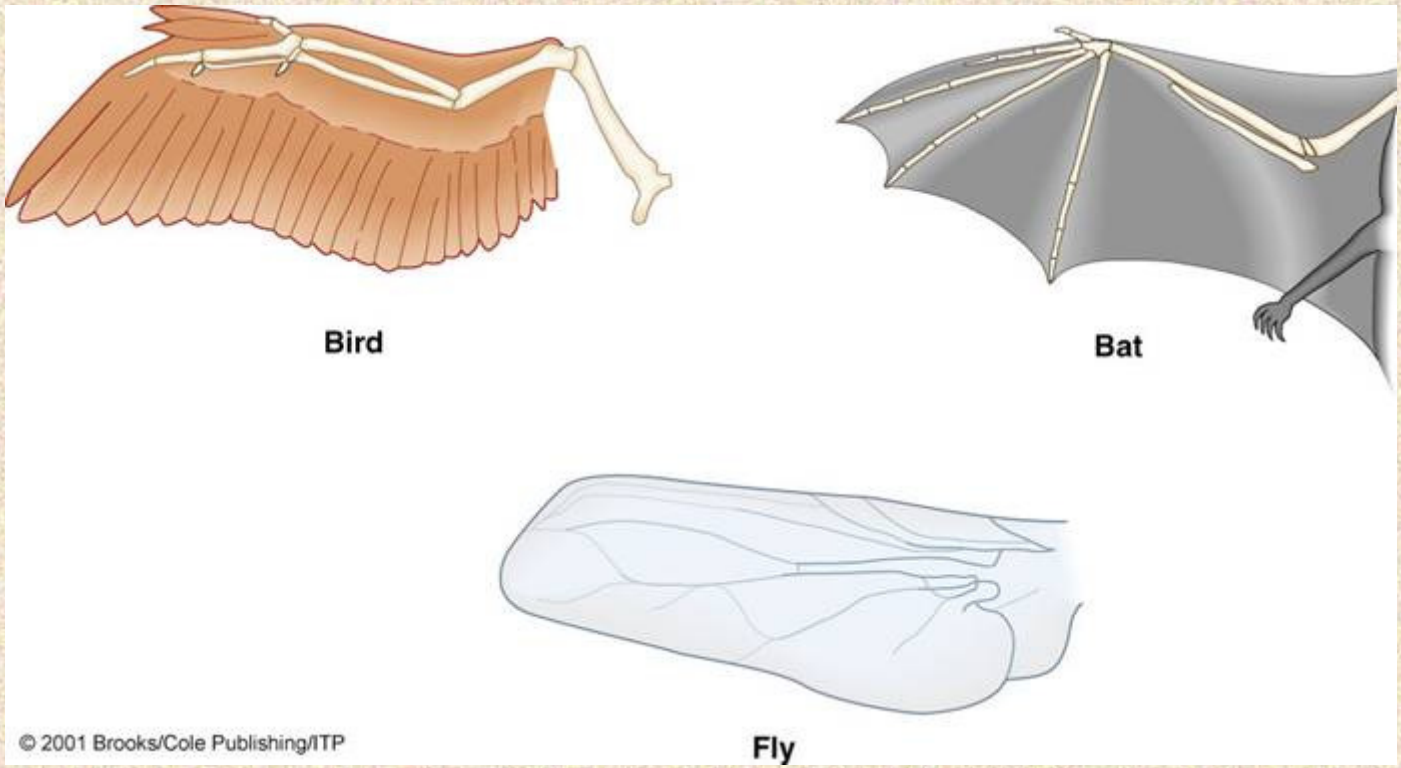
en.wikipedia.org/wiki/Image:Primatenskelett-drawing.jpg

# Homologous Structures

- Forelimbs of humans, whales, dogs, and birds
  - are superficially dissimilar,
  - yet all are made up of the same bones,



# Analogous Structures

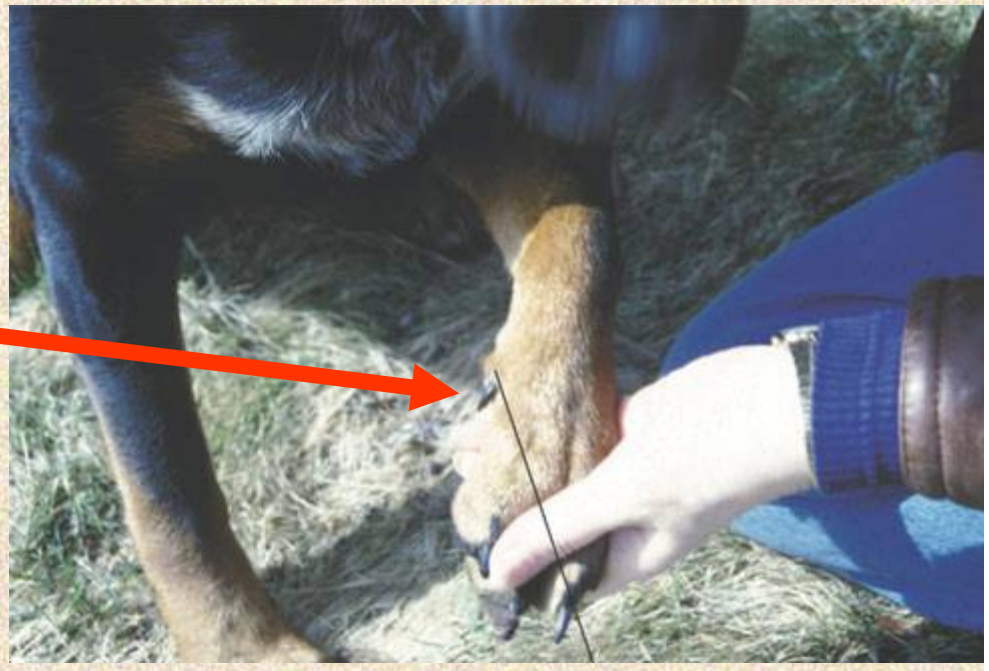



- Wings of insects, birds and bats
  - serve the same function but differ considerably
  - in structure and embryological development
- Are any of these wings
  - both analogous and homologous?

- Yes, bird and bat wings

# Vestigial Structures

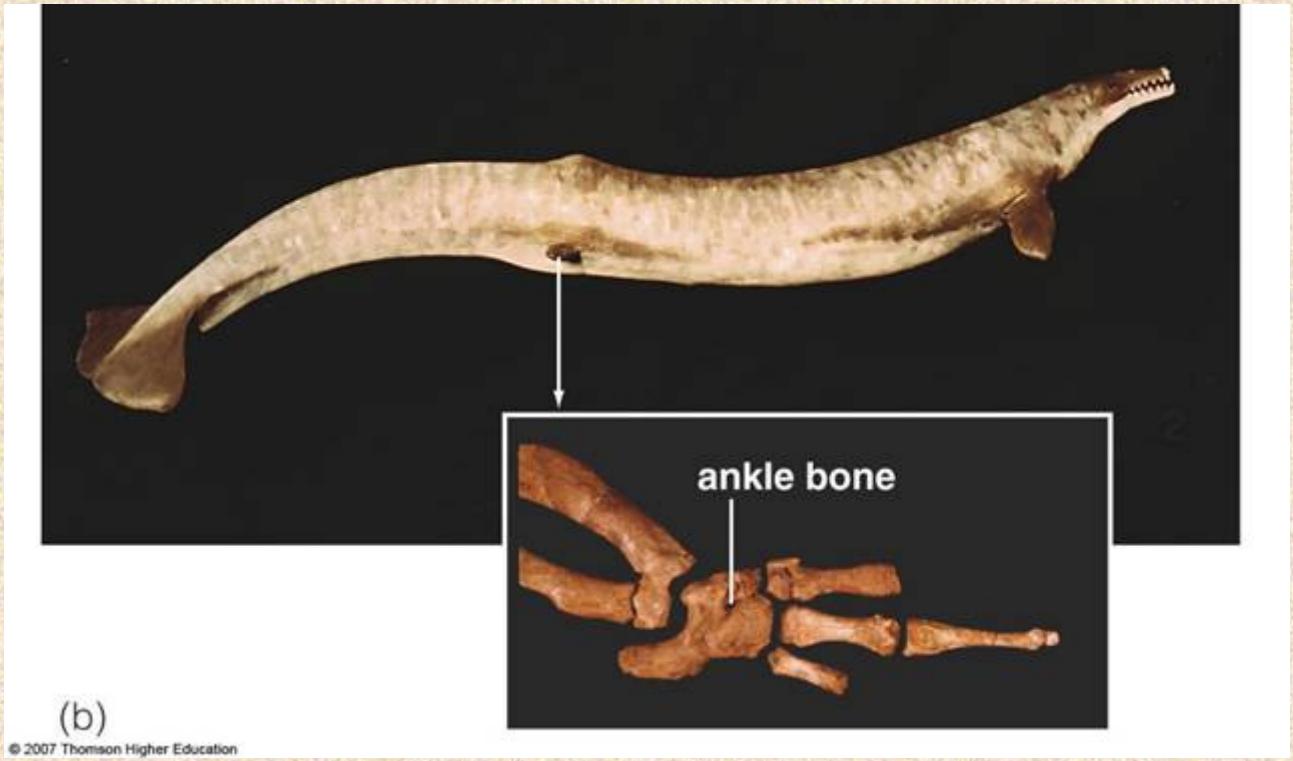
- Vestigial structures are nonfunctional remnants
  - of structures in organisms that were functional
  - in their ancestors



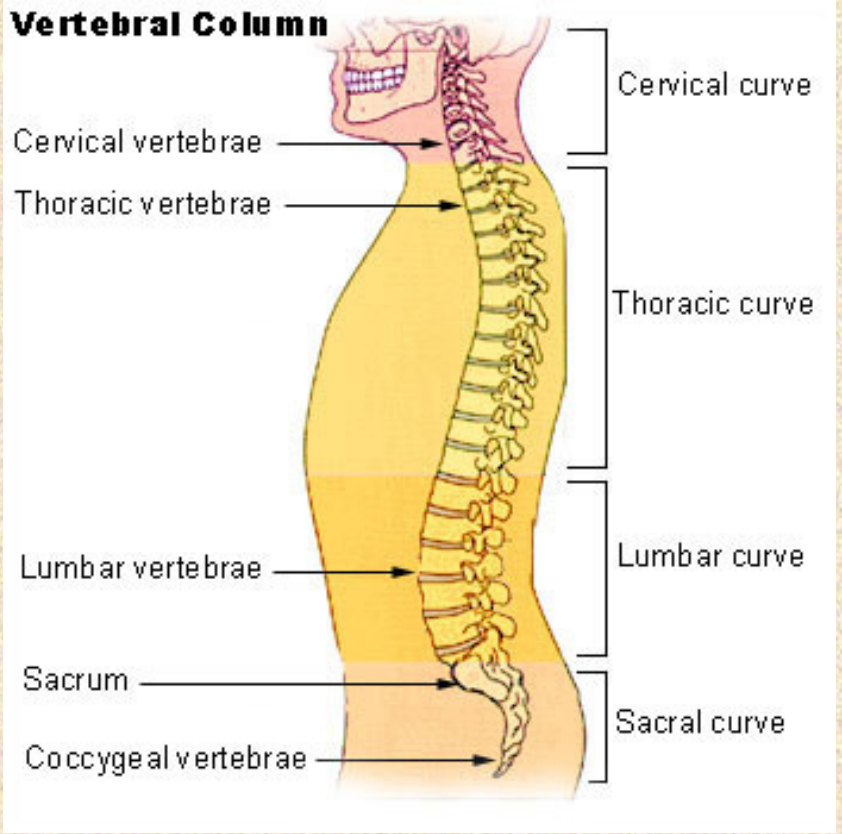
- Why do dogs have tiny,
  - functionless toes on their feet (dewclaws)?
- Ancestral dogs had five toes
  - on each foot,
  - all of which contacted the ground
- As they evolved
  - they became toe-walkers with only four toes on the ground
  - and the big toes and thumbs were lost or reduced
  - to their present state

# Remnants of Rear Limbs in Whales

- The Eocene-aged whale, *Basilosaurus*,
  - had tiny vestigial back limbs
  - but it did not use limbs to support its body weight.



# Vestigial Structures



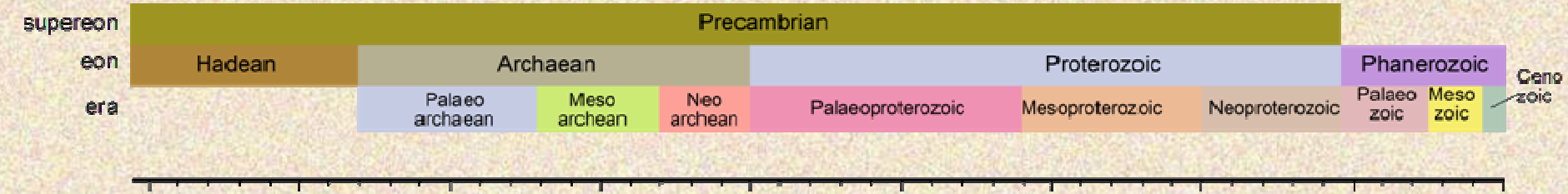

The coccyx is a vestigial tail

- As evolution progresses, some structures get side-lined as they are not longer of use. These are known as vestigial structures.
- The coccyx is a much reduced version of an ancestral tail, which was formerly adapted to aid balance and climbing.
- Another vestigial structure in humans is the appendix.
- Wisdom teeth, body hair.

en.wikipedia.org/wiki/Image:Illu_vertebral_column.jpg

# Fossil Record

http://en.wikipedia.org/wiki/Geologic_time_scale

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origins bacteria complex cells dinosaurs humans

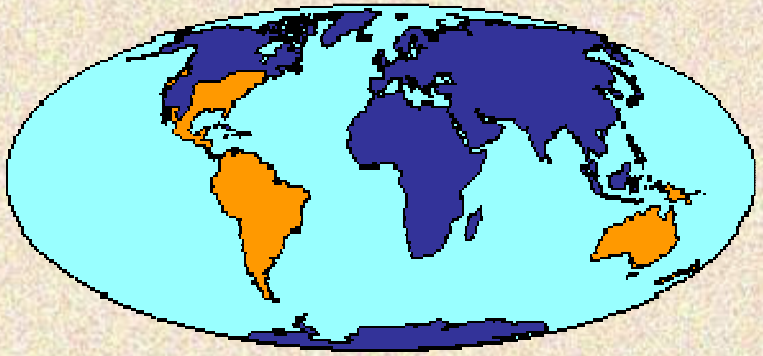
The fossil record shows a sequence from simple bacteria to more complicated organisms through time and provides the most compelling evidence for evolution.

# Transitional fossils


en.wikipedia.org/wiki/Image:Archaeopteryx_lithographica_paris.JPG

- Many fossils show a clear transition from one species, or group, to another.
- Archaeopteryx was found in Germany in 1861. It share many characteristics with both dinosaurs and birds.
- It provides good evidence that birds arose from dinosaur ancestors

# Biogeography



Distribution of marsupials today

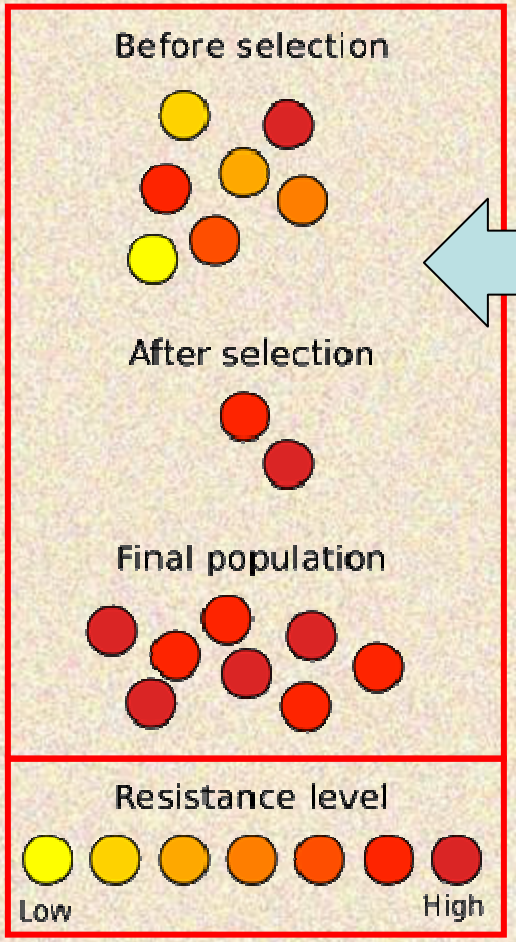

Jurassic Period — 160 mya

Marsupials

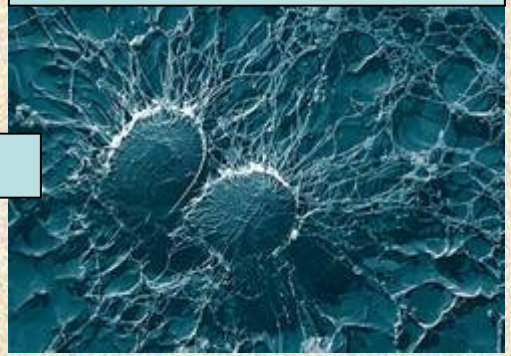
- Geographic spread of organisms also tells of their past evolution.
- Marsupials occur in two populations today in the Americas and Australia.
- This shows the group evolved before the continents drifted apart

evolution.berkeley.edu/evosite/lines/IVCexperiments.shtml
en.wikipedia.org/wiki/Image:Kangaroo_and_joey03.jpg

# Antibiotic resistance




Staphylococcus



- We are all familiar with the way that certain bacteria can become resistant to antibiotics

- This is an example of natural selection in action. The antibiotic acts as an environmental pressure. It weeds out those bacteria with low resistance and only those with high resistance survive to reproduce.

http://en.wikipedia.org/wiki/Image:Antibiotic_resistance.svg
en.wikipedia.org/wiki/Image:Staphylococcus_aureus%2C_50%2C000x%2C_USDA%2C_ARS%2C_EMU.jpg

# What's This Niche Stuff Got to do with Evolution and Biodiversity?

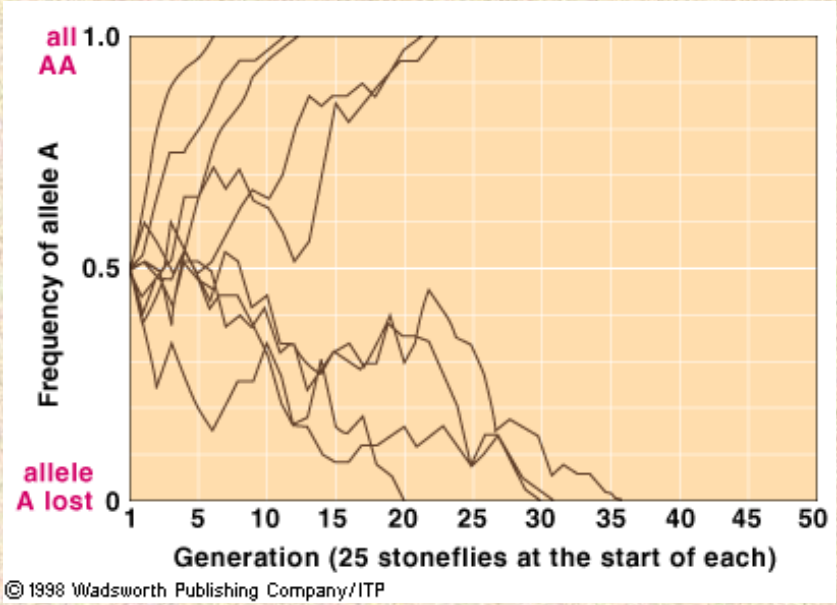
- Hmmmmm….
- Let's think about three key points….
  - The more niches you have in an ecosystem…
  - The more of a generalist species you are…
  - The more of a specialist species you are…

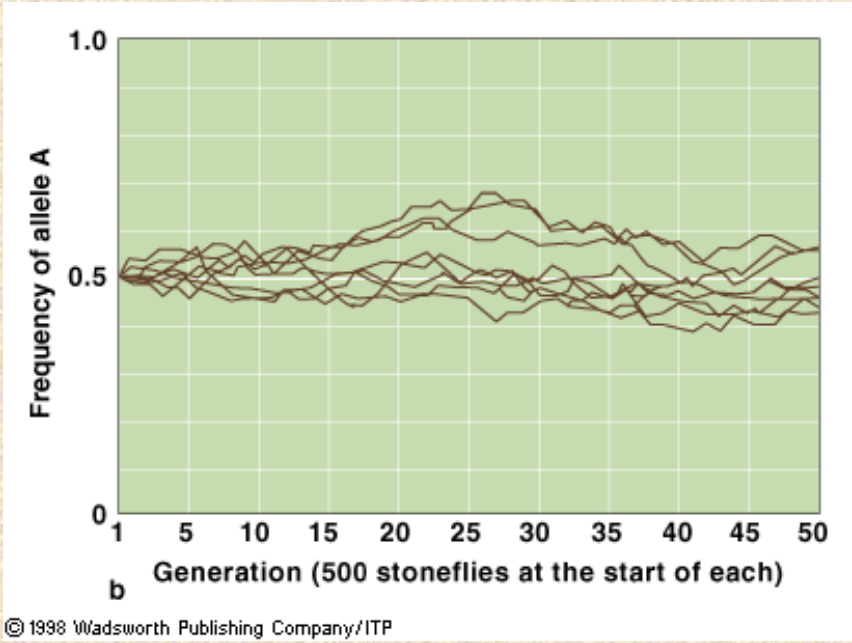
# Gene Flow and Genetic Drift

- **Gene Flow**
  - **Flow of alleles**
    - **Emigration and immigration of individuals**
- **Genetic Drift**
  - **Random change in allele frequencies over generations brought about by chance**
  - **In the absence of other forces, drift leads to loss of genetic diversity**
    - Elephant seals, cheetahs

# Genetic Drift

- Magnitude of drift is greatest in small populations



# Hardy-Weinberg equilibrium

- The Hardy-Weinberg equilibrium describes a model situation in which allele frequencies do not change.

$$p^2 + 2pq + q^2 = 1$$

# Hardy-Weinburg Equilibrium

- Hardy wrote his equations in response to a question posed to him by the geneticist Reginald Punnett at Cambridge University. Punnett wondered why, even though the allele for brachydactyly (short, stubby fingers) is dominant and the allele for normal-length fingers is recessive, most people in Britain have normal-length fingers. Hardy-Weinburg equilibrium is the cornerstone of population genetics. The equation describes a model situation in which allele frequencies do not change across generations and genotype frequencies can be predicted from allele frequencies. In other words, we can predict what happens to traits in a population, as long as certain conditions remain constant. Furthermore, the Hardy-Weinburg equilibrium helps us understand why traits don't slowly move to all dominant traits over time!

# Hardy-Weinburg Conditions

- Mating is random.
- Population size is infinite.
- Large populations aren't affected by genetic drift.
- No gene flow—no migration into or out of the population.
- No mutation.
- Natural selection does not affect survival of any genotypes.

# READY TO DO SOME MATH?