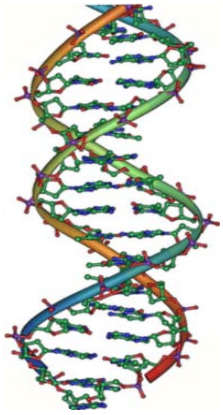
Evolution



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

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

The Tree of Life

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

All living things share a common ancestor ??

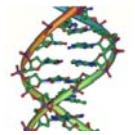
- We can draw a Tree of Life to show how every species is related.
- Evolution is the process by which one species gives rise to another and the Tree of Life grows

Evolution as Theory and Fact

- Confusion sometimes arises as to whether Evolution is a theory or a fact.
- 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 evidence for its occurrence. (But how to explain?)

Rodin's "The Thinker"

Outline



- Part 1: How was evolution discovered?
- Part 2: How does evolution work?
- Part 3: What is the evidence for evolution?

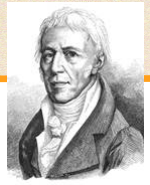
Discovery Fixed species

Michelangelo's fresco on the ceiling of the Sistine Chapel

從古典到文藝復興時期之後，物種長期視為是特別的創造物，永久固定不變。

en.wikipedia.org/wiki/The_Creation_of_Adam

Discovery Transmutation

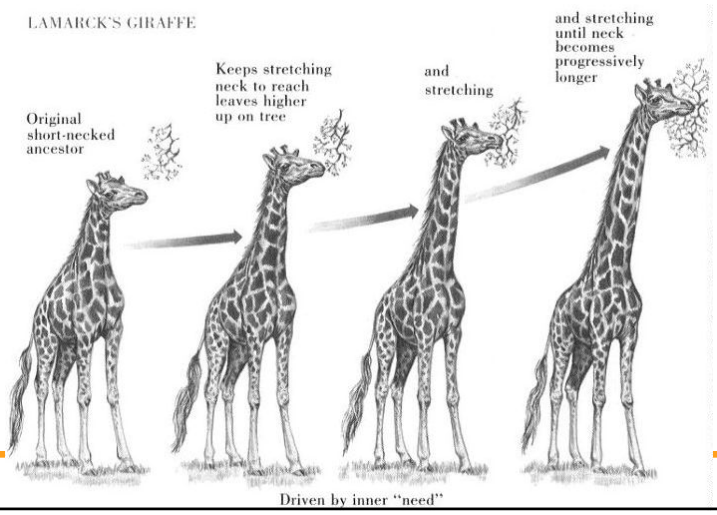


Jean Baptiste **de Lamarck** 1744-1829

Lamarck: **用進廢退說**

- 經常使用器官會漸趨發達，不用的會退化。（個體上成立）
- 後天獲得的變化，可以遺傳給後代if an animal acquired a characteristic during its lifetime, it could pass it onto its offspring.
  - 批評：體細胞的變異不會遺傳到後代

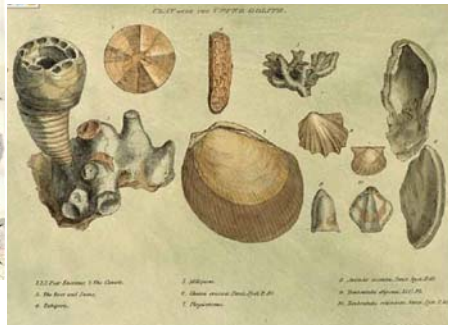
- Hence giraffes got their long necks through generations of straining to reach high branches.



Discovery Fossils and Strata

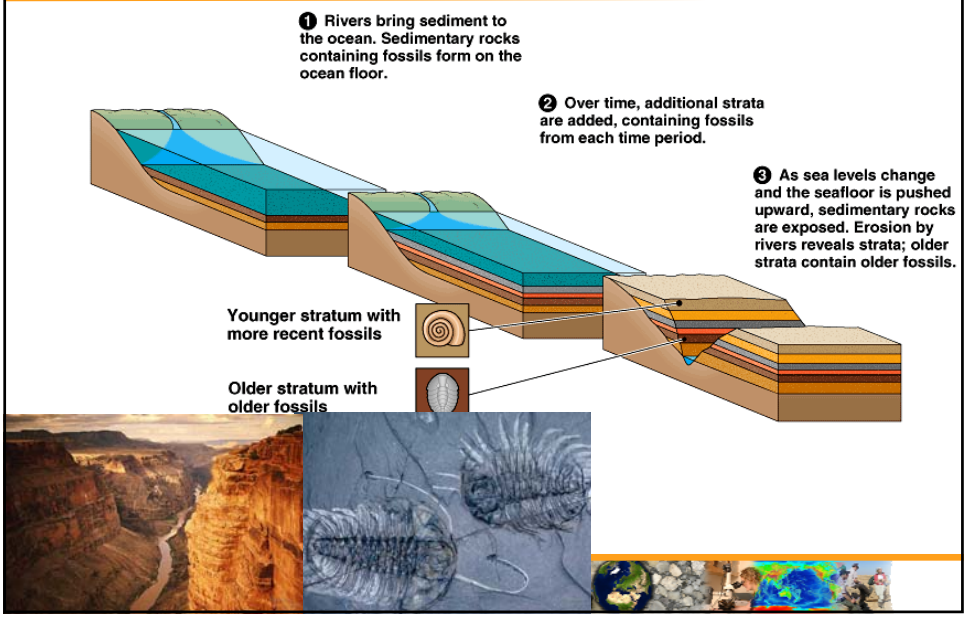
William Smith: geology map & some of his fossil specimens

化石和地層

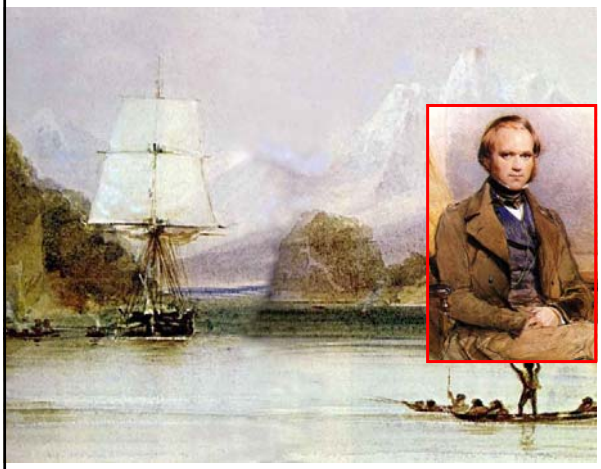


William Smith were mapping the rocks and fossils of Britain.
-- different species existed in the past compared with today.

Formation of sedimentary rock and deposition of fossils from different time periods



Discovery Darwin's Voyage



Charles Darwin toured the world in HMS Beagle (1831-1836).

He was dazzled by the amazing diversity of life and started to wonder how it might have originated

Voyage of the Beagle

Discovery Survival of the Fittest

Origin of Species (1859)

- Darwin proposed how one species might give rise to another.

1. Today's organisms descended from ancestral species.
2. **Natural selection** provided a mechanism for evolutionary change in populations.

Natural Selection explains adaptation

Darwin in 1860

en.wikipedia.org/wiki/Image:Darwin%27s_finches.jpeg

- Where food was limited, competition meant that only the fittest would survive.
- This would lead to the natural selection of the best adapted individuals and eventually the evolution of a new species.

Discovery Genetics

Mendel and his peas

- 1856-63, monk Gregor Mendel cultivated 29000 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

遺傳學之父--孟德爾

- Mendel (1865) Experiments on Plant Hybridization
- Law of Unitary Traits每一種遺傳特質，都由一個遺傳單元控制
- 顯隱律, 分離律Law of Segregation, 自由結合律Law of Independent Assortment

Seed		Flower	Pod		Stem	
Form	Cotyledons	Color	Form	Color	Place	Size
Grey & Round	Yellow	White	Full	Yellow	Axial pods, Flowers along	Long (6-7ft)
White & Wrinkled	Green	Violet	Constricted	Green	Terminal pods, Flowers top	Short (~1ft)
1	2	3	4	5	6	7

Discovery 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

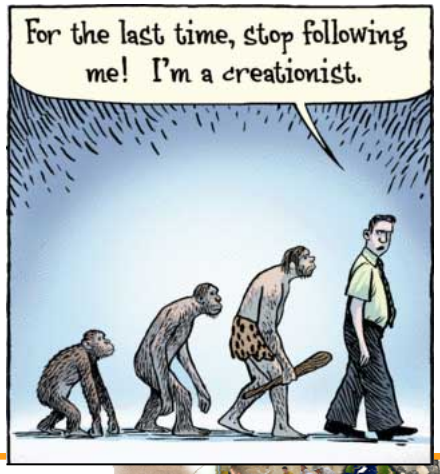
Discovery Opposition

- 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

Outside the Scopes Trial

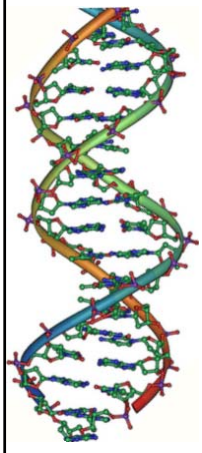
www.templeton-cambridge.org/fellows/vedantam/publications/2006.02.05federal_evolution/

Discussion: Should Creationism and Evolution be given equal time in science lessons?



science.kukuchew.com/wp-content/uploads/2008/01/stop_following_me_creationist.jpg

Mechanism 1: All in the Genes



- 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.

Genotype

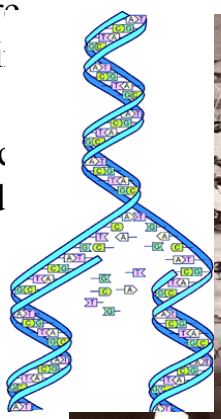
Phenotype

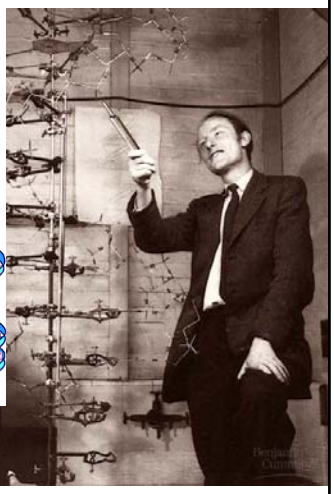
commons.wikimedia.org/wiki/Image:DNA_double_helix_vertikal.PNG

Mechanism 2: DNA

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

Watson and Crick
華森跟克利克
雙股螺旋DNA結構
1962年諾貝爾生醫獎



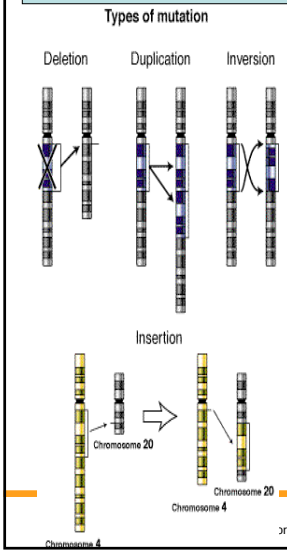


DNA replication

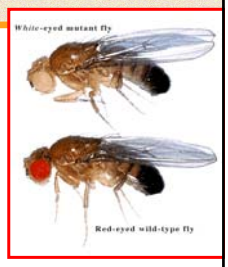
www.chem.ucsb.edu/~kalju/chem110L/public/tutorials/images/WatsonCrick.jpg
en.wikipedia.org/wiki/DNA

Mechanism 3: 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.
- Mutations are rare and often have damaging effects. Consequently organisms have special enzymes whose job it is to repair faulty DNA.



Mutant fruitfly

org/wikipedia/commons/7/79/Types_of_mutation.png
humansystemstherapeutics.com/bb.html

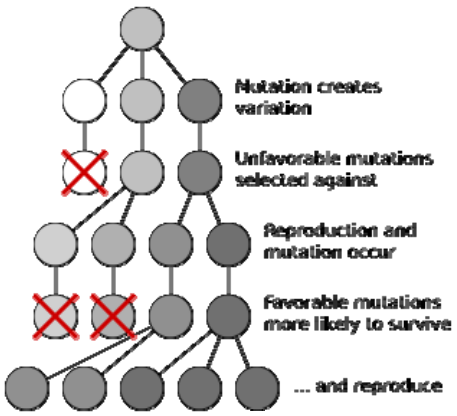
Mechanism 4: Variation

- 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 color comprises brown/blonde alleles.

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

Mechanism 5: Natural Selection

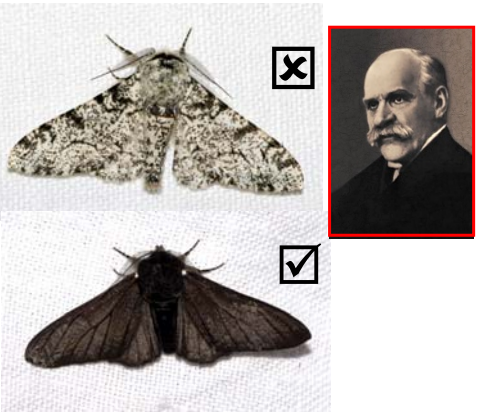
Selection of dark gene



- 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

Mechanism 5: Natural Selection

Haldane and the peppered moth



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

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

Mechanism 6: Microevolution

Dogs are wolves

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

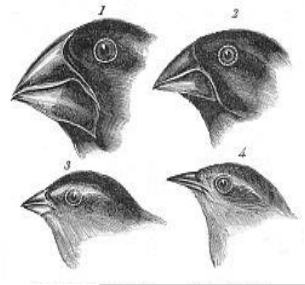
- The dog is another example of how selection can change the frequency of alleles in a population.
- Dogs have been artificially selected for certain characteristics for many years, and different breeds have different alleles.
- All breeds of dog belong to the same species, *Canis lupus* (the wolf) so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

Artificial Selection

- nature provides variation, humans select variations that are useful.
- Example - a farmer breeds only his best livestock

Mechanism 7: Macroevolution

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



Galapagos finches

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

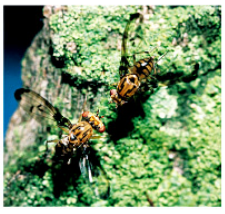
Mechanism 8: Speciation Today?

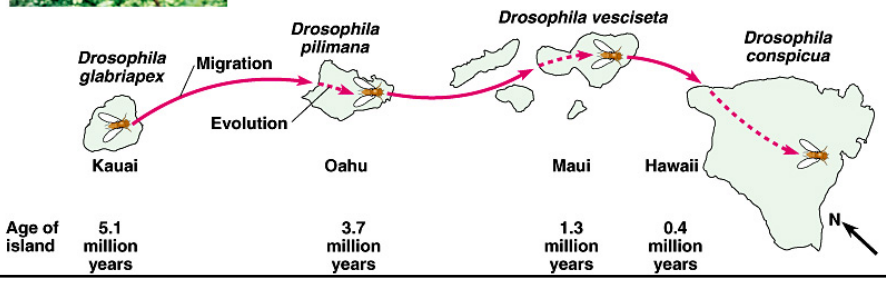
- The mosquito was introduced to the London Underground during its construction around 1900.
- It became infamous in the War for attacking people sheltering from the Blitz.
- Studies indicate several genetic differences from its above-ground ancestors. Interbreeding between populations is difficult suggesting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

London Underground Mosquito

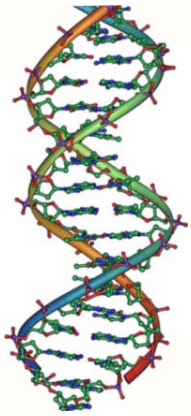
en.wikipedia.org/wiki/Image:Gb-lu-Angel-southbound.jpg
en.wikipedia.org/wiki/Culex

- All of the 500 or so endemic species of *Drosophila* in the Hawaiian archipelago descended from a common ancestor that reached Kauai over 5 million years ago.



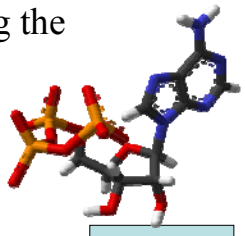


Evidence 1: Biochemistry



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

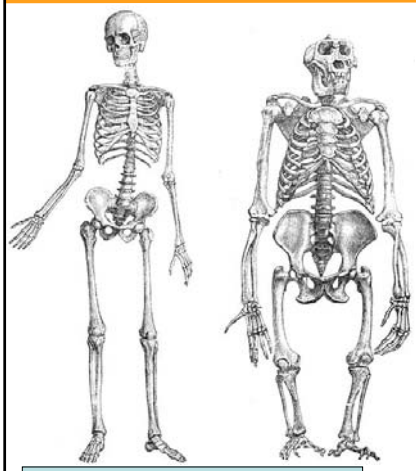
Evidence 2: Similar Genes

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%.

Evidence 3: Comparative Anatomy



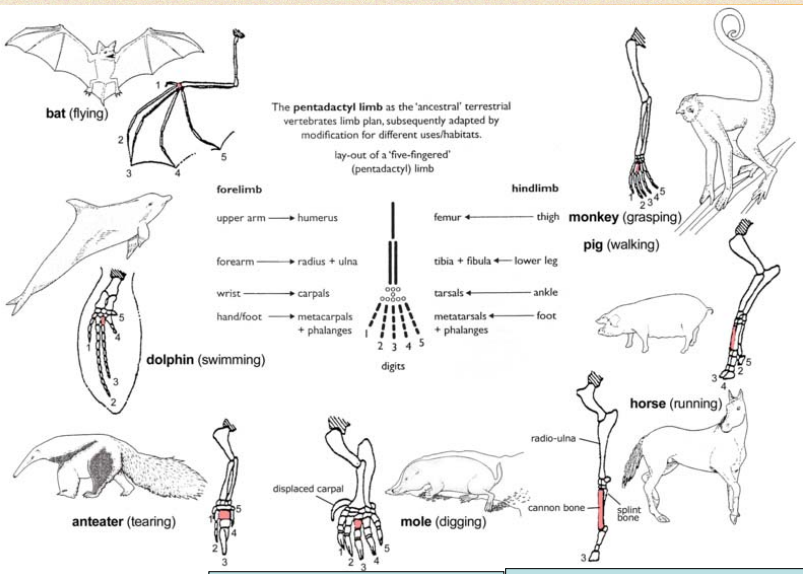
Human and Gorilla

- 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…
- all have a common shared characteristic: bilateral symmetry

Woodlouse

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

Evidence 4: Homology 同源

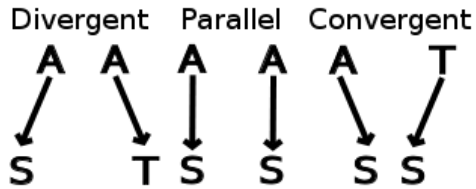


脊椎動物的四肢

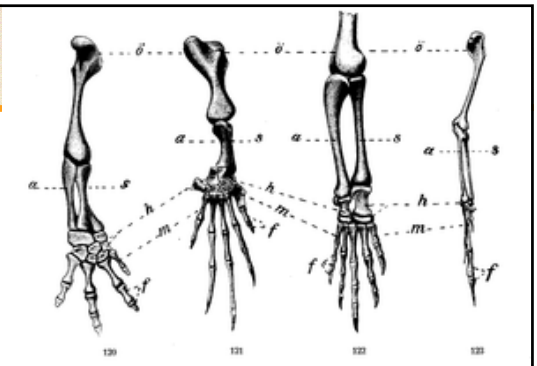
but modified for different uses

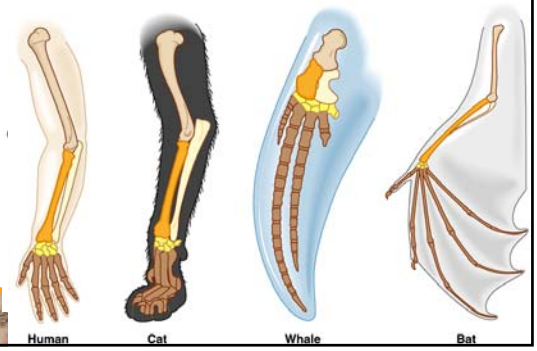
- 在生物學種系發生理論中，若兩個或多個結構具有相同的祖先，則稱它們**同源**（Homology）。
- 演化上：兩個結構由一個共同的祖先演化而來（蝙蝠的翅膀與人類的手臂同源）
- 發育上：兩個結構由胚胎時期的同一組織發育而來（人類女性的卵巢與男性的睪丸同源）。
- **趨同演化**（convergent evolution）：指兩種以上型態或分子具有相同功能或構造，但卻源自不同起源之演化。如昆蟲的翅膀、蝙蝠的翅膀和鳥類的翅膀（功能）相似，卻不同源。

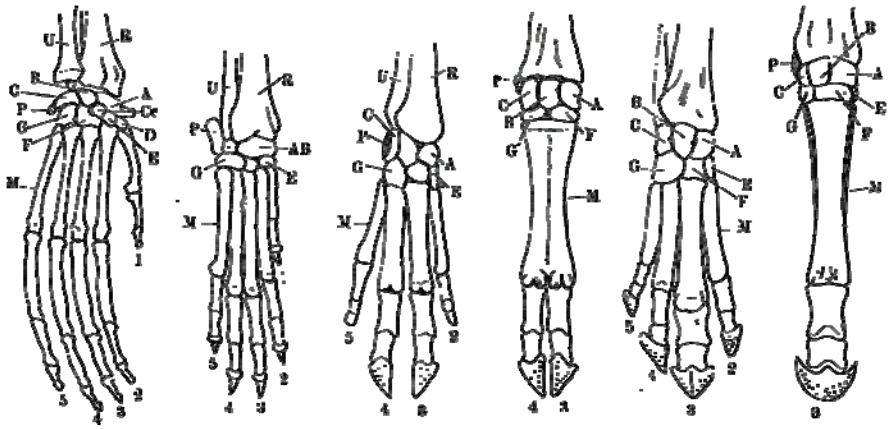
Evolution at an amino acid position from alanine (A) to serine (S) in its present-day form.



- **脊椎動物同源構造比較。上下，左右：有尾目（蠑螈等）、龜、鱷魚、鳥、人、 貓、鯨魚、蝙蝠**



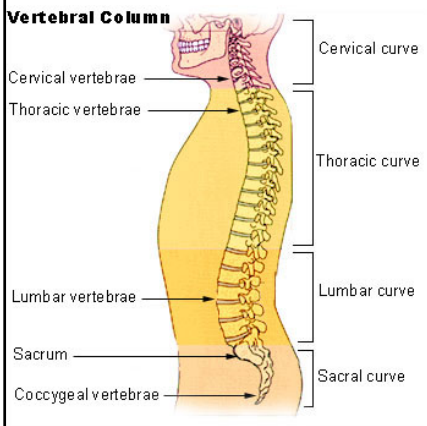




哺乳動物的前肢是同源構造**趨異演化**

趨異演化（Divergent evolution）：兩個或多個特徵具有共同演化起源，但在演化歷程中逐漸分化的現象，又稱適應。如脊椎動物的四肢，可能具有共同起源，但有不同的構造與功能。

Evidence 4: Vestigial Structures



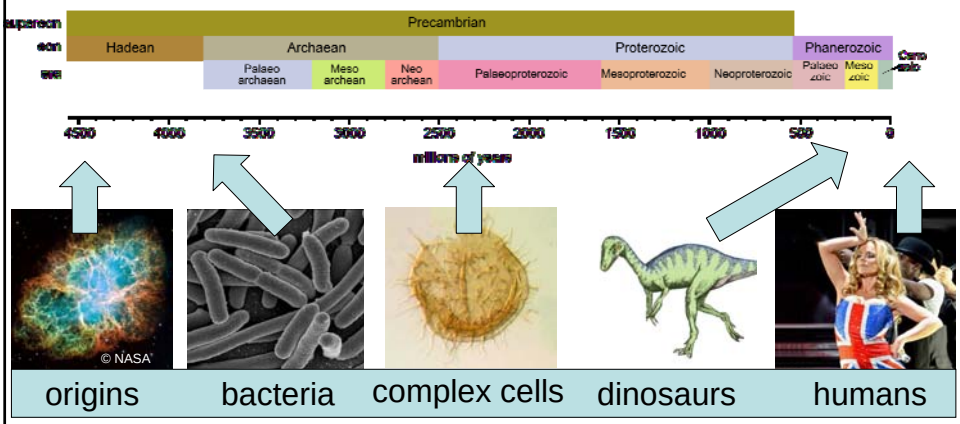
The coccyx is a vestigial tail

- As evolution progresses, some structures are not longer of use -- vestigial structures.
- coccyx尾椎: 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.

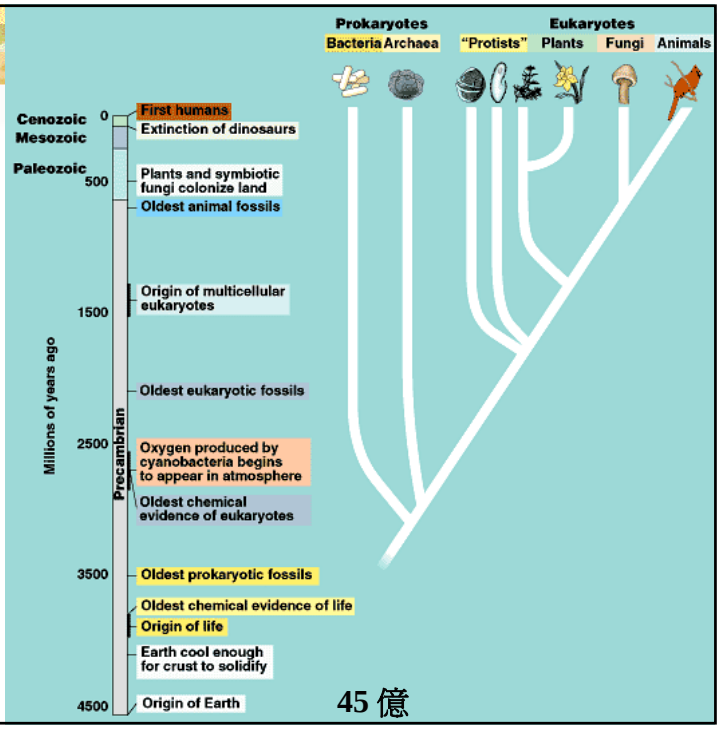
en.wikipedia.org/wiki/Image:Illu_vertebral_column.jpg

Evidence 5: Fossil Record

- from bacteria to more complicated organisms through time.



Some major episodes in the history of life



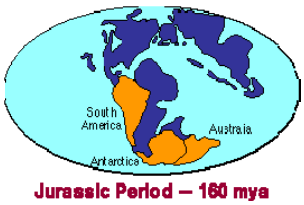
Evidence 6: Transitional fossils

- 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

Archaeopteryx

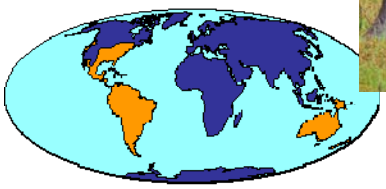
en.wikipedia.org/wiki/Image:Archaeopteryx_lithographica_paris.JPG

Evidence 7: Geography



Jurassic Period – 160 mya

Marsupials



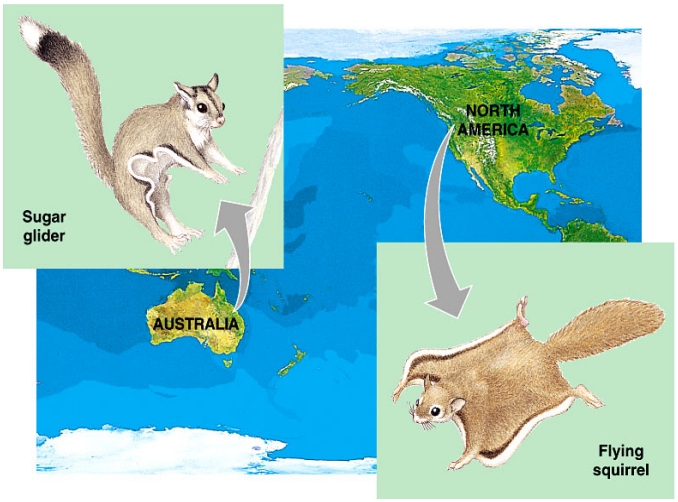
Distribution of marsupials today

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

evolution.berkeley.edu/evosite/lines/IVCexperiments.shtml
en.wikipedia.org/wiki/Image:Kangaroo_and_joey02.jpg

Biogeography: the geographical distribution of species

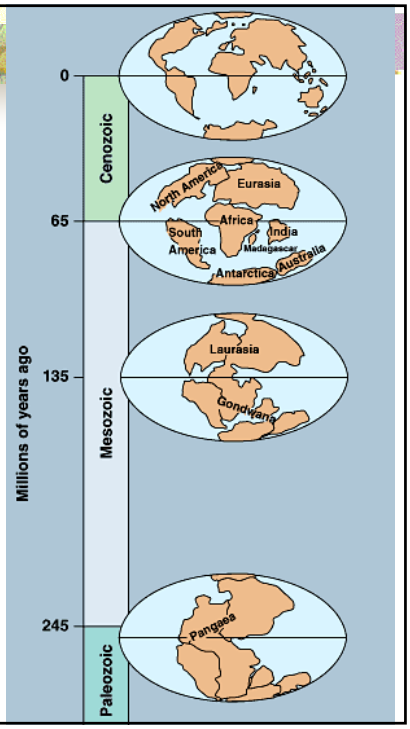
Convergent evolution



生物多樣性與演化

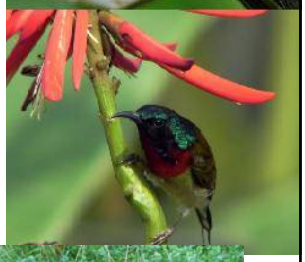
- 趨同演化
- 趨異演化
- 輻射適應
- 共同演化

鴨嘴獸是單孔目產卵哺乳動物



趨同演化

- 新大陸蜂鳥與舊世界太陽鳥
- 袋獾（塔斯馬尼亞惡魔 Tasmanian Devil）與貂熊（狼獾）相似



趨同演化

- 嚙齒目兔豚鼠（南美巴拉圭）
- 紅袋鼠

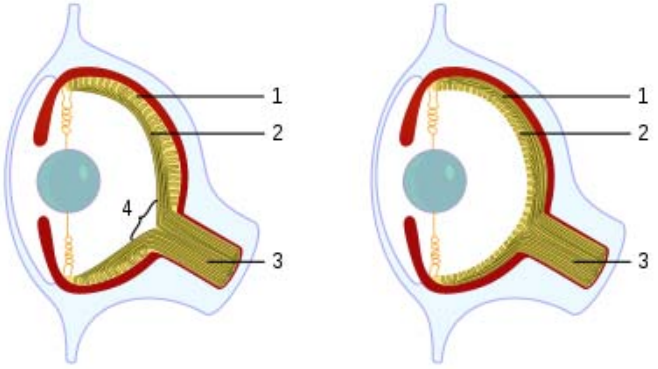
身體上有刺覆蓋

針鼴　刺蝟（趨同演化）

舊世界與新大陸豪豬是齧齒動物
（平行演化 Parallel evolution ）

針鼴是卵生哺乳動物

平行演化 Parallel evolution



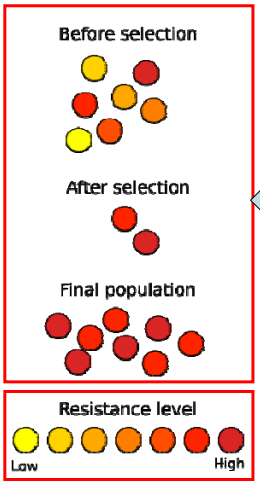
- Vertebrates and octopuses developed the camera eye independently.
- In the vertebrate version the nerve fibers pass in front of the retina, and there is a blind spot where the nerves pass through the retina. In the vertebrate example, 4 represents the blind spot, which is notably absent from the octopus eye. In vertebrates, 1 represents the retina and 2 is the nerve fibers, including the optic nerve (3), whereas in the octopus eye, 1 and 2 represent the nerve fibers and retina respectively.

共同演化（coevolution）

- **共同演化**：二物種之間因互動而有互相適應的構造或行為衍生。
- 根瘤菌與豆科根、花構造與傳粉者的互動演化
- 寄生物與寄主、獵物與獵食者、植食動物與植物防禦的關係。

- 長喙天蛾 *Xanthopan morgani*與大慧星風蘭 *Angraecum sesquipedale* Darwin's orchid之間的共同演化
- In 1867 Alfred Wallace made predictions supporting Darwin's surmise. In 1903, such a moth was discovered in Madagascar.

Evidence 8: Antibiotic resistance

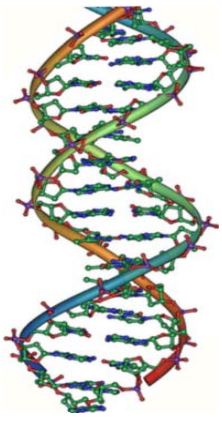


Staphylococcus 葡萄球菌

- certain bacteria can become resistant to antibiotics-- 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_SEM_%2C_ARS%2C_EMU.jpg

Evolution

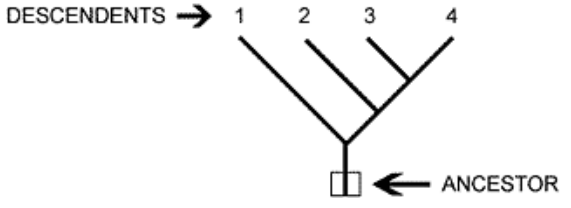


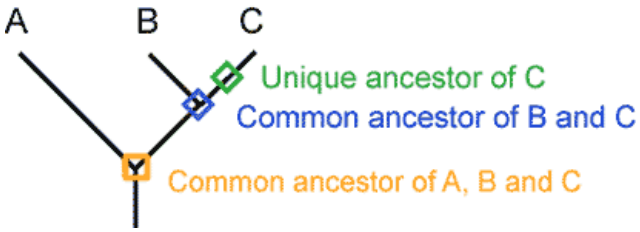
commons.wikimedia.org/wiki/Image:DNA_double_helix_vertikal.PNG

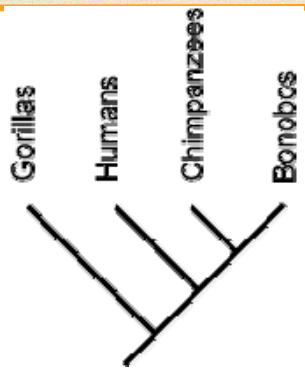
commons.wikimedia.org/wiki/Image:Charles_Darwin_1881.jpg

侏儒黑猩猩

Cladogram 演化分支圖







Did humans evolve from chimps? **NO**

DISTANT COUSINS

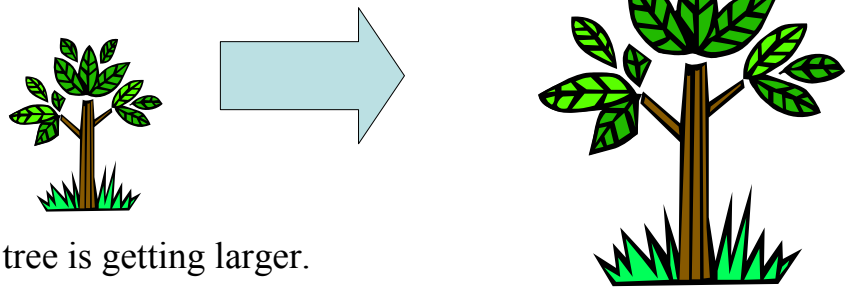
What familial relationship is a good description of the relationship between chimps and humans?

Are humans more highly evolved than chimps?

NO- since the lineage is split, each species has evolved unique traits.

Image courtesy of http://evolution.berkeley.edu/evolibrary/article/0_0_0/evo_01

What is Evolution?



The tree is getting larger.

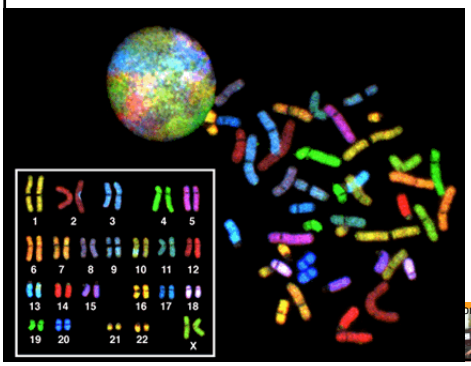
Did the tree evolve?

- Biological evolution is **NOT** just a change over time.
- The definition of evolution is

Descent with Modification

Some sort of change within a lineage.

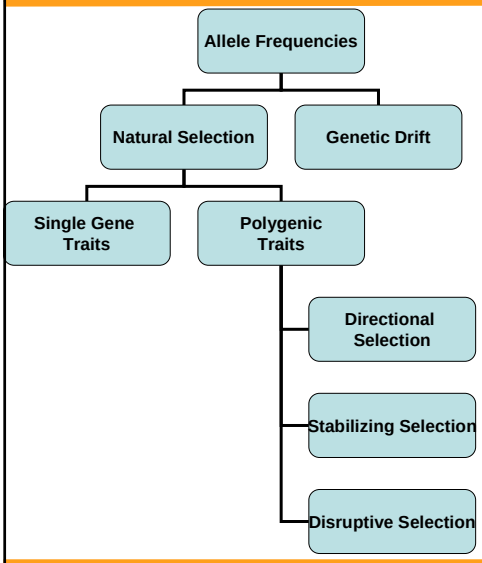
But what is this change?



GENETICS

Change with inheritance over a long period of time.

Evolution



So, we can change our definition of evolution from

DESCENT WITH MODIFICATION

to

DESCENT THROUGH GENETIC INHERITANCE

無 → 有 ???

Image courtesy of http://evolution.berkeley.edu/evolibrary/article/_0_0/evo_26