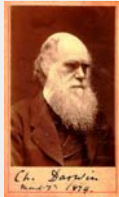


Chapter 3 Charles Darwin (1809- 1882) and Evolution

- 3.1 Charles Darwin: Education and Family
- 3.2 The Voyage on the Beagle
- 3.3 Evolution and Natural Selection
- 3.4 Proofs of Evolution: Homologies, Fossils, Vestigial Structures

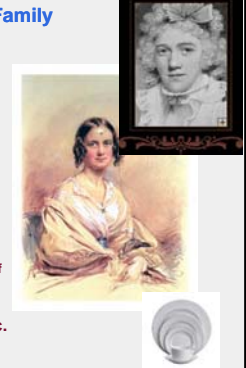


Campbell Biology: p. 495-508



3.1 Charles Darwin: Education and Family

- Born February 12th, 1809
- Father was a doctor.
- Mother was from the Wedgwood family (porcelain).
- Married (1838) to his cousin Emma Wedgwood (1808-1896)
- Had 10 children
- Stops his studies in **medicine** (U. Edinburgh) and takes a more serious interest in religion (CambridgeU).
 - Prerequisite to become a pastor: Bachelor of Arts
- Develops an interest in nature: taxidermy, insect collecting, botany, etc.



3.2 The Voyage on the Beagle

- In 1831, he leaves on the Beagle, a ship commissioned by the British government to do the cartography of the coast of South America.
- Darwin was invited on board as a companion of the captain Fitzroy but quickly became the **naturalist** of the voyage.
- He traveled the world and spends most of his time on land to sample the fauna and flora and to study South-American geology.
- The trip was planned for two years but lasted five years.



3.2 The Voyage on the Beagle

- During the trip, two books had an impact on Darwin
 - William Paley (1743-1805): "Theology, or evidences of the existence and attributes of the deity".
 - Paley is the father of the **Theology of Nature**.
 - Advocates that harmony and design in nature are indicators of the existence and the acts of God (today = **intelligent design**).
 - Charles Lyell : "Principles of Geology".
 - Darwin began his travels thinking like a good protestant: believing in the Great Flood and in Cuvier's catastrophism.
 - When he returned five years later, he was in total agreement with Lyell and Hutton's **principle of uniformity**.



3.2 The Voyage on the Beagle



3.2 The Voyage on the Beagle

- The very distinct fauna of **South America** had a profound effect on Darwin:
 - Why do fauna and flora of Africa, Europe, Australia and South America have relatively few species in common?
 - Why are the animals and plants of the temperate zones of South America resemble the species living in the tropical zones of South America but not the species in temperate Europe?
 - Why are the mammal fossils of South America absent from the current fauna (e.g. Giant Sloth)? Why do these fossils show resemblance with current species found only in South America (e.g. Three-toed Sloth)?



Three-Toed Sloth



Giant Sloth

3.2 The Voyage on the Beagle

- Fauna on the Galápagos Islands surprises Darwin.
 - The fauna on the Islands is unique. Why?
 - Why does it show resemblance with species on the American continent?



Galápagos Marine Iguana (*Amblyrhynchus cristatus*)



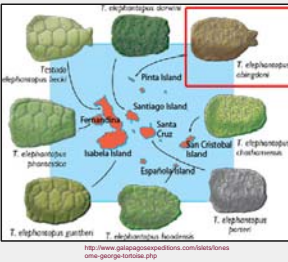
Galápagos Sea lions (closely related to the Californian sea lion)

7


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The Voyage on the Beagle

Why so much shell variability in tortoises in the Galápagos?



http://www.galapagospost.com/last/lonas-one-galago-tortoise.php



Giant Galápagos Tortoise (15 different subspecies on the Islands)

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3.2 The Voyage on the Beagle

Finches of the Galápagos Islands

Why so much morphological variability in one group?

Why does each island, in most cases, have their own species?



(a) Cactus-eater



(b) Insect-eater



(c) Seed-eater




9


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3.3 Evolution and Natural Selection

- In 1837, we find in Darwin's notes the first mention that species show resemblance to each other because they share a common ancestor (not a common environment).
 - Rejects the fixity (no change) of species and accepts the concept of descent with modifications (evolution).
 - Very materialistic view of life in contradiction with the religious dogma of the time.
 - Rejects Lamarck's evolutionary mechanism (environmental determinism)
- Then, he begins the search for an evolutionary mechanism.



Darwin's first phylogenetic tree (1837)



Darwin's tree published in 1859

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3.2 The Voyage on the Beagle

Finches of the Galápagos Islands


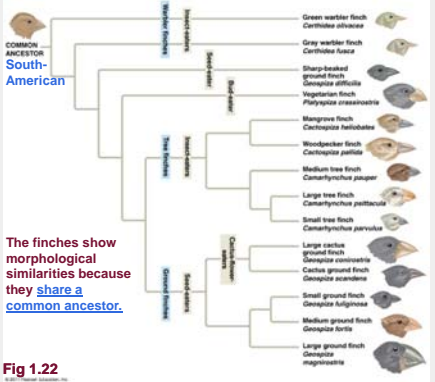


Figure 1.18. Le jeune Charles Darwin.




The finches show morphological similarities because they share a common ancestor.

Fig 1.22


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3.3 Evolution and Natural Selection



Rock hyrax



African elephant



Dugong

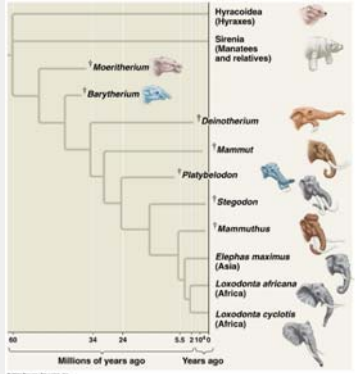
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3.3 Evolution and Natural Selection

•99% of species that have lived on Earth are extinct.

•Most of the evolutionary branches finish in a dead-end (extinction).



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3.3 Evolution and Natural Selection

- In 1838, Darwin read “ An essay on the principle of population” written by the economist Thomas R. Malthus
- This became one of the main sources that inspired him to formulate his famous theory on natural selection.



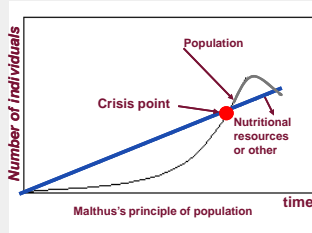
Thomas Malthus
1766-1834

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3.3 Evolution and Natural Selection

- In his book *An essay on the principle of population* (1798), Malthus wrote that:

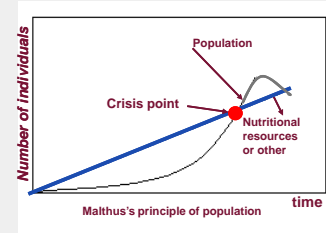
Every human population has a tendency to increase **geometrically**, whereas the available resources to feed these populations increase **arithmetically**.



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3.3 Evolution and Natural Selection

- The human population increases faster than its capacity to feed itself. This leads to **chaos** (famine, sickness, war, etc.) and eventually to a substantial reduction in population size.



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3.3 Evolution and Natural Selection

Darwin's first observation:
All species can produce more offspring than their environment can sustain and many of these **offspring** fail to survive and reproduce

Fig. 22-11



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3.3 Evolution and Natural Selection

- **Darwin's second observation :** Members of a population often vary in their **inherited traits**.



Amphidromus adamsii



Asian ladybird beetles

18

3.3 Evolution and Natural Selection

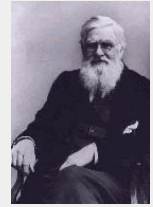


Two inferences:

- Individuals whose **inherited** traits gives them a higher probability of surviving and reproducing in a given environment tend to leave more offspring than other individuals
- From generation to generation, this unequal capacity to survive and to reproduce (**differential reproductive success**) results in an accumulation of favourable traits in a population.
 - This is **natural selection**. It enables the emergence of adaptations.

3.3 Evolution and Natural Selection

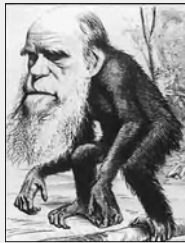
- It is a letter from Alfred Russel Wallace (1823-1913), received in 1853, that forced Darwin to publicly release his ideas.
- Wallace had come to the same conclusions as Darwin concerning the theory of natural selection by observing the fauna of Indonesia.
- Thus, it was **23 years** after his voyage on the Beagle that Darwin publicly released his views on the evolution of species.



Wallace

3.3 Evolution and Natural Selection

- On the same day, in 1858, Darwin and Wallace presented a summary of their ideas on natural selection to the Linnean Society of London.
- In 1859, Darwin publishes the first edition of his book "**On the Origin of Species**". The book became an instant bestseller and created great controversy.
- The 6th and last edition of his book, published in 1872, contains a chapter dedicated to the most important arguments against his theory. Most of these arguments came from his creationist colleagues.



3.3 Evolution and Natural Selection

- Important notions linked with natural selection:
 - Individuals do not evolve, **populations** evolve.
 - Only hereditary traits with variability can evolve.
 - Individuals that have set of traits that leads to greater survivorship and reproductive success are « fitter » compare with other individuals.
 - If a trait is well-adapted to its environment, it confers a higher relative **fitness** (reproductive success) to its bearer.
 - Environmental factors vary in time and space. Thus, selective forces are variable and a trait that increases fitness in a specific environment might loose this fitness in a changed environment.
 - Traits in populations may change and may modify the species.

3.3 Evolution and Natural Selection

- For Darwin this mechanism is valid because:
 - It respects the principle of uniformity of Lyell and Hutton.
 - The results are visible in nature.
 - The mechanism can be verified on current populations (e.g. artificial selection).
 - It is a materialistic concept (no need for divine intervention):
 - The mechanism is **not random**. Natural selection enables individuals that are better adapted to their environment to become more abundant than those who are not (differential reproductive success).
 - Not a quest for **perfection** (evolution is not a directed process). It does not lead to the appearance of "perfect" traits. Organisms only adapt to their environment.



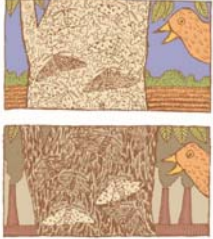
3.3 Evolution and Natural Selection



Fig.22-9

Artificial selection is finalized because the goal, fixed well in advance, precedes the causes. The end result can be obtained in a few generations.
Natural selection is not finalized. It can take a long time for changes to occur (geological time scale).





3.3 Evolution and Natural Selection

Peppered moth (*Biston betularia*)

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3.3 Evolution and Natural Selection: Climate and the Medium Ground Finch

Medium ground finch (*Geospiza fortis*)

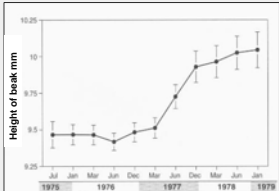
Height of the beak

- Drought in 1977 (also in 1980, 1982)
- Population 1200 adults to 80.
- Selection favouring individuals that have bigger and stronger beaks to break available seeds during the drought.

Daphne Major (Galápagos)

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3.3 Evolution and Natural Selection: Climate and the Medium Ground Finch



Changes in the height of the Medium groundfinch's beak (*Geospiza fortis*) on Daphne Major Island during the 1977 drought.

Graphics adapted from Grant and Grant 2006. How and why species multiply: the radiation of Darwin's finches. Princeton Univ. Press.

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3.3 Evolution and Natural Selection: Humans and Altitude

Mountain life: Adaptation to altitude



Kongmaru Pass (Himalaya – India; 5150m)

François Chapeau: Comes from a population that has always lived under 500m above sea level.




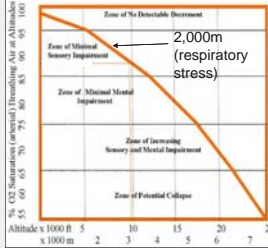
Guide from Ladakh was born on the Qinghai–Tibet Plateau in the Himalayas and comes from a population which lives over 3500m above sea level for at least 3000 years.

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3.3 Evolution and Natural Selection: Humans and Altitude

- Over 2 000m, the partial pressure of O₂ is insufficient for normal saturation of hemoglobin for a traveller in high altitudes.
 - Shortness of breath, altitude sickness

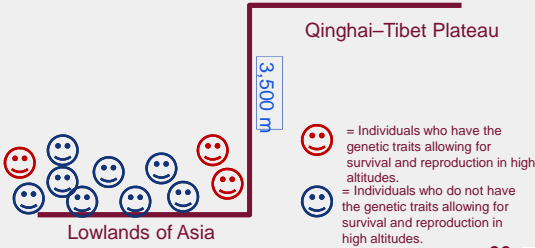
Physiological response (acclimatization): After a few days at high altitude, the body compensates the low partial pressure of O₂ by increasing the concentration of red blood cells in our blood. Serious health risks: thrombosis, pulmonary edema, etc.).

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3.3 Evolution and Natural Selection: Humans and Altitude

Generation 0
More than 3,000 years ago



Qinghai–Tibet Plateau

3,500 m

Lowlands of Asia

- ☺ = Individuals who have the genetic traits allowing for survival and reproduction in high altitudes.
- ☹ = Individuals who do not have the genetic traits allowing for survival and reproduction in high altitudes.

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3.3 Evolution and Natural Selection: Humans and Altitude

Generation 0

Human dispersion

Qinghai-Tibet Plateau

3,500 m

Lowlands of Asia

= Individuals who have the genetic traits allowing for survival and reproduction in high altitudes.

= Individuals who do not have the genetic traits allowing for survival and reproduction in high altitudes.

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3.3 Evolution and Natural Selection: Humans and Altitude

Generation 50

Qinghai-Tibet Plateau

3,500 m

Lowlands of Asia

= Individuals who have the genetic traits allowing for survival and reproduction in high altitudes.

= Individuals who do not have the genetic traits allowing for survival and reproduction in high altitudes.

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3.3 Evolution and Natural Selection: Humans and Altitude

Generation 100

Qinghai-Tibet Plateau

3,500 m

Lowlands of Asia

= Individuals who have the genetic traits allowing for survival and reproduction in high altitudes.

= Individuals who do not have the genetic traits allowing for survival and reproduction in high altitudes.

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3.3 Evolution and Natural Selection: Humans and Altitude

Generation 150 (now)

Qinghai-Tibet Plateau

3,500 m

Lowlands of Asia

= Individuals who have the genetic traits allowing for survival and reproduction in high altitudes.

= Individuals who do not have the genetic traits allowing for survival and reproduction in high altitudes.

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3.3 Evolution and Natural Selection: Humans and Altitude

Many regions in high altitude were independently colonized by humans.

On the Qinghai-Tibet Plateau, human **adaptation** to high altitude differs from the Andes.

Andes (11,000 Years) 550 generations

Qinghai-Tibet Plateau 3,000 years ; 150 generations

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3.3 Evolution and Natural Selection: Humans and Altitude

- ▣ Adaptations
 - ▣ Andes
 - ▣ Higher alveolar surface in lungs, same hemoglobin concentration in blood but each molecule has a higher oxygen capacity;
 - ▣ Qinghai -Tibet Plateau
 - ▣ Deeper breath, faster breathing cycle; larger pulmonary capacity and increased **blood flow**; lower hemoglobin concentration.
 - ▣ Origin of adaptation : **Denisovan gene EPAS1**

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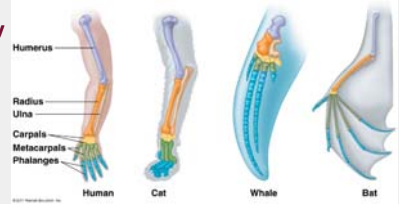
3.3 Evolution and Natural Selection (modified slide)

- In the three cases (moths, finches and humans), the **hereditary traits** that give a **reproductive advantage** (i.e. adaptation) to individuals in a population will be favoured. Thus, from generation to generation, there will be a higher percentage of individuals carrying the adaptation. This is **natural selection**. It's Darwin's descent with modification.
- These adaptations can sometimes redefine a species and, in certain circumstances, define a new species.

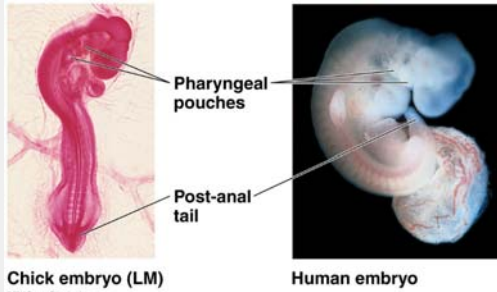
Another example in the book : fig. 22.13

3.4 Proof of Evolution: Homology

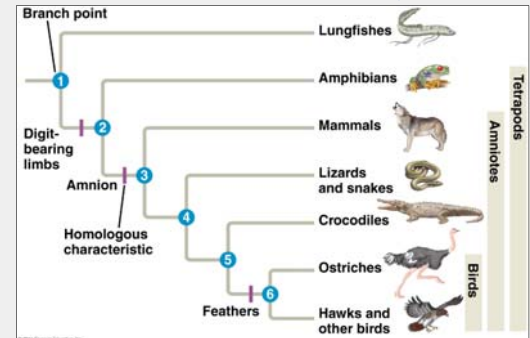
Descent with modification theory (theory of evolution) explains the resemblance between certain traits even if the functions are different.
(Homologous structures)



3.4 Proof of Evolution: Homology



3.4 Proof of Evolution: Homology

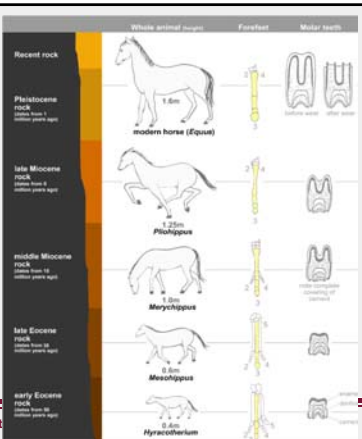


3.4 Proof of Evolution: Fossils

- Evolution of the horse:**



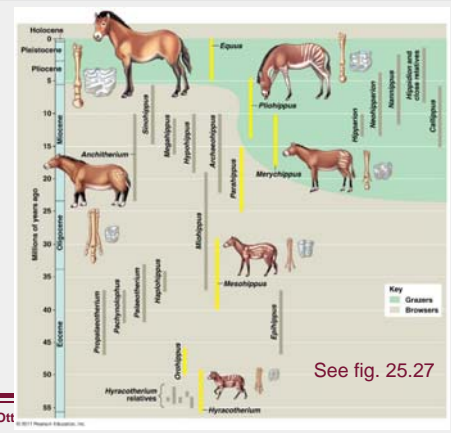
Classic Interpretation (linear evolution)



3.4 Proof of Evolution: Fossils

Evolution of the horse:

More realistic interpretation (phylogenetic tree)

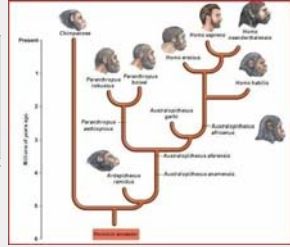


See fig. 25.27

3.4 Proof of Evolution: Fossils



Poster human evolution - © Liboral Stock Science Photo Library - Image No. 649727



3.4 Proof of Evolution: Fossils

Fig. 22.19 (Astragalus)

Most mammals: (a) Canis (dog), (b) Pakicetus, (c) Sus (pig), (d) Odocolleus (deer)

Fig. 22.20

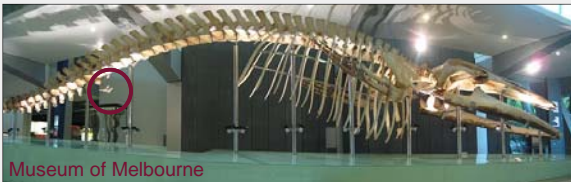
Other even-toed ungulates: Hippopotamuses, †Pakicetus, †Rodhocetus, †Dorudon, Living cetaceans

Common ancestor of cetaceans

Key: Pelvis (purple), Tibia (yellow), Femur (green), Foot (blue)

Unive: 70 60 50 40 30 20 10 0 Millions of years ago

3.4 Proof of Evolution: Vestigial Structures



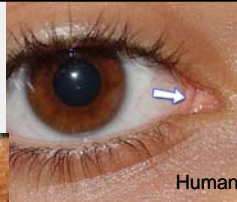
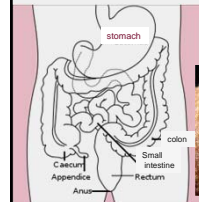
Museum of Melbourne

Skeleton of a dwarf subspecies of a blue whale (*Balaenoptera musculus*) (max length: 24 m).

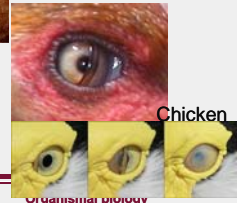
Take note of the reduced vestigial posterior limb, the pelvis reduced to a floating pelvic bone under the spine.

Vestigial structure: anatomic structure that has lost almost all of its initial function.

3.4 Proof of Evolution: Vestigial Structures



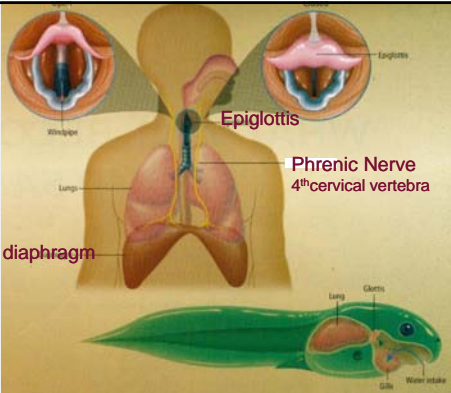
Human



Chicken

- Nictitating membrane or third eyelid.
- Appendix
- Goose bumps and hair

3.4 Proof of Evolution: Vestigial Structures



The hiccups: A heritage from fishes and amphibians

3.4 Proof of Evolution

Discovery of a fossil in the wrong place in the geological archives would be sufficient to refute our concept of evolution

