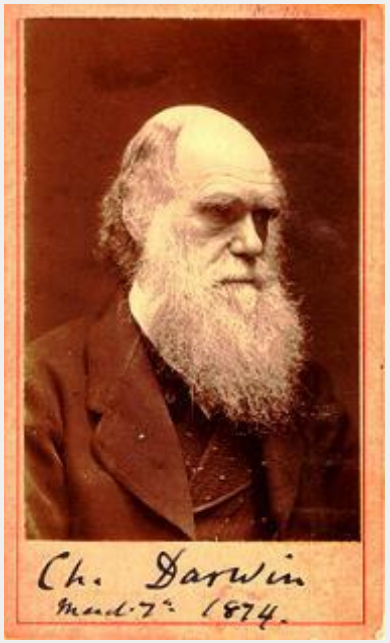
Chapter 3
Charles Darwin (1809- 1882) and Evolution



3.1 Charles Darwin: Education and Family

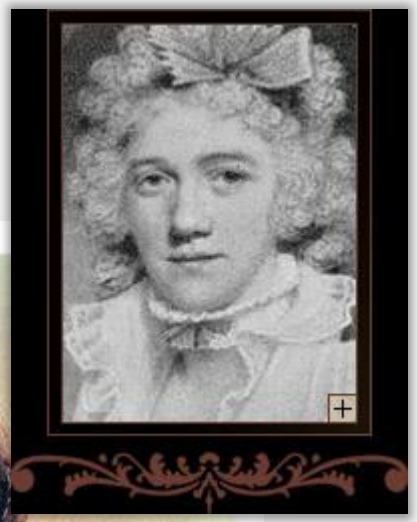
3.2 The Voyage on the Beagle

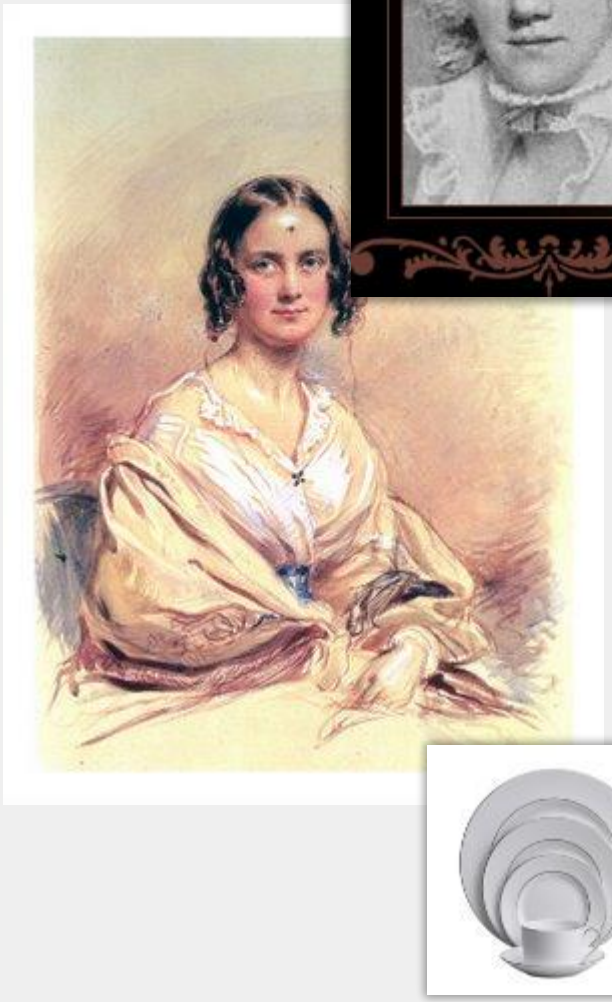
3.3 Evolution and Natural Selection

3.4 Proofs of Evolution: Homologies, Fossils, Vestigial Structures

Campbell Biology: p. 495-508

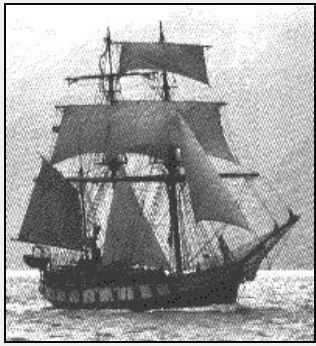
3.1 Charles Darwin: Education and Family



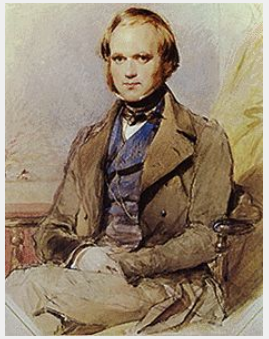


- Born February 12th, 1809
- Father was a doctor.
- Mother was from the Wedgwood family (porcelain).
- Married (1838) to his cousin Emma Wedgwood (1808-1896)
- Had 10 children
- Stops his studies in _medicine_ and takes a more serious interest in religion (CambridgeU).
  - Prerequisite to become a pastor: Bachelor of Arts
- Developed 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 travels the world and spends most of his time on land to sample the fauna and flora and to study South-American geology.
- The trip is planned for two years, lasted five years.



3.2 The Voyage on the Beagle

- During the voyage, 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. This theology advocated 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 expedition 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

Fig. 22.5 The voyage of the HMS Beagle (December 1831- October 1836)

3.2 The Voyage on the Beagle

Three-Toed Sloth

Giant Sloth

- **The very distinct fauna of South America had a profound effect on Darwin:**
  - **Why do the 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)?**

3.2 The Voyage on the Beagle

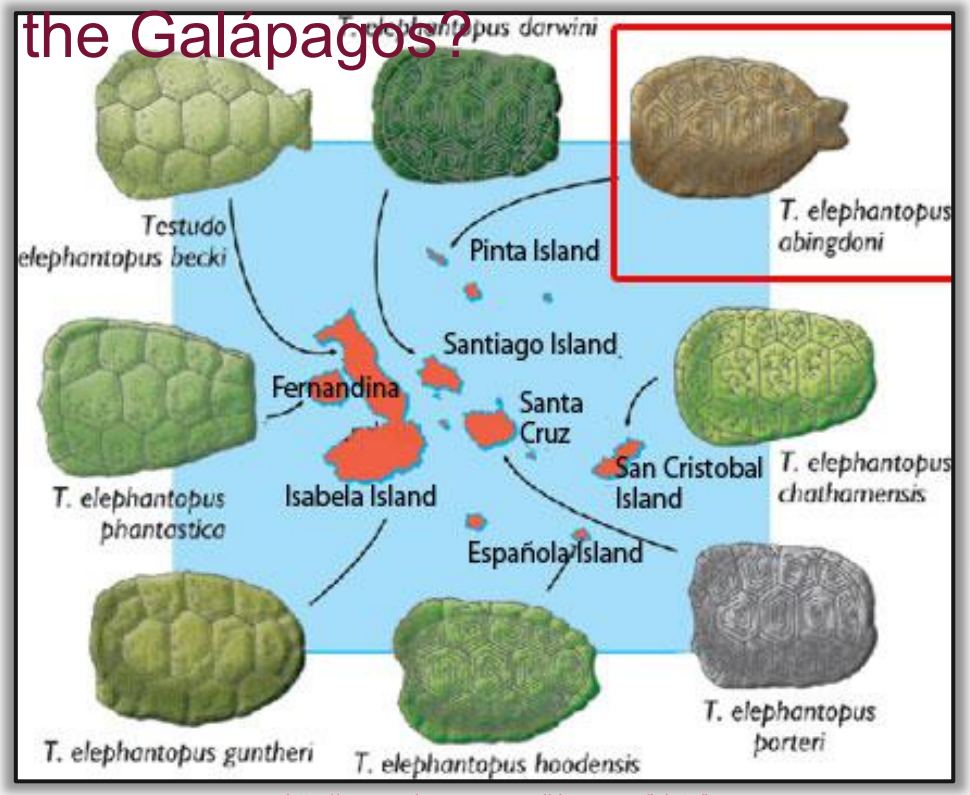
- **Fauna on the Galápagos Islands surprises Darwin.**
  - **The fauna on the Islands is unique. Why?**
  - **Why does it show resemblance with species on the American continent?**

Galápagos marine iguana(*Amblyrhynchus cristatus*) (only iguanas to live in a marine environment; unique to the Islands).

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

The Voyage on the Beagle

Why so much shell variability in Tortoises in the Galápagos?



http://www.galapagosexpeditions.com/islets/lonesome-george-tortoise.php

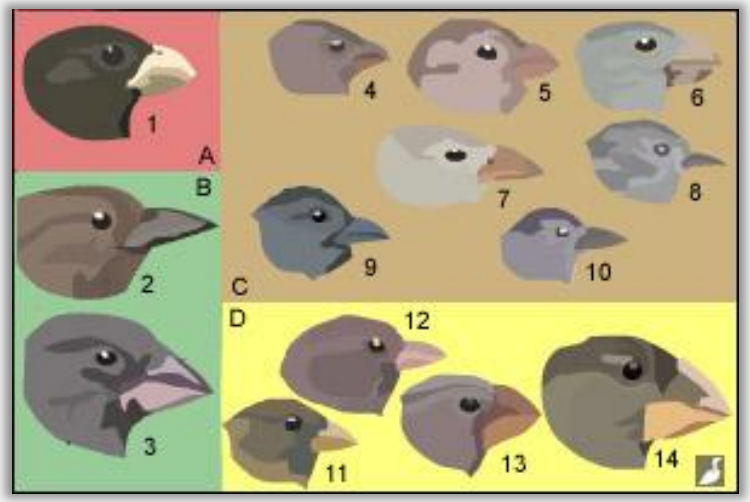
GalápagosTortoise

Giant Galápagos Tortoise (15 different subspecies on the Islands)

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

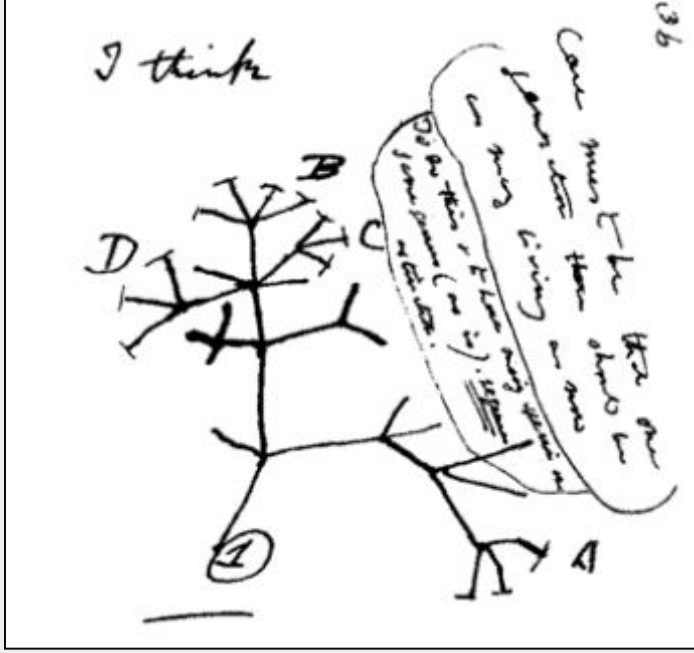
(c) Seed-eater

3.3 Evolution and Natural Selection

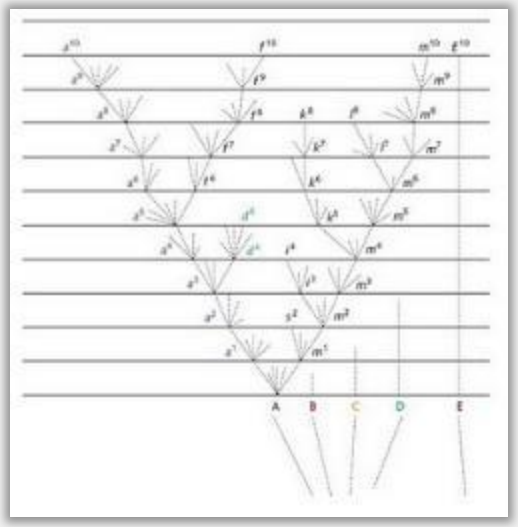
In 1837, we find in Darwin's notes the first mention that species show resemblance to each other because they share a common ancestor (not a common environment).

- Rejects the fixity (no change) of species and accepts the concept of descent with modifications (evolution).
- Very materialistic view of life that is in contradiction to the religious dogma of the time.
- Rejects Lamarck's evolutionary mechanism (environmental determinism)

Then, he begins the search for an evolutionary mechanism.



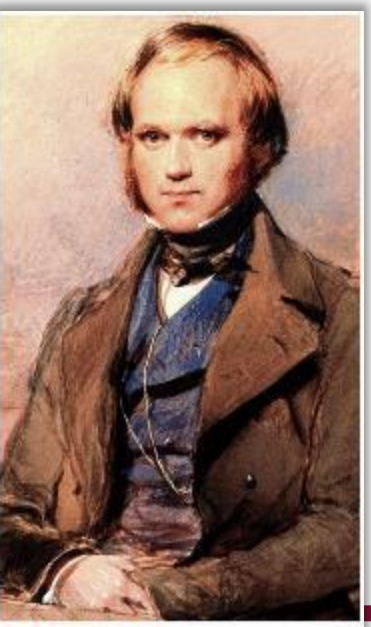
Darwin's first phylogenetic tree (1837)



Darwin's tree published in 1859

3.2 The Voyage on the Beagle

Finches of the Galápagos Islands



▲ Figure 1.18 Le jeune Charles Darwin.

COMMON ANCESTOR

South-American

Warbler finches
Insect-eaters
Green warbler finch *Certhidea olivacea*
Gray warbler finch *Certhidea fusca*
Seed-eater
Sharp-beaked ground finch *Geospiza difficilis*
Bud-eater
Vegetarian finch *Platyspiza crassirostris*
Tree finches
Insect-eaters
Mangrove finch *Cactospiza heliobates*
Woodpecker finch *Cactospiza pallida*
Medium tree finch *Camarhynchus pauper*
Large tree finch *Camarhynchus psittacula*
Small tree finch *Camarhynchus parvulus*
Ground finches
Cactus-flower-eaters
Large cactus ground finch *Geospiza conirostris*
Cactus ground finch *Geospiza scandens*
Seed-eaters
Small ground finch *Geospiza fuliginosa*
Medium ground finch *Geospiza fortis*
Large ground finch *Geospiza magnirostris*

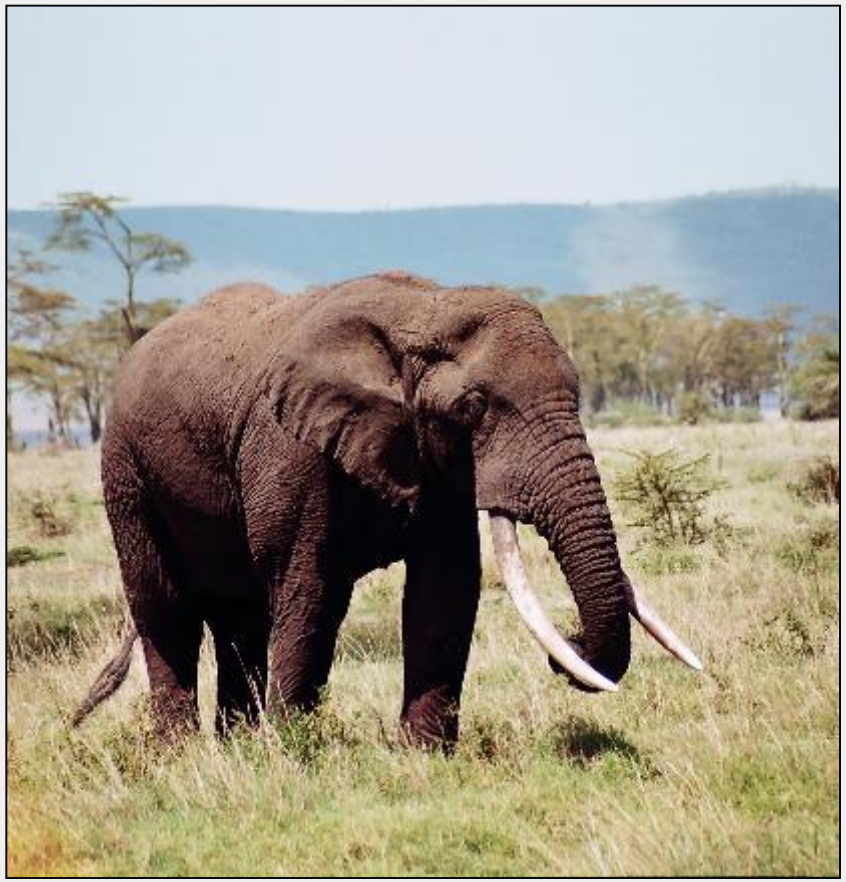
The Finches show morphological similarities because they _share a common ancestor.

Fig 1.22

3.3 Evolution and Natural Selection

Rock hyrax

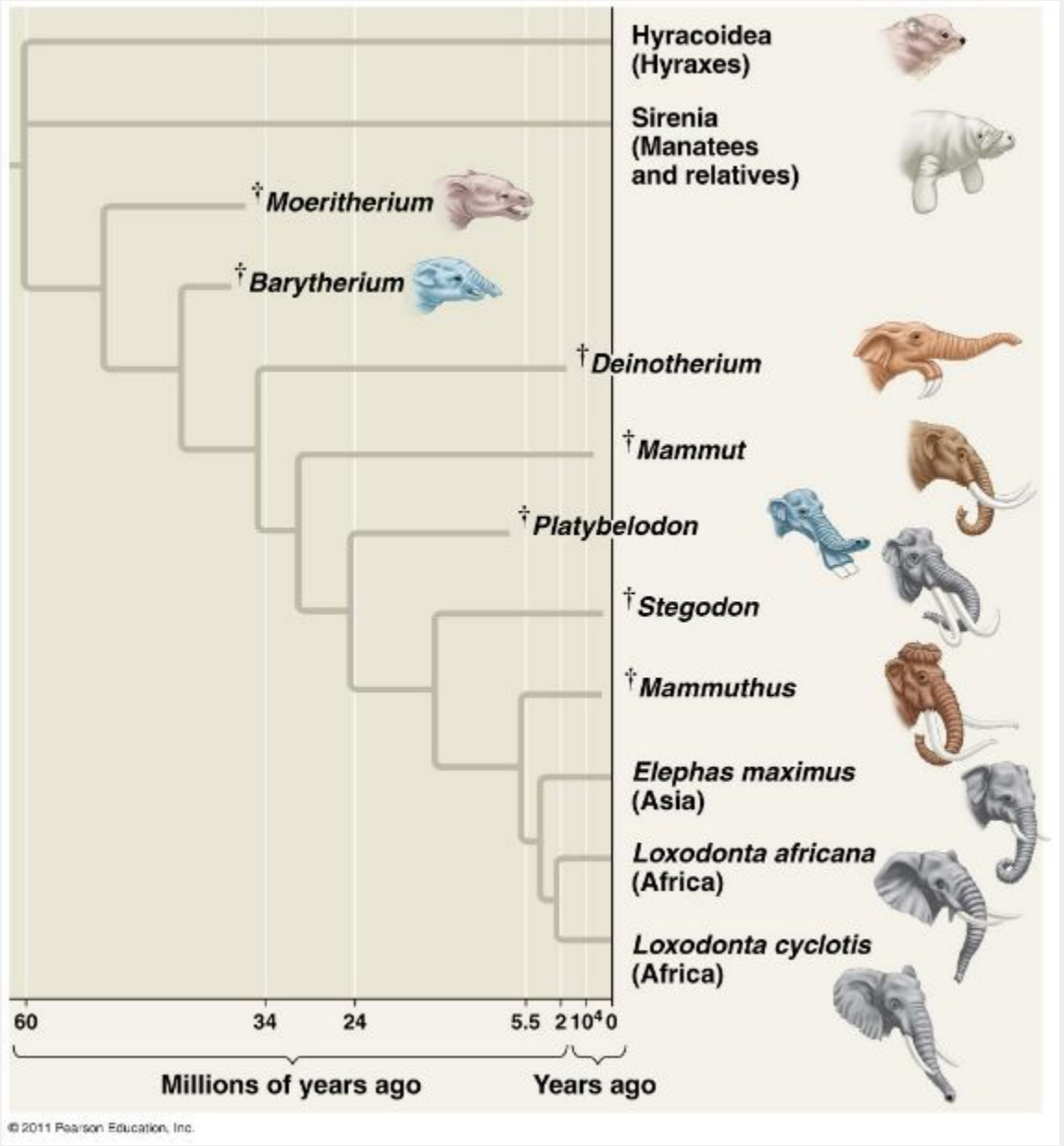
Dugong



African elephant

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).



3.3 Evolution and Natural Selection

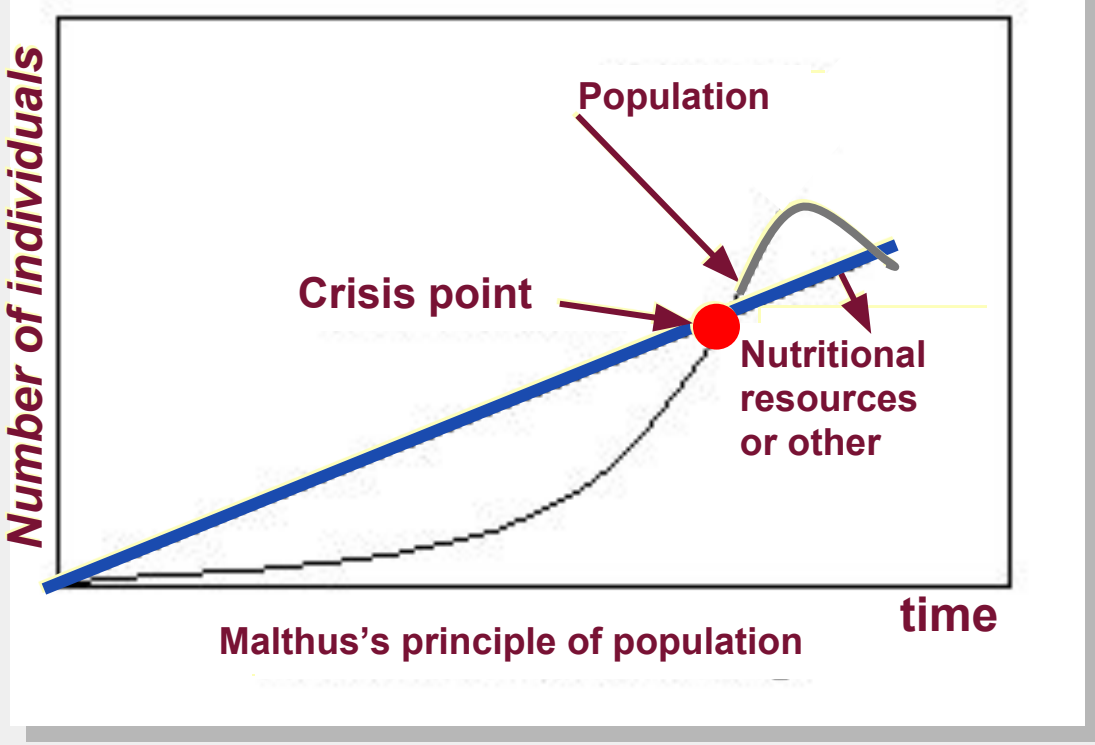
- In 1838, Darwin read “ An essay on the principle of population” written by the economist Thomas R. Malthus
- This reading became one of the main sources that inspired him to formulate his famous theory on natural selection.

Thomas Malthus
1766-1834

3.3 Evolution and Natural Selection

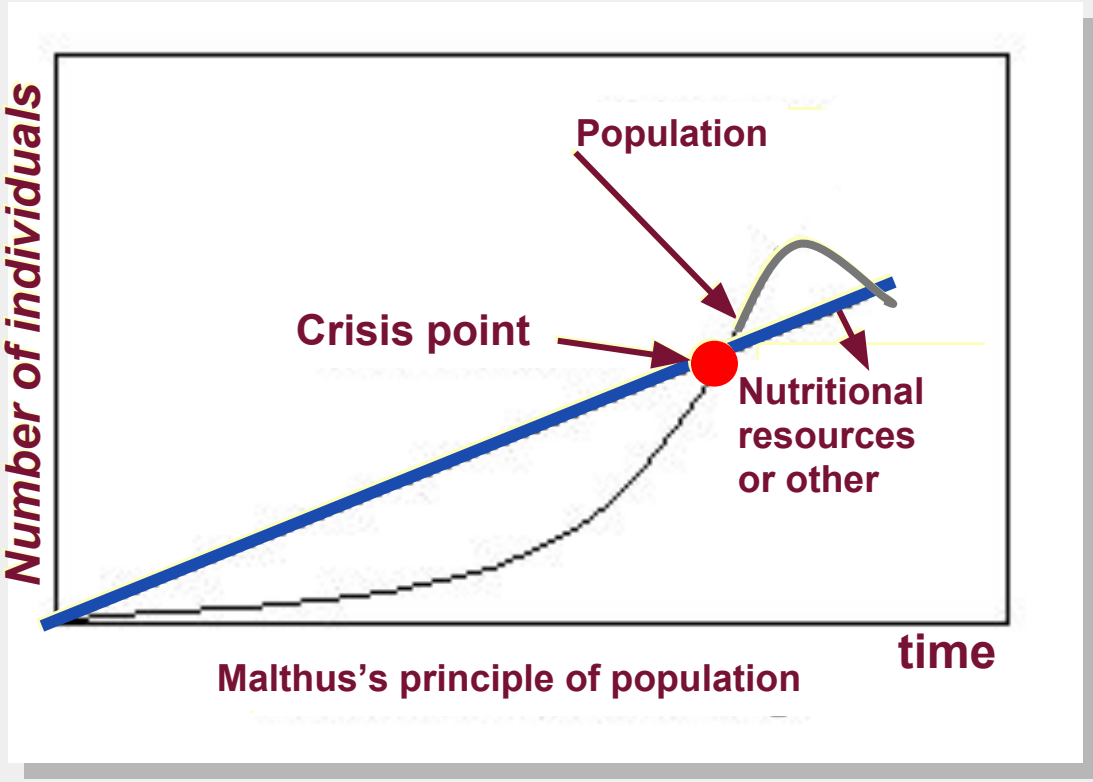
- In his book *An essay on the principle of population (1798),* Malthus wrote that:

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



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.**



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

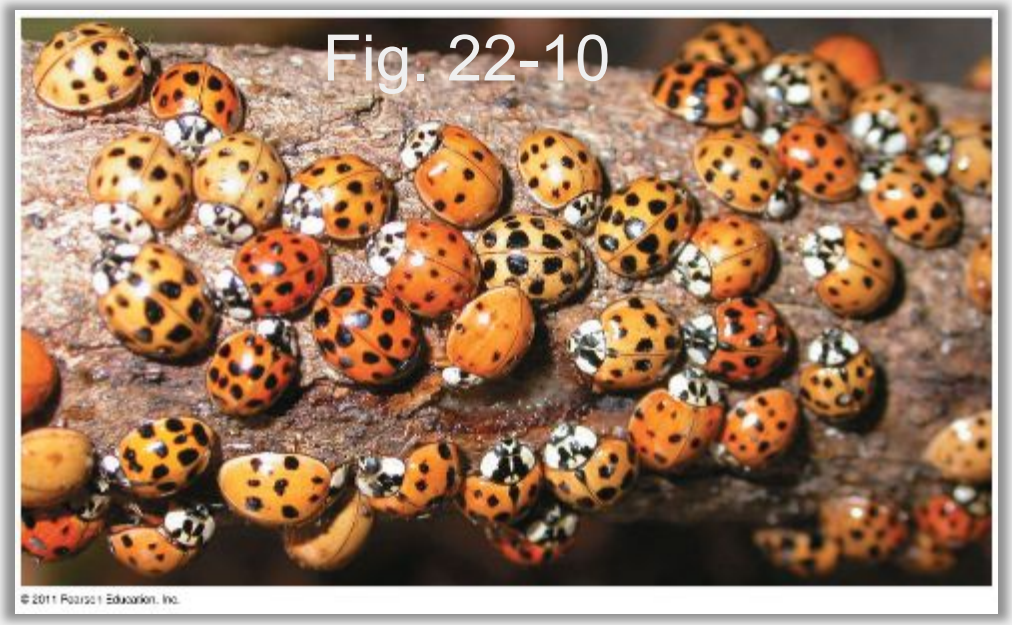
Maple tree and its samaras

Mola mola (Ocean sunfish)

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

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 of survive and reproduce (differential reproductive success) results in an accumulation of favourable traits in a population.
    - **This is natural selection. It enables the emergence of adaptations.**

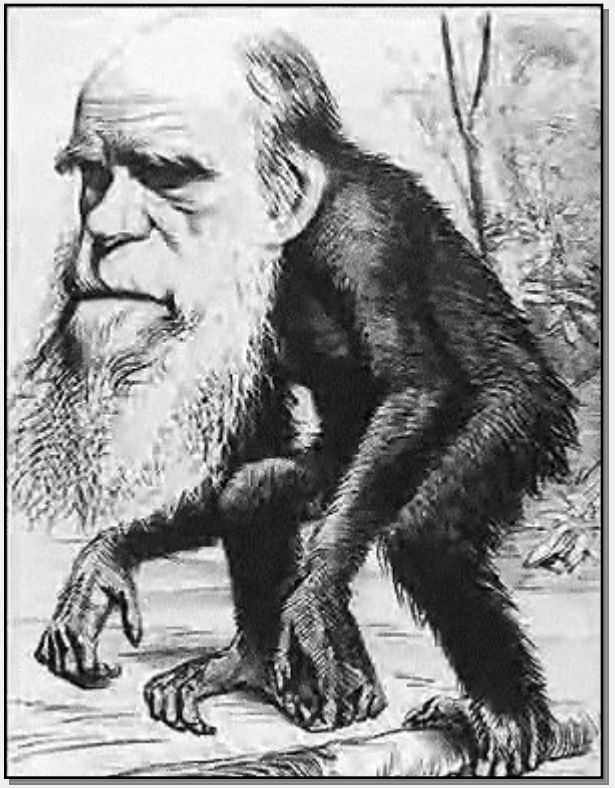
3.3 Evolution and Natural Selection

- 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 resume of their ideas on natural selection to the Linnean Society of London.
- In 1859, Darwin published 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 are subject to natural selection.**
  - **For evolution to occur, we need genetic variability.**
  - **Natural selection corresponds to differential reproductive success within a population from generation to generation.**
  - **With time, natural selection enables individuals to become better _adapted_ to their environment.**
  - **Environmental factors vary in time and space. Thus, the selective forces are variable.**
  - **Traits in populations will change and can modify the species.**

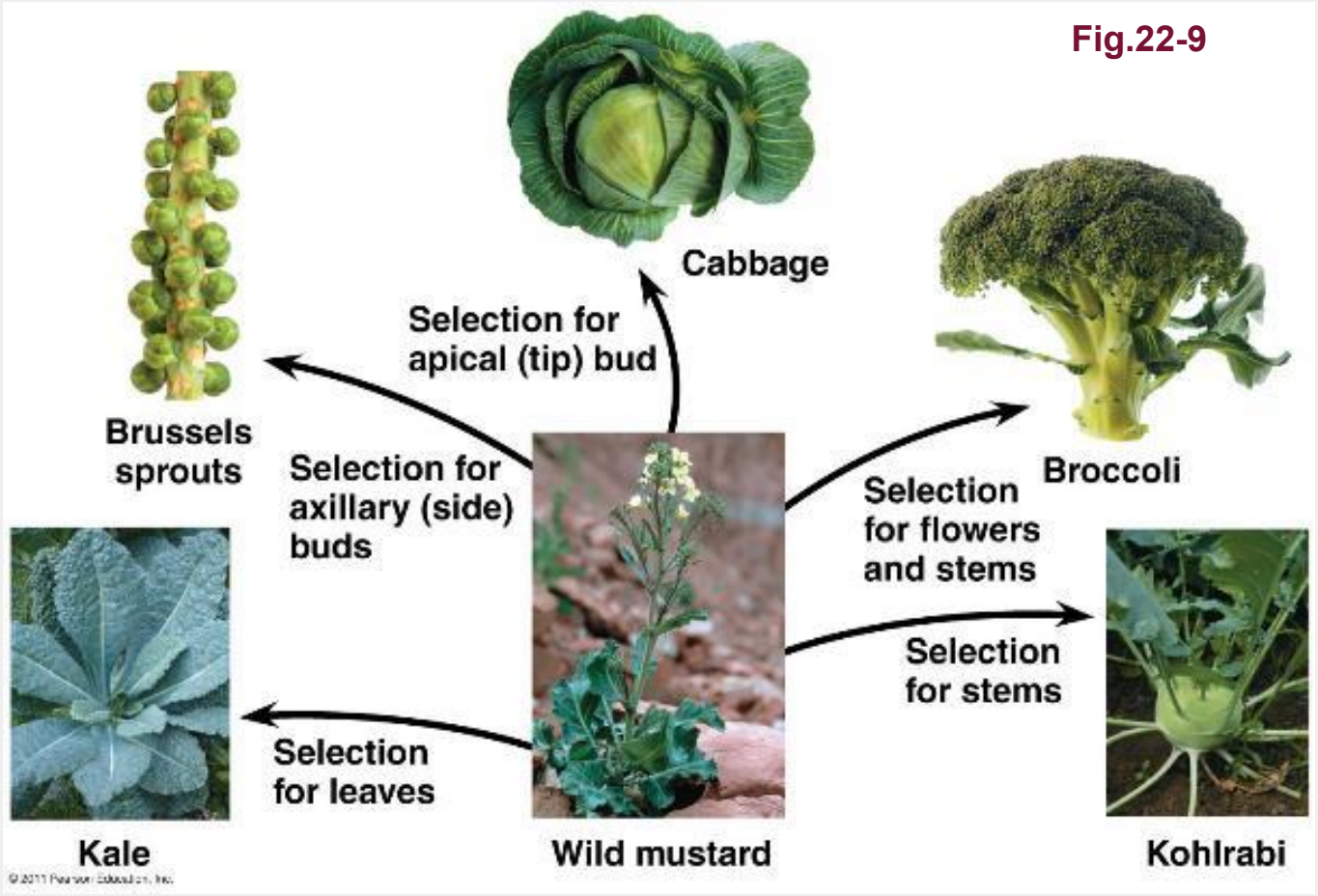
3.3 Evolution and Natural Selection

For Darwin this mechanism is valid because:

- It respects the principle of uniformity of Lyell and Hutton.
- The results of natural selection 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.

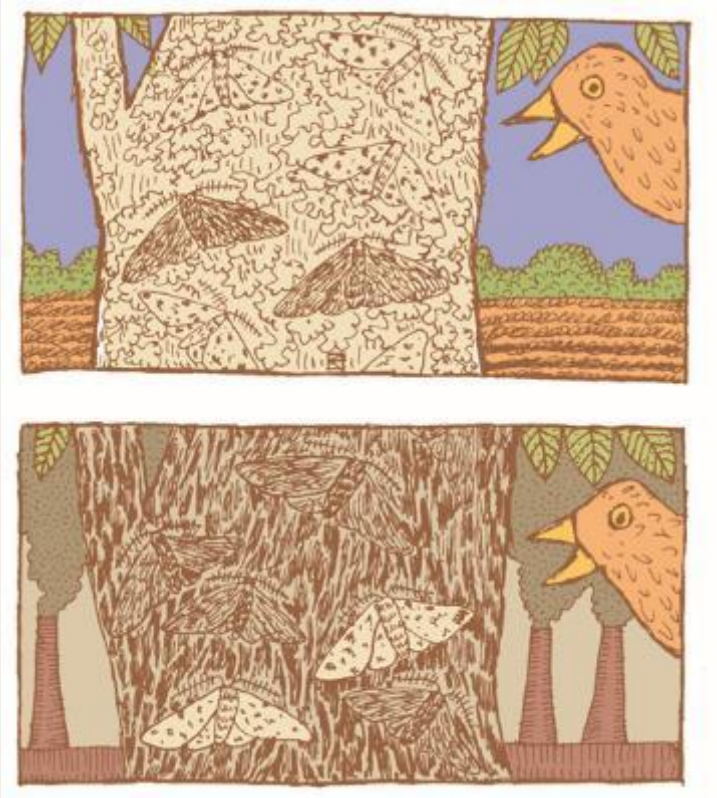
3.3 Evolution and Natural Selection

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).

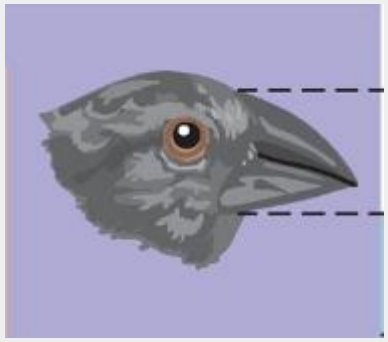
3.3 Evolution and Natural Selection



Peppered moth
(*Biston betularia*)

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

Medium ground finch
(*Geospiza fortis*)

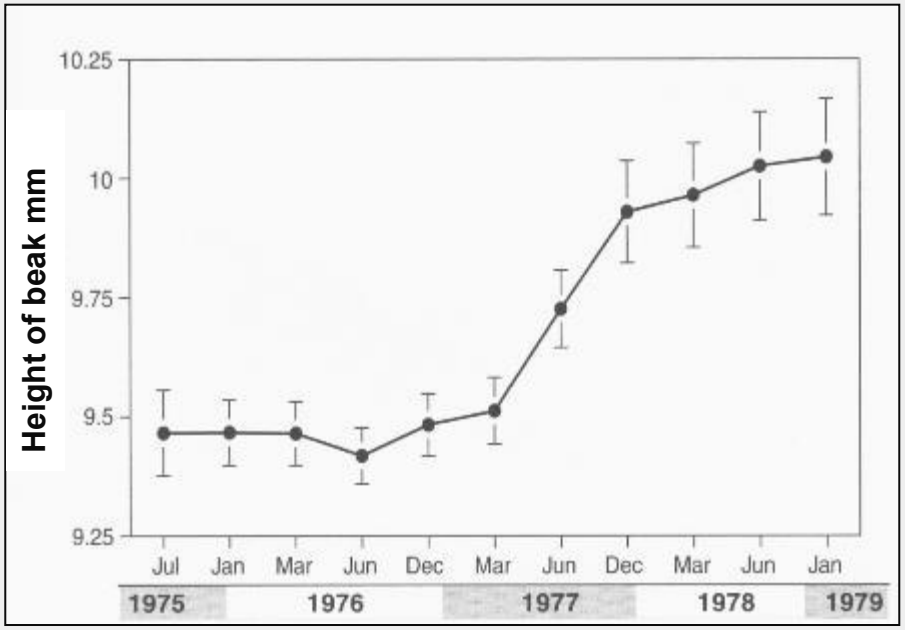


Height of the beak

Daphne Major
(Galápagos)

- 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.

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



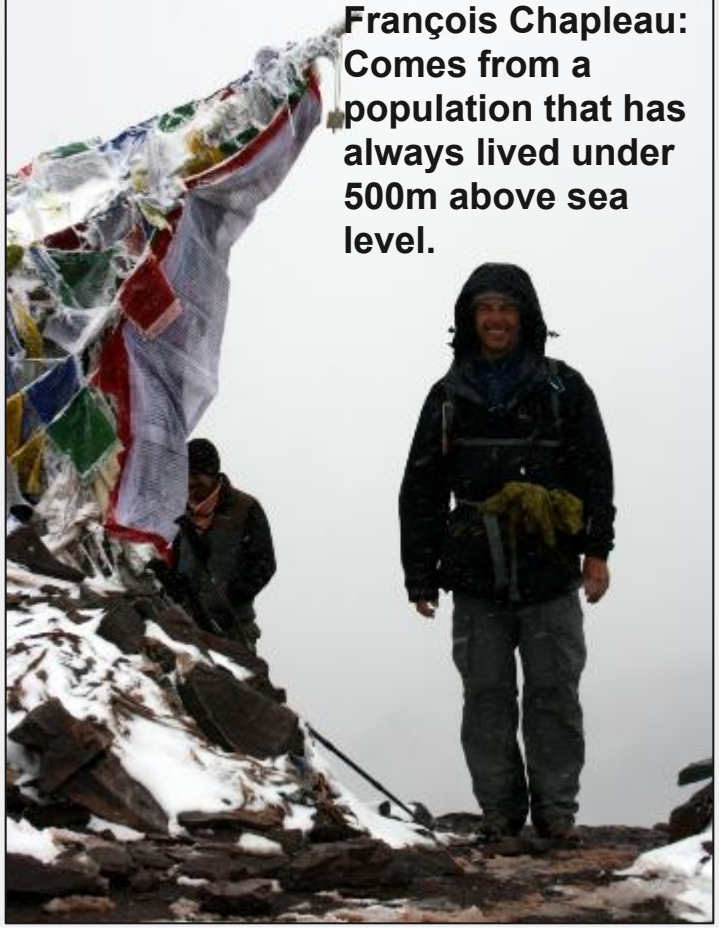
Changes in the height of the Medium groundfinch's beak (*Geospiza fortis*) on Daphne Major Island during the 1977 drought.

Graphics adapted from Grant and Grant.2008. **How and why species multiply; the radiation of Darwin's finches. Princeton Univ. Press.**

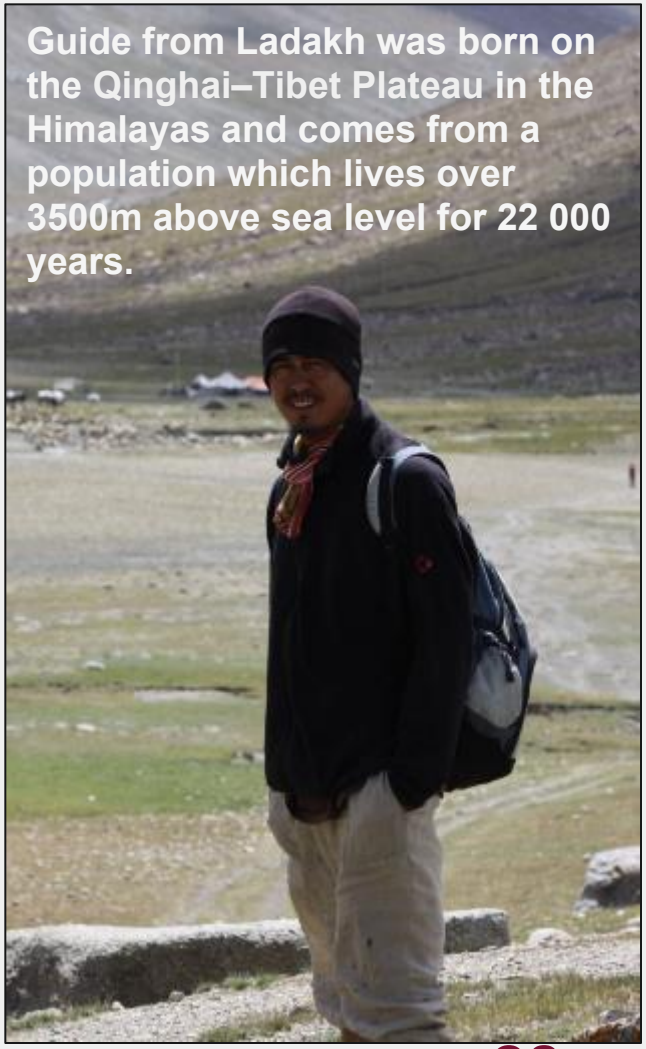
3.3 Evolution and Natural Selection: Humans and Altitude

Mountain life:
Adaptation to altitude

Kongmaru Pass (Himalaya – India; 5150m)



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

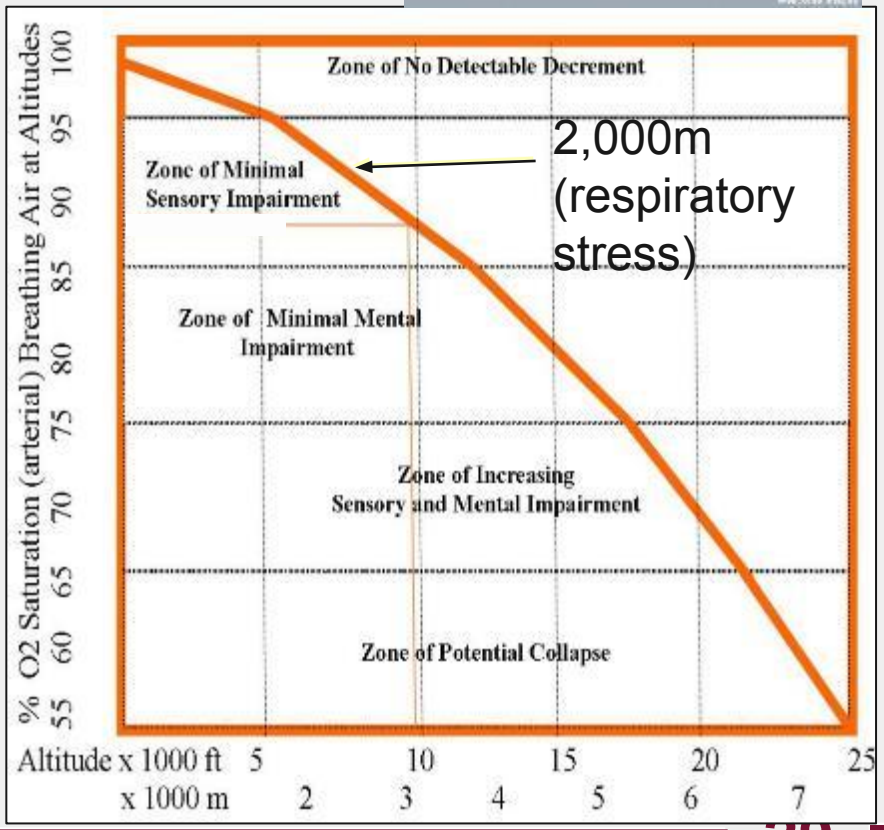


Guide from Ladakh was born on the Qinghai–Tibet Plateau in the Himalayas and comes from a population which lives over 3500m above sea level for 22 000 years.

3.3 Evolution and Natural Selection: Humans and Altitude

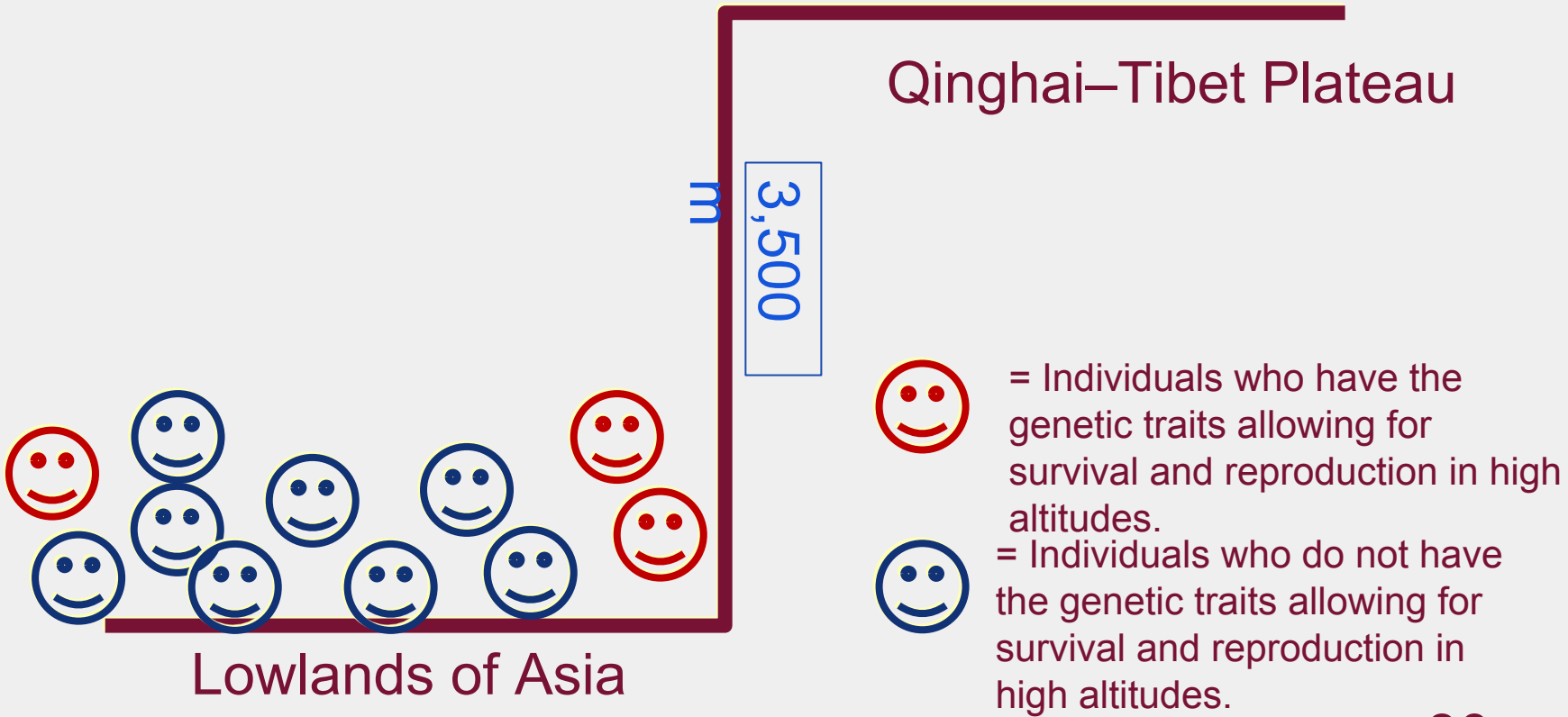
- Over 2 000m, the partial pressure of O_2 is insufficient for normal saturation of hemoglobin for a traveller in high altitudes.
  - Shortness of breath, altitude sickness

Physiological response (acclimatization): After a few days at high altitude, the body compensates the low partial pressure of O_2 by increasing the concentration of red blood cells in our blood. Serious health risks: thrombosis, pulmonary edema, etc.).

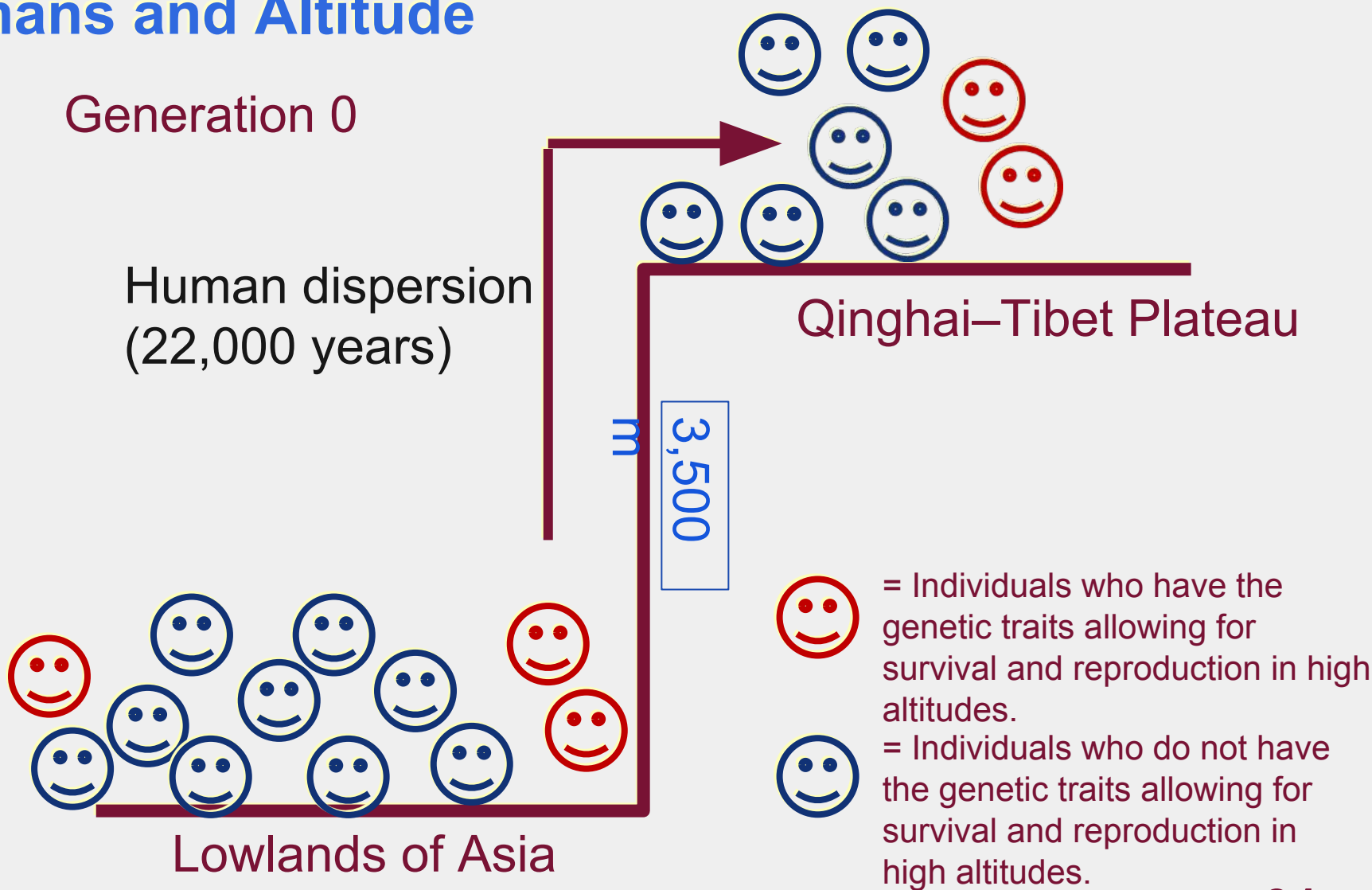


3.3 Evolution and Natural Selection: Humans and Altitude

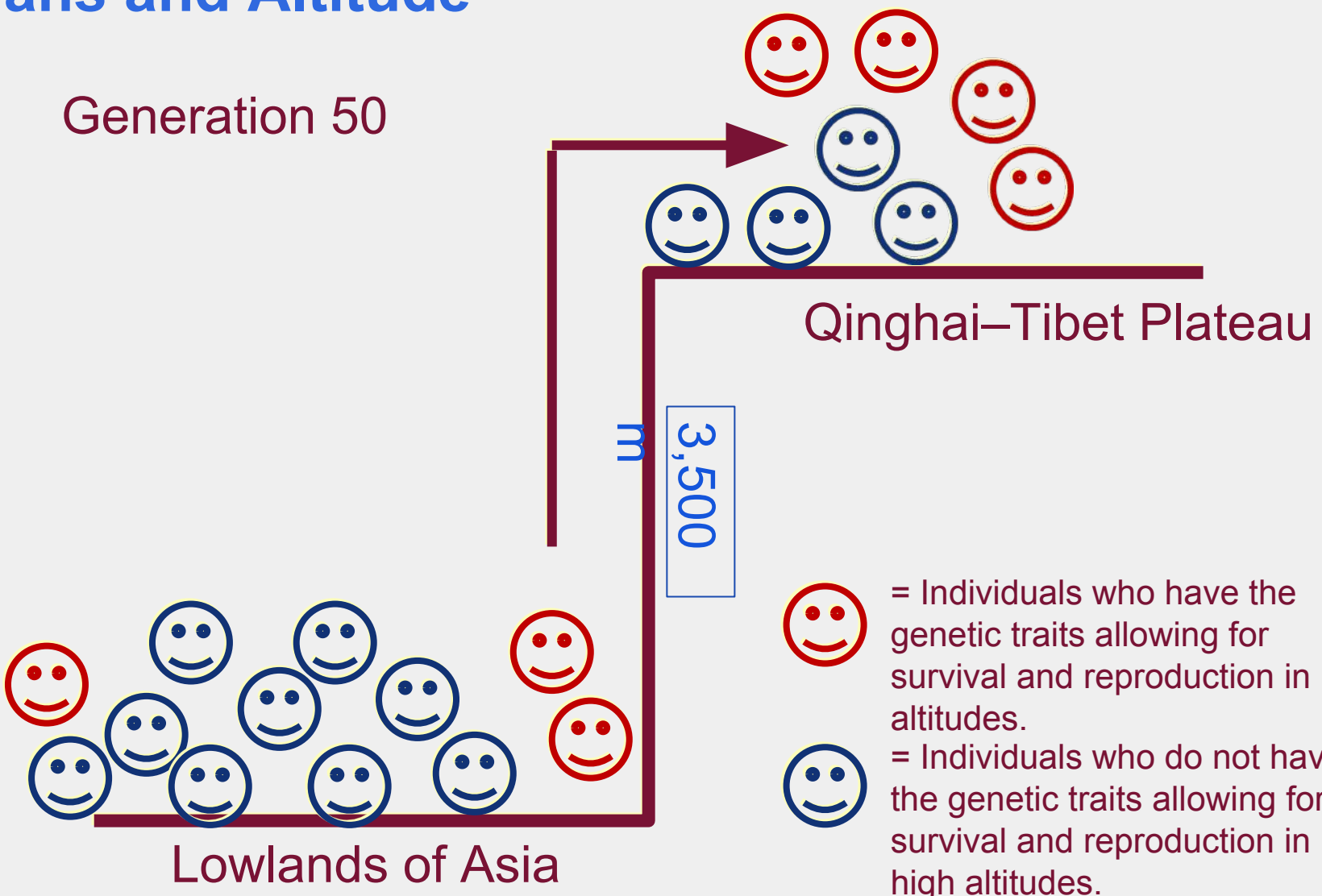
Generation 0
More than 22,000 years ago



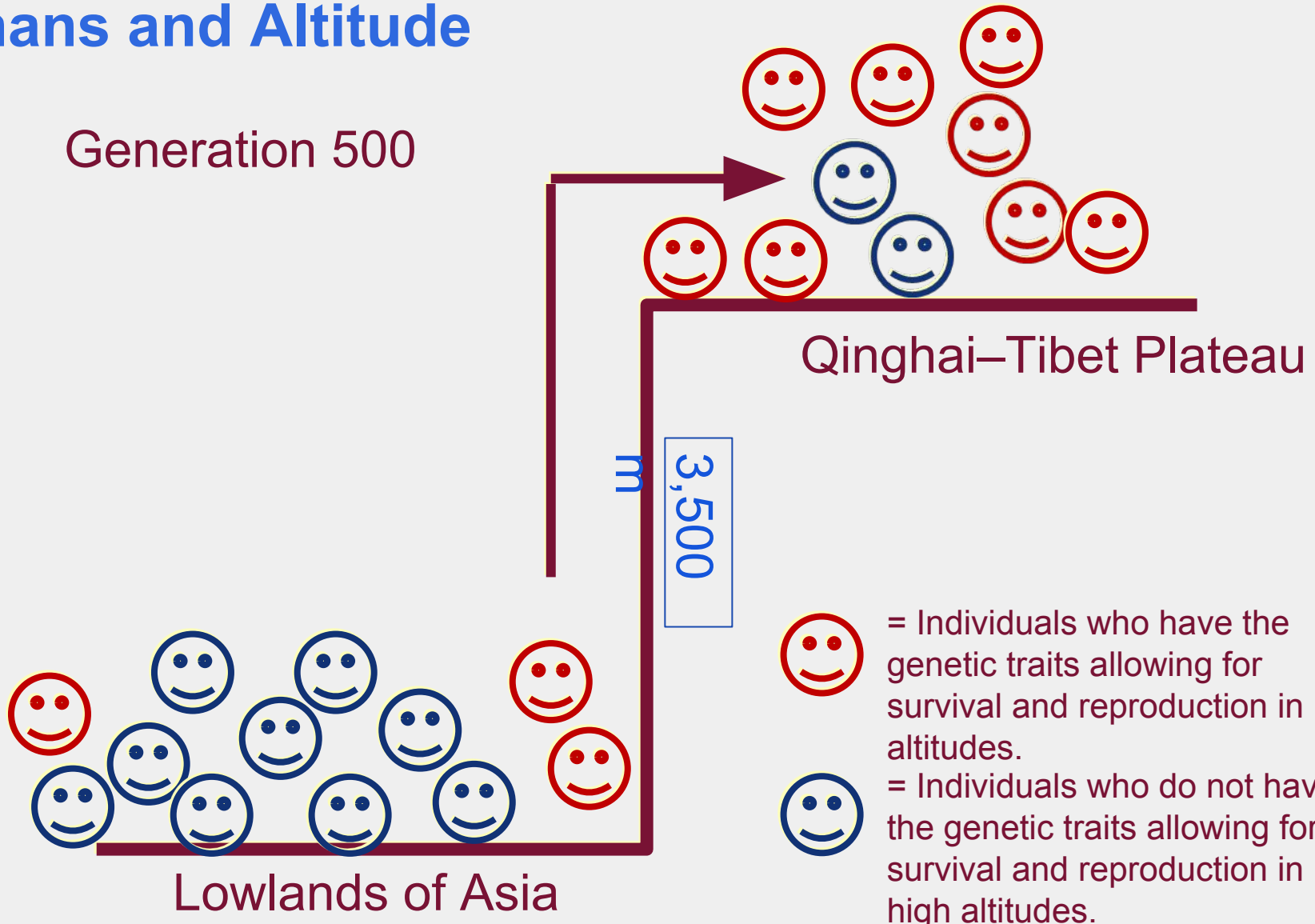
3.3 Evolution and Natural Selection: Humans and Altitude



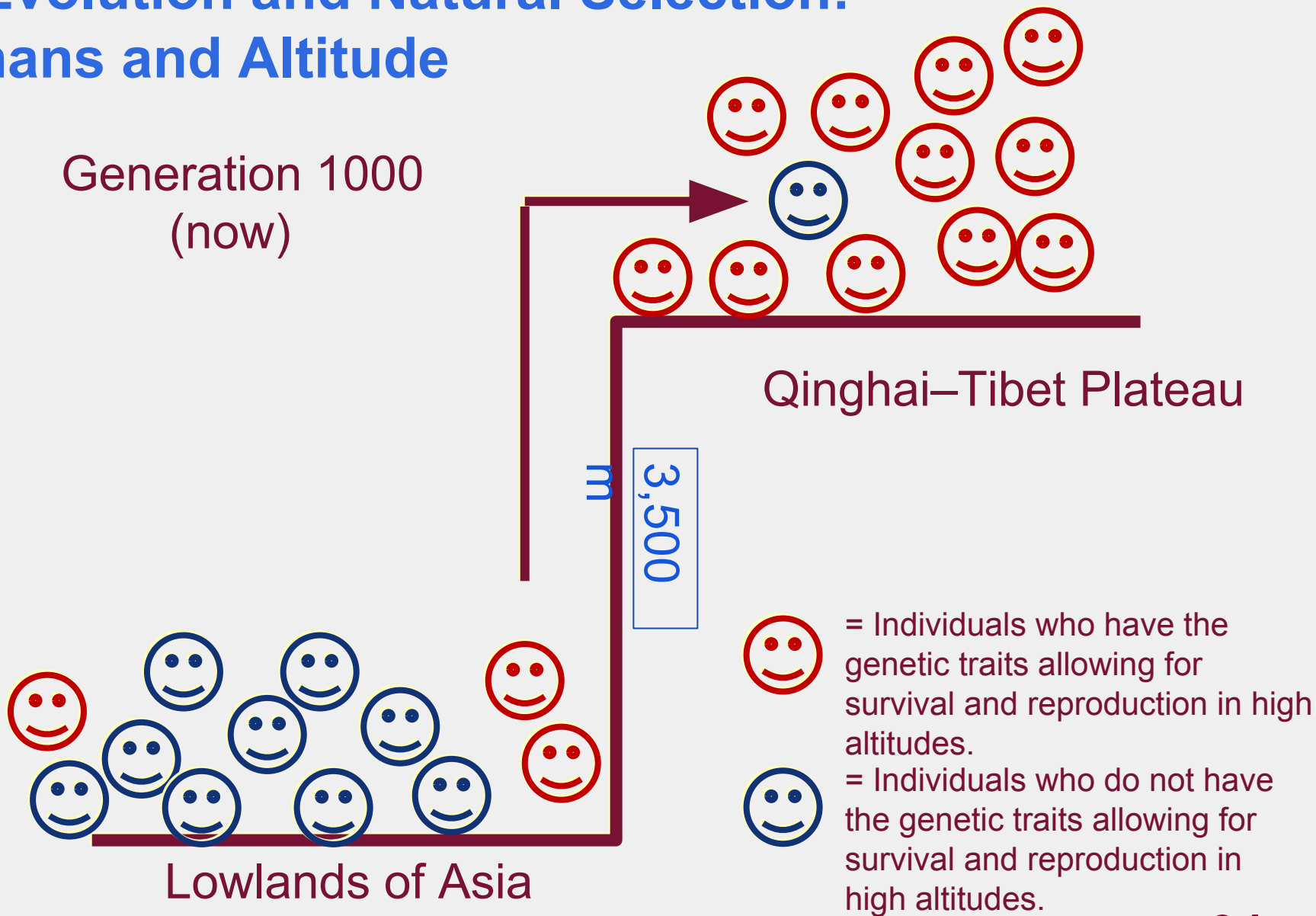
3.3 Evolution and Natural Selection: Humans and Altitude



3.3 Evolution and Natural Selection: Humans and Altitude



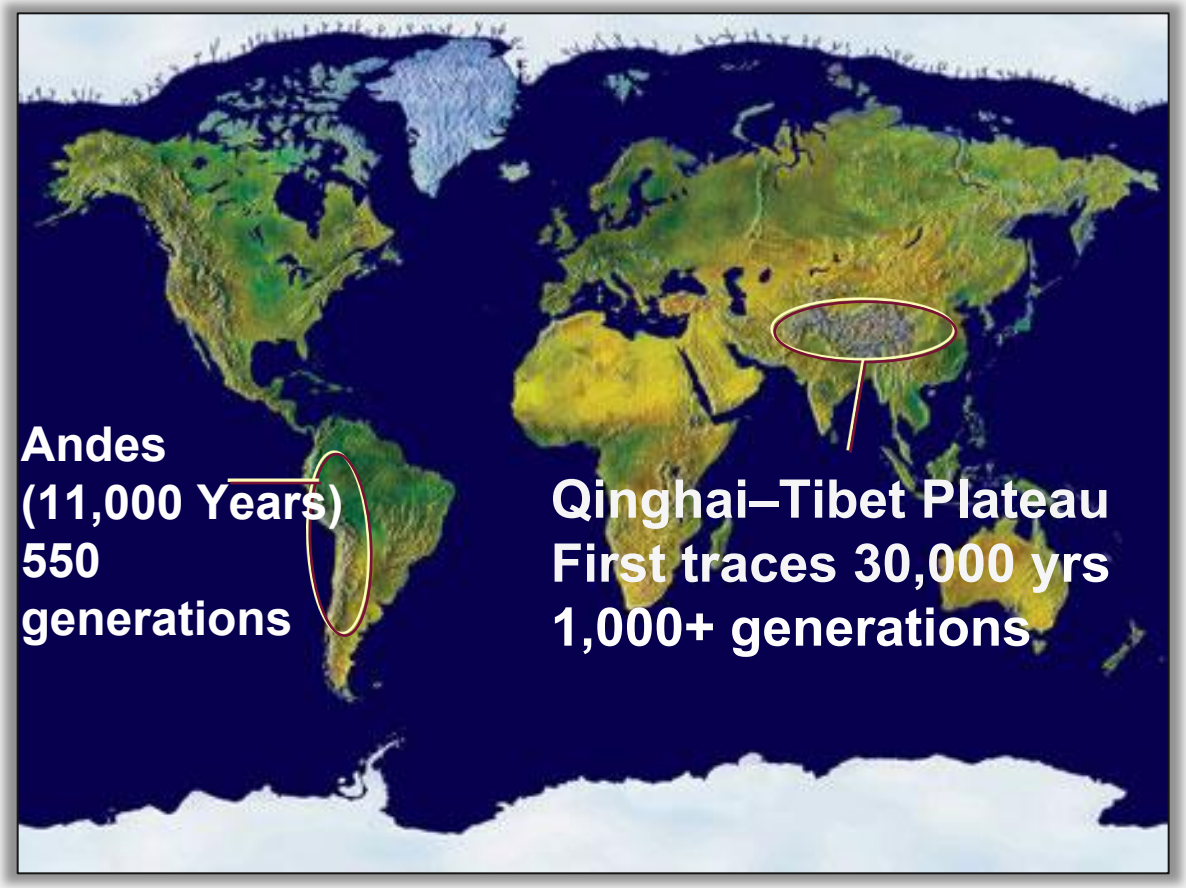
3.3 Evolution and Natural Selection: Humans and Altitude



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.



3.3 Evolution and Natural Selection: Humans and Altitude

- Adaptations
  - Andes
    - Increase in hemoglobin concentration (red blood cells).
  - Qinghai–Tibet Plateau
    - Deeper breath, larger pulmonary capacity and increased blood flow.

Natural selection keeps the individuals with the genetic traits that allow adaptation to high altitude. This means that individuals that have the mutation are at an advantage for survival and reproduction (production of offsprings).

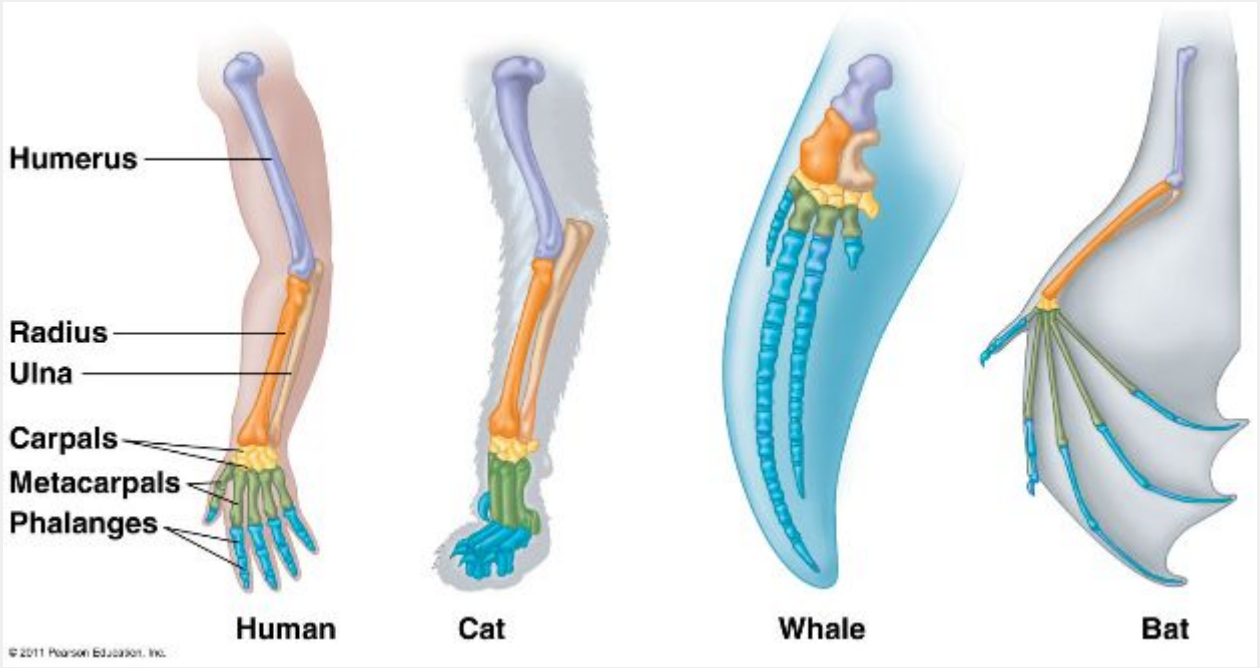
3.3 Evolution and Natural Selection (modified slide)

- In the three cases (moths, finches and humans), the _hereditary_ 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. It's evolution.
- These adaptations can sometimes redefine a species and, in certain circumstances, define a new species.

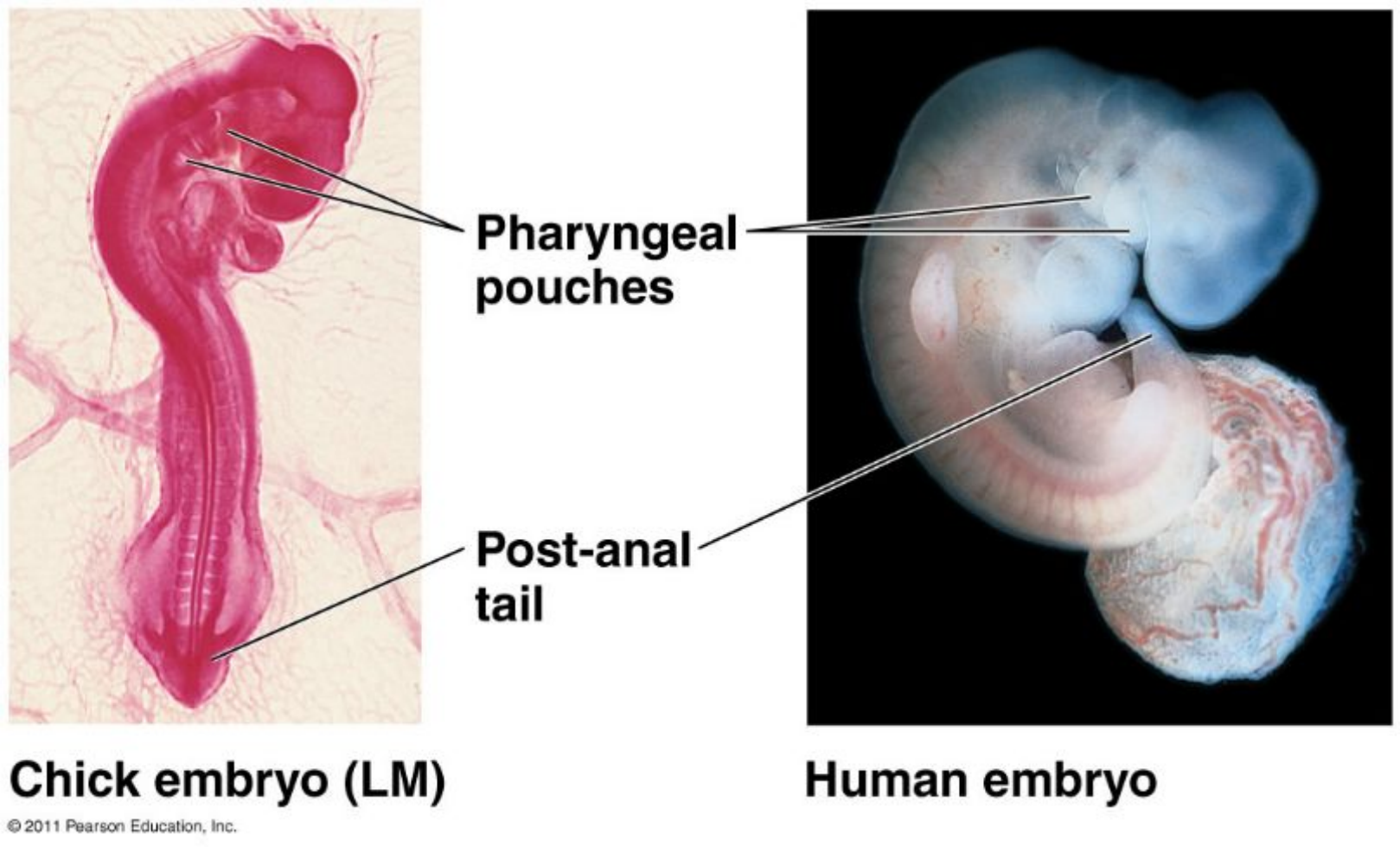
Another example in the book : fig. 22.13

3.4 Proof of Evolution: Homology

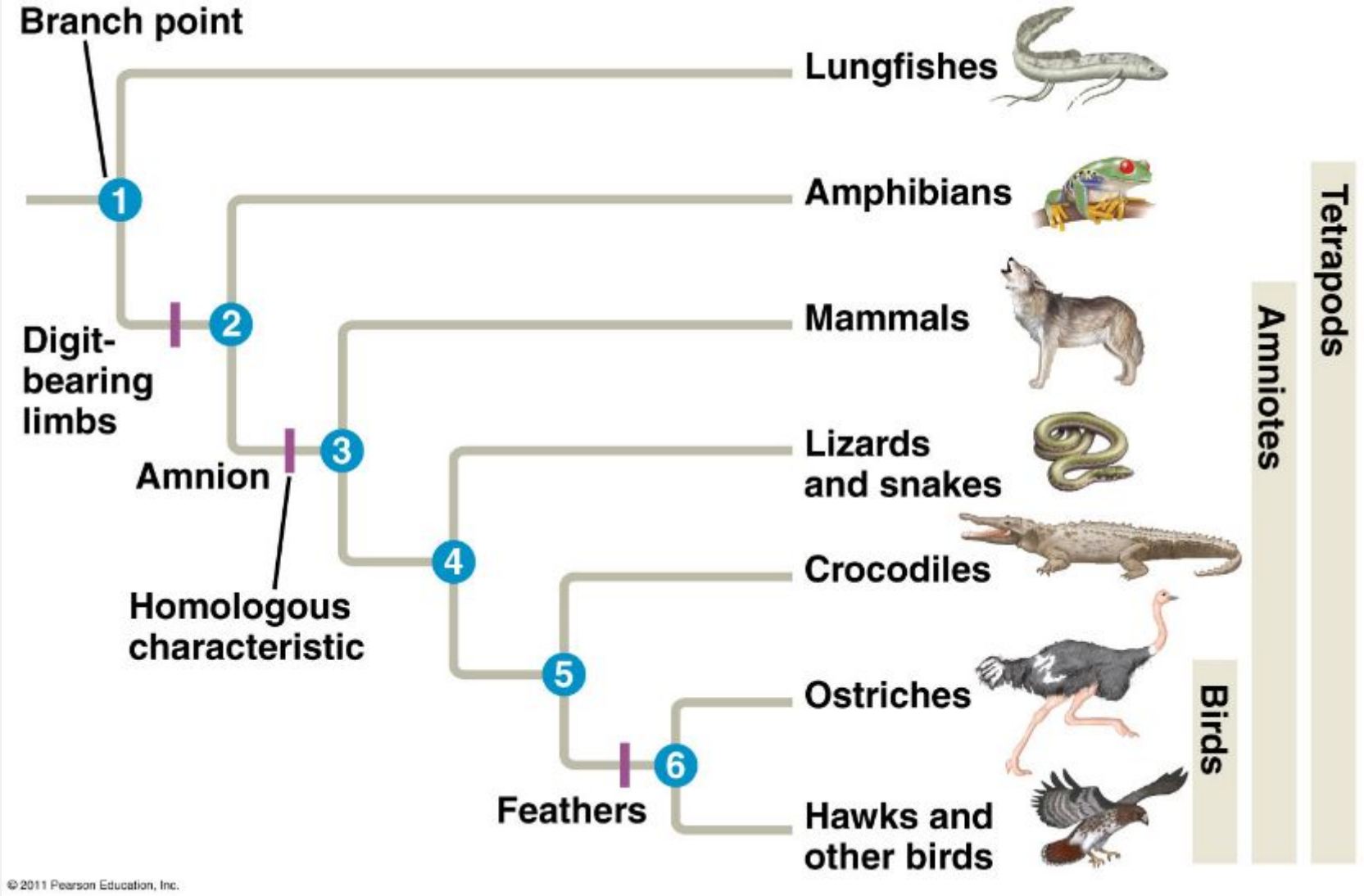
Descent with modification theory (theory of evolution) explains the resemblance between certain traits even if the functions are different. (homologous structure_____ _____)



3.4 Proof of Evolution: Homology



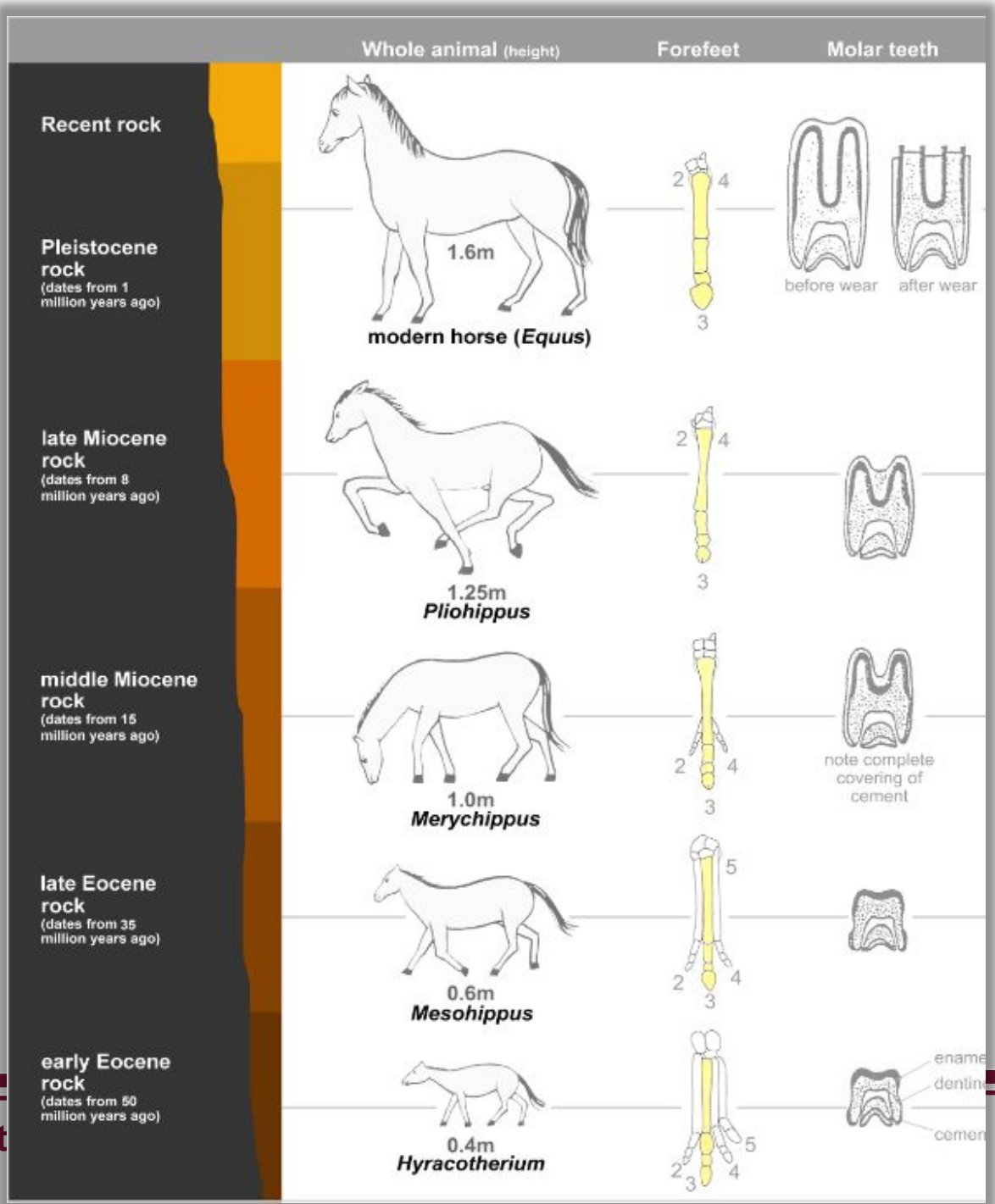
3.4 Proof of Evolution: Homology



3.4 Proof of Evolution: Fossils

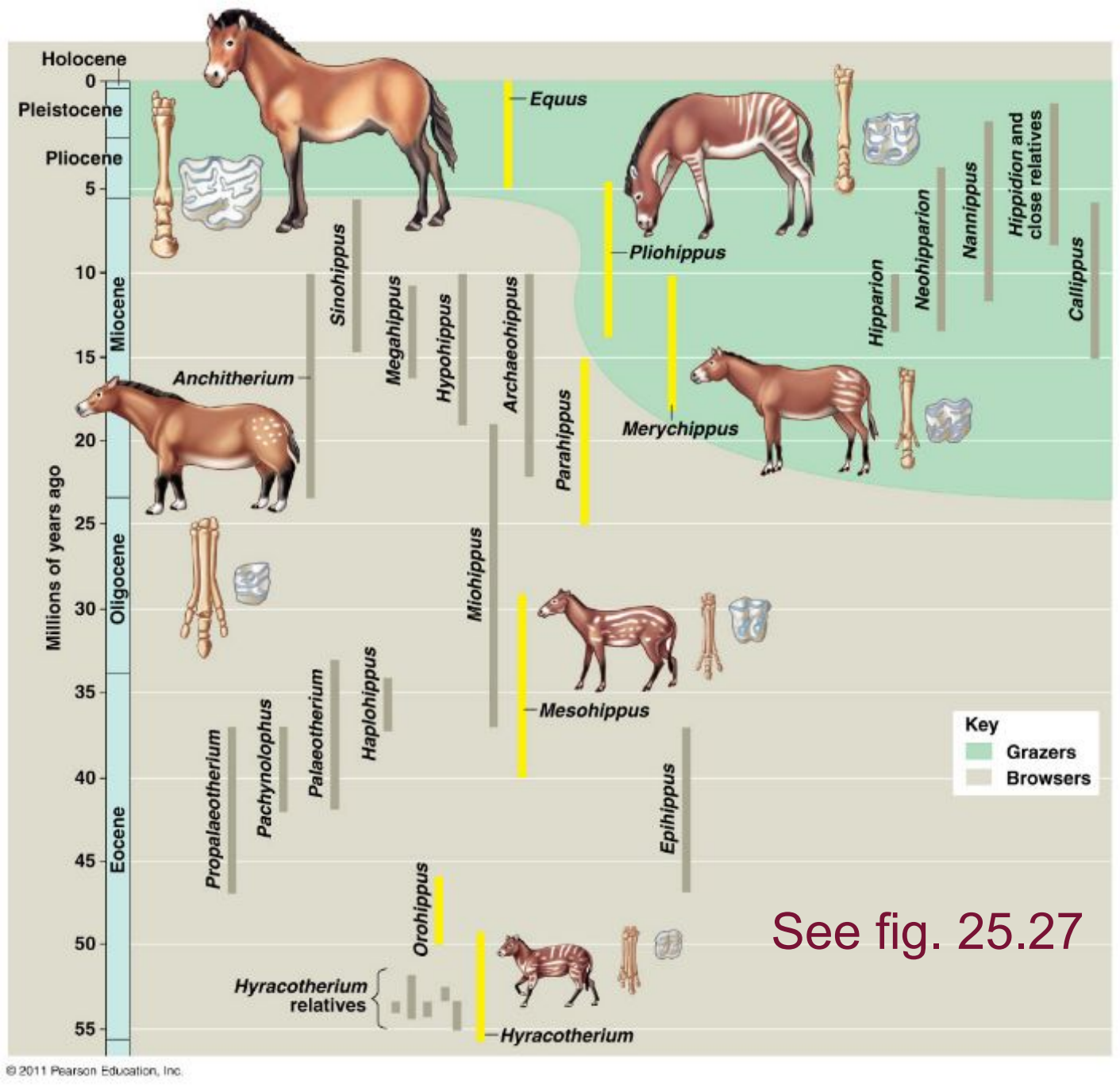
- **Evolution of the horse:**

Classic Interpretation (linear evolution)



3.4 Proof of Evolution: Fossils

Evolution of the horse:

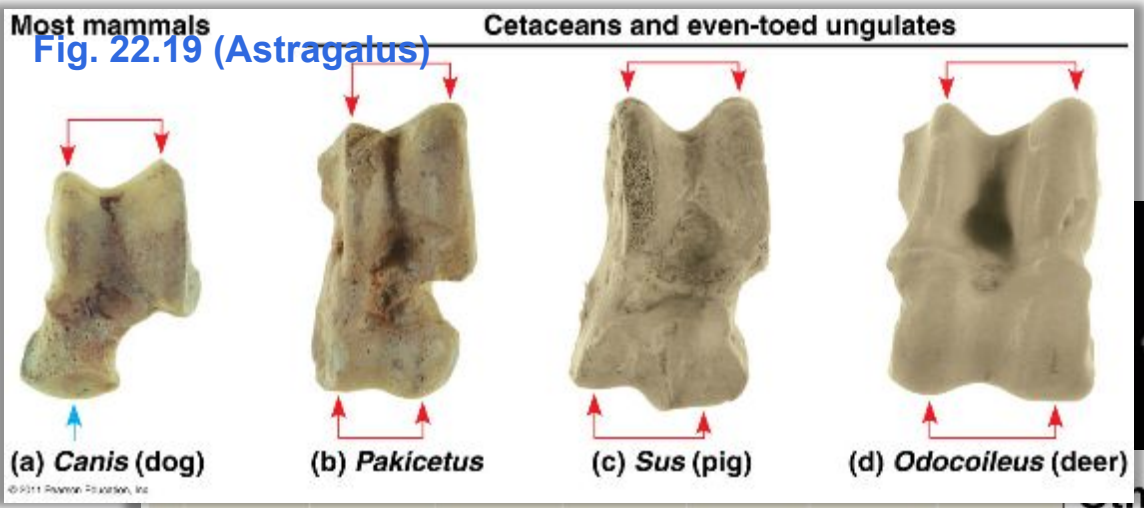


See fig. 25.27

More realistic interpretation (phylogenetic tree)

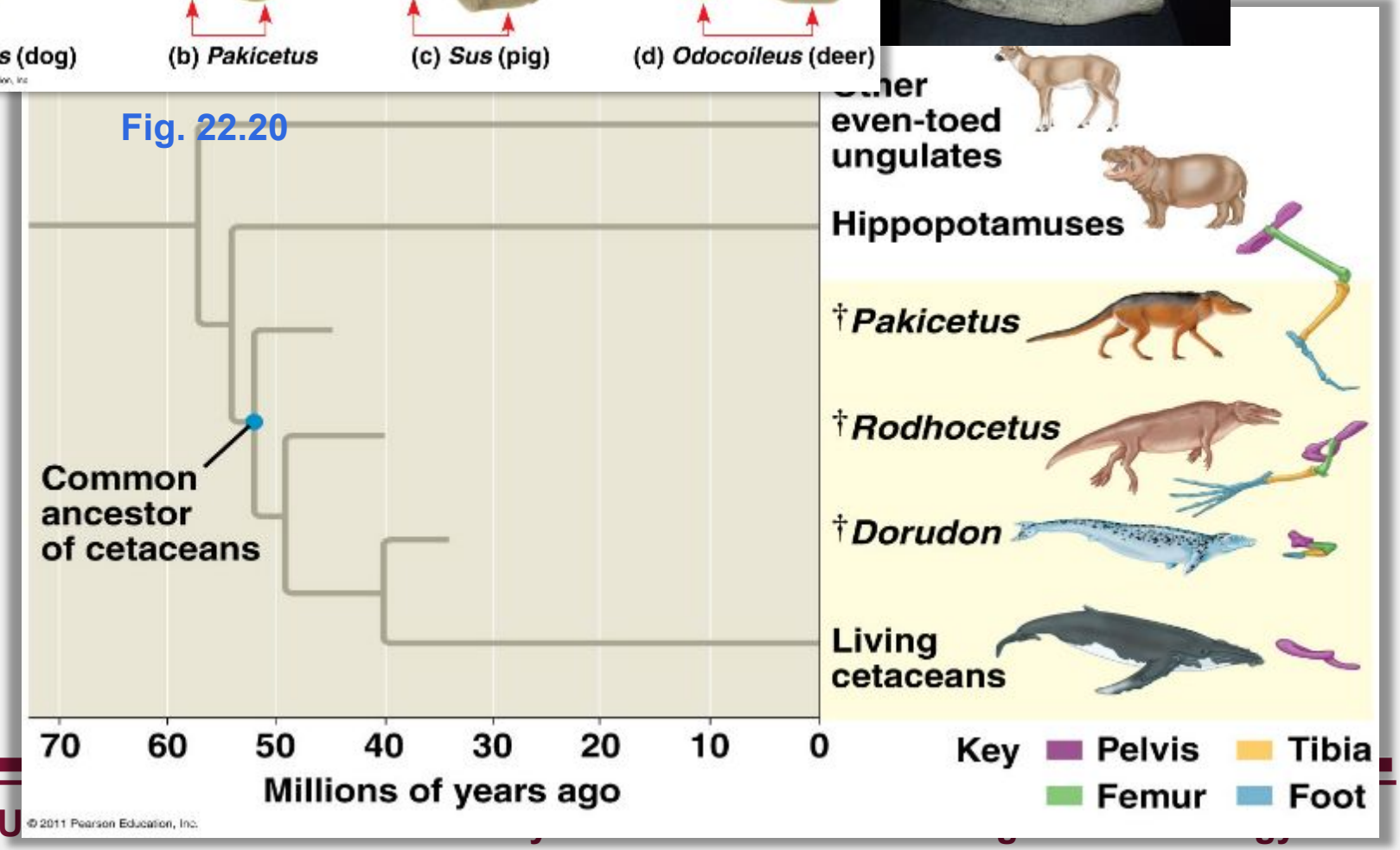
3.4 Proof of Evolution: Fossils

Fig. 22.19 (Astragalus)

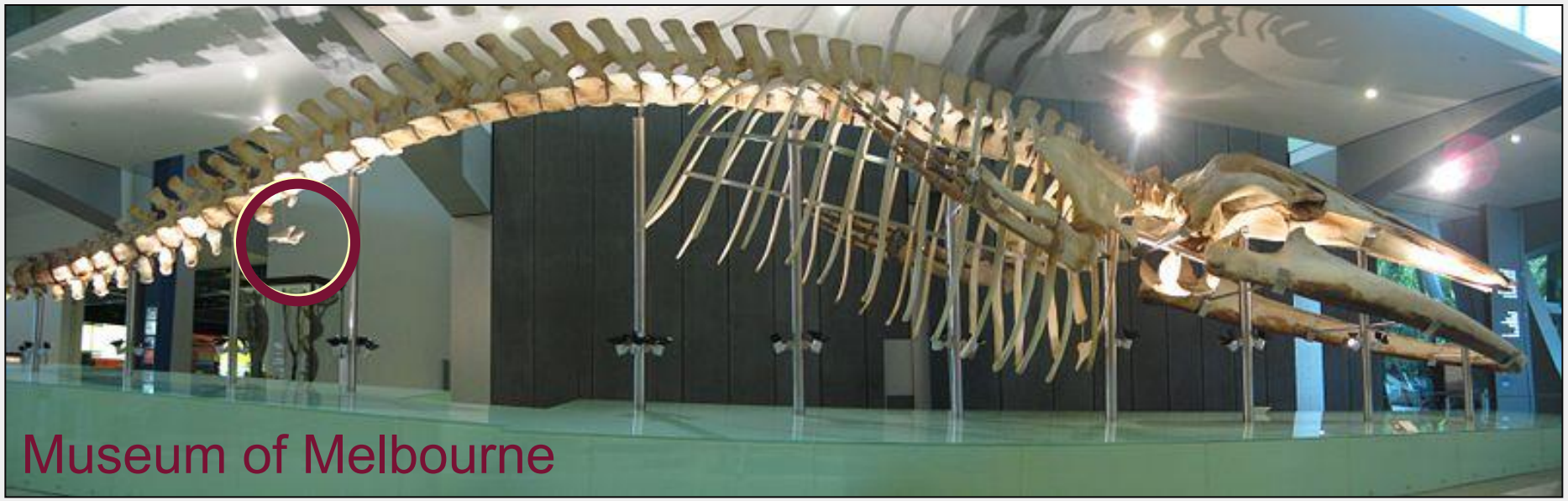


Pakicetus

Fig. 22.20



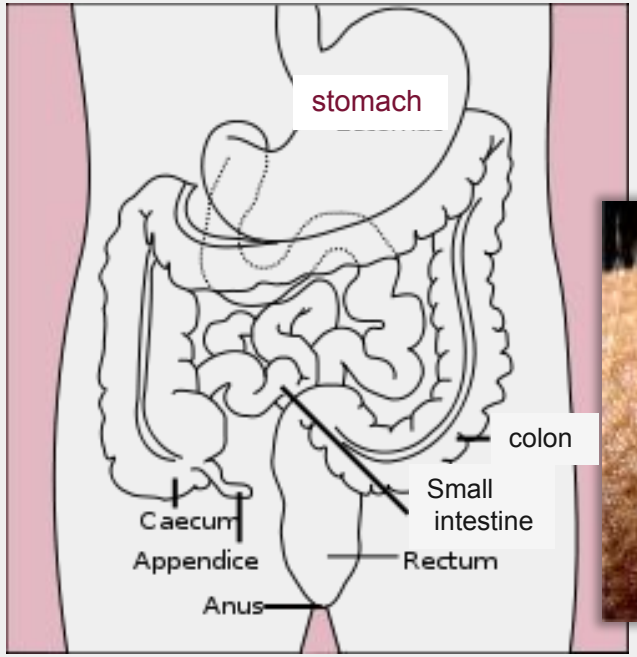
3.4 Proof of Evolution: Vestigial Structures

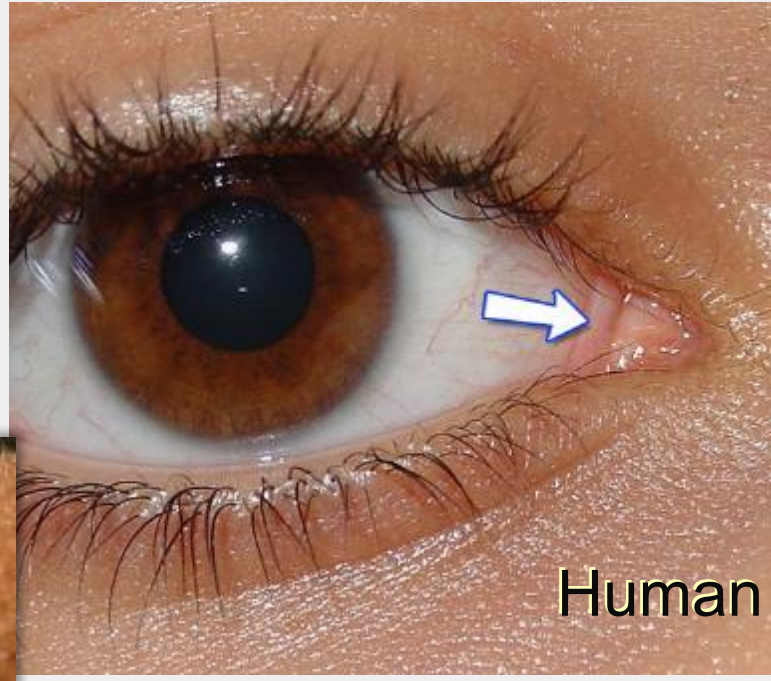


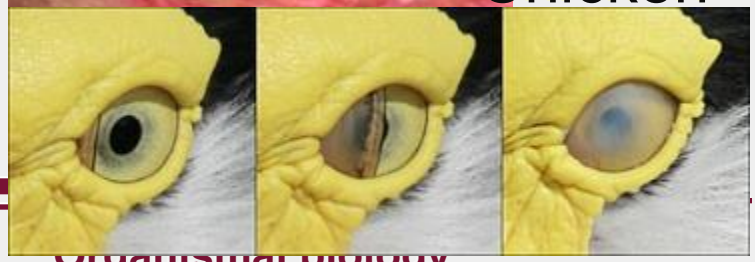
Skeleton of a dwarf subspecies of a blue whale (*Balaenoptera musculus*) (max length: 24 m).
Take note of the reduced vestigial posterior limb, the pelvis reduced to a floating pelvic bone under the spine.

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

3.4 Proof of Evolution: Vestigial Structures



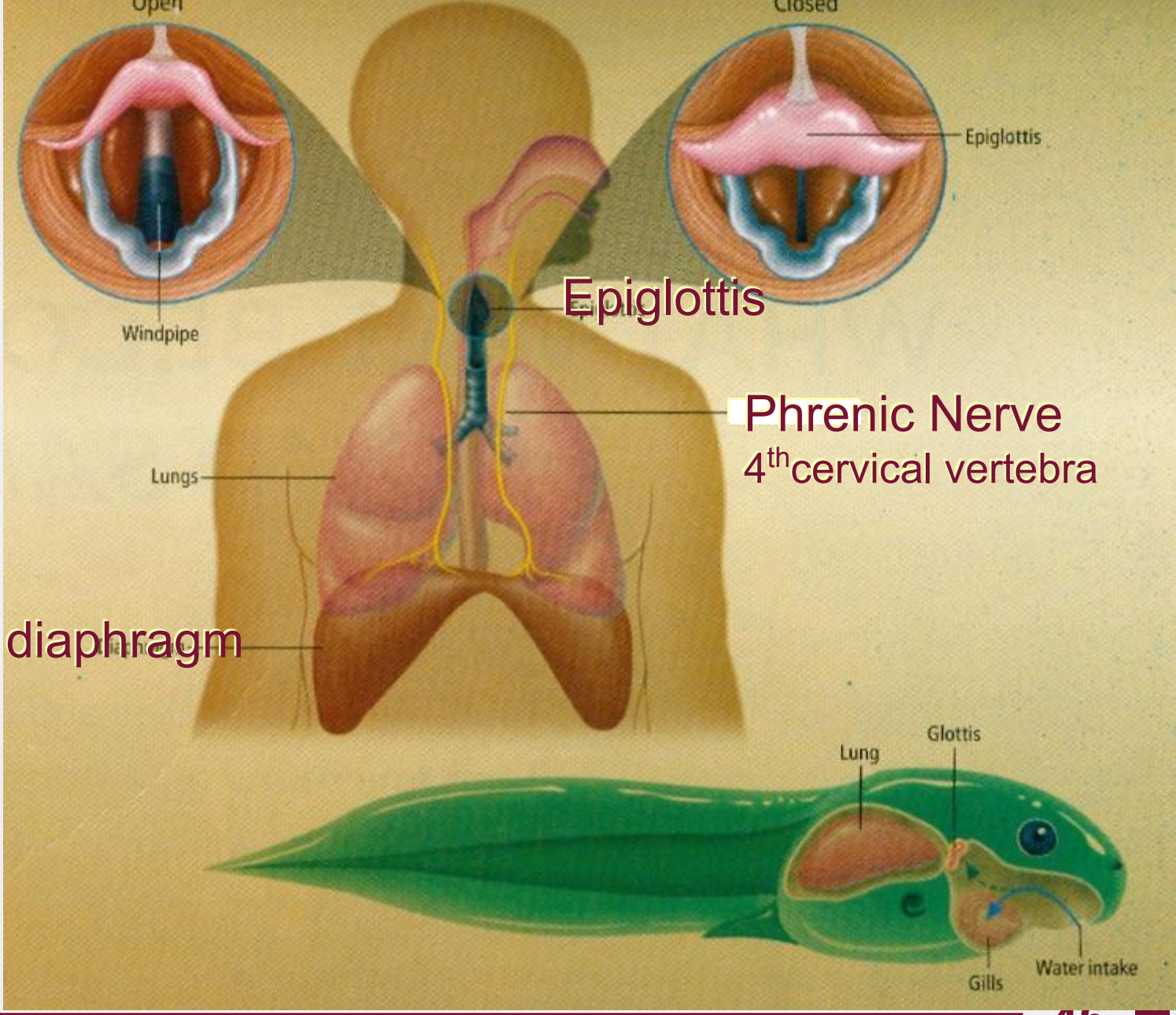




- Nictitating membrane or third eyelid.
- appendix
- goose bumps and hair

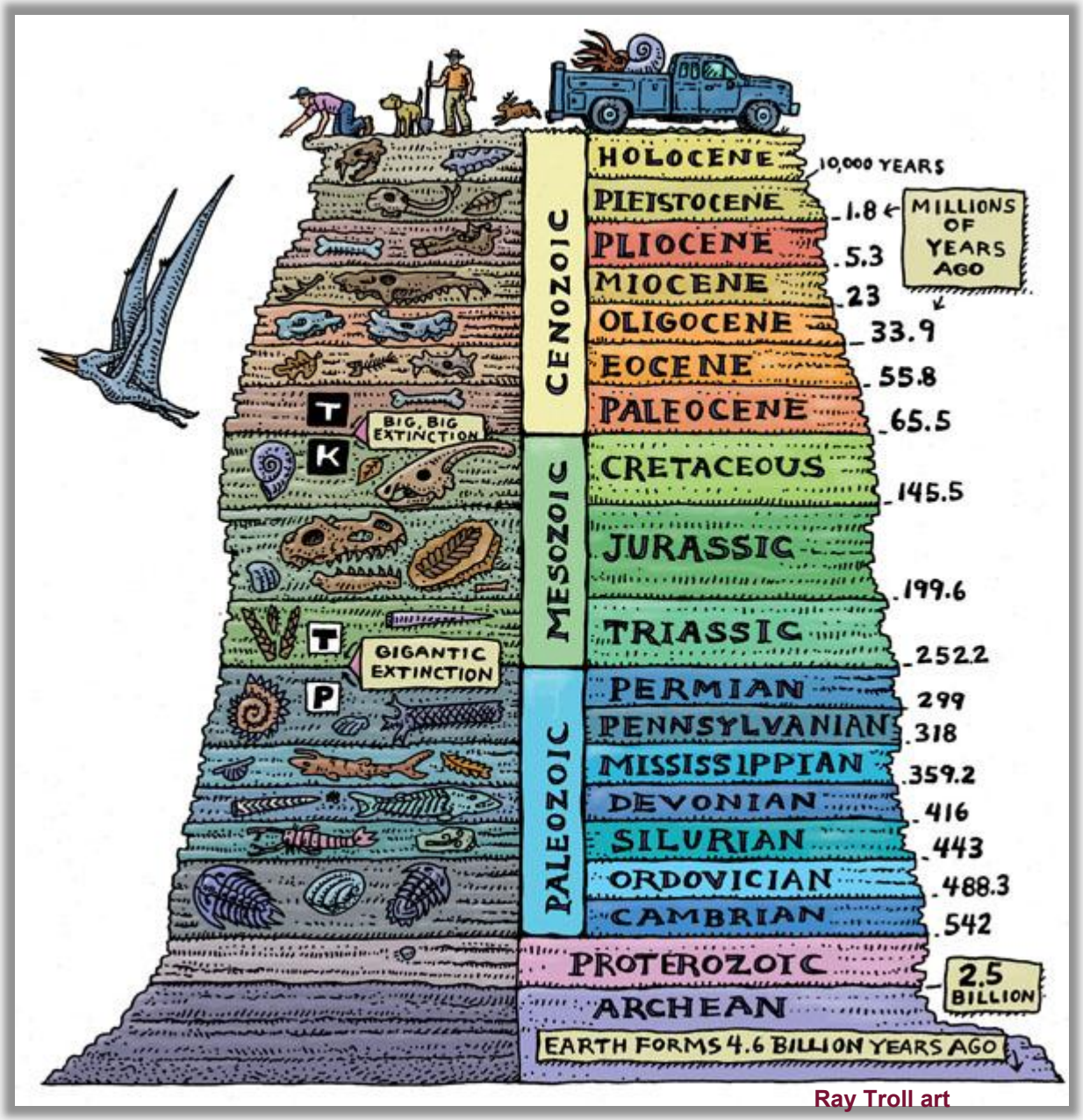
3.4 Proof of Evolution: Vestigial Structures

The hiccups : A heritage from fishes and amphibians



3.4 Proof of Evolution

Discovery of __ fossil in the wrong place un the geologival archives ____ _____ would be sufficient to refute our concept of evolution



Ray Troll art