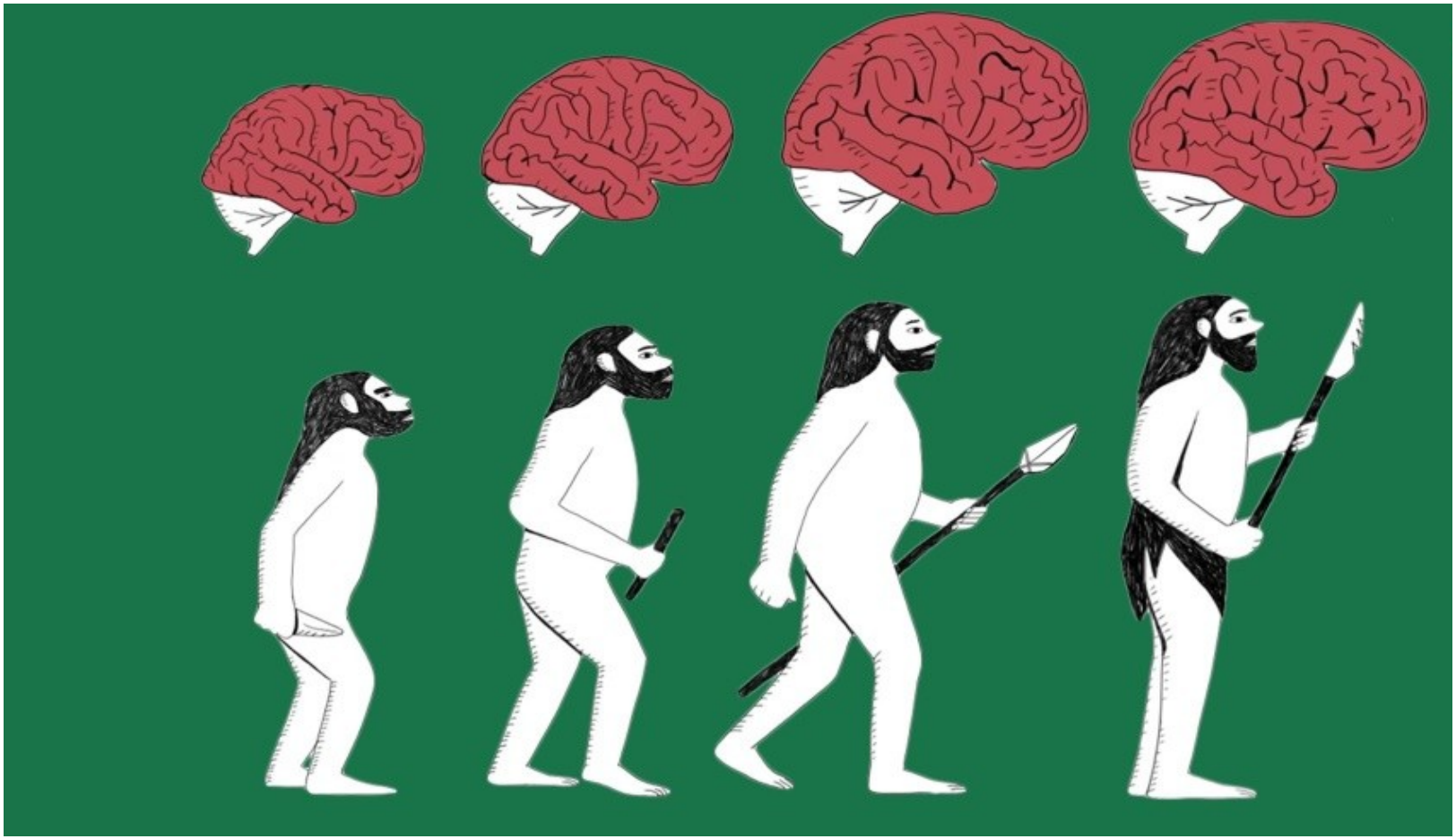
UNIT 4: EVOLUTION
New curriculum



4.1. EVOLUTION

4.1.1. Definition

❖ **Evolution** is a change in genetic composition of a population over successive generations, which may be caused by meiosis, hybridization, natural selection or mutation.

✓ This leads to a sequence of events by which the population diverges from other populations of the same species and may lead to the origin of a new species.

✓ The theory of evolution describes how the various forms of life on Earth (including humans) emerged and evolved.

✓Evolution means gradual changes over a period of time.

Theories of the origin of life

- The origin of life means the emergence of heritable and evolvable self-reproduction.
- “Origin of Life” is a very complex subject, and often times controversial.
- There are several theories about the origin of life. Some of them are mentioned below.

1. Special creationism

Special creationism explained that the formation of life on earth may have been taken place due to **supernatural** or **divine forces**.

- ✓ **Creationism** (or special creationism) is a theory claiming that the different forms of life on Earth were created by a supreme being
- ✓ Is nearly always linked to religion.
- ✓ However, acceptance of evolution is linked to scientific thinking.

Con`d

- **Scientific thinking** by observation and empirical testing using instruments. That results the development of scientific theory.
- **Religion** mainly focuses on spritual matters that cannot be seen, touched or measured.
- Less concerned with empirical observable facts and testable hypothesis, but rather with faith, the believe cannot proven.
- There are different versions of special creation, linked with different religion;

  -Young Earth creationism

  - Old Earth creationism

  - Day-age and gap creationism

  - Progressive creationism

  - Theistic evolution/Evolutionary creationism

  - Intelligent design

Con`d

- **Young earth creationism;-**
- Suggest the earth is only a few thousands years old.
- Earth was created in six 24- hours days.
- According this , geological events are interpreted in light of Noah' flood.
- **Old earth creationism;-** Accept that life was created by God as it was put in Genesis but explains that the earth is very old.
- **Day age and gap creationism;-**
- Considers that each of the six- days in Genesis represent a billion or so years of geologic time, making the day just symbolic.

Con’d

- Both day-age and gap creation accepts that the creation theory story actually took longer than 6- earth days.

➢ **Progressive creationism;-**

- Accepts the big bang on the origin of the universe.
- It accepts fossil record of a series of organism, but denies genetic relationship between ancients and modern species. Modern species are not seen as being genetically related to ancient ones.
- **Big Bang** is the explosion of a single extremely dense mass of matter that started the universe according to a popular theory Big bang theory.

➢ **Theistic evolution (evolutionary creationism;-**

- Proposes that God invented evolution and takes some form of an active part in ongoing process of evolution.
- This theory is promoted by catholic church pope and mainline protestants.
- It also invokes the role of God in areas not discussed by science, like the creation of the human soul.

Con`d

- **Intelligent design;-**
- Newest (latest) version of creationism and maintains that God's handiwork.
- That claim that life developed due to combination of natural forces and the intervention of supernatural forces.

2. Spontaneous generation (abiogenesis)

- Suggests that life can evolve spontaneously' from non-living objects.

- The Greek philosopher Aristotle (384-322) was one of the earliest scholars to articulate the theory.

- It was once believed that life could come from nonliving things, such as mice from corn, flies from bovine manure, maggots from rotting meat, and fish from the mud of previously dry lakes.

Con’d

- **In 1668, Francesco Redi**, an Italian scientist, designed a scientific experiment to test the spontaneous creation of maggots by placing fresh meat in jars.
  - One jar was left open; the others were covered with a cloth. Days later, the open jar contained maggots, whereas the covered jars contained no maggots.
  - He did note that maggots were found on the exterior surface of the cloth that covered the jar.
  - Redi successfully demonstrated that the maggots came from fly eggs and thereby helped to disprove spontaneous generation.
- **In 1748, the English priest John Needham** (1713–1781) reported the results of his experiments on spontaneous generation.
  - Needham boiled mutton broth and then tightly stoppered the flasks.

Con’d

- A few years later, the Italian priest and naturalist Lazzaro Spallanzani (1729–1799) improved on Needham’s experimental design by first sealing glass flasks that contained water and seeds.

- If the sealed flasks were placed in boiling water for 3/4 of an hour, no growth took place as long as the flasks remained sealed.

- He proposed that air carried germs to the culture medium, but also commented that the external air might be required for growth of animals already in the medium.
- The supporters of spontaneous generation maintained that heating the air in sealed flasks destroyed its ability to support life.

Con'd

➢ **Louis Pasteur, French scientist**, showed that broth (or wine) only went sour if micro-organisms were allowed to enter.

• Also no micro-organisms appeared in the broth unless they were allowed to enter from the outside.

• Pasteur made a series of flasks with long, twisted necks ("swan-neck" flasks), in which he boiled broth to sterilize it.

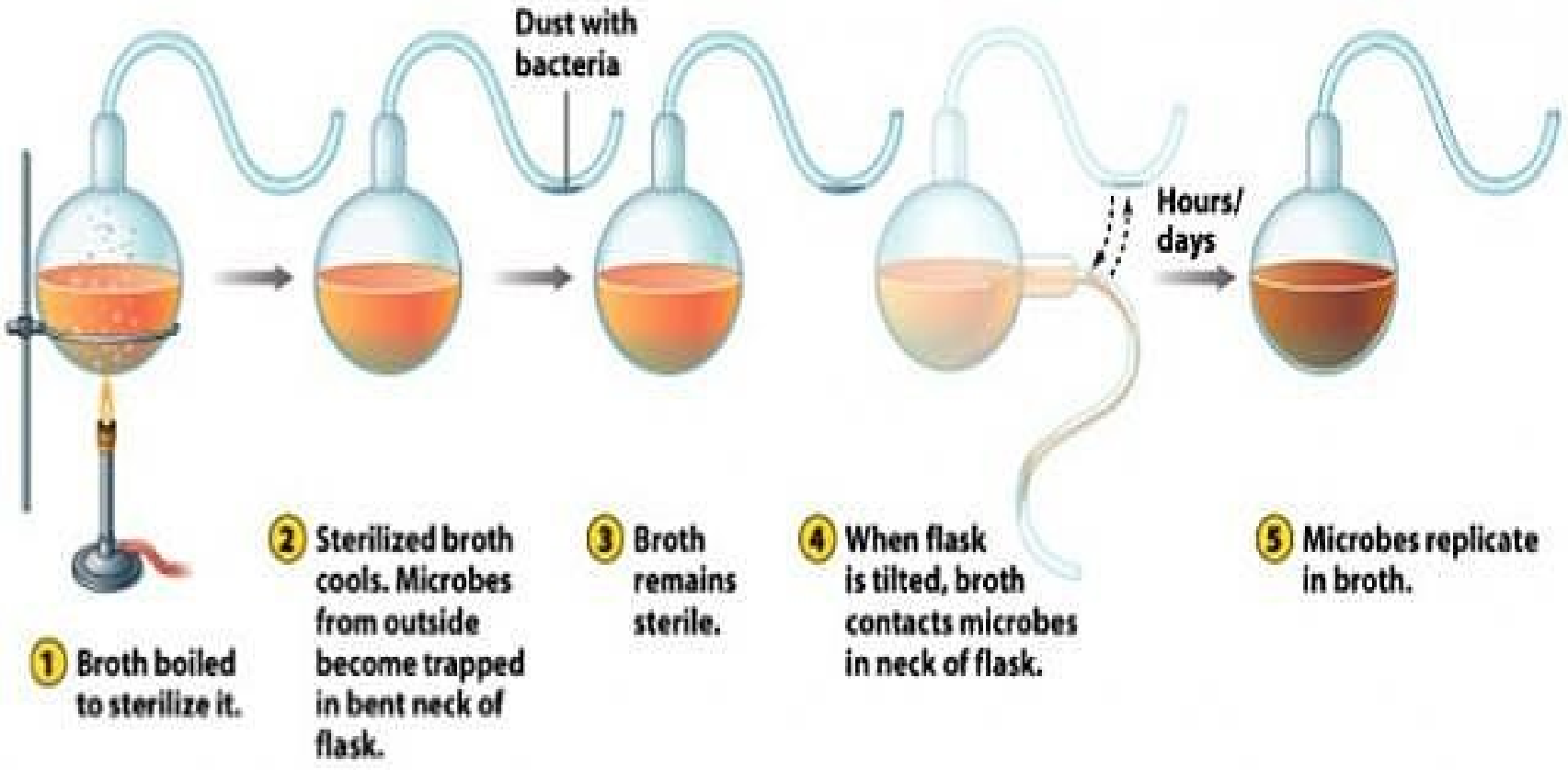
• His design allowed air inside the flasks to be exchanged with air from the outside, but prevented the introduction of any airborne microorganisms, which would get caught in the twists and bends of the flasks' necks.

•However, the necks be broken, microorganisms would be introduced, contaminating the flasks and allowing microbial growth within the broth.

• Pasteur's set of experiments irrefutably disproved the theory of spontaneous generation and also articulated "Omne vivum ex vivo" ("Life only comes from life")

Con’d

•These two scientists showed that both macro-organisms (flies) and micro-organisms (bacteria) could only arise from pre-existing organisms, disproving the theory of spontaneous generation.



generation

3. Eternity of life

- **Eternity of life theory-** claims that the Universe has always existed and that there has always been life in the universe.
- In this theory of life, there is no beginning and no end to life on Earth and so life neither needs special creation nor does it need to be generated from non-living matter.
- Supporters of this theory believe that life is an inherent property of the Universe and it has always existed as has the Universe.

4 .Cosmozoan theory, Panspermia or Spore broth theory

- **Cosmozoan theory** claims that life on Earth originally came from elsewhere in the Universe (possibly from another planet).
- According to **Cosmozoan theory** life has reached this planet Earth from other cosmological structures, such as meteorites, in the form of highly resistant spores.
- This theory was proposed by Richter (1865).
- According to this theory, 'protoplasm' reached the earth in the form of spores or germs or other simple particles from some unknown part of the universe with the cosmic dust, and subsequently evolved into various forms of life.
- Helmholz (1884) speculated that 'protoplasm' in some form reached the earth with falling meteorites.

4. Biochemical origin (abiogenesis)

- **Biochemical theory** suggests that life on Earth originated as a result of a number of biochemical reactions producing organic molecules which associated to form cells.

- two biologists working early in the 20TH Century.

✓**Aleksandr Oparin,** a Russian biologist who first put forward his ideas in 1924, and

✓**John Haldane**, an English biologist independently put forward almost identical ideas in 1929 (before Oparin's book had been translated into English).

➢Both believed that organic molecules could be formed from abiogenic materials in the presence of

- an external energy source such as ultraviolet radiation and

- the primitive atmosphere was reducing (very low amounts of free oxygen)

➢Primitive atmosphere contained **ammonia , water, methane and hydrogen**

Con`d

- **Oparin suggest that;-** simple organic compound were formed in the atmosphere and reacted to form a complex molecules.
- Molecules might have formed colloidal aggregates, or coacervates in aqueous environment.
- The coacervates were absorbed and assimilated organic compounds from their surrounding, like metabolizing cells, and eventually gave rise to the first true cells.

- **Haldane proposed that similarly;-** life were formed in the sea as result of chemical reactions powered by solar energy.
- A hot dilute soup of organic monomers and small polymers were formed. He called this soup ‘prebiotic soup’
- Oparin’s coacervates’ and Haldane’s prebiotic soup gave us the combined biochemical theory of origin of life.

Evidences for biochemical origin of life

- **Staney Miller** conduct spark discharge experiment in 1953.
- He passed electric sparks repeatedly through a mixture of gase containing methane (CH_4), ammonia (NH_3), water (H_2O) and hydrogen (H_2) to represent primitive atmospheres.

- He was able to produce organic molecules such as amino acid, pentose hexose sugars and hydrogen cyanide (HNC).
  - Amino acid - essential to form proteins (building blocks of protein).
  - Pentose sugar - used in nucleotides formation.
  - Hexose sugar – are needed in respiration and polysaccharides (starch) formation.
  - HCN – can act as precursor of nitrogenous base found in nucleotides.

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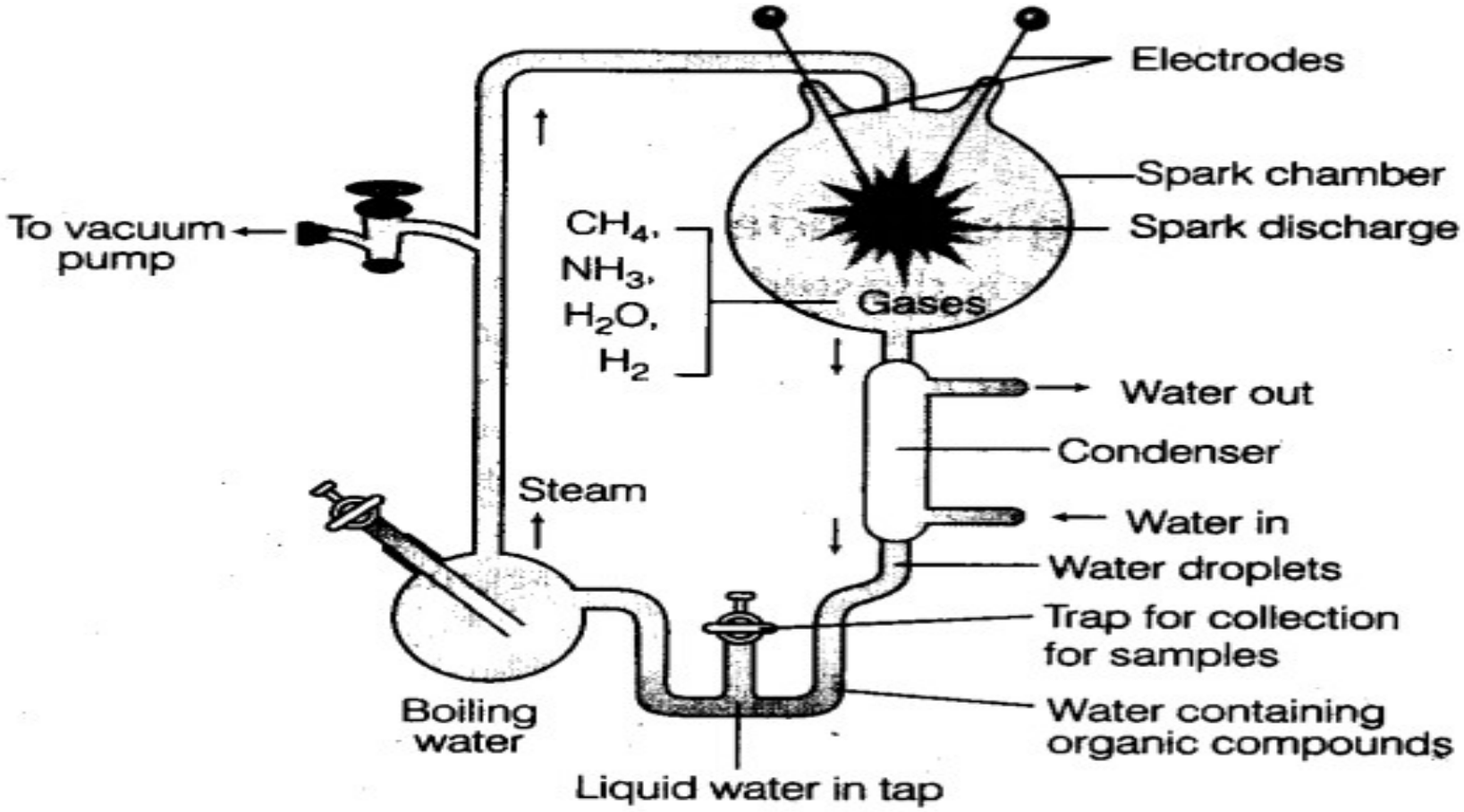

Figure 4.7 Stanley Miller's spark-discharge

Evolution of Autotrophs

- **Autotrophs** form the basis for **all food chains**: they are the organisms which create sugars, proteins, lipids, and other materials for life.
- The first organisms appeared about 4 billion years ago were **prokaryotes.**
  - ✓ They **had no true nucleus.**
  - ✓ It seems likely also that they had RNA rather than DNA as their genetic material.
- In the primitive atmosphere gaseous oxygen is unavailable .
- The level of oxygen has increased after the evolution of photosynthetic organism.
- The age of earth is estimated to be about 4.5 billion years.
- The first organisms (heterotrophs, prokaryotes) appeared 3.5 – 4 billion years ago.

❖ **The three distinct lines of evolution leading to;**

I. **Archaebacteria**;- prokaryotes including thermophilic sulphobacteria, methanobacteria and halophilic bacteria

II. **Eubacteria;-** prokaryotes; ordinary bacteria and Cyanobacteria (blue-green bacteria and sometimes known as **blue-green algae**).

➢ **Eubacteria** in modern biological classification, all these bacteria considered to be the **true bacteria**

➢ **Have rigid cell wall**.

III. **Eukaryotes;-** eventually evolving into protoctistans, fungi, plants, animals (nearly all are aerobic).

❖ One great change that affected the evolution of early life forms was the shift from the **reducing atmosphere to an atmosphere containing oxygen.**

- This took place about 2.4 billion years ago.

- Bacteria are the only life forms found in the rocks for a long time, 3.5 to 2.1 billion years ago.
  - 3.5 – 2.1 billion years ago ; bacteria were the only life forms
  - 2.4 – 2.1 Billion years ago ; oxygen concentration, started to rise
  - 2.1 – 1.9 billion years ago ;eukaryotes become numerous
  - 0.9 billion years ago ;fungi like organisms appeared
  - 0.6 – 0.7 bya (700-600 mya) ; animal evolved

- As rise of oxygen in the athmosphere due to photautotrophs lead to evolution of aerobic respiration as energy releasing pathway, release more energy than anaerobic and gave way to the evolution of more active organism E.g animals

What are chemoautotrophs? How do they differ from photoautotrophs?

The two major types of autotrophs are chemoautotrophs and photoautotroph.

1. **Photoautotrophs;-** are organisms that use light energy and inorganic carbon to produce organic materials.

- Eukaryotic photoautotrophs absorb energy through the chlorophyll molecules in their chloroplasts.
- Cyanobacteria are photoautotrophs ; they use light as source of energy and CO_2 as source of carbon (photosynthesis).

- They are one of the earliest of autotrophy (photosynthetic), but they do not use chlorophyll, by another pigment phycocyanin (blue green appearance) to capture energy.

Chemoautotrophs;-

- are organisms that obtain their energy from a chemical reaction (chemotrophs) but their source of carbon is the most oxidized form of carbon, carbon dioxide (CO_2).
- The best known chemoautotrophs are the chemolithoautotrophs that use inorganic energy sources, such as ferrous iron, hydrogen, hydrogen sulfide, elemental sulfur or ammonia, and CO_2 as their carbon source.
- All known chemoautotrophs are prokaryotes, belonging to the Archaea or Bacteria domains.
- They have been isolated in different extreme habitats, associated to deep-sea vents, the deep biosphere or acidic environments.
- This form of energy conservation is considered one of the oldest on Earth.

Keywords

- **Autotrophs** are organisms that produces organic molecules from inorganic material
- **Heterotrophs** are organisms that consume producers or other consumers
- **Aerobic respiration** is a means by which cells release energy from organic molecules using oxygen
- **Prokaryote** is an organism consisting of a prokaryotic cell. All bacteria are prokaryotes
- **Eukaryote** is an organism consisting of one or more eukaryotic cells. All organisms other than bacteria are eukaryotes
- **Archaebacterium** is the first bacteria (and thus the first living organisms) to develop on Earth. They are now only found in extreme conditions
- **Eubacterium** is any bacteria that is not an archaebacterium is a eubacterium

4.1.2.Theories of evolution

1. Lamarckism

- Jean-Baptiste De Lamarck (1744 - 1829) was a great French naturalist.
- **Lamarckism** is the theory developed by the French biologist Jean-Baptiste Lamarck that claimed that organisms passed on to subsequent generations traits acquired during their lifetime
- He proposed 'the theory of inheritance of acquired characters' in 1809. He postulated:

A. New Needs: Changes in environment factors like light, temperature, medium, food, air etc or migration leads to origin of new needs in living organisms. To fulfil these new needs, living organisms have to exert special efforts like changes in habits or behavior.

Con’d

B. Use and disuse of organs: ´ The new habits involve the greater use of certain organs to meet new needs, and the disuse or lesser use of certain other organs which are of no use in new conditions.

C. Inheritance of acquired characters: he believed that the favorable acquired characters are inheritable and are transmitted to the offsprings so that these are born fit to face the changed environmental conditions and the chances of their survival are increased.

D. Speciation: Lamarck believed that in, so that new characters accumulate generation after every generation, new characters are acquired and transmitted to next generation.

- After a number of generations, a new species is formed.

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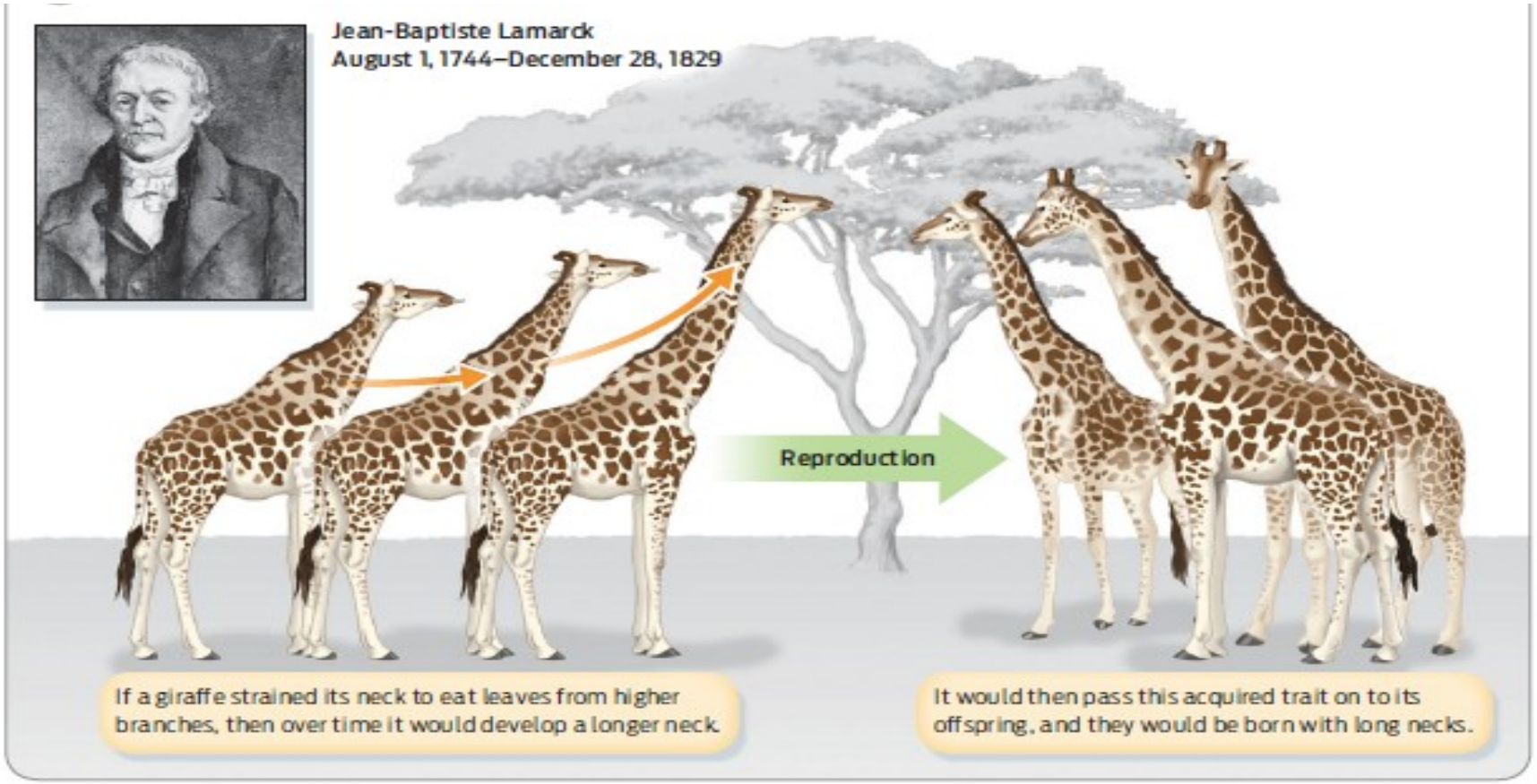

Figure 4.10 Lamarck’s ideas of use and disuse and the inheritance of acquired traits

Use and disuse

- Lamarck suggests that when a structure or process is continually used, that structure or process will become enlarged or more developed.
- **E.g** the elongated neck of the giraffe, the elongated webbed toes of water birds
- Conversely, any structure or process that is not used or is rarely used will become reduced in size or less developed.
- For example;- the smaller and undeveloped wings of Penguins.

➢ According to Lamarck, a given giraffe could, over a lifetime of straining to reach high branches, develop an elongated neck.

Inheritance of acquired traits

- Lamarck believed that traits changed or acquired during an individual's lifetime could be passed on to its offspring.
- Giraffes that had acquired long necks would have offspring with long necks rather than the short necks their parents were born with.

- Lamarckian inheritance, has since been disproved by the discoveries of genetics.

- However, Lamarck did believe that evolutionary change takes place gradually of evolution and constantly.

Significance of Lamarckism

A. It was first comprehensive theory of biological evolution.

B. It nicely explains the existence of vestigial organs in animals due to their continuous disuse.

- Vestigial organs are organs that are a part of the organism that are no longer in use.
- That can be used to determine the relatedness of different species.
- For example, the bone structures of the front flippers of a whale contain bones of limbs that exist in mammals such as cows.

C. It explains the development of strong jaw muscles and claws in the carnivores due to their continued extra use.

D. It stimulated other biologists to look for the mechanism of organic mechanism.

2. Darwinism (Theory of natural selection)

- Proposed by Charles Darwin (1809-1882 A.D.), an English naturalist.
- Darwin & Alfred Russell Wallace published ‘origin of species by natural selection’
- Darwin visited five of the Galapagos Islands and made drawings and collected specimens.
- Darwin studied the f**inche**s found on the different islands and noted that there were many similarities between them, as well as obvious differences.
- He concluded that an ‘ancestral finch’ had colonized the islands from the mainland and, in the absence of predators, were able to adapt to the different conditions on the islands and, eventually, evolved into different species.
- Some of the finches had evolved into insect eaters, with pointed beaks.
- seed eaters with beaks capable of crushing the seeds.

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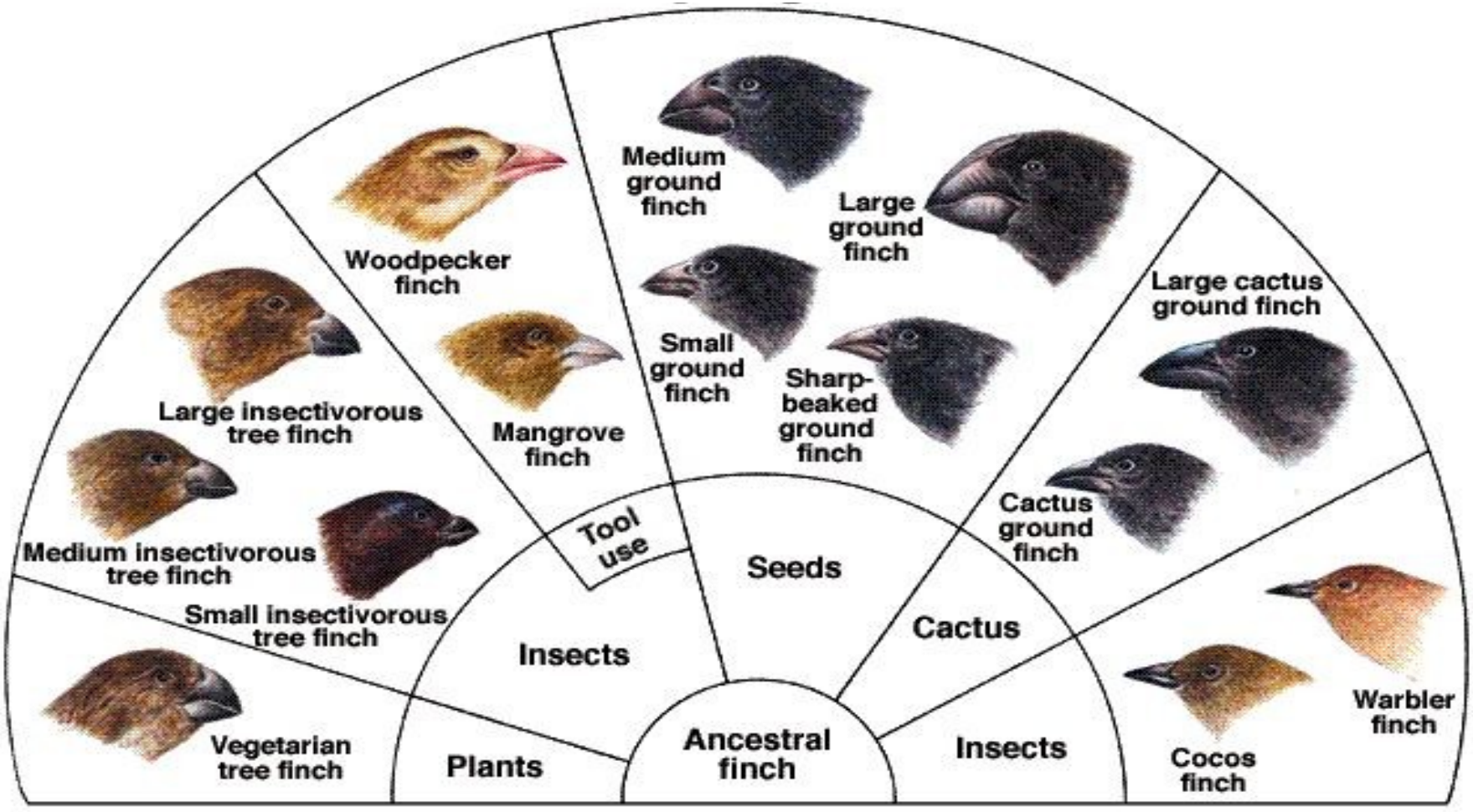

Figure 4.12 Darwin’s Theory of Finches on the Galapagos Islands

Basic postulates of Darwinism

- **Geometric increase**: (over production) All species tend to produce more offspring than can possibly survive.
- However, the space and the availability of food supply is limited to support the number of organisms that increase in a geometric ratio.
- **Struggle for existence**: Since the number of individuals produced is far more than the number that can be supported, there is an everlasting competition between organisms at all levels of life.
- **Variation under nature**: No two individuals of a species are exactly similar and they have some differences.
- Variations give rise to new characters and heredity passes them on to the next generation (inheritance of useful variations).

Con’d

- **Natural selection** or **survival of the fittest**: Due to struggle for existence and useful heritable variations, only those individuals survive which show high selective value and in the course of time they develop various adaptive modifications to suit the changed conditions of life. Such selection was called natural selection by Darwin.
- **Origin of species**: In the course of long periods of time the best fitted and suitable individuals survived and adjust to the nature.
- As environment is ever changing, further changes occur and thus new adaptations appear in organisms.
- The later descendants after several generations become quite distinct from their ancestors. On this way new species appear.

3. Neo-Darwinism theory

- **Neo-Darwinism** a revised version of Darwin's theory of evolution by means of natural selection.
- This theory, which is now accepted by most biologists, combines Darwin's original theory, genetic theory and theories about animal behavior.
- Genes determine organism's features.
- **Gene pool** all alleles or all genes found in the organism.
- **Postulates of Neo-Darwinism are:**
  - Genetic variability
  - Natural selection
  - Reproductive Isolation

4.1.3.The evidence for evolution

4.1.3.1 Comparative anatomy

- **I**s one of the strongest forms of evidence for evolution.
- It assumes that organisms with similar anatomical features are closely related evolutionarily, and that they probably share a common ancestor.
- **Homologous structures** are structures with the same basic anatomy and a common evolutionary origin but having same or different function
- Are evidences of a common origin and divergent evolution.

- Example of homologous structures is the forelimb of mammals.

When examined closely, the forelimbs of humans, whales, cats and bats are all very similar in structure.

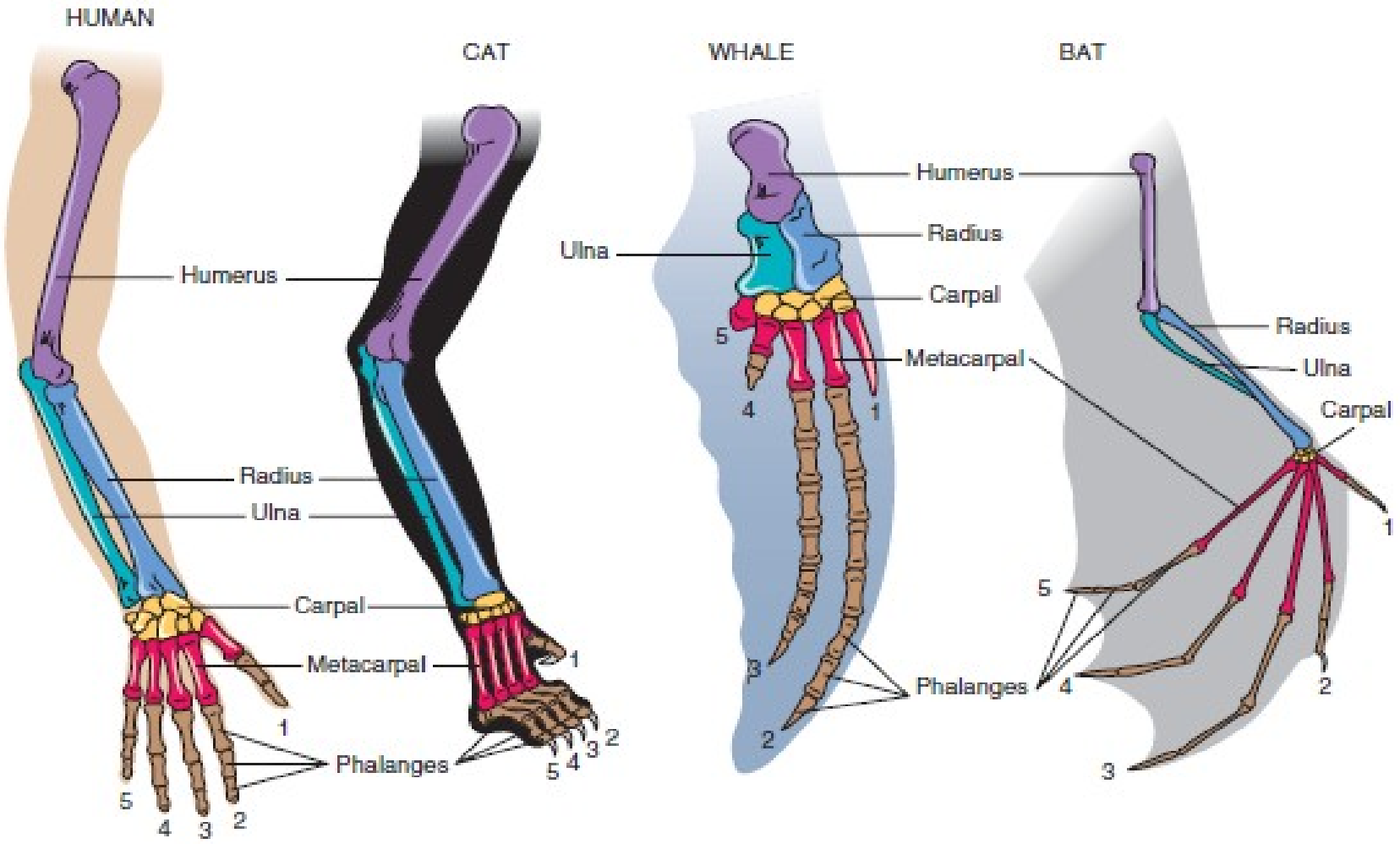

Figure 4.13 The homologous forelimbs of mammals.

Con’d

- Each possesses the same number of bones, arranged in almost the same way while they have different external features that function in different ways as:
  - arm for manipulation in humans
  - leg for running in cats
  - flipper for swimming in whales
  - wing for flying in bats

- By comparing the anatomy of these limbs, (**pentadactyl limb**) share a common ancestor

- **Pentadactyl limb** is a limb with five digits

Con'd

- Sometimes organisms have structures that function in very similar ways, morphologically and developmentally these structures are very different. (called analogous structures).
- Different structurally, but have the same function, that indicate the two species do not share a common ancestor.

- E.g the wings of a bat, bird and mosquito all serve the same function, yet their anatomies are very different.

- They are analogous structures that have evolved separately

- **Analogous structures** having the same function but different anatomy and different evolutionary origin.

For example, the bird wing has bones inside and is covered with feathers while the mosquito wing has neither of these.



Figure 4.14 Analogy in animals

4.1.3.2 Embryology

- **Comparative embryology** studies the development of embryos of vertebrates before they hatch or born.
- This development shows similarities which supports a common ancestry.
- For example early in development, all vertebrate embryos have gill slits and tails.
- However, the 'gill slits' are not gills; they connect the throat to the outside, but in many species they disappear later in the embryonic development.
- In fish and larval amphibians they contribute to the development of gills.
- The embryonic tail does not develop into a tail in all species.
- In humans, it is reduced during development to the coccyx, or tailbone.
- The similarity in the development of vertebrates also suggests a common ancestor.

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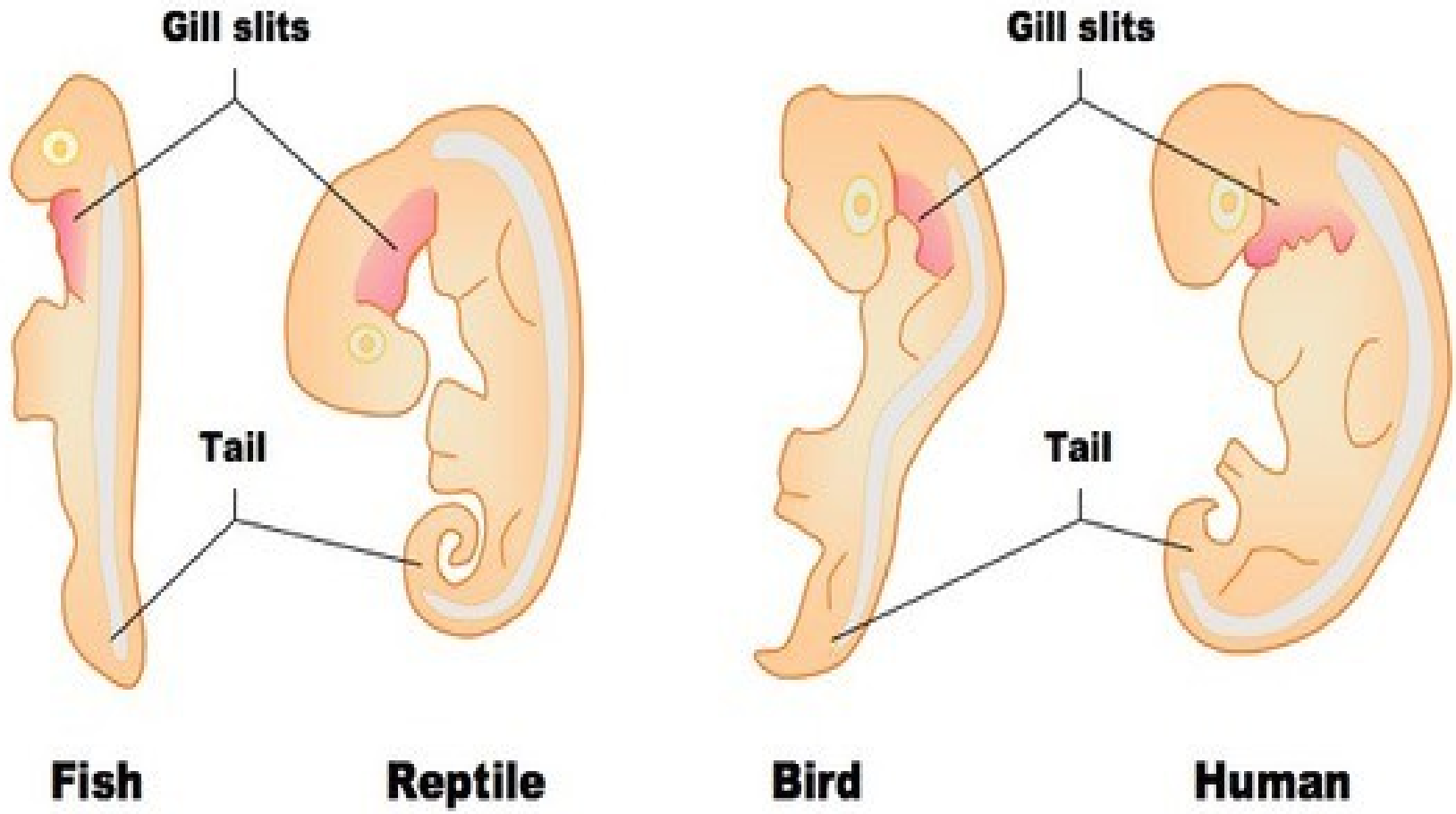


Figure 4.15 Similarities in development of embryos.

4.1.3.3 Palaeontology (Paleontology)

- **Palaeontology** ;- is the study of fossils (ancient life or past life).
- Fossils are formed when certain remains of organisms or plants get embedded in the soil or water and are preserved for many hundreds of years.

- They appear either as skeletal remains, footprints, moulds or intact structures as found in the snow.

- By studying fossils, we are able to establish similarities between the organisms in the present to its ancestor in the past.

- Fossils are very important evidence to prove the theory of evolution and common ancestry.

We can group fossils into two categories:

- **Category 1:** The remains of dead animals or plants or the imprint left from the remains, including:
  - bones
  - hair
  - teeth
  - the hardened shell of an ancient invertebrate
  - skin impressions
  - such as a trilobite or an ammonite
- an impression of an animal or plant, even if the actual parts are missing
- **Category 2**: Something that was made by the animal while it was living and that it has hardened into stone since then; these are called trace fossils and include:
  - footprints
  - burrows
  - coprolite (animal faeces)
- Type I fossils can be the actual organism or part of an organism, like a piece of bone or hair or feather as it actually was.

Con’d

- For example, this spider has been trapped, completely unchanged, inside the amber for millions of years.
- Amber is fossilised resin from trees.
- This spider probably became stuck inside the sticky resin and could not escape.
- As the amber became fossilised, the spider was protected from micro-organisms and the air which would have led to its decomposition.
- In many fossils like this, the soft parts of the body have been lost, but the exoskeleton is perfectly preserved. In some cases, however, the er



Figure A spider preserved in am

Dating Fossils

❖ ***How can we date fossils?***

- There are **2 method** of fossil dating (i.e **determine the age of fossil**)

1. **Stratigraphy (Relative dating);-** used to deduce the relative ages of fossil.

- Sedimentary rocks are laid down in layers (strata) which help to deduce how the organisms have changed over time.
- The **oldest strata** and the oldest fossils are found in **the lowest layers** and
- More **recent rocks** and fossils in the **layers above them nearest to the surface.**
- The thickness of each stratum is a measure of the time period during which that stratum was formed.
- **Stratigraphy** ;- analysing the sequence and thickness

- **Geological time period are divided in to ears and periods.**
  period are subdivision of eras.

eras	periods	Million years ago
Cenozoic era	Quaternary tertiary	65million years ago up to now
Mesozoic era	Cretaceous Jurassic Triassic	250-65 million years ago
Palaeozoic era	Permian Carboniferous Devonian Silurian Ordovician Cambrian	560-250 million years ago

2. Absolute (actual) dating or Radiometric dating

- Uses **radioactive elements** to determine the **actual age** of rocks or fossils.
- Some **minerals in rocks** and **organic matter** (Example: **wood, bones, and shells)** can contain **radioactive isotopes.**
- The abundances of parent and daughter isotopes in a sample can be measured and used to determine their age.
- **Radiometric decay;** unstable atomic molecules **loses energy** by **releasing radiation** to more stable state.
- Expressed in terms of **half life**
- **Half-life** :-**The amount of time it takes for half of the parent isotopes to decay into daughter isotopes**
- After **one half-life, only 50%** of the original radioisotope remains.
- During each succeeding half-life, half of the remaining radioisotope is converted to **decay product** (s).

How do scientists actually date the rocks?

- **scientists use one of two techniques:**
  - **Radiocarbon dating, or**
  - **Potassium–argon dating.**
- Both these techniques rely on the principle that radioactive atoms decay into other atoms over time.

I. Radiocarbon dating (C-14 dating)

- Radioactive carbon (C14) decay into non-radioactive nitrogen (N).
- **50% of the existing C-14** will decay after each successive half-life.
- The **half life of** C-14 is **5730 years**.
- After 5730 years, the amount of C-14 that remain in the fossil will be **50%**
- After a **second half-life(11460 years**), 50% of this will have decayed and **25% of the original** number will still be radioactive

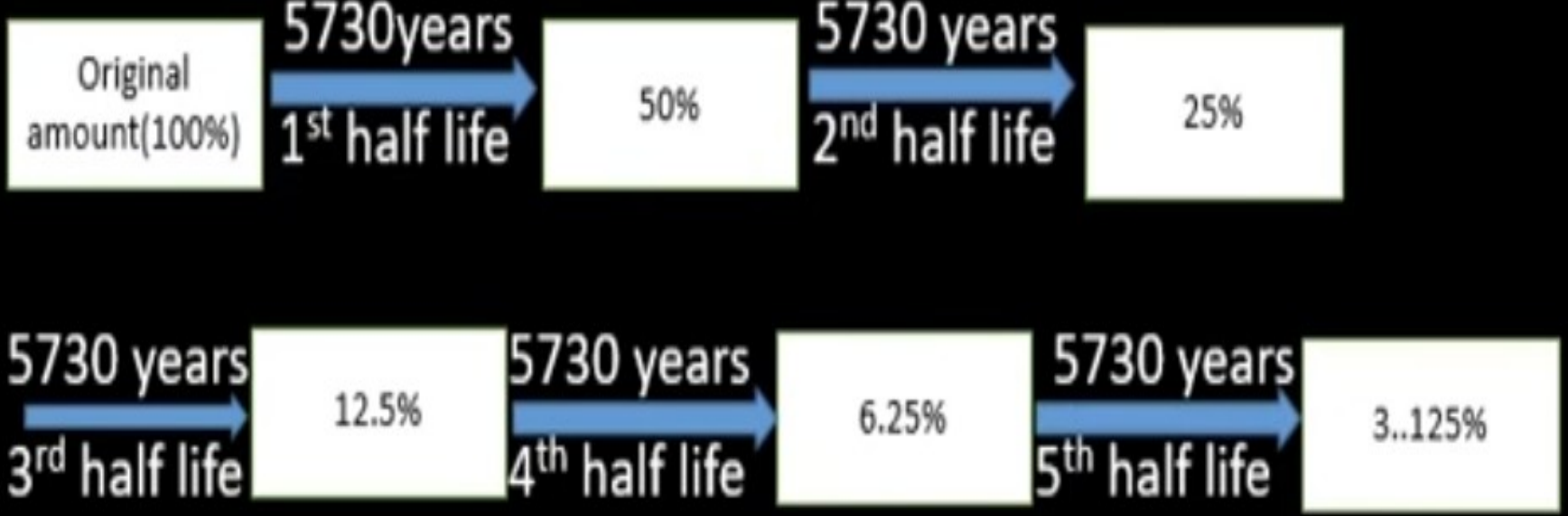
- **Radiocarbon dating is accurate** with fossils that are up to **only 60,000** years old.
- For **older fossils** and rocks a radiocarbon element **do not used**.

II. Potassium-Argon dating

- Radioactive potassium (K40) decay into argon atoms (A40).
- Its **half life is 1.3 million years**.
- This dating is suitable for fossils **older than 60,000 years** though it can not be used for younger ones.

Radiocarbon dating (C-14 dating)

✓The following shows the amount of C-14 that remain after each successive half –life starting from the original amount considered as 100%



CLASS WORK

Q1. What is the age of fossil containing 25% of the original carbon-14 atoms?

Q2. What percentage of the amount of carbon -14 originally present in a fossil what would be left after its second half-life?

❑ Comparative biochemistry

- ❖ Organisms that **share very similar molecules** and biochemical pathways are **closely related evolutionarily**.
- ➢ Chemicals that used in such analysis include **DNA, protein**.
- ➢ Species that are closely related are believed to have the **most similar DNA and proteins**;
- ➢ Those that are **distantly related** are assumed to **share fewer similarities**.
- ➢ **Protein ;- amino acid sequences** in different individual is compared. **Example: Cytochrome C , Haemoglobin**
- ➢ A **comparison of DNA** sequences shows that **98% of our DNA** is the same as **chimpanzees** which confirms that chimpanzees are the **closest relatives**

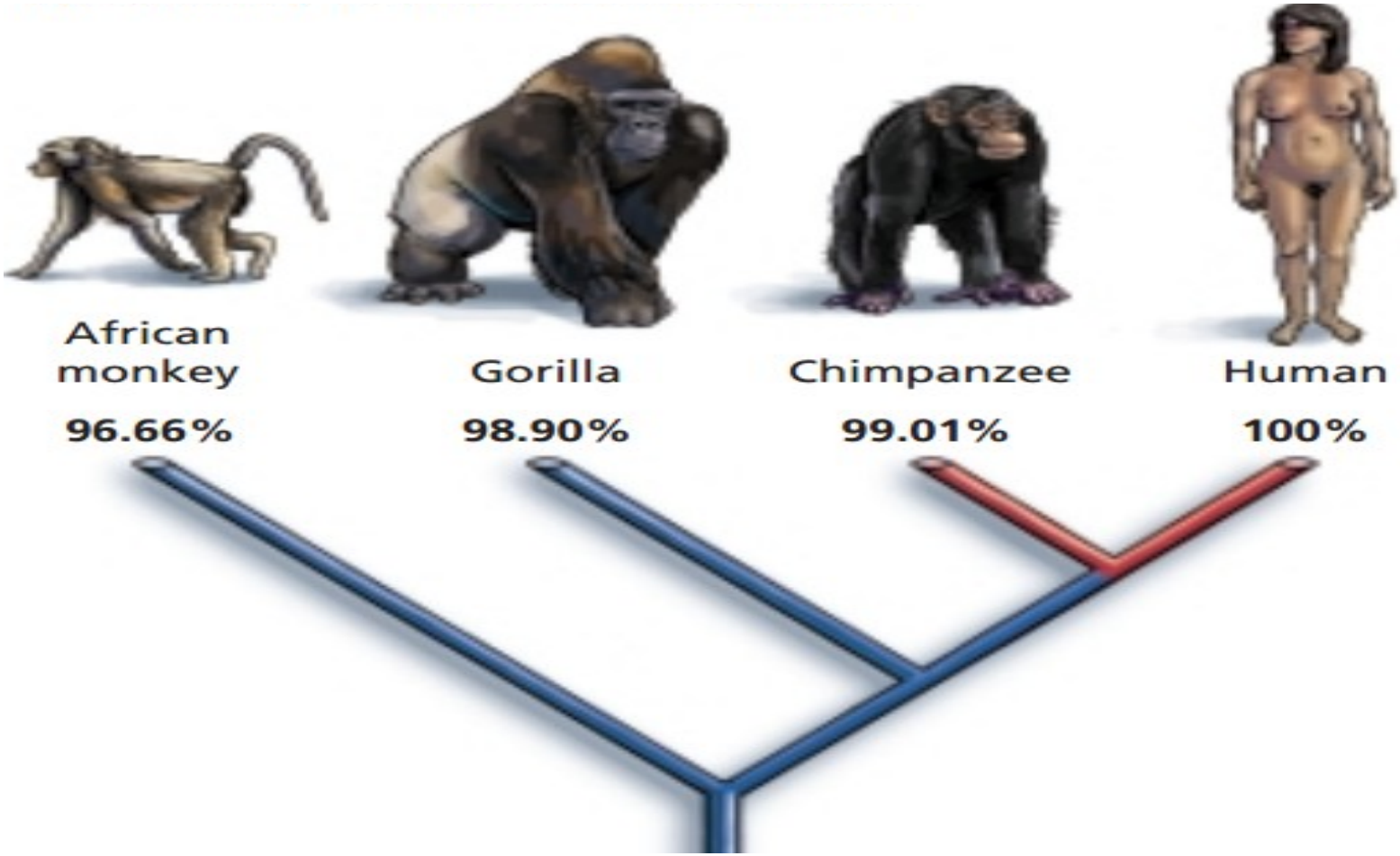


Figure A phylogenetic (evolutionary) tree of some animals based on differences in DNA

- **Hemoglobin** is the molecule found in **RBCs** that **carries oxygen**

- ✓ **Example**, the **haemoglobin of the lamprey** (a **primitive fish-like animal**) has **only one polypeptide chain**.
- ✓ Most animals have **haemoglobin with four chains**, but the **chains do vary**.
- ✓ **Example ;- Birds = 45 , dog = 32, frog = 67 , lamprey = 125 amino acids.**
- ✓ **Macaque is evolutionary more related to humans than the others, while, Lamprey is more distantly related to humans (diverge long ago)**

- **Haemoglobin cannot be used for plants and algae because they do not posses it.**

❖ Similarity and differences between the polypeptide chains of hemoglobin in four primate species (page 187)

Species	Alpha-hemoglobin (141 amino acids)	Polypeptides chains Beta-hemoglobin (146 amino acids)	Y-hemoglobin
Human	+	+	+
Chimpanzee	+	+	+
Gorilla	1	1	1
Gibbon	3	3	2

Natural selection: Definition, Types & Examples

- **Natural selection** is the 'driving force' behind evolution.
- It is the process that **brings about changes** (**over time)** in populations that can, eventually,
- lead to different populations of the same species to become different species.
- Those members of a species which **are best adapted to their environment** will **survive and reproduce in greater** numbers than others that are **less well adapted**.
- They will pass on their advantageous alleles to their offspring and, in successive generations, the frequency of these alleles will increase in their **gene pool.**

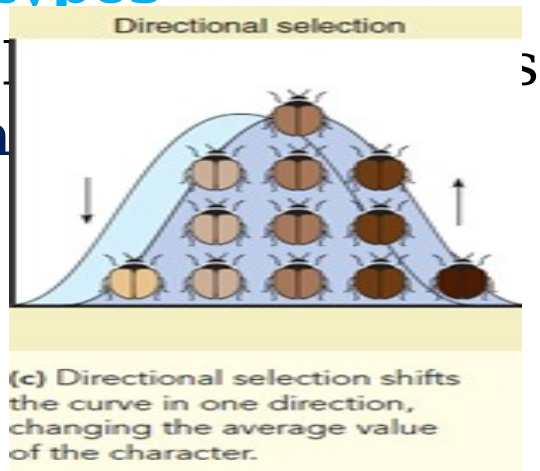
Species is a group of **similar organisms** with a **similar biochemistry**, **physiology and evolutionary history** that **can interbreed to produce fertile** offspring.

- **Example;-** **Mule** is a hybrid produced from **horses** and **donkeys**, so it **cannot be considered as a species**.
- Because **mule is sterile (not fertile)** **cannot produce its own offspring**

❖Types of natural selection

1. Directional selection;- favor **one of the extreme phenotypes**

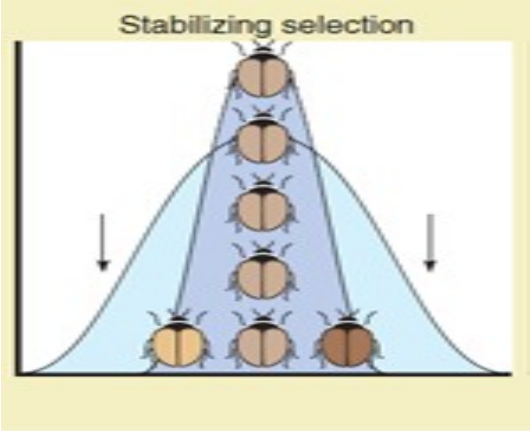
is a type of sel s in favor of **one extreme features of a**



(c) Directional selection shifts the curve in one direction, changing the average value of the character.

2. Stabilizing selection (Normalizing selection)

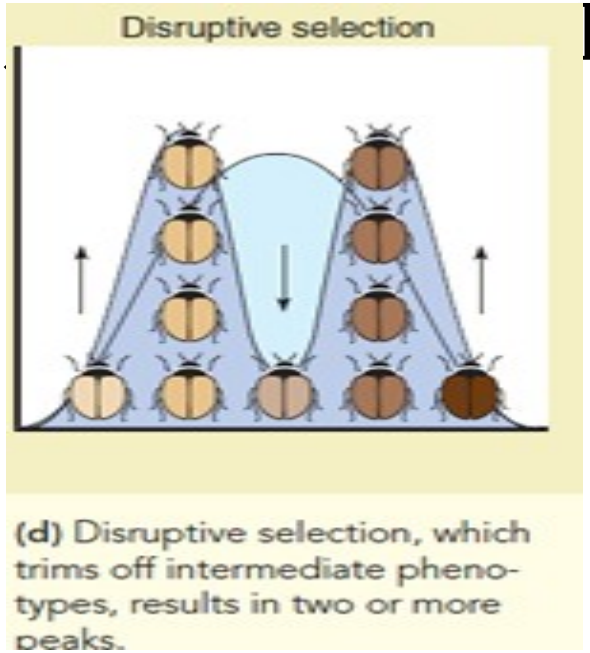
- Favors to the **intermediate (mean) phenotype**.
- Works is favors of **the mean feature and works against the extreme features**.
- It operate in a **stable environments**.
- In a stable environment, individuals at **both ends of the ranges** of values for a feature are the **least well adapted**.



(b) As a result of stabilizing selection, which trims off extreme phenotypes, variation about the mean is reduced.

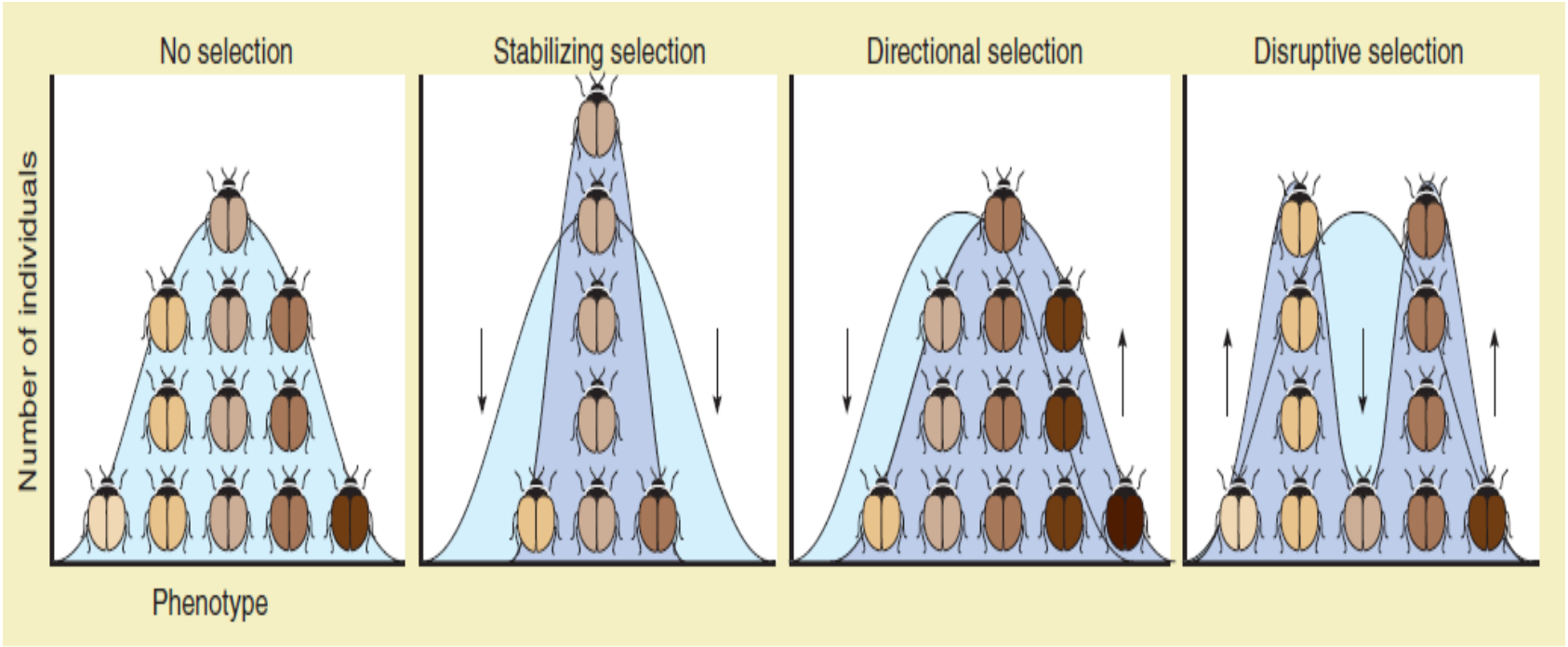
3. Disruptive Selection (diversifying)

- Works in favors of the extreme feature, away with the mean.
- Both extremes has some **advantages than mean** value.
- Example hes



(d) Disruptive selection, which trims off intermediate phenotypes, results in two or more peaks.

❖Types of natural selection



(a) A character that is under polygenic control (in this example, wing colors in a hypothetical population of beetles) exhibits a normal distribution of phenotypes in the absence of selection.

(b) As a result of stabilizing selection, which trims off extreme phenotypes, variation about the mean is reduced.

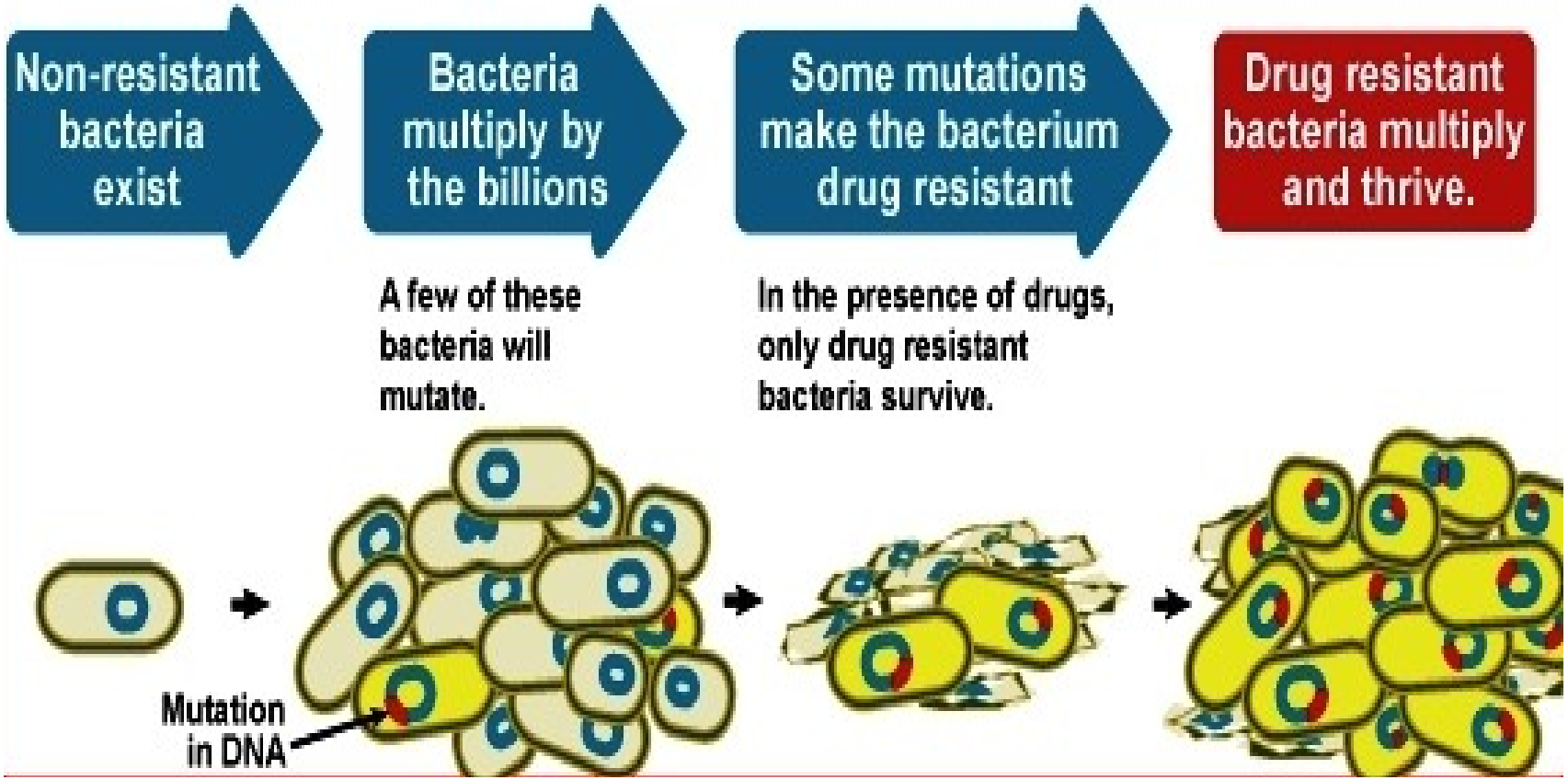
(c) Directional selection shifts the curve in one direction, changing the average value of the character.

(d) Disruptive selection, which trims off intermediate phenotypes, results in two or more peaks.

Figure 4.23 A summary of the different types of natural selection

- **Antibiotic resistance** – a modern example of natural selection in action
- The **spread of antibiotic resistance** in pathogenic bacteria is a simple and elegant example of evolutionary adaptation by natural selection.
- **Bacteria can become resistant to antibiotics** through mutations that **alter the cellular targets of antibiotics**.
- The acquisition of resistance is a very rare event; for example, resistance mutations usually occur in less than 1 in a million bacteria.
- However, **resistant bacteria** can **continue to grow and reproduce under antibiotic treatments** that effectively paralyse or kill their antibiotic susceptible neighbours.

Drug resistance in bacteria is often the result of a genetic mutation



- **Figure 4.24** Drug resistance in bacteria is often the result of a genetic mutation

❑ Pattern of evolution

- **Evolution over time can follow several different patterns**.
- **There are three main types of evolution**:

1. Divergent Evolution (adaptive radiation)

- ✓ The evolution from **one species of animals or plants of a number of different forms.**
- ✓ Often occurs when **closely related species diversify to new habitats**.
- ✓ On a large scale, **divergent evolution** is responsible for the creation of the current diversity of life on earth from the first living cells.
- ✓ On a smaller scale, it is responsible for the evolution of **humans and apes** from **a common primate ancestor**.

2. Convergent Evolution

- ✓ Takes place when **species of different ancestry begin to share analogous traits**.
- ✓ because of a **shared environment or other selection pressure**.
- ✓ Example: **whales and fish**
- ✓ have some **similar characteristics** since both had to evolve methods of **moving through the same medium: water.**

3. Parallel Evolution

- ➢ The development of related along **similar evolutionary passes due to strong selection pressures** acting on all of them in the same way.
- ➢ Occurs when **two species evolve independently** of each other, maintaining the **same level of similarity**.

Types of Speciation

❑ *What is a speciation?*

➢ ***Is*** the process by which new species are formed from population of a species. The process by which a new species evolve.

- **Natural selection** provides a mechanism by which new populations of a species can arise. The are two mechanism of speciation:

1. **Allotropic speciation (**geographical isolation)

- Occurs when a population from an existing species becomes geographically isolated and the isolated population develops into a new species

E.g a river , mountain and land mass

2. **Sympatric speciation (**disruptive selection)

- Is a process of formation of new species as a results reproductive isolation
- Occurs when a population from an existing species develops into a new species without becoming geographically isolated from other members of the original species.

Con’d

- As long as two populations are able to interbreed, they are unlikely to evolve into distinct species.
- Both allopatric and sympatric speciation involves isolating mechanisms that prevent different populations from interbreeding for a period of time.
- mutations that arise in one population cannot be passed to the other.
- genetic differences between the two populations increase.
- Eventually, the two populations will become so different that they will be unable to interbreed or they are ‘reproductively isolated’.
- Any interruption in courtship, fertilization, embryo formation, or offspring development can be a reproductive barrier.

Con’d

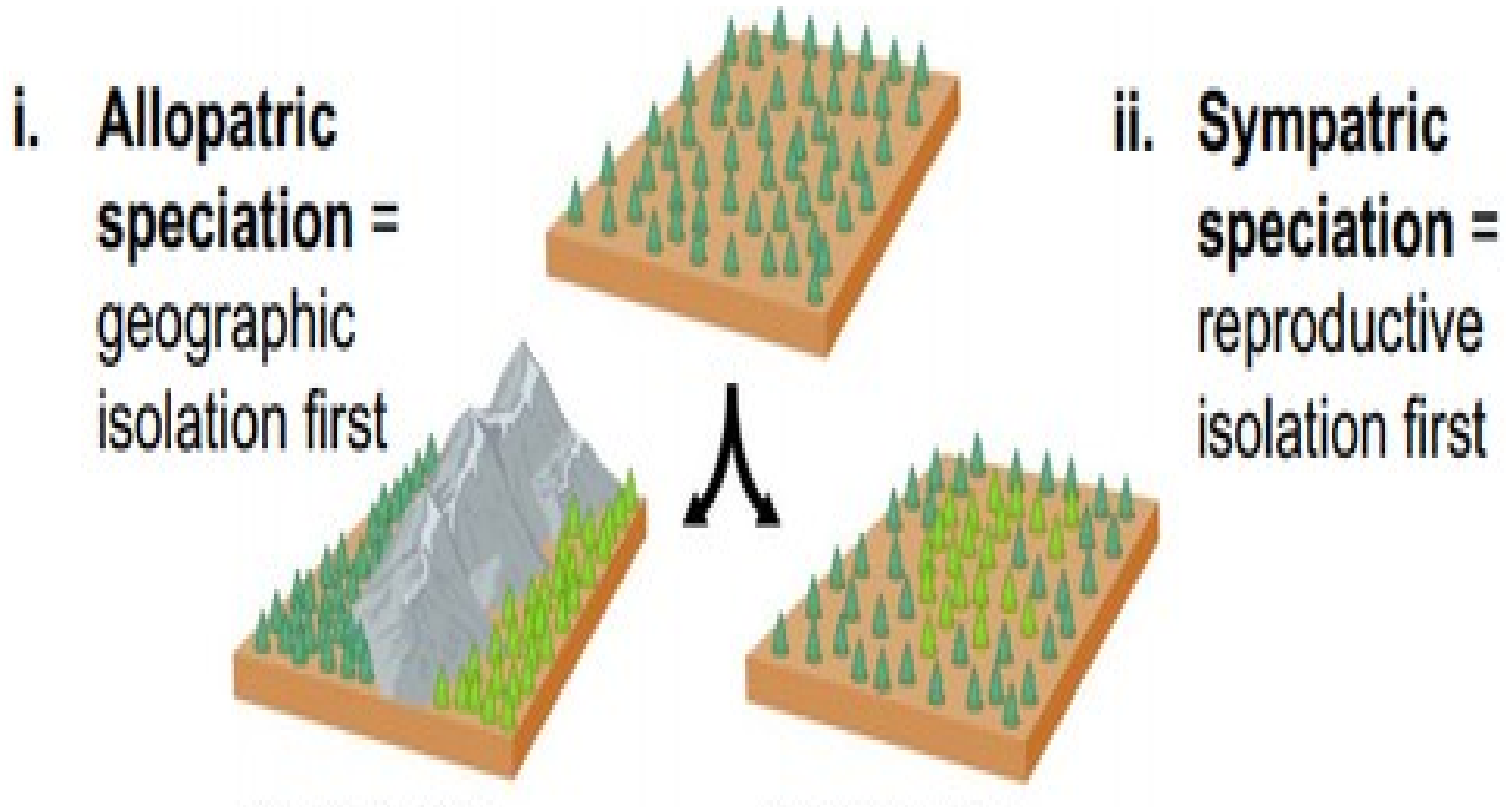


Figure 4.26. The difference between Allopatric and Sympatric speciation

Reproductive Isolation Mechanisms

I. prezygotic reproductive barriers

- act *before* fertilization to prevent individuals of different species or populations from mating,
- Prevent fertilization
- Affect the ability of two species to combine gametes and form a zygote.

1. Ecological (or habitat) isolation:

- Similar species reproduce in different habitats
- For example, one species of ladybird beetle eats one type of plant, while a closely related species eats a different plant.

- The different habitat preferences are the reproductive barrier that keeps the gene pools of the two species separate.

Con’d

2.Temporal isolation:

- Two species that share a habitat will not mate if they are active at different times of day or reach reproductive maturity at different times of year
- Similar species reproduce at different times

3. Behavioral isolation:

- Similar species have distinctive courtship behaviors
- The males of two species of tree frogs, for instance, use distinct calls to attract mates. Female frogs choose males of their own species based on the unique calls.
- sexual selection in many birds is based on intricate mating dances

Con’d

4. Mechanical isolation:

- In many animal species, male and female parts fit together almost like a key in a lock.
- Similar species have structural differences in their reproductive organs
- Any change in the shape of the gamete-delivering or –receiving structures may prevent groups from interbreeding.

5. Gametic isolation:

- Gametes of similar species are chemically incompatible
- If a sperm cannot fertilize an egg cell, then no reproduction will occur.
- In the absence of a “match,” fertilization will not occur, and the gene pools will remain separate.

II. postzygotic reproductive barriers

- act *after* fertilization to prevent the development of viable offspring, or to reduce the offsprings' fertility.
- Reduce viability or fertility of hybrid
- Sometimes called hybrid incompatibility.
- Postzygotic reproductive barriers include the following:

1. Hybrid inviability:

- Interspecific hybrid dies at early stage of embryonic development
- A hybrid embryo may die before reaching reproductive maturity, typically because the genes of its parents are incompatible.
- Since the hybrid offspring cannot reproduce, the gene pools of the parent species remain isolated from one another.

2. Hybrid infertility (sterility):

- Interspecific hybrid survives to adulthood but is unable to reproduce successfully
- Some hybrids are infertile.
- A familiar example is the mule, a hybrid offspring of a female horse and a male donkey.
- Mules are infertile because a horse’s egg has one more chromosome than a donkey’s sperm cell.
- The animal can grow and develop, but meiosis does not occur in the mule’s germ cells because the chromosomes are not homologous

3. Hybrid breakdown:

- Some species produce hybrid offspring that are fertile.
- Offspring of interspecific hybrid are unable to reproduce successfully
- When the hybrids reproduce, however, their offspring may have abnormalities that reduce their fitness.
- Some second-generation hybrid offspring of the mosquito species *Aedes aegypti* and *Aedes mascarensis*, for example, have abnormal genitalia that make mating difficult.
- The strong selective pressure against hybrid offspring limits gene flow between the two mosquito species.

What is polyploidy and why is it important in plant evolution?

- Poly- means many.
- **Polyploid** cells have many sets of chromosomes per cell
- Some human liver cells have 92 chromosomes per cell – they are **tetraploid** and have four sets of chromosomes per cell.
- **Polyploidy** occurs when an organism has more than two sets of homologous chromosomes
- **Tetraploid:** a tetraploid organism has four sets of homologous chromosomes
- Polyploidy has been important in plant evolution because it has allowed infertile hybrids to become fertile.
- When different species form hybrids, very often the hybrid cannot produce offspring because all the chromosomes cannot form bivalents (homologous pairs) in meiosis.
- So, they cannot form sex cells and cannot reproduce.
- If the chromosome number were to double, then all chromosomes would be able to form homologous pairs.
- Meiosis and sex-cell formation can take place and the hybrid is now fertile

4.1.5. Human evolution

- Who are we and where have we come from?
- There has been a ‘line of evolution’ for millions of years that has given rise to old world monkeys, new world monkeys, the great apes and the different species of humans that have lived.

- But, we are *Homo sapiens* and we are the latest of several humans to live on the planet.

- **Homo sapiens** is the species that all humans alive today belong to.
- We have two features in particular that distinguish us from other primates. These are:

  - A very large brain, and

  - Bipedalism – the ability to truly walk on just two legs.

Over the details, they all agreed about the idea – a line evolution that has branched to give the different groups of primates (including apes and humans) that exist today has existed in not too distant past.

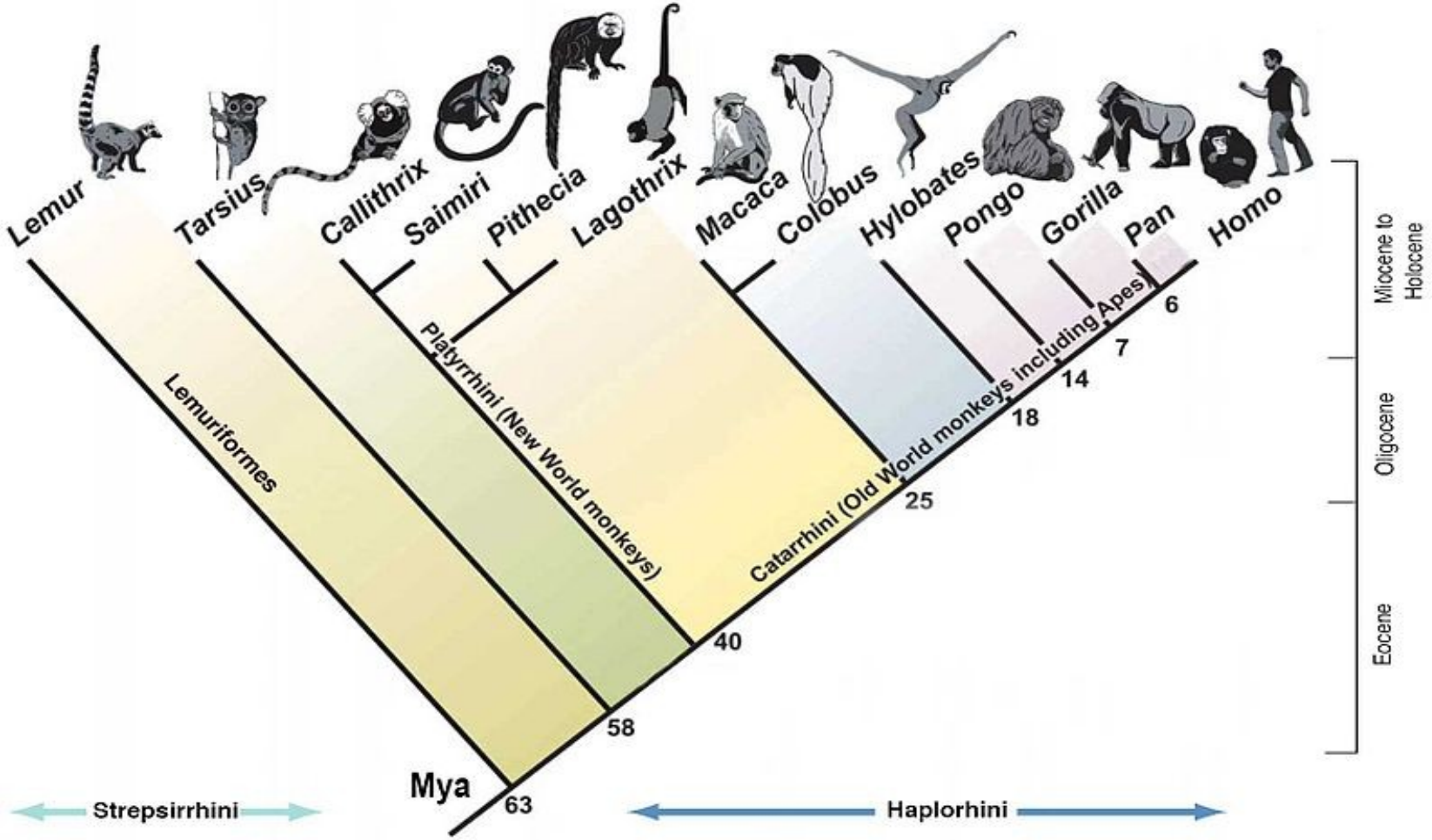


Figure 4.27 The evolutionary tree for modern primates

con;’d

- **Genus** (plural **genera**) a group of closely related species
- **Hominin** any member of the genus Homo. This includes modern humans (Homo sapiens), neanderthals and Homo erectus

- **Hominid** a group of species that includes all the species belonging to the genus Homo along with other species such as Ardipethecus ramidus and Australopithecus afarensis (Lucy).

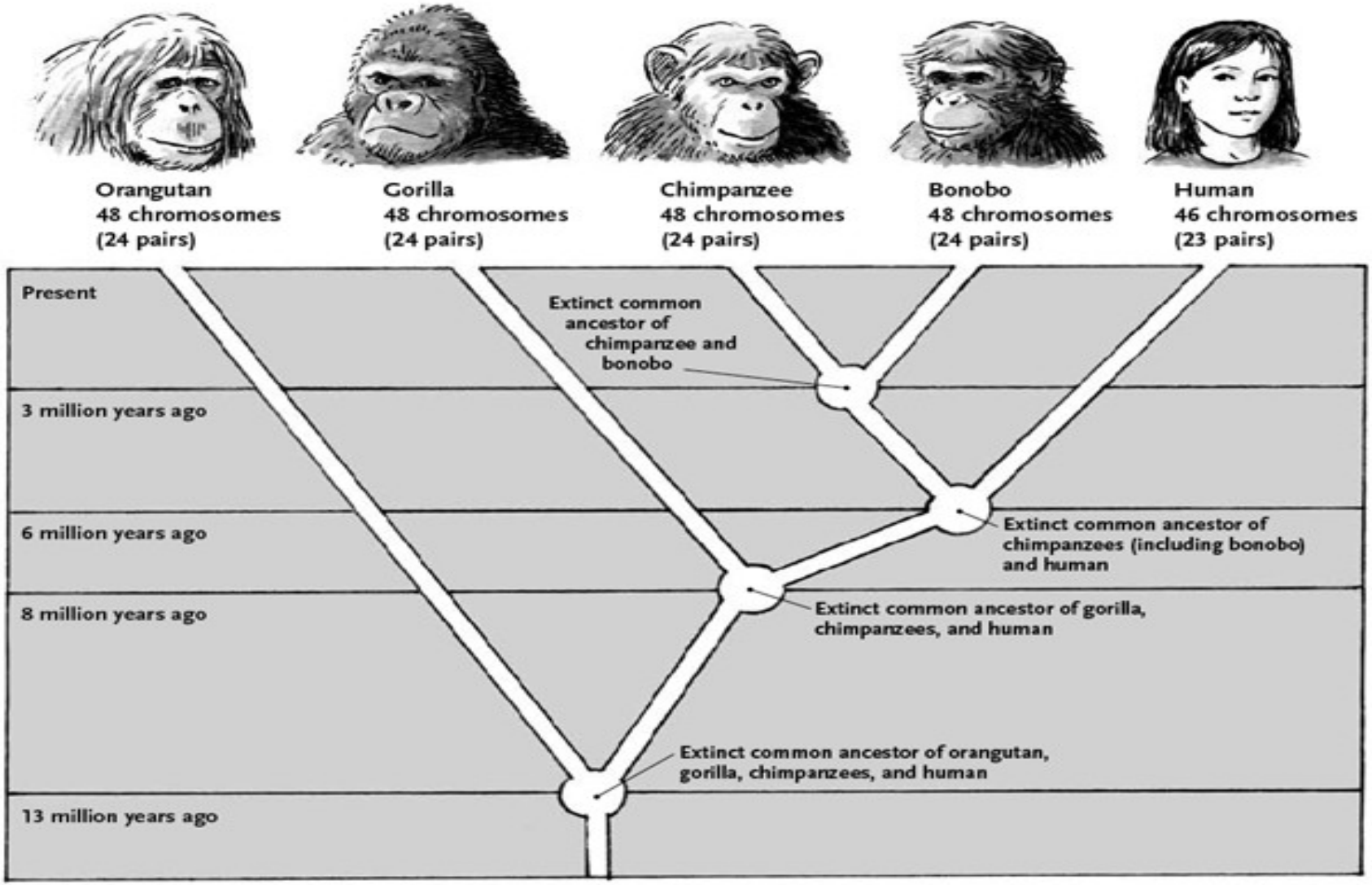
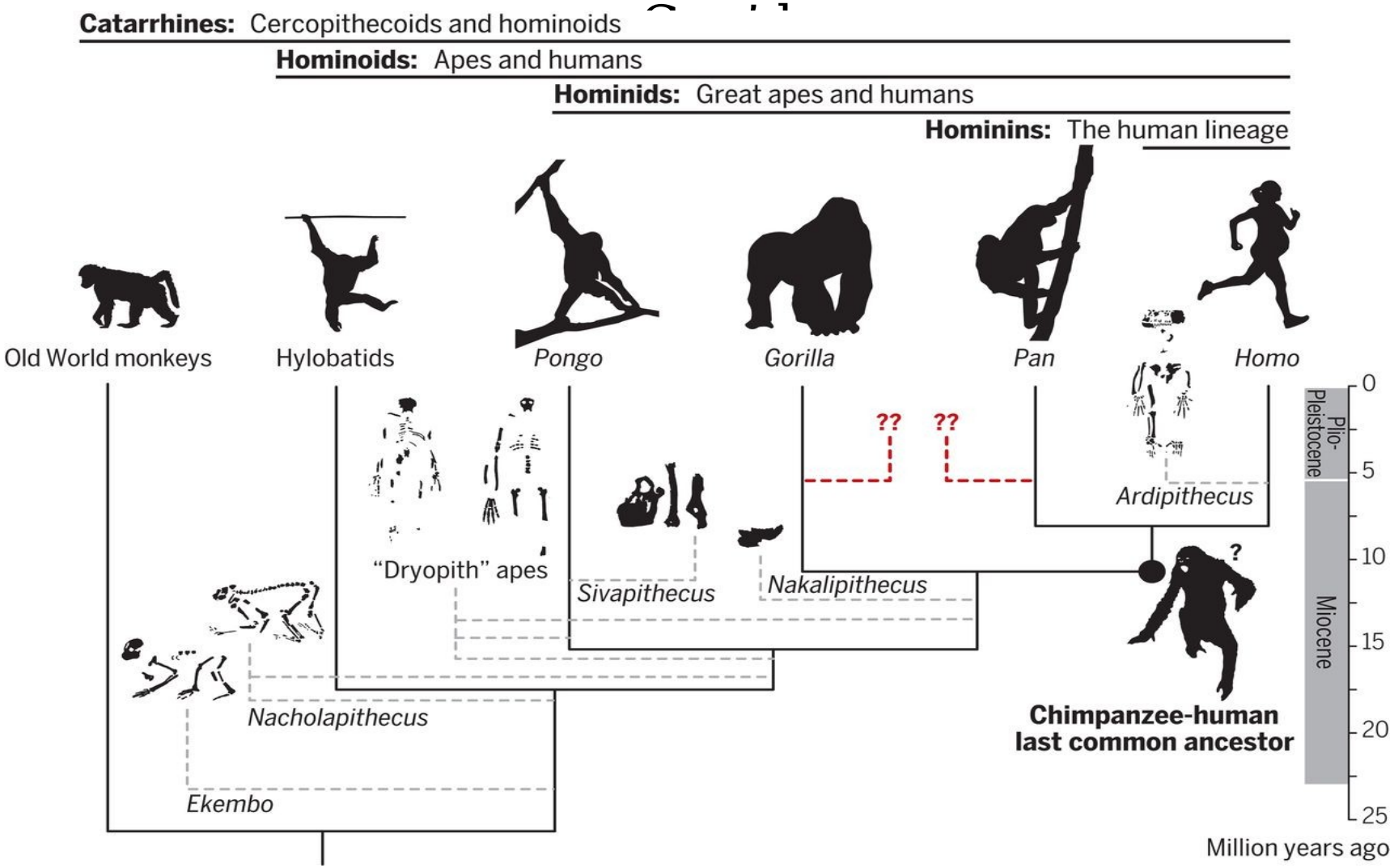


Figure 4.28 The evolutionary tree of humans and the great apes

Con’d

- Branching points in the evolutionary tree represent ancestors.
- For example, humans and chimpanzees both evolved from a common ancestor that lived about 6 million years ago.
- There were other humans before us and, before them, what we might call ‘pre-humans’.
- However, all humans belong to the **genus** *Homo*.



- **Figure 4.29** A timeline for the major hominin and hominid species

Lucy and Ardi

- Both Lucy and Ardi are important fossils in explaining the evolution of modern humans and chimpanzees from a common ancestor.

➢ **Lucy (Australopithecus afarensis)**

- was discovered by Donald Johanson and Tom Gray in 1974 at Hadar, Ethiopia.
- Lucy is a fossil dated at about 3.2 million years.
- She was an adult female of about 25 years and belonged to the species *Australopithecus afarensis*.
- Her skeleton was about 40% complete, an unusually high proportion for a fossil skeleton.
- Her pelvis, femur (the upper leg bone) and tibia show that she was bipedal (could walk upright on two legs).
- There is also evidence that Lucy was partly arboreal (tree-dwelling).
- She was about 107 cm (42″) tall and about 28 kg (62 lbs) in weight.

- At the time she was discovered, Lucy represented one of the oldest fossil hominins.
  The proportions of her humerus and femur were mid-way between those of modern humans and chimpanzees.

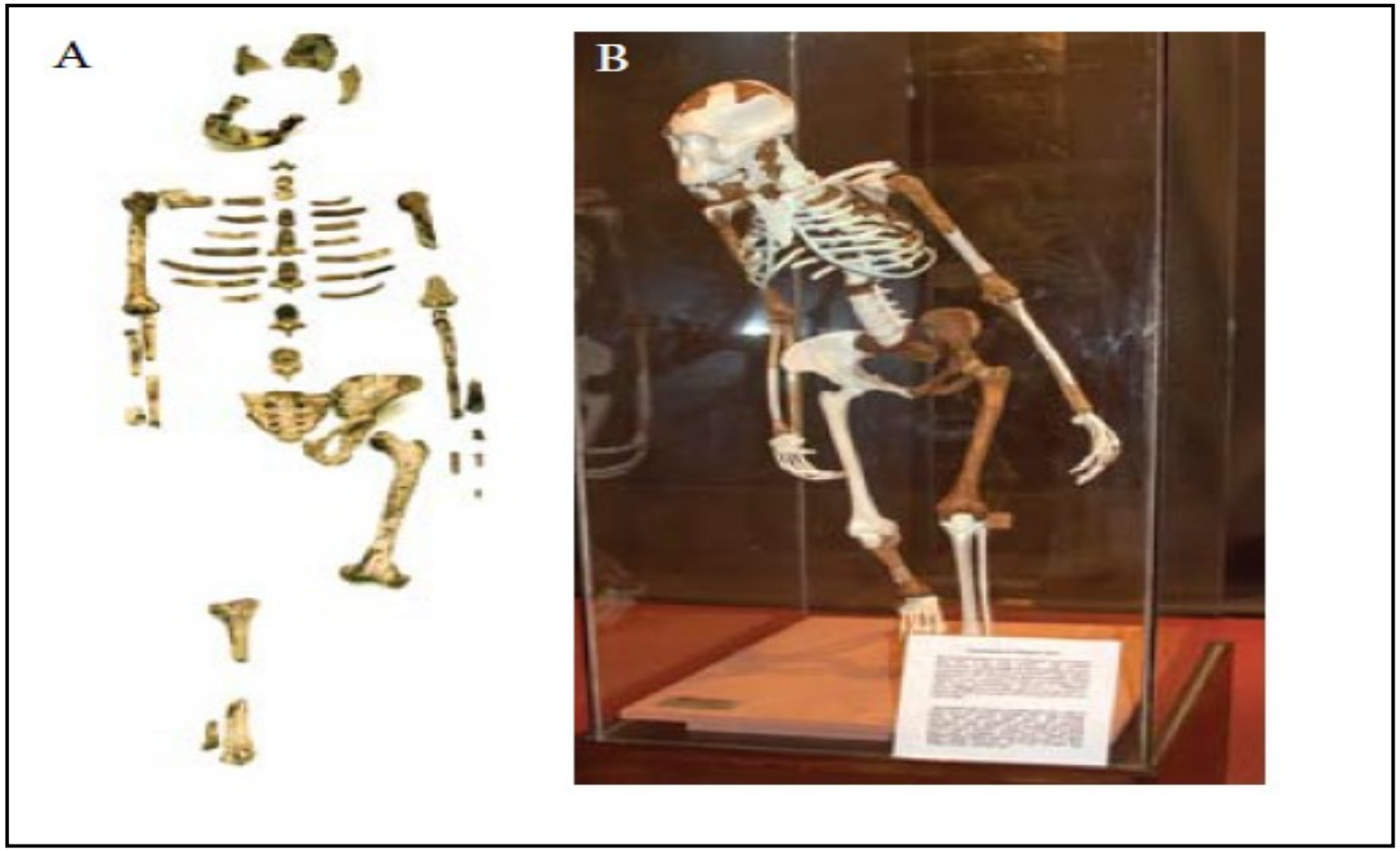


Figure 4.31 A – The original Lucy fossil; B – The Lucy display including reconstructed parts

Con’d

- Lucy had a brain about the same size as that of a chimpanzee,
- Bipedalism came before big brains.

2. Ardi (*Ardipithecus ramidus)*

- was first discovered in 1992, in the Afar dessert in Ethiopia, but it was only in 2009 after many years’ analysis,
- Ardi was 1.2 million years older than Lucy,
- was also female who belonged to the species *Ardipithecus ramidus*.
- Ardi was that she was also bipedal.
- At 4.4 million years old, Ardi is the nearest fossil to the ‘common ancestor’ of humans and chimpanzees that has so far been found.

➢ This finding finally proved that the common ancestor of humans and chimpanzees could not have resembled a chimpanzee, as chimpanzees are not truly bipedal.

However, there was signs of being adapted for both bipedal walking and arboreal life.



Figure 4.32 A relatively complete skeleton of *Ardipithecus*, which lived 4.4 million years ago.

B: *Ardipithecus* shows signs of being adapted for both bipedal walking and arboreal life

How brain size changed during human evolution?

- During the course of human evolution, the brain has got bigger.
- The brain has increased in size as a proportion of body mass.
- Species of *Australopithecus* have a brain that is between 0.7% and 1.0% of their body mass, whereas modern humans have a brain size between 1.8% and 2.3% of their body mass.
- The brain of *Homo sapiens* uses 25% of the resting energy requirement, compared with 8% in the great apes.
- A larger brain allows humans to:
  - run faster and in a more upright posture
  - plan in advance to avoid attack
  - develop and use tools and weapons

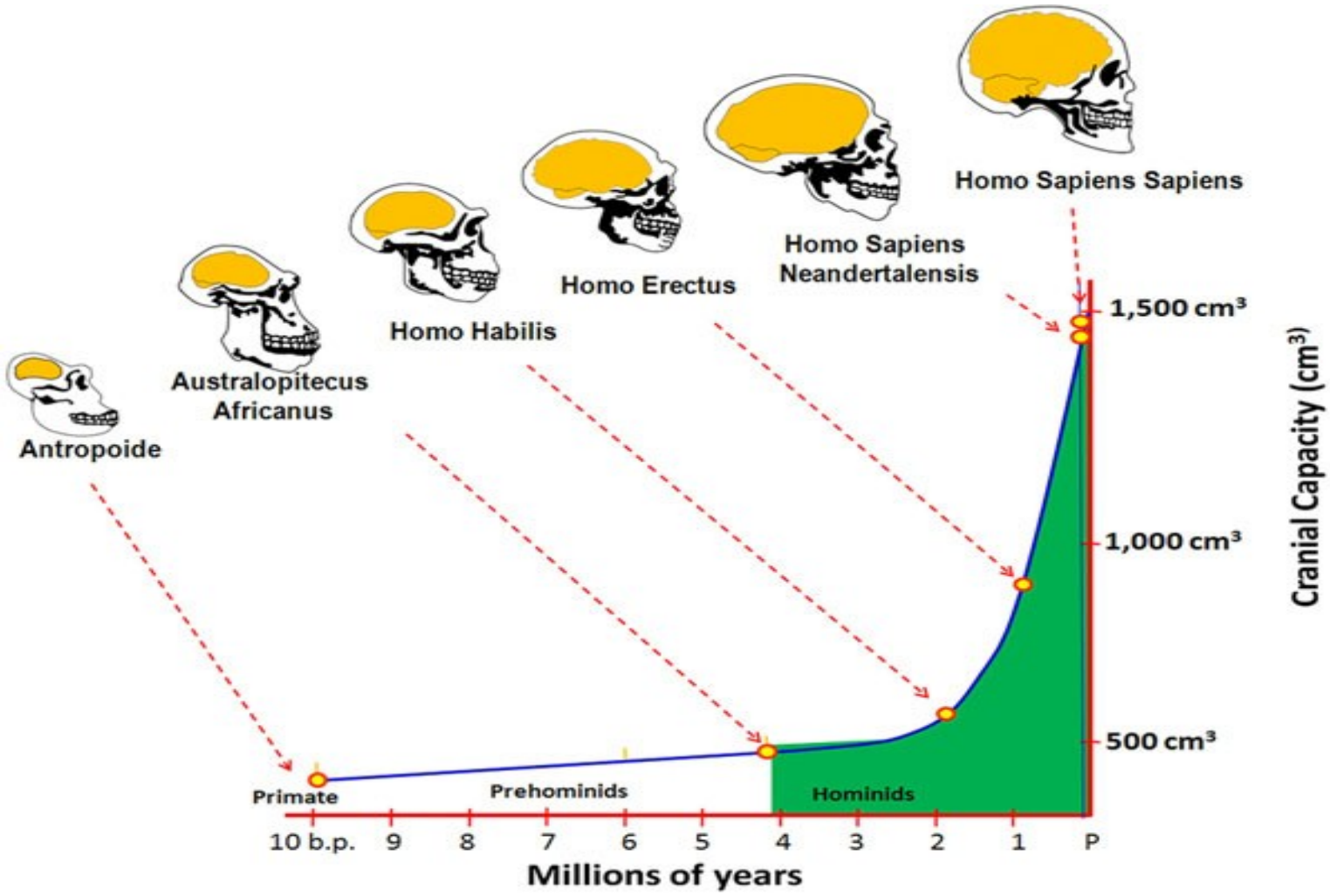


Figure 4.33 Brain size in different hominids

Are we still evolving?

- *Homo sapiens* (modern humans) first appeared in Africa and have since migrated to all other parts of the world.
- As humans moved from Africa into different areas of the world, they encountered different environments.
- For example, as humans encountered colder climates, body features that gave a survival advantage to conserve heat were selected for. These included:

✓ a shorter, squatter body shape; this reduces the surface-area-to-volume ratio and so reduces the rate of heat loss by radiation

✓ an increased layer of adipose tissue under the skin to act as insulator.

✓ increased hairiness; this reduces heat loss by convection

Human races

- Based on a recent genetic analysis there are three main races

1. **African** (Negroid), 100 million people from Africa and Melanesians of the South Pacific.
2. **Eurasian** (Caucasoid), 1000 million people with variable skin colours ranging from white to dark brown. Under Eurasian classification, three subdivisions exist:

A. **Nordic** – often tall, blonde and narrow-headed; includes people from Scandinavian and Baltic countries, Germany, France, Britain

B. **Mediterranean** – usually lighter in body build, dark and narrow-headed; such as;-France, Spain, Italy, Wales, Egypt, Jews, Arabs, Afghanistan, Pakistan, India.

C. **Alpine** – usually broad-headed, square jaws, olive skin, brown hair;

3. **East Asian** (Mongoloid), most numerous of the present-day populations and split into three groups:

– Eastern Siberians, Eskimos and the Northern American Indians

– Japanese, Koreans and Chinese

4.1.6. Mutation

- **Mutation** is a random change in genetic information
- A **mutation** can be caused by several factors but is divided into two parts.
- If the agent that caused the mutation cannot be identified then it is known as a **spontaneous mutation**.
- If the mutation can be identified then it is called an **induced mutation**.
- Cause of mutations are radiation, x-ray, ultra-violet radiation, nuclear radiation and certain chemical substances.
- These agents can also be called **mutagenic agents** or **mutagens**.
- There can be large structural changes involving the whole chromosomes or parts of chromosomes, or changes that involve only a single base.

Point (gene) mutation

- is a change in a single nucleotide in DNA.
- The different point mutations are:
  - substitution
  - addition
  - deletions
- occur quite randomly when the DNA is replicating and each involves a change to just one base
- usually less serious than a chromosomal alteration.
- Example;- a mutation that changes the codon **UUU** to the codon UCU.

Table 4.2 Description of point mutation

Type	Description	Example	Effect
Silent	mutated codon codes for the same amino acid	CAA (glutamine) → CAG (glutamine)	none
Missense	mutated codon codes for a different amino acid	CAA (glutamine) → CCA (proline)	variable
Nonsense	mutated codon is a premature stop codon	CAA (glutamine) → UAA (stop) usually	serious

- **Substitution**
- The triplet ATT (isoleucine) has been changed to ATG (methionine)

Con’d

- As a result, a different protein will be synthesised, which may or may not be significantly different from the original.
- One different amino acid in a protein does not always make a functional change.

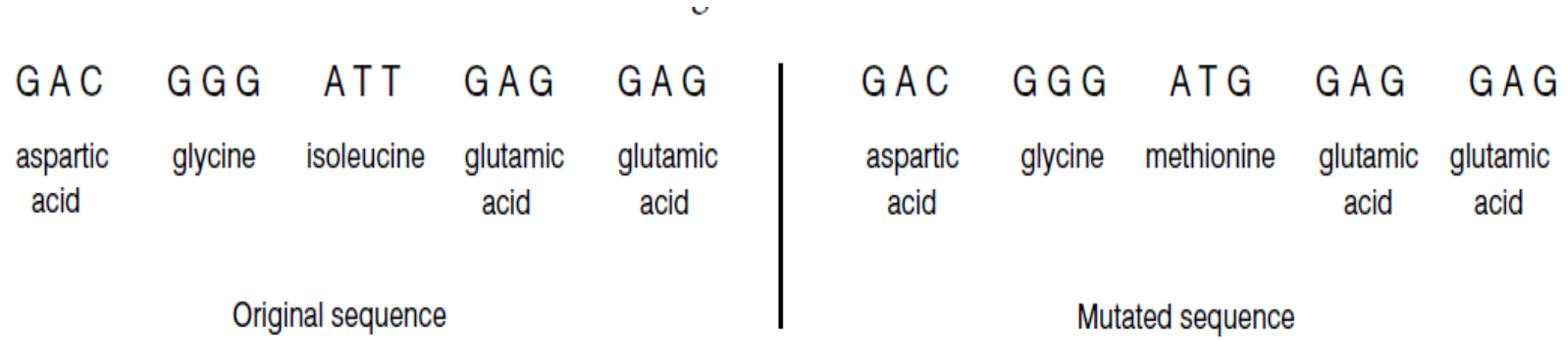


Figure 4.35 A substitution mutation

Con’d

- If a substitution of just one base in the sixth triplet of the gene coding for one of the four polypeptides in the haemoglobin molecule alters the triplet from GAG to GTG.
- This results in the amino acid valine replacing glutamate in the polypeptide chain. The different haemoglobin molecule formed results in the condition known as **sickle-cell anaemia**

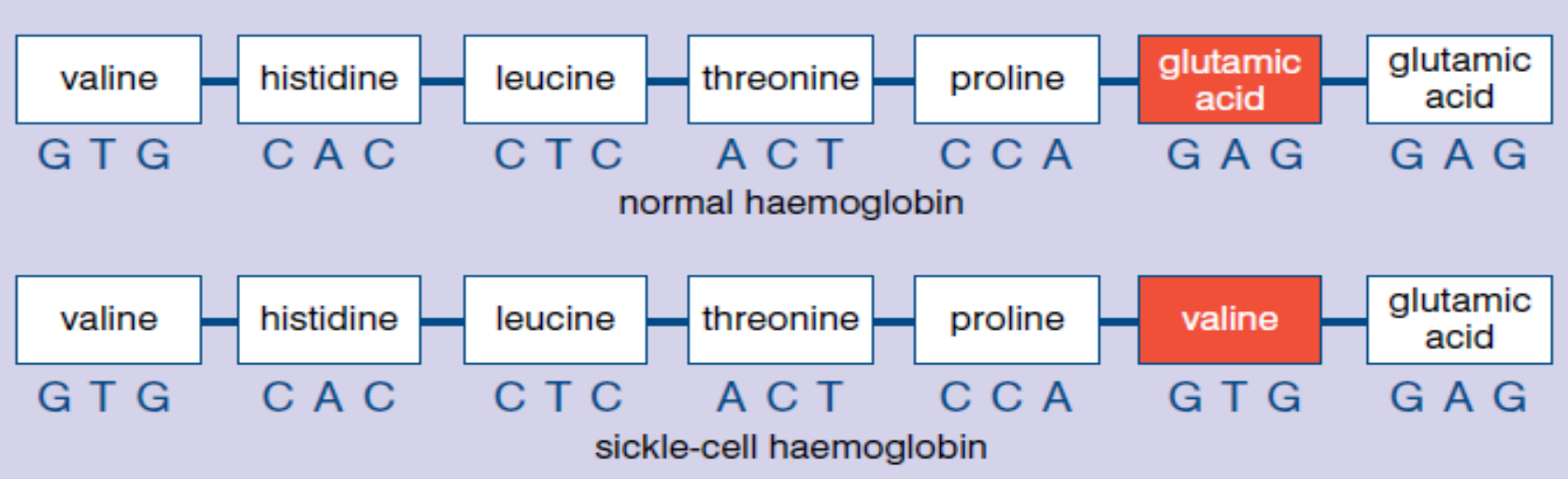


Figure 4.36 Sickle-cell anaemia

Addition and deletion

- **Deletion mutation,** a base is 'missed out' or omitted during replication, whereas in
- Additions, an extra base is added**.**

- Both deletion and additions are more significant mutations than substitutions.

- Because there is one fewer or one extra base, the whole sequence after the point of the mutation is altered.
- Occur frameshift mutations.

- A totally different mRNA is produced (if one is produced at all) and a non-functional protein or no protein at all.

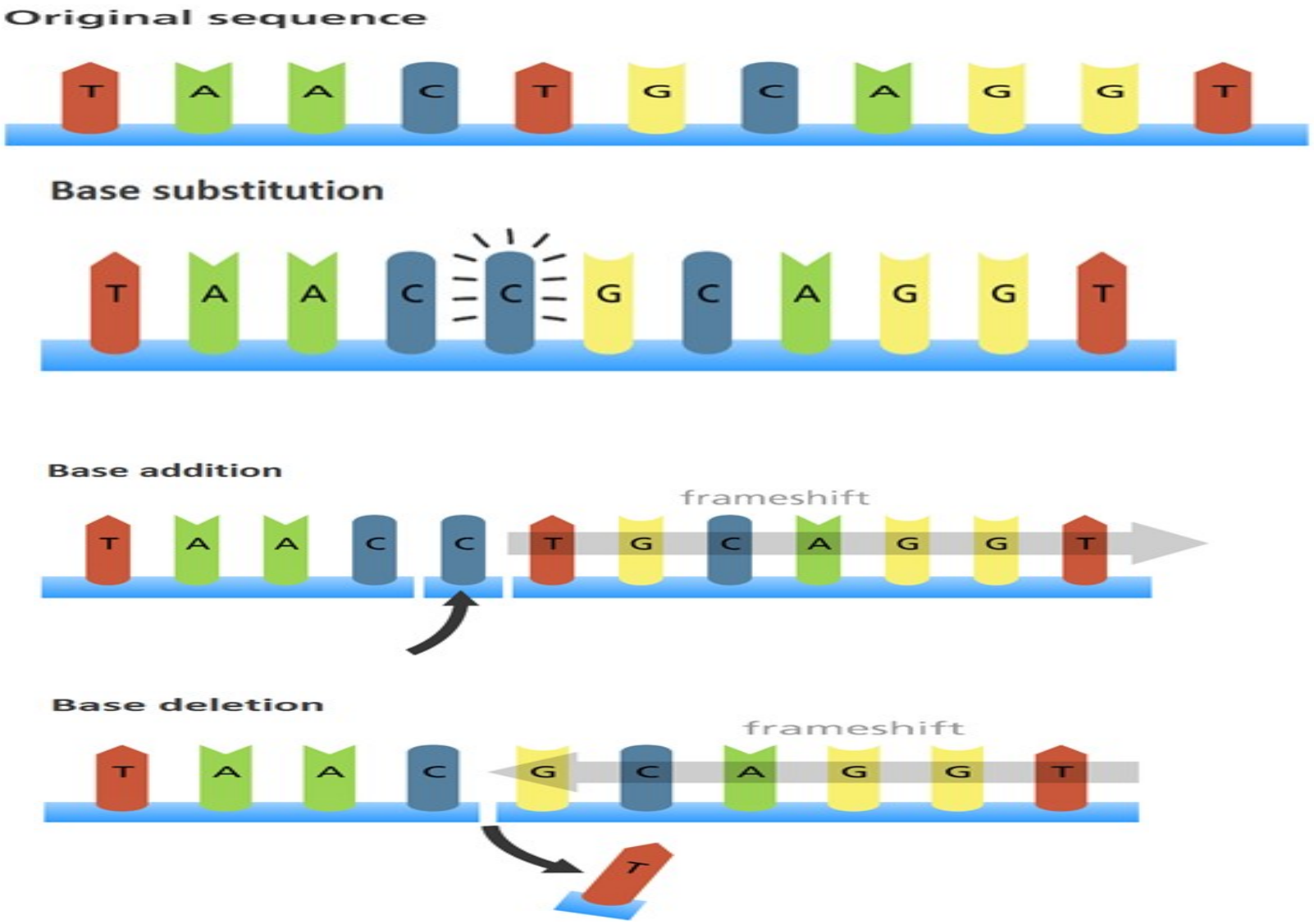


Figure 4.37 Types of point mutation

What are the causes of mutation?

- Mutations occur spontaneously and randomly.
- They are accidents that mistakenly occur when DNA is replicating.
- Mutations are rare events,
- Each cell contains 6 × 109 (six billion) base pairs that might mutate!
- Mutations arise at the rate of 1 in 50 × 106 (one in fifty million) base pairs.
- Each new cell will have, on average 120 mutations.

- This mistakes or mutation seem not worrying . Because :
  - most of these mistakes (mutations) are detected and repaired, and
  - 95% of our DNA is non-coding, so most mutations are unlikely to affect coding genes.

- The rate of mutation can be increased by a number of factors including
  - Carcinogenic chemicals, E.g. those in tobacco smoke
  - High-energy radiation, E.g. ultraviolet radiation, X-rays

What are the consequences of gene mutations?

- Mutations that occur in a normal body cell (a non-sex cell) will have one of the following four possible consequences:

  - It will be completely harmless.
  - It will damage the cell.
  - It will kill the cell.
  - It will make the cell cancerous, which might kill the person.

- these cases, mutation will not be passed on to the next generation.

- However, if the mutation occurs in a sex cell or a cell that will divide to give rise to a sex cell, then it may be passed on to the next generation.

2. Chromosomal mutation

- occurs when there is any change in the arrangement or structure of the chromosomes.
- occur most often during meiosis at crossing over in prophase I.

- Such as duplication, deletion, inversion and translocation.

- They are much bigger events than point mutations and usually result in the death of a cell.

- They may also affect the whole organism.

- For example, if essential parts of the DNA are affected by chromosomal mutations, a foetus may be aborted.

There are different types of chromosome mutations

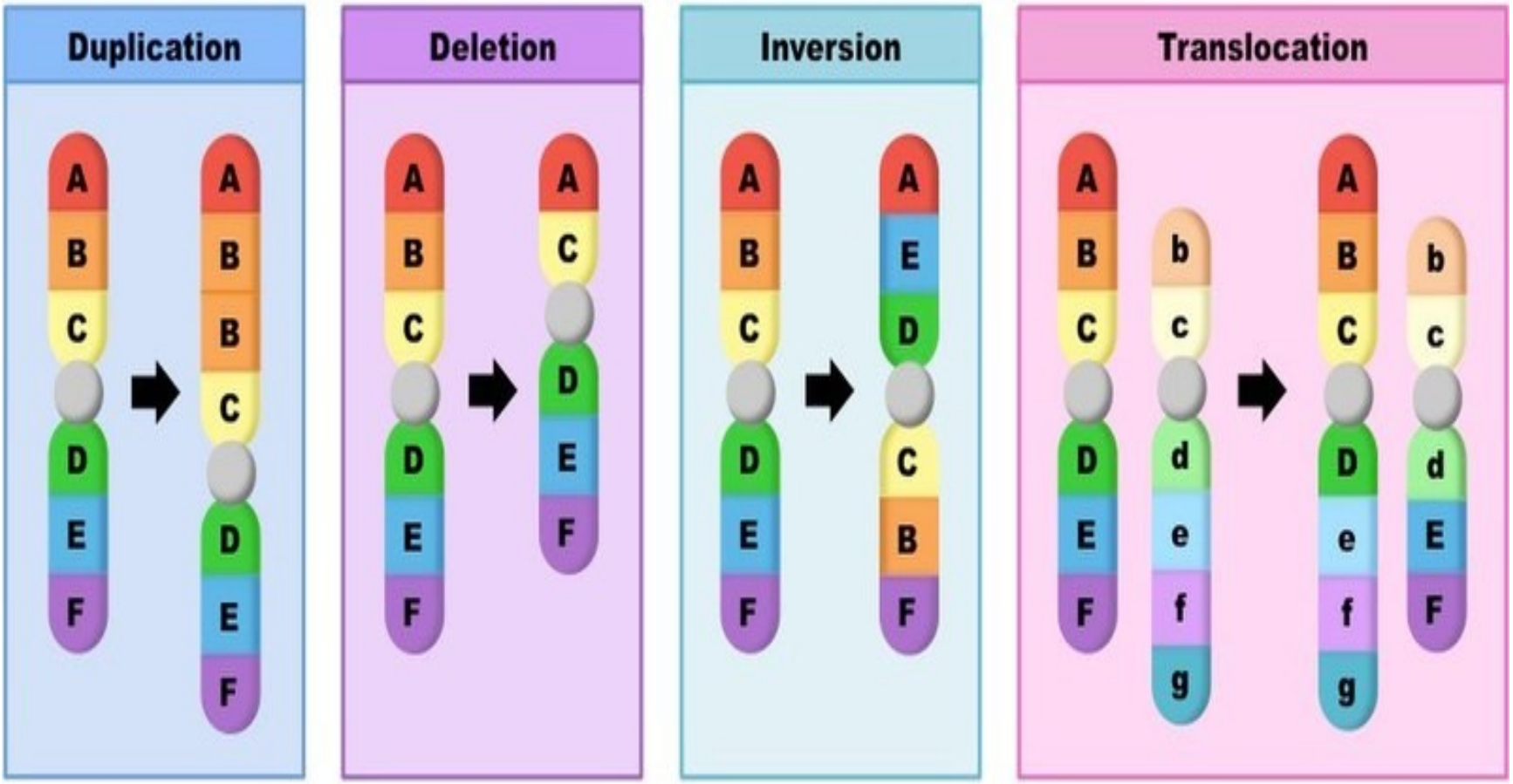


Figure 4.38. Types of Chromosomal mutations

Types of Chromosomal Mutations

A. Chromosomal Mutations I

- involve the processes of inversion, deletion, duplication/amplification or translocation

I . Inversion chromosomal mutation

- its segments are reversed from end to end.
- A piece of the chromosome is removed then reattached but in the opposite direction than it was originally.

II. Deletion

- occur when a piece of a chromosome accidentally gets removed or deleted.

III. Duplication/Amplifications

- an extra copy of a segment or the entire chromosome is present in the nucleus.

IV. Translocation chromosomal mutation

- This happens when a segment of a chromosome breaks off and then relocates to a completely different chromosome.
- **Reciprocal translocation** occurs when pieces of chromosomes “swap” places.
- **Robertsonian translocation** occurs when a segment of a chromosome is attached to another chromosome, causing an elongation of it.

- The translocation of chromosome 21 onto the 14th chromosome causes the common genetic mutation of **down syndrome**.

B. Chromosomal Mutations II

- consists of aneuploidy and polyploidy.
- The general category of these is called heteroploidy

***1.* Aneuploidy**

- This mutation either causes the loss or addition of a chromosome by the contortion of the chromosome set.
- **Non-disjunction** during meiosis or mitosis usually results in this mutation.

2. Polyploidy

- This mutation causes the creation of two sets of genomes within an organism.
- it can be observed in some plants.
- It usually causes effects like giantism and the reduction of fertility.

The Advantages of Chromosomal Mutations

- In some cases, chromosomal mutations can benefit the organism.
- Some mutations can help the organisms to survive better than others.
- Lactose tolerance became an advantage to have over others when numerous populations depended on cows and goats as sources of food.
- Some of these can cause numerous problems within animals, plants, and humans.

➢ **Genetic Disorder**

- is a disease caused by a mutation in one or a few genes. A human example is cystic fibrosis
- These are specific disorders or disabilities caused by mutations within the organism's DNA.

A chromosomal disorders list can be seen below:

- Trisomy 21: Down Syndrome
- Trisomy 18
- Trisomy 13
- Klinefelter Syndrome (xxy)
- XYY Syndrome
- Turner Syndrome (x0)
- Triple X Syndrome (xxx)

4.1.7. Genetic Drift

- What is genetic drift?
- **Genetic drift** is a mechanism of evolution in which allele frequencies of a population change over generations due to chance events.
- Genetic drift is change due to "sampling error" in selecting the alleles for the next generation from the gene pool of the current generation.
- genetic drift;- Allele frequencies can change due to chance alone.
- Drift is a binomial sampling error of the gene pool.
- the alleles that form the next generation's gene pool are a sample of the alleles from the current generation.
- Alleles can increase or decrease in frequency due to drift.
- The average expected change in allele frequency is zero since increasing or decreasing in frequency is equally probable.
- The variance in the rate of change of allele frequencies is greater in small populations than in large populations.

Hardy–Weinberg Equilibrium

- At Hardy–Weinberg Equilibrium, Allele Frequencies Do Not Change.
- Each genotype's frequency is the number of individuals with that genotype, divided by the total size of the population.

- For example, if 64 of the 100 individuals in a population are homozygous recessive, then the frequency of that genotype is 64/100, or 0.64

- Hardy–Weinberg equilibrium is the highly unlikely situation in which allele frequencies and genotype frequencies do not change from one generation to the next.

It occurs only in populations that meet the following assumptions:

(1) Natural selection does not occur;

(2) Mutations do not occur, so no new alleles arise;

(3) The population is infinitely large, or at least large enough to eliminate random changes in allele frequencies;

4) Individuals mate at random; and

(5) Individuals do not migrate into or out of the population.

- Hardy–Weinberg equilibrium is named after mathematician
- Godfrey H. Hardy and physician Wilhelm Weinberg.
- They independently developed two simple equations that represent the relationship between allele frequencies and genotype frequencies.
- assuming that a gene has two possible alleles, with frequencies **p** and **q**.
- The first equation represents the frequencies of both alleles in the population:

$$p + q = 1$$

Con’d

- The two frequencies add up to 1 because the two alleles represent all the possibilities in the population.
- For example, the frequency of the dark fur allele (D) is 0.6; the frequency of the alternative allele d, which confers tan fur, is 0.4.
- (Tally the D and d alleles in the picture of the ferrets to verify these numbers.)
- At Hardy–Weinberg equilibrium, we can use allele frequencies to calculate genotype frequencies, according to the second equation
    - **p2 + 2pq + q2 = 1**
- In the proportion of the population with genotype DD equals p2 (0.36 for our ferrets) and the proportion with genotype dd equals q2 (0.16).
- To calculate the frequency of the heterozygous class, multiply pq by 2 (0.48).
- Since the homozygotes and the heterozygotes account for all possible genotypes, the sum of their frequencies must add up to 1.

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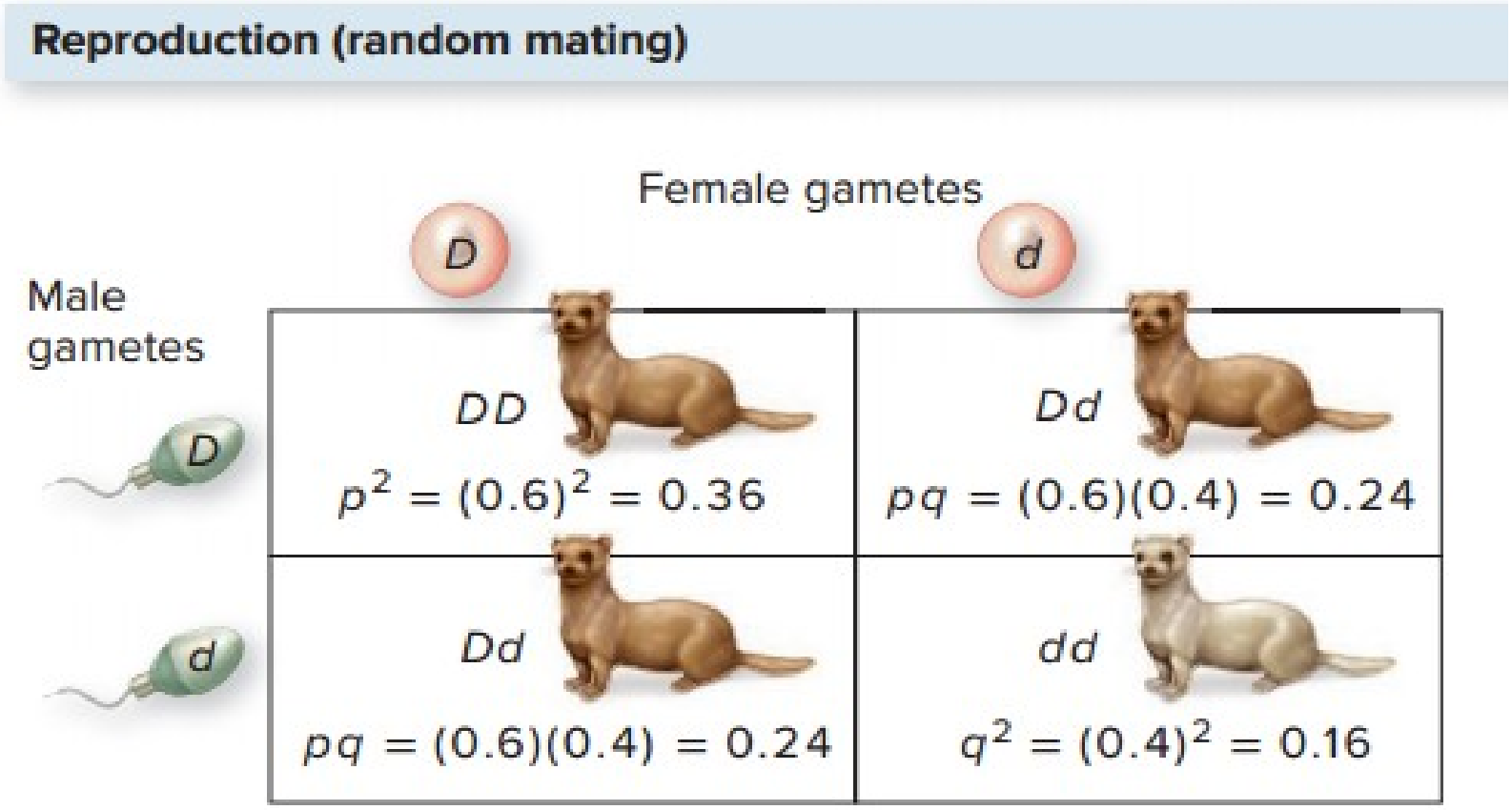
Allele frequencies: $p + q = 1$

Definition/equation	Example
p = frequency of dominant allele	p = frequency of *D* (dark fur) = 0.6
q = frequency of recessive allele	q = frequency of *d* (tan fur) = 0.4
$p + q = 1$	$0.6 + 0.4 = 1$

Genotype frequencies: $p^2 + 2pq + q^2 = 1$

Definition/equation	Example
p^2 = frequency of *DD* genotype	$0.6 \times 0.6 = 0.36$
$2pq$ = frequency of *Dd* genotype	$2 \times 0.6 \times 0.4 = 0.48$
q^2 = frequency of *dd* genotype	$0.4 \times 0.4 = 0.16$
$p^2 + 2pq + q^2 = 1$	$(0.6)^2 + (2 \times 0.6 \times 0.4) + (0.4)^2 = 1$



- Hardy–Weinberg Equilibrium. At Hardy–Weinberg equilibrium, allele frequencies remain constant from one generation to the next; evolution does not occur.”

Table 4.3 Conditions for Hardy-Weinberg Equilibrium

Condition	Consequence if Condition Does Not Hold
1. No mutations	The gene pool is modified if mutations occur or if entire genes are deleted or duplicated.
2. Random mating	If individuals mate within a subset of the population, such as near neighbors or close relatives (inbreeding), random mixing of gametes does not occur and genotype frequencies change.
3. No natural selection	Allele frequencies change when individuals with different genotypes show consistent differences in their survival or reproductive success.
4. Extremely large population size	In small populations, allele frequencies fluctuate by chance over time (a process called genetic drift).
5. No gene flow	By moving alleles into or out of populations, gene flow can alter allele frequencies.

The genetic bottleneck effect

- The **bottleneck effect** is an extreme example of genetic drift that happens when the size of a population is severely reduced.

- Events like natural disasters (earthquakes, floods, fires) can decimate a population, killing most individuals and leaving behind a small, random assortment of survivors.
- The smaller population will also be more susceptible to the effects of genetic drift for generations (until its numbers return to normal), potentially causing even more alleles to be lost.
- Imagine a bottle filled with marbles, which, represent individuals in a population.
- If a bottleneck event occurs, a small, random assortment of individuals survive the event and pass through the bottleneck (and into the cup), while the vast majority of the population is killed off (remains in the bottle).

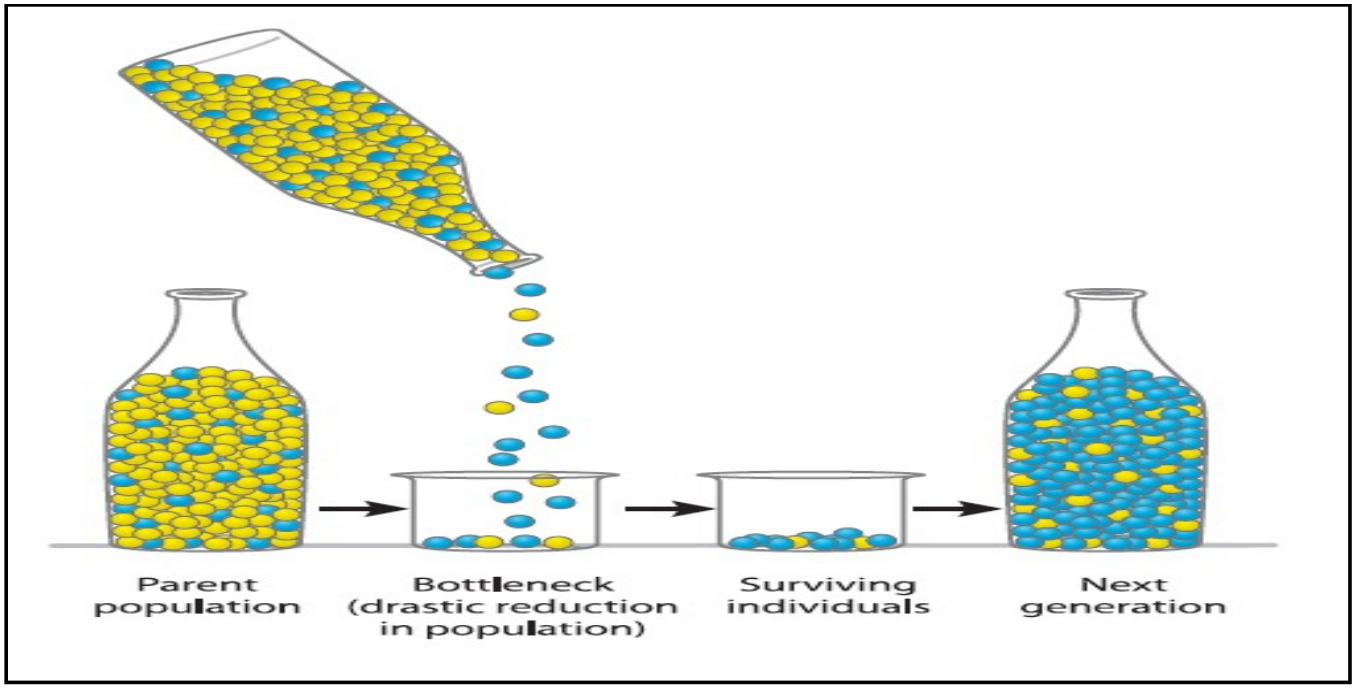


Figure 4.40. Bottleneck effect eliminates genes from a population

- The genetic composition of the random survivors (Figure 4.40) is now the genetic composition of the entire population.
- A population bottleneck yields a limited and random assortment of individuals.
- This small population will now be under the influence of genetic drift for several generations.

The founder effect

- The **founder effect** is another extreme example of genetic drift that occurs when a small group of individuals breaks off from a larger population to establish a colony.
- The new colony is isolated from the original population, and the founding individuals may not represent the full genetic diversity of the original population.
- That is, alleles in the founding population may be present at different frequencies than in the original population, and some alleles may be missing altogether.
- The small size of the new colonies means that they will experience strong genetic drift for generations.
- The founder effect is occur due colonization.

4.1.8. Gene flow (immigration and emigration)

- **Gene flow** *is (*also called migration)
- any movement of individuals, and/or the genetic material they carry, from one population to another
- **Migration**: The permanent movement of genes into or out of a population, causing a change in allele frequency
- Gene flow includes lots of different kinds of events, such as pollen being blown to a new destination or people moving to new cities or countries.
- gene flow can be a very important source of genetic variation.

- ✓ **Immigration** is when new organisms join a population, changing allele frequencies.
- ✓ **Emigration** is when members of a population leave, taking with them their genes.

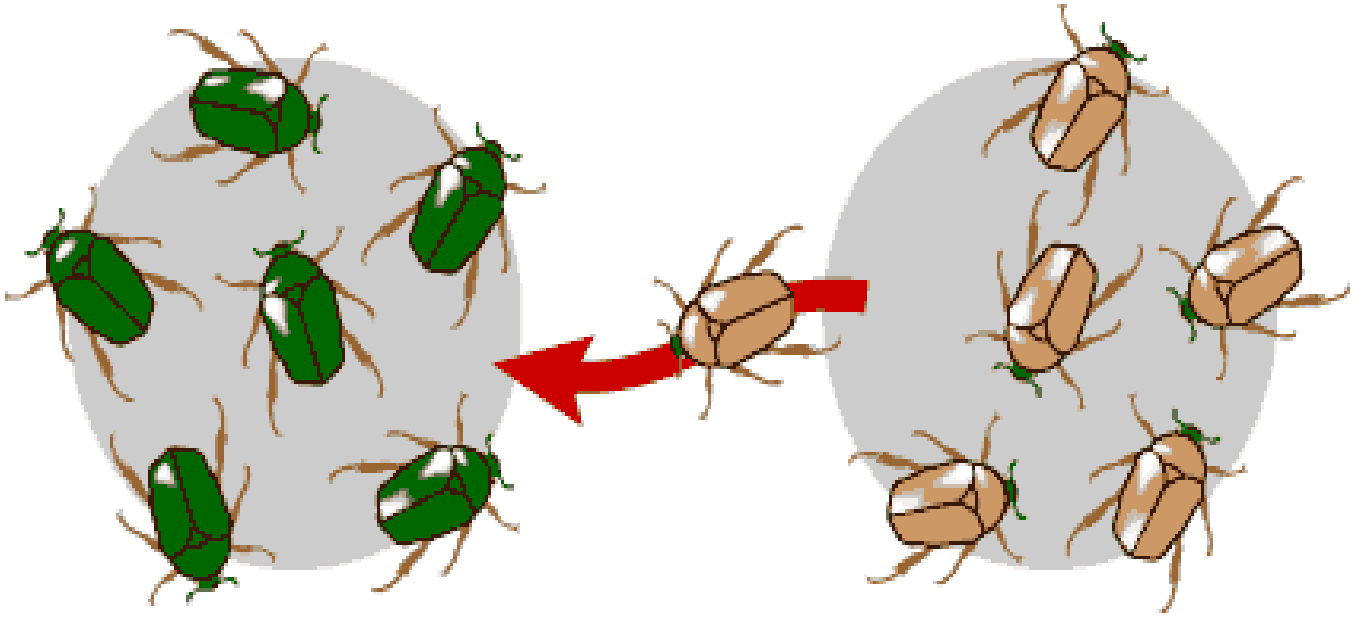


Figure 4.42 Gene flow (immigration)

- These phenomena change the overall balance of the gene pool of the populations.
- Gene transfer is the flow of alleles from one species to another.
- Horizontal gene transfer is especially common in bacteria.

4.1.9. Causes of species extinction

- Evidence suggests that anthropogenic effects and natural disaster played significant role for the direct and indirect causes of species extinction.

➢ **Causes of Extinction**

- Mutations
- Loss of Genetic Diversity
- Volcanoes, floods, drought
- Predation
- Competition
- Disease
- Spread of invasive species
- Increased human population
- Pollution, Climate change/Global warming
- Destruction/Fragmentation of habitat