

8. EVOLUTION

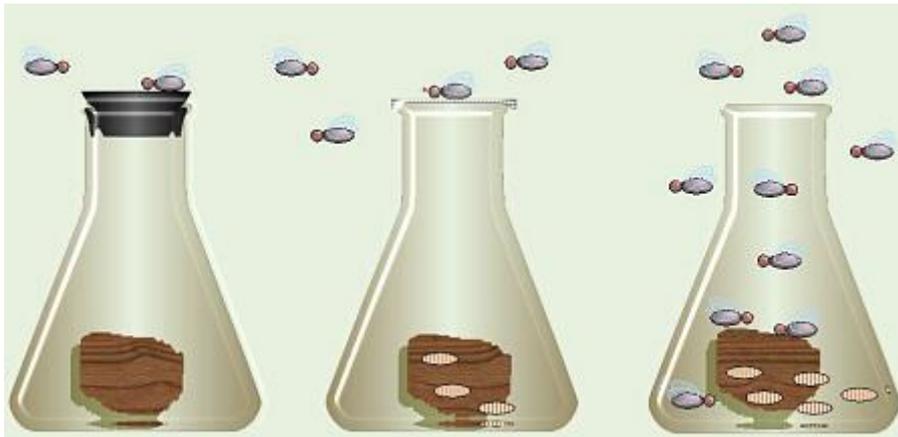
The origin of life: This question has troubled mankind throughout time. The main theories are as follows:

Divine Origin: The belief that life was created by God during a single week. As you would understand this point of view has no interest to scientists as it can not be proven.

8.1 THE THEORY OF SPONTANEOUS GENERATION

The theory of spontaneous generation was believed for centuries, since at least the time of Aristotle (4th Century BC, classical Greek philosopher). People, including scientists, believed that higher living organisms, including man, had a divine origin; however, simple living organisms could come into being by spontaneous generation. This was the idea that non-living objects can give rise to living organisms. It was common “knowledge” that simple organisms like worms, beetles, frogs, salamanders and mice among other, could come from dust, mud, etc., and food left out, quickly swarmed with life. Doctor Van Helmont gave a recipe to obtain mice in 21 days from a few grains of wheat and some dirty shirts or rags.

In the XVII century, F. Redi, an Italian physician proved that ‘worms’ were really the maggots of insects, and that neither maggots nor insects appeared in meat if female insects had not been able to lay eggs on the meat.



Only flies can make more flies. In the uncovered jars, flies entered and laid eggs on the meat. Maggots hatched from these eggs and grew into more adult flies. Adult flies laid eggs on

the gauze on the gauze-covered jars. These eggs or the maggots from them dropped through the gauze onto the meat. In the sealed jars, no flies, maggots, nor eggs could enter, thus none were seen in those jars. Maggots arose only where flies were able to lay eggs.

Other scientists, such as Schwann and Spallanzani, carried out experiments with similar results, however, the idea of spontaneous generation was still under debate. By 1860, the debate had become so heated that the Paris Academy of Sciences offered a prize for any experiments that would help resolve this conflict. The prize was claimed in 1864 by Louis Pasteur, as he published the results of an experiment where he proved that microorganisms did not arise by spontaneous generation in media broth, but that microorganisms would come from other places colonizing the broth. In order to prove this, Pasteur carried out the following experiment:

Pasteur boiled broth in order to sterilize it in flasks with long, S-shaped necks (swan-neck flasks). He did not seal any of the flasks, therefore allowing fresh air to enter the flasks as they cooled. He did the same in normal flasks, but these were closed with cotton plugs. Air could enter all of the flasks, but the long, swan neck or the cotton plugs filtered out any bacteria present in the air. So the broth did not spoil, it stayed sterile.

He subsequently broke the long necks of some of the swan-neck flasks, but kept the cotton plugs in the other flasks. Broth in flasks with necks opening straight up spoiled (as evidenced by a bad odour, cloudiness in previously clear broth, and microscopic examination of the broth confirmed the presence of bacteria), whilst broth in swan-neck flasks did not, even though fresh air could get it.

Broth in flasks with cotton plugs did not spoil, even though air could get through the cotton. If the neck of a swan-neck flask was broken off short, allowing bacteria to enter, then the broth became contaminated. Pasteur claimed that microorganisms were in the air, in the experimental utensils, and even on the hands of the people running the experiments. With his experiments a new era started in the history of clinical surgery etc. Still today, some of Pasteur's original flasks are on display in France, and are sterile.

(This section here below, highlighted in grey, will not enter in the exam still, reading it through might help you in your understanding)

8.2 PANSPERMIA THEORY

Panspermia literally means seeds everywhere. It suggests that life could have existed on another planet and moved to Earth by meteorites, comets etc. Currently, this theory can not be proven. Additionally, it simply transports the question somewhere else.

8.3 CHEMICAL EVOLUTION THEORY

This theory states that the first living organisms that appeared on Earth arose from inorganic matter in a time when the chemical environment and conditions of the planet were very different from today's conditions. In this idea, pre-biological changes slowly transformed simple atoms and molecules into the more complex chemicals needed to produce life. On the Earth, about 4000 million years ago there was a reducing atmosphere (lacking in oxygen) and a series of inorganic compounds (carbon monoxide and carbon dioxide, ammonia, water, etc.). Additionally, the numerous electric storms as well as the ultraviolet radiation from the Sun were an important energy source. The first organic molecules arose and were the precursors of living organisms. Over time, simpler organic molecules joined to form more complex structures: macromolecules, aggregates, microspheres (coacervates). These more complex structures eventually gave rise to the first primitive cells. By the process of evolution and after millions of years, the prokaryote and eukaryote cells that we know today were formed from those first primitive cells.

8.4 PRE-EVOLUTIONIST VIEWS

There are two theories about the existence of living organisms on Earth as well as two different views about the dynamics among living organisms. **Creationism** states that life on Earth was created by God, in one or multiple 'creation events'. On the other hand, there is also the belief that a divine action is not necessary to explain the origins of life. Additionally, the doctrine of **fixed species** believes that the different forms of life that had been individually made by the Creator have stayed immutable over the history of life.

Opposite to that there is the theory of **evolution**, which states that species derive from other species as a result of successive transformations or evolution.

The Book of Genesis (from the Bible), explains how species were created by God in the immutable and definite form that we know today. Due to the pressures and the great influence of the Church, the prejudice against evolution were firmly embedded in Western thought. Scientific thought adopted creationism and the doctrine of fixed species up until the beginning of the XIX century. Even as Darwinism emerged, biology in Europe and America was dominated by natural theology, a philosophy dedicated to discovering the Creator's plan by studying his works. A major objective of natural theology was to classify species in order to reveal the steps of the scale of life that God had created. In the XVIII century, Carolus Linnaeus (1707-1778), a Swedish physician and botanist (father of taxonomy and binomial nomenclature system of naming organisms) sought and found order in the diversity of life. But placing certain species under taxonomic banners implied no evolutionary kinship to Linnaeus. As a natural theologian, he believed that species were permanent creations, and he developed his classification scheme only to reveal God's plan. As Linnaeus himself put it, *Deus creavit, Linnaeus disposuit*- " God creates, Linnaeus arranges."

At the beginning of the XIX century, the great French anatomist Georges Cuvier (1769-1832), explained the existence of fossils based on the view of Earth's history known as *catastrophism*; during catastrophic events (such as floods or drought), species, created by God, would die. After such periodic catastrophes two things could happen: God created life anew (the new species being different from the extinct ones, although occasionally having similar characteristics), or the ravaged region would be repopulated by foreign species immigrating from other areas. This would explain the existence of species in the fossil record different to the ones of the time.

Also, during the XVIII century, an important step toward the modern theory of evolution was presented by Georges-Louis Leclerc Comte de Buffon (1707-1788). He studied animals and plants fossils, proposing that species had not been created as they appeared, but rather that species of the time were modified forms of common ancestors. He writes that living creatures evolve according to natural laws. However, his heretical* ideas were later recanted under pressure: "I abandon everything in my book ... contrary to the narrative of Moses."

***Heretic:** A person who holds controversial opinions, especially one who publicly dissents from the officially accepted dogma of the Roman Catholic Church.

EVOLUTION

Evolution refers to the processes, more or less gradual, that have transformed life on Earth from its earliest forms to the vast diversity that characterizes it today. The first primitive living organisms are dated as far back as 3800 million years ago. In fact everything in the Universe evolves, nothing stays still. We can talk about the evolution of a star, the evolution of the lithosphere... and the evolution of living organisms. It seems obvious that living beings have appeared and disappeared throughout geologic time, and that many species, nowadays with different characteristics, have common ancestors. It is known that there are species that existed in past times and are now extinct, and others which did not exist in older geologic times but that exist today. Generally speaking, evolutionary change is based on the interactions between populations of organisms and their environment. As there have been changes in the environment, different characteristics have been needed in order to adapt to such changes. The different

evolution theories study evolution, its history (that is to say the interactions among populations of organisms), and the mechanisms by which life evolves.

8.5 EVOLUTION THEORIES

1. Lamarck's Theory of Evolution (1744- 1829)

What is his theory based on?

1. Evolution was driven by an innate tendency towards higher and greater complexity, towards perfection. (**vital force**).
2. This innate tendency to perfection is influenced by environmental changes, therefore becoming better adapted to their environments. These environmental changes would create '**new needs**' in organisms, needing to use certain organs or characteristics more than others.
3. This use and disuse of certain organs causes those organs that are used more often to cope better with the environment, making them become larger and stronger, while those that are not used deteriorate. In other words: **the function makes the organ**. So, organisms could acquire certain characteristics throughout its lifetime, and lose others.
4. Lamarck believed that the modifications an organism acquires during its lifetime are passed to its offspring (**inheritance of acquired characteristics**).
5. One species can not transform into any other species, but only into a similar one where the species can evolve gradually.

Lamarck established the fact of evolution, but his theory had several flaws:

- There is no evidence to prove that innate tendency (vital impulse) of organisms toward complexity.
- **Acquired characteristics are not inherited.** We all know that physical exercise will make our muscles develop, but such acquired physical characteristics (which are not genetic) are not passed down to offspring. Such acquired characteristics are produced by environmental factors and development, but not by genes. Only those characters which are regulated by genes are hereditary, and only if such genes are found in the reproductive cells. Whatever happens to somatic cells due to their use or disuse will not affect the genes in the gametes, therefore it will not be hereditary. F.L. August Weissmann (1834-1914) carried out the following experiment to refute Lamarck's theory: He cut off the tails of fifteen hundred mice, repeatedly over 20 generations, and reporting that no mouse was ever born in consequence without a tail. According to Lamarck and his theory, the disuse of the tail should have given offspring without a tail or with an undeveloped tail, however that was never the case.

Evolution of the giraffe according to Lamarck: The ancestors of the giraffe (with a short neck and short legs), also ate leaves. As the lower leaves were eaten, it had to stretch its neck to new lengths in pursuit to eat the higher leaves. Due to that 'innate impulse', its neck and legs began to grow. The long neck and legs of the giraffe Lamarck reasoned, evolved gradually as the cumulative product of a great many generations of ancestors stretching higher and higher, which would be inherited by offspring.

2. Darwin's theory of evolution

Charles Darwin (1809-1882) was born in the West of England (Shrewsbury), in the same year that Lamarck published his theory of Evolution. Darwin was 22 years old when he sailed from England with the *Beagle* in December 1831; a voyage around the world that would last five years. During the expedition Darwin collected thousands of specimens of the exotic and exceedingly diverse faunas and floras of different places. He was also able to observe the various adaptations of plants and animals that inhabited such diverse environments. After returning from his voyage, Darwin spent almost 20 years analyzing and studying all the data obtained during those five years. Another naturalist, Alfred Wallace who was working in the East Indies, sent a manuscript to Darwin in which he developed a theory of natural selection essentially identical to Darwin's.

Together, in 1858 they published together their theory on Evolution (it should be called the Darwin-Wallace theory), which replaced Lamarck's evolutionary theory. Darwin explained his theory in his book *The Origin of Species*, where he presented his theory of natural selection as the mechanism of evolution. Basically, his **theory of natural selection** is based on three observations and two conclusions from such observations:

1st Observation: In the absence of environmental pressures (or normal conditions), all species have such great potential fertility that their population size would increase exponentially if all individuals that were born reproduced successfully.

2nd Observation: However, in normal conditions, most populations are stable in size, except for seasonal fluctuations.

1st CONCLUSION: Therefore, not all gametes produced by an individual end up becoming zygotes; not all zygotes become adults; and not all the adults survive and reproduce. So, production of more individuals than the environment can support leads to a struggle for existence among individuals of a population, with only a fraction of offspring surviving each generation.

3rd Observation: Individuals of a population vary extensively in their characteristics. There are not two individuals exactly alike. (Think of your classmates, you each have your particular characteristics, which define you).

2nd CONCLUSION: Survival in the struggle for existence is not random, but depends in part on the hereditary constitution of the surviving individuals. Those individuals whose inherited characteristics fit them best to their environment are likely to leave more offspring than less fit individuals.

A few comments about this theory:

- According to Darwin, evolution is gradual, slow and continuous: there are no sudden or brusque changes. It is a gradual accumulation of minute changes.
- Environmental factors are what drive natural selection. With time, those individuals with characteristics less fit to their environment would disappear,

and those with favourable variations would be perpetuated. (Survival of the fittest).

- Over vast spans of time, and always due to environmental factors, a group of individuals could accumulate a considerable amount of favourable characteristics giving rise to a new species from the original population.
- Still nowadays, many people mistakenly believe that it is Darwinism that explains evolution. There are many objections to the Darwinian view, (many of those objections were presented whilst he was still alive).
- When Darwin had to explain what caused individual variations among organisms of a population he had to borrow Lamarck's acquired characteristics theory (Weissman will not carry out his experiments until 1880). Mendel enunciated the laws of heredity six years after Darwin published his book, however Mendel's work was not recognized or appreciated until 30 years later, which considerably slowed down the understanding of evolutionary mechanisms.
- Another objection: if natural selection only preserves or eliminates what already existed, how can it create new species? As we will see, natural selection does create new species.

Evolution of the giraffe according to Darwin: The variability which appeared in giraffe populations in each generation (some would stretch their neck or legs more than others) gave rise to the appearance of some individuals within the population with longer legs and a longer neck. These characters were transferred to their offspring. At first, this was not of any advantage to the individual, as there were enough low leaves on trees. However, as the lower leaves became scarce, only the individuals with the longer neck and longer legs could reach the higher leaves, which allowed them to survive through generations and have more offspring. With time it became the only type of giraffe that existed.

TODAY'S THEORY OF EVOLUTION (The modern evolutionary synthesis or neo-Darwinism)

A comprehensive theory of evolution that became known as the **modern synthesis or neo-Darwinism** was forged in the early 1940s. This theory is not the work of one but many scientists. It is called the synthesis because it integrated discoveries and ideas from many different fields, including population genetics, paleontology, taxonomy, etc)

It brings together Charles Darwin's theory of the evolution of species by natural selection with Gregor Mendel's theory of genetics as the basis for biological inheritance. Major figures in the development of the modern synthesis include Ronald Fisher, Theodosius Dobzhansky, J.B.S. Haldane, Sewall Wright, Julian Huxley, Ernst Mayr, George Gaylord Simpson and G. Ledyard Stebbins.

We can define evolution as **the natural selection (which is seen through differential reproduction), that acts upon genetic variations (which are the outcome of mutations or sexual recombination) which appear among the members of a population.**

Some important aspects of this definition are:

- A population is a localized group of individuals belonging to the same species, where the individuals interbreed amongst themselves, and occasionally, with members of other populations.
- As a result of this closed sexual interaction in a population, a gene flow is created (that is to say that the genes of the different individuals circulate within the population, and could be transmitted to the entire population).
- The genetic variations among individuals could be due to: **mutations** (this variations can take place in individuals with both types of reproduction, asexual and sexual); and **meiotic or sexual recombination** (this takes place during meiosis I, therefore, it can only happen in individuals with sexual reproduction).
- Because of mutations and meiotic recombinations, individuals with new characteristics are constantly born. If those individuals survive and have offspring, their new characteristics will stay within the gene pool or group of genes of the population. In successive generations those genetic variations could be passed down to many (or all) members of the population.
- Whether that would happen or not depends on natural selection (some individuals have more offspring than others). Those organisms best adapted to a given environment will be most likely to survive to reproductive age and have offspring of their own. Organisms that are successful in their environments will be more likely to be successful in reproduction, and therefore the better-adapted organisms will reproduce at a greater rate than the less well-adapted organisms. Therefore, the genes of the ones that reproduce more will predominate in the gene pool of the population. This is known as **differential reproduction**.
- It is important to understand that it is just how well adapted they are, but how well they are able to reproduce, in order to be able to pass down the new characters. (Though they usually go hand and hand). For example, it could be that an individual is very well adapted to its environment, however, it has a mutation that makes it sterile. Would this individual have any impact in the evolution of its population?
- The process of evolution has therefore two stages: first of all genetic variation must occur due to mutations and/or meiotic recombinations; and second, those variations must spread throughout the population by differential reproduction (natural selection) in successive generations.
- Individuals do not evolve, populations do. The genetic characteristics that an individual has usually don't vary throughout its life and once it dies they disappear. However, if the individual reproduces sexually, it could introduce genetic variations to its offspring.
- The process of evolution does not follow a fixed pattern, as genetic variations happen randomly. This does not mean that evolution lacks a driving force: as the individuals that are most successful in reproduction are those that are best adapted, the driving force of evolution is natural selection.
- Therefore, natural selections acts by means of differential reproduction, and not by the struggle for survival.

Evolution of the giraffe according to the modern evolutionary synthesis:

The ancestors of today's giraffes did not have a long neck nor long front legs. By mutation and/or genetic recombination new individuals presenting a long neck and/or long legs appeared in a population. Those new individuals were better adapted to the environment. They ate more, found mating partners more easily and therefore reproduced more often. With time they became the only existing giraffes. Obviously the individuals that presented the short neck and short legs (both negative characteristics), as they were less well adapted to the environment, they did not reproduce as successfully as the well-adapted giraffes. And eventually the less favorable genes disappeared from the population.