**Textbook Reference: Section 19.3**

Early life forms have evolved into a diverse array of organisms present on Earth today. Use Figure 19.10 on pages 660- 61 to complete the table below:

|  |  |  |  |
| --- | --- | --- | --- |
| Million Years Ago | **Period Era** | | **Major events and Life Forms** |
| 3500 |  | |  |
| 3000 |  |
| 2000 |  |
| 540 |  |  |  |
| 510 |  |  |
| 439 |  |  |
| 408 |  |  |
| 362 |  |  |
| 320 |  |
| 290 |  |  |
| 245 |  |  |  |
| 208 |  |  |
| 146 |  |  |
| 66 |  |  |  |
| 1.6 |  |  |
|  | | | |

**Textbook Reference: Section 19.1**

1. Use page 644 of your textbook to define each of the following:

1. Evolution
2. Adaptation
3. Variation
4. Use the peppered moth story as an example of evolution and adaptation. (page 644-46)
5. Distinguish between the processes of natural selection and artificial selection. (page 647-48)

Theories

**Textbook Reference: Section 19.2**

1. **Georges Cuvier (1769-1832)**

Cuvier was a French scientist who largely developed the science of paleontology. The study of fossils helps provide support for the theory of evolution. .Cuvier realized that each layer of rock is characterized by a unique group of fossil species. The deeper or older the layer, the more dissimilar plant and animal forms become from modern life. He also realized that the extinction of species was a regular occurrence in the history of life on Earth, as well as, the appearance of new species. Cuvier also proposed the idea of catastrophism in which catastrophes such as floods, disease and drought periodically destroyed species.

**B. Lamarck’s Theory (1809)**

Lamarck produced two laws to account for changes in organisms:

**(i)**. **The Law of Use or Disuse**

This law states that if an organism uses a particular organ it remains active and strong but if it is not used then it becomes weak and eventually disappears. For example, The necks of giraffes were originally short because they feed upon grasses and shrubs close to the gound. As the food supply near the ground decreased, giraffes had to stretch their necks to reach food in trees.

# The Law of Inheritance of Acquired Characteristics

This law states that the characteristics of an organism developed through use and could be passed on to the offspring of the next generation. For example, since giraffes stretched their necks during their lifetime then this trait was passed onto their offspring.

Lamarck’s Theory was rejected for the following reasons:

1. There was a suggestion that an organism could change its structure because it felt a need to do so. This is false.
2. Acquired characteristics can not be inherited. Only genetic traits can be inherited
3. All experiments conducted to support the theory have failed. Weismann cut off the tails of mice for 22 generations. The mice of new generations were always born with tails of normal length.

**C. Darwin’s Theory (1859)**

Darwin’s Theory was the result of information from a number of different sources:

## Maltus’ Essay

Thomas Maltus, in an essay on the Principle of Population, stated that the ever increasing human population was exceeding the food supply needed to feed it. To keep a balance between the need for food and the supply of food, millions of individuals had to die by disease, starvation or war.

This idea helped Darwin to formulate the concept of natural selection. Darwin realized that all organisms overpopulate and therefore all individuals can not survive. Those that do not survive have more favorable variations. Nature selects the survivors. The result of natural selection would be evolution since these favorable variations would be passed on to their offspring.

1. **Selective Breeding**

Darwin studied the practice of selective breeding. Selective breeding was common in plant and animal breeding at the time. Farmers could alter or improve crops and livestock by selective breeding. This fact made Darwin wonder if some form of selection occurred in nature.

1. **Lyell’s Book**

Charles Lyell was a geologist and in his book proposed that the earth was very old, that it had been slowly changing, and was still changing. His ideas also lead Darwin to think that perhaps living things also changed slowly over long periods of time. It also led him to believe that the Earth was older than 6000 years as suggested by biblical scholars. Lyell, however, believed that the Earth’s features were in a slow state of change and changes did not occur due to catastrophic events as suggested by Cuvier.

1. **Darwin’s Personal Observations**

Darwin traveled on the HMS *Beagle* in from 1831 –1836 as the ship’s naturalist. Darwin made personal observations of animal species, in particular finches, on the Galapagos Islands. Darwin observed 14 species of finch that were similar to each other in many ways and similar to the species of finch found on the mainland. The notable difference lay in the shape of their beaks. It appeared to Darwin that the different beak shapes were adaptations for eating the certain types of food characteristic of the various geographic locations. For example, some beaks were adapted to be large and crushing bills to eat seeds, some were parrot-like to eat fruit and some were chisel-like to probe for insects in the bark of trees.

He published his observations in 1859 under the title *On the Origin of the Species by Means of Natural Selection*. **Alfred Russel** **Wallace** was also a naturalist at the time and had written an essay that supported Darwin’s theory.

The major points of Darwin’s Theory are:

1. *Overproduction*

Most species produce far more offspring than are needed to maintain the population. Species populations remain more or less constant, despite this fact.

1. *Competition (Struggle for Existence)*

Since living space and food are limited. Offspring in each generation must compete against themselves and with other species for the necessities of life. Only a small fraction can possibly survive long enough to reproduce.

1. *Variation*

The characteristics of individuals in any species are not exactly alike. These differences are called **variations**. Some variations may not be important. Other variations may affect an organism’s chances of survival and therefore are of vital importance.

1. *Adaptations*

Because of variations, some individuals will be better able to survive and reproduce than others. Individuals with favorable adaptations will have a greater chance of living longer and reproducing. An **adaptation** is any kind of inherited trait that improves an organism’s chance of survival and reproduction in a given environment.

1. *Natural Selection (Survival of the Fittest)*

Those individuals in a species with characteristics that give them an advantage are better able to compete, survive and reproduce. Those with the poorer characteristics die without leaving offspring. Since nature selects the organisms that survive, the process is called **natural selection**.

1. *Speciation (Origin of New Species)*

Over many generations, favorable characteristics gradually accumulate in the species and unfavorable ones disappear. Eventually, the accumulated changes become so great that the net result is a new species.

### Major Weaknesses in Darwin’s Theory

The major weaknesses in the theory revolved around Darwin’s inability to account for the mechanisms of inheritance of traits. It does not explain how variations originate and are passed on to the next generation. It does not distinguish between variations caused by hereditary differences and variations caused by the environment. For example, fertile soil can influence height differences in plants.

It was believed at the time that offspring inherited a blend of the characteristics of their parents. It was argued, an individual with a new, desirable characteristic appearing in the population, would by necessity mate with an individual lacking this characteristic. In the offspring, the characteristics would be blended. The adaptive value of the desirable characteristic would be diminished. In the following generation, the offspring would again find the other “less fit” individuals as mates. Thus, the desirable characteristic would be diluted over the generations’ rather than retained.

The solution to the problem arose after Darwin’s death with the work of Gregor Mendel. Mendelian genetics and the concept of mutations supported Darwin’s theory by proving that *variations* do occur within a species and that these variations are genetic in origin and as such be passed on form one generation to the next.

### Comparison between Lamarck’s and Darwin’s Theories:

## Major Similarity

Both believed that evolution was related to a change in the environment.

## Major Differences

1. Numbers

Lamarck believed that individuals evolved while Darwin believed that evolution occurred within a population. Darwin said that evolution occurred when an entire population changed.

1. Timing

Lamarck believed that variations occurred after the environment changed. Darwin believed that variations were always present and when the environment changed those organisms with the most suitable variations for the new environment survived while those with the less suitable variations died off.

### Synthetic Theory of Evolution

#### This theory is a combination of Darwin’s basic theory and present day knowledge in the areas of genetics and population genetics. In particular, the emphasis today is placed upon the concept that evolution happens to populations, not individuals, through a change in the allele frequency within the gene pool of a population over time.

#### The change in gene frequency is brought about by natural selection. Natural selection “removes” those genes which reduce the fitness of the individuals that possess them through the death of such organisms and favors those that result in adaptations that increase the organism’s chance of survival.

### Evidence of Evolution

### Textbook Reference: Section 19.3

# Evolution is the progressive genetic change in the allele frequency found in a group of organisms over time. It is process by which existing species change or branch into new species. In a general sense, evolution means a gradual change over time. Since its formation about 4.5 million years ago, the earth itself has changed continuously. This slow change is known a geologic evolution. Many species have also changed since they first appeared on earth. This process is known as organic evolution. The theory of evolution (organic) attempts to explain why living organisms are so similar in their biochemistry and molecular biology but are so different in their form and function.

The genetic change of populations over time is believed to be the result of the following:

1. *Mutations* that arise with changes in DNA.
2. *Genetic recombination* that is the formation of new combinations of alleles during sexual reproduction. Genetic combination is caused by two factors: crossing over and independent assortment.
3. *Migration* because as organisms move into a population they may bring in genes that are not already present
4. *Genetic drift* in which a change in the gene pool of a small population is brought about by chance

***Paleontology*** is the study of fossils. A fossil is any remains or signs of remains of an organism that lived in the past. Fossils offer direct evidence of the pathways taken by living organisms in their evolutionary history or ***phylogeny***. Fossils are one of the strongest sources of evidence for evolution.

## Fossil Formation

There are five main methods of fossil formation:

1. *Preservation of the actual organism*. They are usually preserved in a specific substance. These substances may include:
2. Ice: Some animals are permanently frozen in ice. ie. the woolly mammoth
3. Amber: Amber is the resin (gum) from some trees. This resin with trap insects.
4. Tar pits: These are naturally occurring in warmer climates. Animals fall into these pits and their skeletal remains are solidified along with the tar before they can decompose.
5. Volcanic ash: During volcano eruptions a tremendous amount of ash is produced. This ash covers over organisms and acts as a preservative especially in the case of reptiles.
6. *Petrification*: In this case, the organism becomes covered in water containing a high mineral content. Gradually, the original substances of the organism dissolve and are replaced by minerals such as silica, calcite or iron compounds from the water. The remains of the organism are turned into stone. ie, petrified tree or forest
7. *Carbonization*: Carbonization is the process whereby large carbon deposits of oil, coal and gas are produced. It is the result of large groups of organisms that are compacted together before they can decay. In coal deposits, it is not uncommon to find the fossils of the organisms that produced the coal fields.
8. *Molds and Casts*:
9. Molds: sediment in which an organism is embedded hardens, preserving the shape of the organism after its remains decompose.
10. Cast: A mold becomes filled with minerals and then hardens, producing a copy of external features of an organism.

Most fossils are found in sedimentary rock formed when soil and rock particles are laid down at the bottom of lakes and oceans, Gradually new layers form over older ones causing the layers to compress and harden. Over long periods of time, these layers can be uplifted by geological processes and appear at the earth’s surface.

1. *Imprint:*  An imprint is formed when an impression made in mud by a living organism is preserved when the mud is transformed into rock.

## Fossil Record

The human life span is so short in relation to the earth’s history that it is difficult to visualize the enormous time span represented by fossil record.

The fossil record is not complete in any one location but is compiled from rock layers in many locations around the world. Evidence and research is not based upon guesswork but on careful observations, comparisons of rock layers and fossils, and quantitative measurement and analysis of age.

Fossils can be used to examine early life forms and examine changes in these life forms over time. The oldest fossil record contains fossils of very simple organisms. Fossils of more recent origin represent more complex organisms. If the time difference between two groups is great, these differences between the two groups is also great.

By piecing together fossil evidence according to age and similarity of structure, scientists have been able to study patterns of relationships among organisms. These patterns are often referred to as “trees of life” or *phylogenic trees*.

**Dating Fossils**

It is important to know the age of fossils. This is done in two major ways:

1. *Relative Dating by Deposition of Sediment*

Most fossils are formed in sedimentary rocks. Examining layers of sedimentary rocks gives the relative age of fossils. The relative age is determines by a fossil’s position in the sedimentary layers. The fossils in the layers on the bottom are assumed to be the oldest and those layers at the top are assumed to be the youngest unless the geology of the area assumes otherwise.

Scientists have discovered that it takes approximately 1000 years of sediment to produce 30 cm of sedimentary rock. By knowing the depth the fossil is located, one can determine the relative age of the fossil. Example: 150cm deep means a relative age of 5000 years.

1. *Absolute Dating by Radioactive Dating*

Radioactive dating of the fossil or rock in which the fossil is found gives as absolute age. The method is based on the rate of radioactive decay in isotopes of the particular elements. Isotopes are atoms of the same element that vary in the number of neutrons that they possess. A radioactive nucleus has an unstable nucleus that undergoes spontaneous change, releasing particles and energy. In doing this, the radioactive isotope breaks down and often becomes a new element. Radioactive isotopes will change at known rates and can be used to determine the age of an organism

Living organisms accumulate certain radioactive isotopes when they are living. Once these organisms die, the radioactive isotopes start to breakdown. The rate of this breakdown is called half-life. Half-life is the amount of time it requires to breakdown half of the originally accumulated radioactive compound and have it replaced by one half decay product.

Geologists have calculated the ratios of isotopes and their decay products as they exist after certain time lapses. These ratios can be used to determine the age of the fossil, as well as, using the proportion of isotope remaining in the fossil-bearing rock. The greater the amount of decay product the older the fossil.

Examples include some of the isotope pairs found in the following table:

|  |  |  |
| --- | --- | --- |
| **Isotope Pair** | **Half-Life in Years** | **Useful Range in Years** |
| Carbon 14/Nitrogen 14 | 5730 | 60 x 103 |
| Uranium 235/Lead 207 | 700 x 106 | Over 500 x 103 |
| Potassium 40/Argon 40 | 1.25 x 109 | Over 500 x 103 |
| Uranium 238/Lead 206 | 4.5 x 109 | Over 100 x 106 |
| Rubidium 87/Strontium 87 | 4.88 x 109 | Over 100 x 106 |

**Evidence From Living Things**

Living organisms provide us with evidence that developmental patterns, body structures and chemical processes show similarities that suggest a common ancestry or a common design among some organisms. There are four branches of science that provide evidence that support the concept of evolution.

1. **Biogeography**

This is the study of the geographic distribution of species. If the environments are close geographically, then they are more likely to be populated by similar species. For example, Australia has many marsupials (kangaroos with pouch for partial outside development) but few placental mammals.

1. **Comparative Anatomy**

This is the science where the anatomy of different organisms is compared for similarities and differences. The presence of certain types of similarities will indicate a common evolutionary relationship. The closer the similarities, then the closer the relationships between the organisms. One of the structures that scientists search for are called **homologous structures**. These are structures that are found in different organisms that are similar in shape, structure and origin. For example, the hearts of various classes of organisms are considered to be homologous structures.

**Analogous structures** such as the wing of a bird and the wing of a butterfly have similar tructures but are quite different anatomically and are good indicators that these organisms did not evolve from a common ancestor.

Scientists also look for **vestiges** or **vestigial organs**. These are structures that have lost their functional but were functional in an ancestor of the organism. Examples are the tailbone and the appendix in man and the vestigial bones in snakes and whales where there were once limbs.

**4. Comparative Embryology**

An embryo is an organism that is in the early stages of development. Scientists compare the structures of the embryos of different organisms. The comparisons of the embryological development of different species provide evidence of their relationship. The closer the resemblance between the embryos, the greater the evolutionary relationship. For example, the embryos of all vertebrates are very similar during the early stages of development. .Early in development, humans have gill slits and a tail. The gill slits eventually develop into the tube that connects that middle ear to the throat.

**5. Molecular Biology**

Scientists compare the chemical composition of different organisms. The presence of certain types of similar chemicals indicates a common evolutionary relationship. The closer the similarities, then the closer the relationship between the organisms. They look at such things as the sequence of amino acids in the proteins of organisms. For example, the hemoglobin of the monkey is closely related to the hemoglobin of man. The insulin from a pig or cow can be used to treat diabetes in humans. Cytochrome c is a protein found in the electron transport chain of all aerobic organisms. Cytochrome c in chimpanzees is identical to the cytochrome c in humans. However, human and fish cytochrome c differ by an average of 22 amino acids.

1. **Genetics**

Scientists have concluded that genes are similar in organisms that are closely related. The closer the structures of the DNA molecule then the closer the organisms are related. For example, lobster, shrimp and crayfish all have very similar DNA.

Evidence in Support of the Modern Theory of Evolution

**Textbook Reference: Section 19.3**

Use pages 659-667 of your text to describe the following types of evidence in support of the modern theory of evolution.

1. Fossil Record
2. Biogeography
3. Comparative Anatomy

* Homologous structures
* Analogous structures

1. Comparative Embryology
2. Heredity
3. Molecular Biology

**Evolution in Action**

**Textbook Reference: Section 20.3 and Section 21.2**

**Industrial melanism** is a modern day example of evolution that has occurred over a short period of time. It occurred in England during the industrial revolution and involved the peppered moth. This moth before 1850 had a light color except for a few black moths with a pigment called **melanin**. Tress before the 1850 had a light colored bark and the light colored moths blended in so they could escape certain birds that preyed on them putting them at an advantage.

In 1850, the industrial revolution resulted in the tress turning black due to soot and smoke. This meant that the light moths had lost their advantage and that the black moths had become better adapted to their environment. Over the next 50 years, the peppered moth went from a predominantly light to a dark organism.

# Importance of Melanism

Industrial melanism is important for three reasons:

1. It shows that evolution is an interaction between the organism and the environment. The trait that makes the moth best adapted to the environment dominates.
2. It points out that evolution is dependent on genetic change within the population.
3. Shows the presence of variability in a population. Alleles for light color and dark color are in the gene pool.

# Hardy-Weinburg Law

The Hardy-Weinburg Law is a concept that is employed to discover whether or not evolution is occurring in a population. The law states that under certain conditions, allele frequencies will remain constant (**genetic equilibrium**) in a gene pool and there will be no evolution. In other words, the frequency of dominant and recessive alleles remains constant from generation to generation. The five conditions that must be met for this law to hold true are:

1. The population must be large. In a small population, alleles of low frequency may be lost or the frequency may change due to **genetic drift**.
2. Individuals must not migrate into or out of the population. Any individuals that do so may change the **allele frequency** of the population.
3. **Mutations** must not occur because mutations obviously change the allele frequency of the population.
4. Reproduction must be completely at random. This means that every individual, whatever its genetic make-up, should have an equal chance of producing offspring.
5. No genotype is more likely to survive and have offspring than any other genotype. This means equal viability, fertility and mating ability of all genotypes. There is no selection advantage.

If the allele frequency in a population changes, then the Hardy-Weinburg Law fails and it is therefore a sign that evolution is occurring. The extent of variation from the Hardy-Weinburg prediction is a measure of how rapid the evolutionary change is occurring.

The Hardy-Weinburg principle consists of a mathematical formulae based upon the allele frequency within a given population and then shows how the allele frequency will remain in equilibrium provided certain conditions are met.

**Formula**: p + q = 1

p2 + 2pq + q2 = 1

* p is the dominant allele frequency
* q is the recessive allele frequency

The total frequencies add up to 1 to represent 100%

The significance of the Hardy-Weinburg Law can be seen in the following areas:

1. It explains the distribution of some genetic traits
2. It explains why some recessive traits do not disappear altogether and why some dominant traits do not increase in distribution.
3. It shows that in a natural setting the necessary conditions for genetic equilibrium may not be met and that the allele frequencies can change.
4. It shows that if allele frequencies are changing, then the rate of change may be related to the pace of evolutionary change. It also illustrates the effects that natural changes can have on allele frequencies and thus, the means by which evolution can take place.

## Major Parts of the Synthetic Theory of Evolution

1. **Overproduction**

Most species produce far more offspring than are needed to maintain the population. Species populations remain more or less constant because there is only a small fraction of the offspring that live long enough to reproduce.

1. **Competition (Struggle for Existence)**

Since space and food are limited, offspring in each generation must compete among themselves and with other species for the necessities of life. Only a small fraction can survive long enough to reproduce

1. **Variation**

Genetic variations exist within the gene pool of all populations. Some variations may not be important. Others may affect an individual’s ability to get food, to escape enemies, or to find a mate. Because of variations, some individuals may be better adapted to survive and reproduce than others

1. **Adaptations**

Because of variations, some individuals will be better able to survive and reproduce than others. Individuals with favorable adaptations will have a greater chance of living longer and reproducing. An **adaptation** is any kind of inherited trait that improves an organism’s chance of survival and reproduction in a given environment.

1. **Natural Selection**

Through the process of natural selection the genetic variations that provide the greatest amount of adaptability for the members of the population survive within the gene pool. The less favorable variations die out and disappear from the gene pool. Natural selection disturbs the genetic equilibrium of a population and results in a change in the allele frequencies within that population.

1. **Speciation**

This is a two step process that involves geographic isolation followed by reproductive isolation.

**Geographic isolation** occurs when a population is divided by a natural barrier such as a mountain, river, landslide and so on. As a result the gene pool of each group becomes isolated and the two can no longer interbreed. Over a period of time, under the influence of natural selection, their gene pools begin to change as each group adapts to its new environment.

**Reproductive isolation** is reached when the changed in the gene pools of each group become great enough that they will no longer be able to interbreed and produce fertile offspring, even if they could get together. Factors that contribute to reproductive isolation include differences in mating habits and courtship patterns, seasonal differences in mating, and the inability of the sperm to fertilize the egg. In some cases, where fertilization has taken place, the genes and chromosomes are so different that the zygote does not develop or the embryo is prevented from developing normally.

The key to speciation is that isolating a group of organisms separates its gene pool from the rest of the species. Through mutation, genetic recombination and natural selection a different gene pool will evolve in each group.

A species may now be defined as:

* A group of organisms that look alike and can interbreed under natural conditions to produce fertile offspring
* A species is a closed gene pool into which “foreign” genes can not enter through normal mating

Speciation may occur in a number of different ways:

* **Polyploidy**: Speciation may occur suddenly when abnormal meiosis or mitosis results in polyploidy. Such organisms produced in this manner are usually plants and contain more than the normal number of chromosome sets. They can therfore only interbreed among themselves
* **Adaptive radiation**: This is when a single ancestral species evolves into a number of different species. For example, Darwin’s finches on the Galapagos islands.

The conditions necessary for adaptive radiation are:

* New environment for the evolving species. When the new species reach these new environments, they will enter various ecological niches.
* A way by which the evolving species can reach these new environments. Migration plays a key role in this process
* The new environment must be free from competition with similar forms
* There can not be too many new predators

## Convergent Evolution

Convergent evolution is a process by which unrelated species produce descendants that display similarities due to the fact that they encountered similar problems in adapting to and occupying a similar niche within a common environment. The environment selects similar adaptations in unrelated species. For example, The wings of birds, bats and butterflies are all used for flight but have evolved differently. Wings are examples of **analogous structures.**

## Pace of Evolution

At present, scientists do not agree on the rate at which evolution occurred. Two opposing viewpoints are:

**Gradualism** is based on Darwin’s theory. It states that the new species arise through the gradual accumulation of small variations. In other words, evolution occurs slowly and continuously over long periods of time.

**Punctuated equilibrium** was proposed by Steven Gould and Niles Eldridge. A species remains in equilibrium (unchanged) for extended periods of time and then in a relatively short period of time, rapid change occurs. In other words, the long period of equilibrium is interrupted, or punctuated, by a short period of evolution.

## The Controversy over Evolution

As one can see from the study of evolution, from its earliest beginnings to the present day there is a great deal of controversy regarding the theory including:

* The mechanisms of evolution
* The theories of evolution
* The pace of evolution
* Is evolution occurring today
* Has evolution occurred at all
* What about the theory **creationism**? Is there some divine intervention that resulted in the existence of the human race?

Such controversy is healthy since it forces us to review our established beliefs and to constantly explore other possibilities.

Evolutionary Mechanisms

Use pages 687-696 and pages 709 to define each of the following:

1. Mutations
2. Genetic Drift
3. Bottle Neck Effect
4. Founder Effect
5. Gene Flow
6. Non-Random Mating
7. Natural Selection
8. Stabilizing Selection
9. Directional Selection
10. Disruption Selection
11. Sexual Selection
12. Speciation

Evolutionary Mechanisms to Speciation

**Textbook Reference:Section 21.2 and Section21.3**

Use pages 709-711 and pages 720-23 to describe each of the following:

1. **Biological Barriers to Reproduction and Speciation**
2. **Pre-zygotic Barriers**

* **Behavioural Isolation**
* **Habitat Isolation**
* **Temperal Isolation**
* **Mechanical Isolation**
* **Gametic Isolation**

1. **Post-Zygotic Barriers**

* **Hybrid Inviability**
* **Hybrid Sterility**
* **Hybrid Breakdown**

# Other Mechanisms to Speciation

1. **Adaptive Radiation**
2. **Convergent Evolution**
3. **Divergent Evolution**
4. **Coevolution**

**The Origins of Life**

**Textbook Reference: Section 21.4**

There are many theories on the origin of life. Some of these include:

# *Creationism*

This is the theory that states that there is some ultimate being that produced the universe and the life within the universe.

*Spontaneous Generation*

This was a theory supported by the English scientists named John Needham. The theory states that living organisms arise form nonliving matter. It was later disproved by Louis Pasteur

*Panspermia Theory*

Another theory, the Panspermia theory, explained that life originated elsewhere in the universe and somehow found its way to Earth by intelligent beings or by chance, such as by meteorites. The fact that rocks have traveled from Mars to Earth lends support to this theory. It is also known that microorganisms can remain dormant for a long period of time and survive under space conditions. Therefore, it seems possible that microorganisms from Mars or from meteors could have reached Earth and survived.

# *Intelligent Design*

This is the concept that all biological origins on earth have followed a pattern which set out as a product of some intelligent cause or agent.

*Gaia Hypothesis*

This comes from the Greek word, meaning “mother earth”. It was developed by James Lovelock. It suggests that the earth, including all of its abiotic and biotic components may constitute a huge, living, self-regulating system. It states that the **biota** (the sum of all organisms) controls various properties of the atmosphere, ocean and lands.

# *Lynn Margulis Hypothesis or Symbiotic Theory of Eukaryotic Organisms (Symbiogenesis)*

This was developed as a result of observations of organelles, such as chloroplasts and mitochondria, and it revealed that they were similar to prokaryotic cells. It is the belief that through symbiotic relationships, these organelles become incorporated into eukaryotic cells through partnerships that formed between cells. Through the relationship these organelles became functional structures within the partner cells in return for nutrition, protection and so on.

# *Graham Cairns-Smith and Self-Replicating Molecules*

Cairns-Smith proposed that the first organisms came from inorganic crystals of clay. Like all crystals, clay mineral self assemble in specific patterns that are determined by the minerals that composed them. Clay surfaces attract organic molecules. The repeating pattern of mineral crystals could have acted as a mechanism to store and transmit coded information. Thus, these organisms could have carried information and lead to the formation of self-replicating molecules such as RNA and DNA

# *Haldane- Oparin Hypothesis or Heterotrophic Hypothesis (1920-30)*

This is the most widely accepted theory and suggests that the first organic compounds were formed by natural chemical processes on the primitive earth and that the first life-like structures developed from **coacervates** (aggregates of large protein-like molecules) and were heterotrophs. The major concepts that make up this hypothesis are:

* Primitive atmosphere was very hot and consisted of hydrogen (H2), water vapor (H2O), ammonia (NH3) and methane (CH4).
* Oceans when first formed were not much below the boiling point of water. They have been described as “hot, thin soup” in which chemical reactions occurred rapidly.
* Energy in various forms such as UV light, lightening and volcanic heat was available to bring about the synthesis of organic compounds from the inorganic compounds listed above.
* These newly created organic compounds formed aggregates, or clusters, of larger molecules called coacervates that may have resembled cells.
* Numerous chemical reactions occurred within the coacervates making them more complex. They developed biochemical systems to process organic nutrients from their environment as a means of generating energy within themselves. These structures were referred to as heterotrophs (**heterotroph hypothesis**).
* Energy produced through the first heterotrophs was anaerobic since no oxygen was present in the earth’s primitive atmosphere. This would release carbon dioxide into the oceans and atmosphere
* Eventually organisms developed that could use light energy and formed the first photosynthetic organisms. This added oxygen to the oceans and the atmosphere.
* The presence of oxygen allowed for the development of organisms with the capacity for **aerobic respiration**. Aerobic respiration is much more efficient than **anaerobic** **respiration**, so aerobic organisms became dominant.
* These early life forms were prokaryotic and as evolution continued organelles began to form and collect through symbiotic relationships, forming eukaryotic cells.

This hypothesis is supported by the experiments of Miller and Urey (1953). Miller and Urey produced an experiment to try and prove the origin of life. They took the materials present on the earth at that time: methane, ammonia, water and hydrogen and placed them in a flask. They exposed the flask to sparks to represent the sunlight and lightening on the earth at that time. They discovered that from such an experiment it was possible to create organic compounds (amino acids) that could have been the beginning of life on earth.