Cycle 10: Diversity of Life

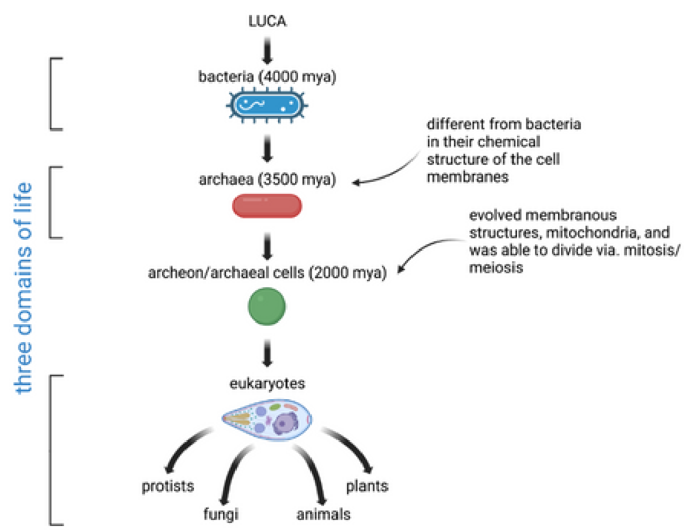
Introduction to Cellular Life

All life, either multicellular or unicellular organisms, are descended from a common ancestor. All cellular life shares common characteristics, which are the following:

1. Made of cells surrounded by a lipid cell membrane
2. Contains DNA, i.e. the heritable genetic code (note that all life uses the same code)
3. Follows the central dogma: DNA ⇒ RNA ⇒ proteins/enzymes
   a. Uses the same proteins/enzymes to do this (e.g. ribosomes, polymerases)
4. Use the same energy currency: ATP
   a. Uses the same proteins/enzymes to generate ATP
5. All life shares ~50 genes
   a. The more closely related you are, the more genes shared

Evolutionary History and LUCA

As previously mentioned, all life is related through common descent. This common descendant is called LUCA (Last Universal Common Ancestor). It most likely exhibited the following characteristics: cellular, prokaryotic (likely bacterial), anaerobic, autotrophic (ability to synthesize organic molecules), and use of chemical energy from hydrothermal vents.



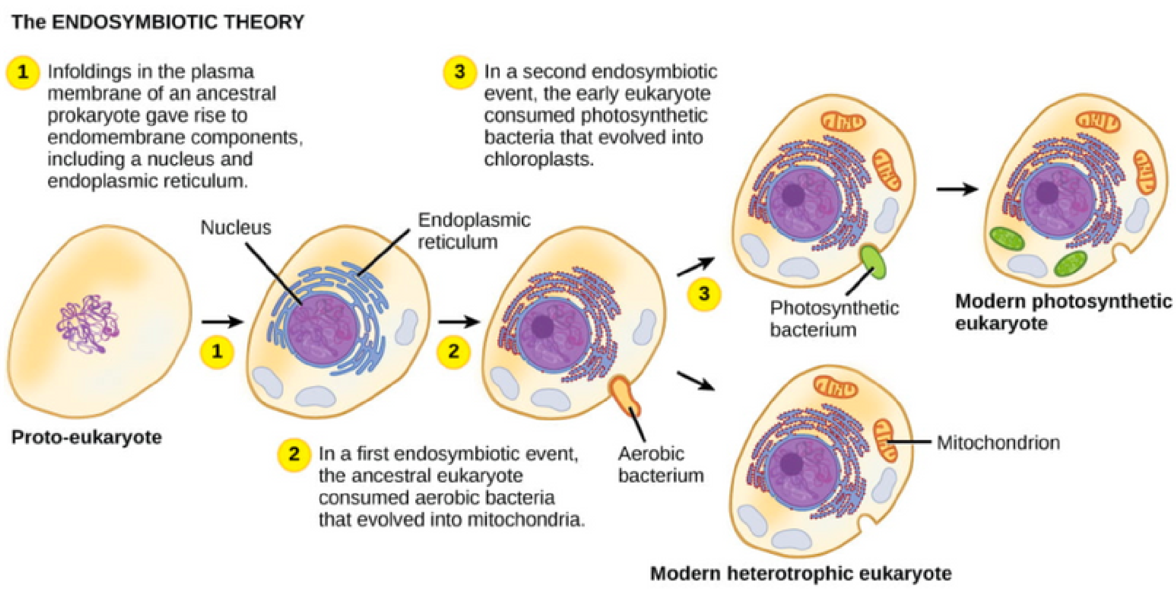
The archaeal cells evolved membrane-bound organelles similar to present-day eukaryotes such as a nuclear envelope, an endoplasmic reticulum, and Golgi complex. Over time, they also became mitochondria. Mitochondria are not like other organelles, as they have their own DNA, which is mostly in the form of a **circular chromosome**. With this chromosome, they encode genes to make their *own ribosomes* and other proteins, can undergo **division** of preexisting mitochondria, and their *membranes* contain proteins for the electron transport chain.

But why are they different from other organelles? This is explained by the **Theory of Endosymbiosis.**

Introduction to the Theory of Endosymbiosis

This theory states that mitochondria evolved from an aerobic carbohydrate-eating (heterotrophic) bacterial symbiont. Over time, this symbiont lost the genes required to live independently as some of its genes are transferred to the host cell's DNA in the nucleus while others stay within the symbiont.

The Theory of Endosymbiosis also explains the origins of chloroplasts. Similarly to mitochondria, chloroplasts were originally from a bacterial symbiont, however, this symbiont was a photosynthetic symbiont called a cyanobacteria. Chloroplasts also have similar characteristics as mitochondria as they have circular DNA, genes for ribosomes and proteins, can divide independently, and have an electron transport chain for photosynthesis. Remember that chloroplasts are only in plant cells, while mitochondria are in both plants and animal cells.



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Evolutionary Timeline

Throughout the history of the Earth, life has constantly evolved and changed. 3000 mya all life on earth was microbial (unicellular) and it wasn't until ~1000 mya that the first multicellular organisms evolved. These evolved from LUCA → bacteria → archaea → opisthokonts → animals → chordates. Opisthokonts are a group of eukaryotes that include fungi and animals. The fungi were the first opisthokonts to evolve around 1000 mya → choanoflagellates, around 900 mya → animals, around 800 mya. Chordates (animals with a dorsal nerve cord) then evolved ~565 mya and modern descendants of the earliest chordate lineages are the sea squirt and lancelet.

The first event recorded was the Cambrian Explosion (~540 mya) which is characterized by the emergence of many phyla that make up modern animals. This was shown by the sudden appearance of complex animals in the fossil record as organisms prior to this event did not fossilize well. These complex animals include vertebrates (evolved ~540 mya) such as lungfish, sharks, and rays. Plants also began to evolve and live on land (~470 mya).

Mass Extinction Events

There have also been many mass extinction events that have occurred. These mass extinction events opened habitats for other forms of life to evolve. The first mass extinction event was the **Ordovician-Silurian mass extinction** which occurred ~440 mya where most of the life was in the sea. After this mass extinction event, 85% of sea life was lost and the evolution of animals on land began with amphibians appearing ~340 mya and reptiles appearing ~310 mya.

The next mass extinction event was the **Late Devonian mass extinction** which occurred ~370 mya and 70% of animal species were lost. However, the cause of the extinction event is unknown. The following mass extinction event is the **Permian mass extinction** which occurred ~250 mya and 96% of all species were lost. All current existing animals evolved from the remaining 4% that survived.

Around 200 mya, the **Triassic-Jurassic mass extinction** occurred and 50% of species were lost. This event opened up habitats on land for dinosaurs to evolve. As well, it allowed for the evolution of early placental and non-placental mammals (e.g., kangaroos, platypuses, etc.) around ~180 million years later. The **placenta** is an organ that develops as the embryo develops to provide nutrients and nourishment and take away waste. It first evolved via the aid of a retrovirus which integrated into the host genome. The envelope gene from the retrovirus-infected mammal is called *syncytin* which promotes the fusion of cells and helps with the development of the placenta.

The last mass extinction event is the **K/T mass extinction** (Cretaceous-Tertiary mass extinction) and this occurred 65 mya. During the event, 75% of plants and animals were lost, including dinosaurs, other large animals, and most flowering plants. However, this event opened up habitat for the diversification of mammals (age of the mammals)

Evolution of Humans

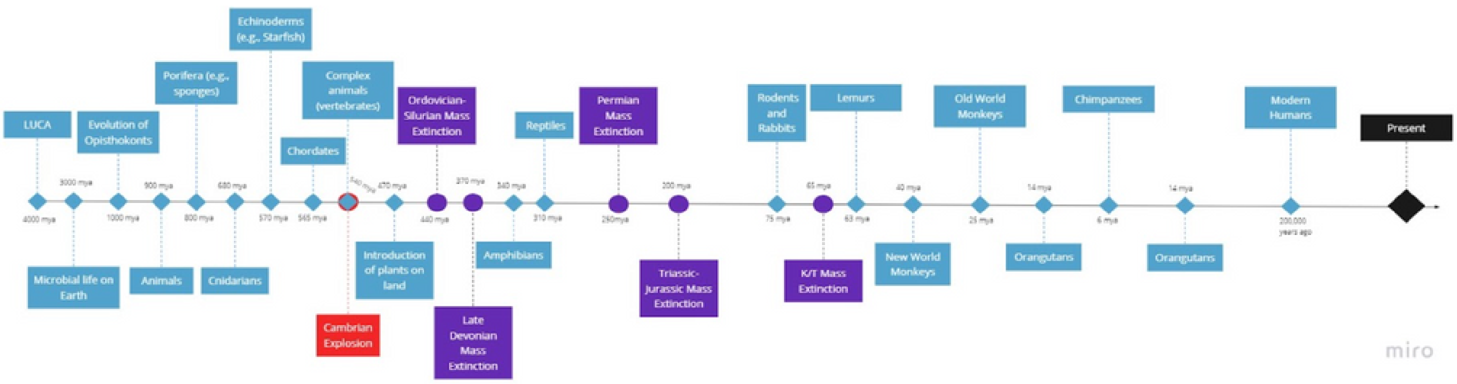
Humans have evolved for millions of years to now have certain characteristics that make them unique. These include bigger brains, upright posture, bipedal, flexible and precise grip, hairlessness, blushing, social and cultural cognition, and language.

You may have heard that humans have evolved from chimpanzees or other existing apes, however, this is a common misconception as we evolved from a common ancestor that we shared in the past with chimpanzees. As well, there wasn't a direct evolution to humans and it took a long time for us to evolve to become homosapiens.

Homosapiens coexisted with Neanderthals, Denisovans, and probably other hominins for thousands of years. There has been evidence of gene flow between the three groups from preserved bones in which similar DNA sequences were found. This likely means that our human ancestors likely interbred with them.

Even though it may not seem like it, human evolution is still occurring. Gene flow likely has a much greater effect as humans can move from continent to continent, however, genetic drift is much less likely in humans as human populations keep increasing. Mutations are a major source of evolutionary change and increased exposure to sunlight and chemicals can increase mutations in humans. There are also other forces for adaptations from new food sources and environments, such as:

1. Amylase copy number (enzyme in the saliva) has increased – adaptation to the carbohydrate-rich food we now eat
2. Lactase persistence (lactose tolerance) – adaptation to human population consuming milk
3. Oxygen transport at high altitudes – adaptation due to populations that live at high altitudes
4. Pale skin at high latitudes – adaptation to less intense sunlight at high latitudes; allows for greater absorption of vitamin D
5. Immune receptors – adaptation to parasites
6. Larger rain size and development language via FOXP2 regulatory gene (we share this gene with Neanderthals) – adaptation to greater demand for communication



Hallmark of Human Evolution: the Hypothesis Behind Increased Brain Size

Humans have evolved a bigger brain which has helped to store more information, rapidly collect and process information, solve problems, and create abstract ideas and images. However, big brains are costly and have both energetic and structural costs. Due to the large brain size, it makes up 2% of body weight but requires 20% of oxygen and energy. Additionally, due to its structure, it makes childbirth more difficult.

Why did we evolve to develop an increased brain size? In short, it's because the benefits outweigh the costs. Nevertheless, there are 4 hypotheses that explain why we evolved to have large brains.

The first hypothesis is the **ecological-intelligence hypothesis** which states that we developed large brains to tackle environmental challenges (e.g., finding food) and for survival (e.g., tool use, language, planning). However, this hypothesis is not necessarily accurate as other animals can do the same without the development of a large brain.

The next hypothesis is the **social-intelligence hypothesis**. This hypothesis is based on the competitive and cooperative challenges of living with other members of the same species. Cooperation and coordination, but also deception, coercion, and manipulation lead to success and this required the presence of a large brain.

Following this hypothesis is the **cultural-intelligence hypothesis** which combines the ideas of both hypotheses above. It states that we evolved larger brains for the social learning of ecologically relevant skills such as cooperative hunting and building shelter.

The last hypothesis is the **mating-mind hypothesis** which states that bigger brains evolved as an elaborate trait (sexual selection). The larger brain size allowed for greater ornamentation in attracting mates such as art, wordplay, humour, and music, which resulted in mating success.

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