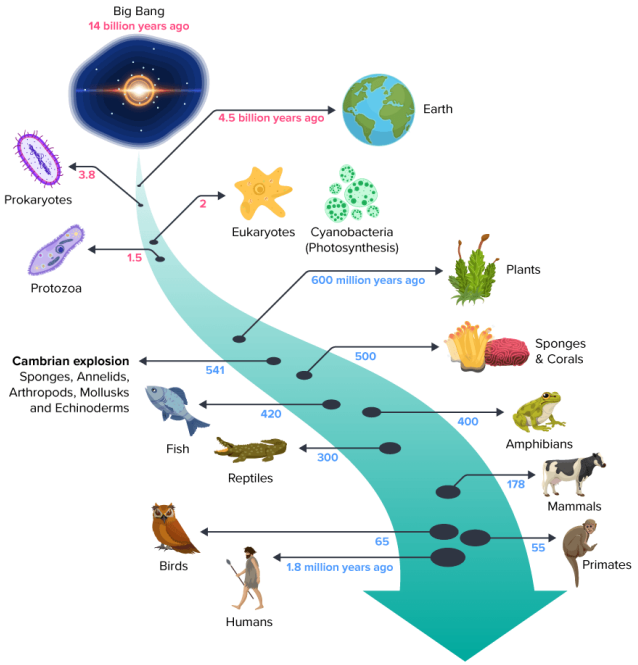
Introduction to evolution and natural selection

"Nothing in biology makes sense except in the light of evolution."

– Theodosius Dobzhansky

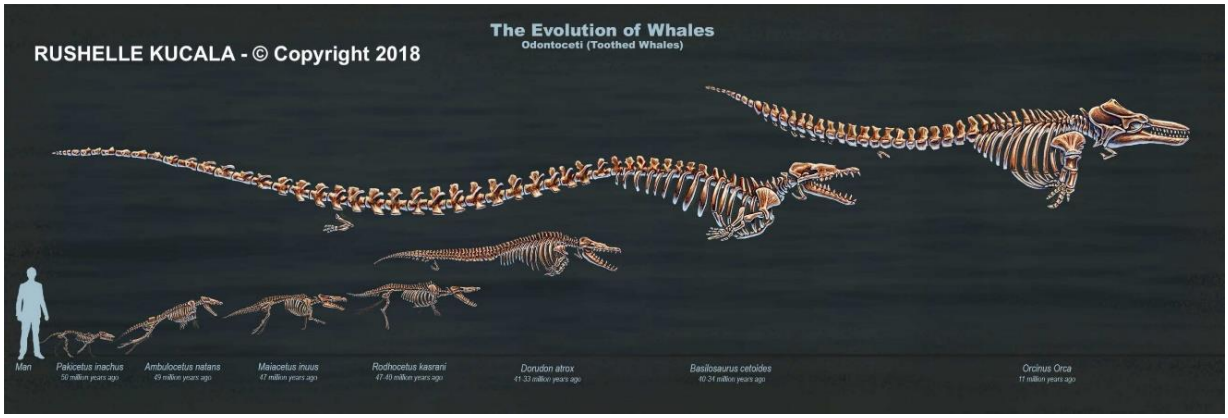
Evolution is the process by which modern organisms have descended from ancient ancestors. This process, known as **descent with modification**, occurs over many generations through a combination of natural selection and genetic change.

Fossils are used as evidence of evolutionary trends because they provide a record of ancient life. By studying the characteristics of fossilized organisms, scientists can learn about the evolutionary relationships between different species.

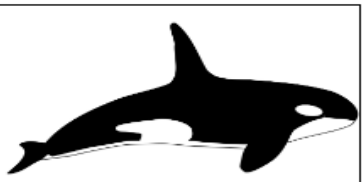


Below is a simple example using fossil evidence to show the evolutionary trend of whales over 50 million years. It shows changes such as:

- Removal of hind legs
- Change in the shape of the skull to make sonar possible



Whale evolution

		
Pakicetus (about 50 million years ago). 1 – 2 meters long.	*Basilosaurus* (41 to 34 million years ago). About 16 meters long.	Humpback whale (current). 12 – 16 meters long.

While some species have changed significantly over time, others have remained almost unchanged. These species, known as "**living fossils**," have low diversity and have persisted for long periods of time. An example of a living fossil is the **coelacanth**, a type of fish that was thought to have gone extinct 66 million years ago.

Why has the coelacanth been so successful?

(1) One possibility is that it has been successful in adapting to its environment and has had few predators, allowing it to survive and reproduce without the need for significant evolutionary changes.
(2) Another possibility is that the coelacanth has a simple life cycle and reproductive strategy, which allows it to survive and reproduce in a wide range of conditions. It may not have been exposed to the same selective pressures that have led to the evolution of other species.

How does evolution work?

Natural selection, also known as "**survival of the fittest**," is a basic mechanism of evolution. It occurs when individuals with characteristics that increase their chances of survival are more successful and pass these characteristics from one generation to the next. Over time, these characteristics become predominant within a population.

Mutations, which are changes in an organism's genetic material, also play a role in natural selection. If a mutation gives an individual an advantage in its environment, it is more likely to survive and reproduce. Over time, these advantageous mutations can become a predominant characteristic within a population.

The process of natural selection can be understood in terms of gene pools. A **gene pool** is the total collection of genes in a population at a given time. The traits that are present in a population at a given time are determined by the gene pool. If a trait is advantageous and increases an individual's chances of survival and reproduction, it becomes more prevalent in the gene pool over time.

Example: Peppered moth

1. During the Industrial Revolution in England, the trees where the peppered moth lived became covered in soot from factories.
2. This made the lighter-colored moths more visible to predators, while the darker moths were better camouflaged.
3. The lighter moths had a disadvantage and were less likely to survive and reproduce.
4. A mutation for darker coloration occurred in some individuals, giving them a survival advantage.
5. The proportion of darker moths in the population increased over time due to natural selection.
6. The trait for darker coloration became more prevalent in the gene pool as a result.

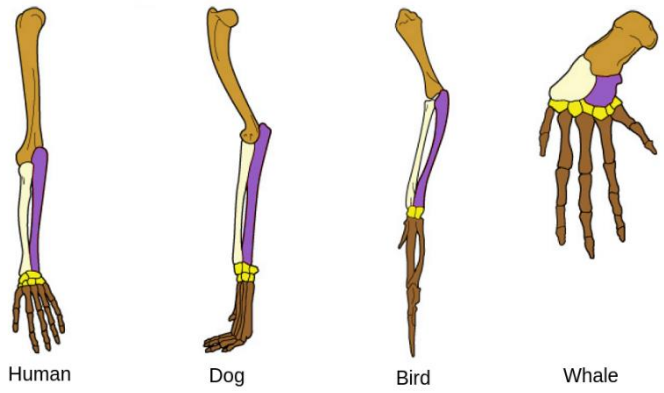
Extinction, fossil evidence and history of earth

Extinction is the dying out of a species because it cannot adapt to new environmental conditions. This can occur naturally as part of the evolutionary process, but it can also be caused by human activity such as habitat destruction, overhunting, and pollution.

Mass extinctions, which are periods of time in which a large number of species go extinct in a relatively short period, have played a significant role in evolution. These events can have a drastic effect on the diversity of life on Earth and can free up niches for new species to evolve and fill.

There is evidence of **common descent,** or the idea that all living things are descended from a common ancestor, in a number of ways:

(1) Structural and embryonic similarities between different organisms. Eg: similar bone structures in the forelimbs of animals such as **birds, bats, and whales** suggests that they may have evolved from a common ancestor



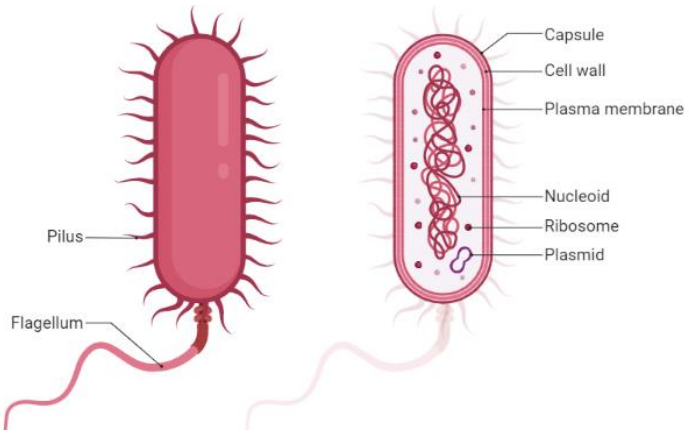
(2) Geographic distribution of organisms. Eg: species in certain geographic regions only such as the kangaroo

(3) Fossils

The **early Earth** (4.5 billion years ago) contained **water** and a primitive atmosphere containing greenhouse gases such as **carbon dioxide, methane, and ammonia**, but ***NO oxygen***. Over time, the Earth's atmosphere and climate have changed, leading to the evolution of new species and the extinction of others.

Prokaryotes

The first anaerobic prokaryotic cells appeared on Earth about 3.5 billion years ago. These cells, which are the most ancient known form of life, were simple and **lacked a nucleus or other membrane-bound organelles**. Bacteria, which are a type of prokaryote, are still found on Earth today and are important for a variety of ecological processes.



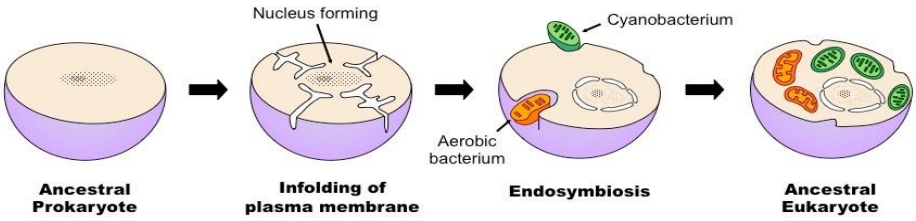
Photosynthetic bacteria, which are capable of producing their own food through photosynthesis, appeared on Earth shortly after the first prokaryotes. These bacteria released **oxygen** as a by-product of photosynthesis, which accumulated in the atmosphere. It had 2 main effects:

(1) The presence of oxygen in the atmosphere led to the **mass extinction** of many organisms that were not able to survive in an oxygen-rich environment.
(2) The increased oxygen levels in the atmosphere formed the **ozone layer**, which protects life on Earth from harmful UV radiation. This facilitated the colonization of land by organisms, as it allowed for the development of more complex life forms that were able to survive in terrestrial environments.

Eukaryotes

Eukaryotic cells are **larger and more complex** than prokaryotic cells, and they have a **nucleus** and other **membrane-bound organelles**. It is believed that eukaryotic cells evolved from prokaryotic cells through a process known as endosymbiosis, in which one type of prokaryote lived inside another prokaryote and eventually became a permanent part of the host cell.

Organelles such as **mitochondria** and **chloroplasts**, which are important for energy production and photosynthesis, respectively, are thought to have originated through endosymbiosis. These organelles are thought to have evolved from prokaryotic cells that lived symbiotically within host eukaryotic cells, contributing to the complexity of eukaryotic cells.



➔ **Single-celled eukaryotes**, which are a type of cell that is more complex than prokaryotes, developed **sexual reproduction** as a way to increase genetic diversity. Sexual reproduction involves the exchange of genetic material between two individuals, resulting in offspring that are genetically different from their parents. This increases the rate of evolution because it produces **a greater variation** in offspring, increasing their ability to adapt to changing environments. This is because **different combinations of genetic material may lead to the development of traits that are better suited to the environment**.

➔ **Multicellular organisms**, which are composed of many specialized cells that work together to perform specific functions, developed from colonies of undifferentiated cells. These colonies of cells became organized and specialized, leading to the development of tissues and organs. Multicellular organisms also exhibit **division of labour**, which is the specialization of cells to perform specific functions. This allows for increased efficiency and the ability to perform more complex tasks.

Problem of multicellular organisms:

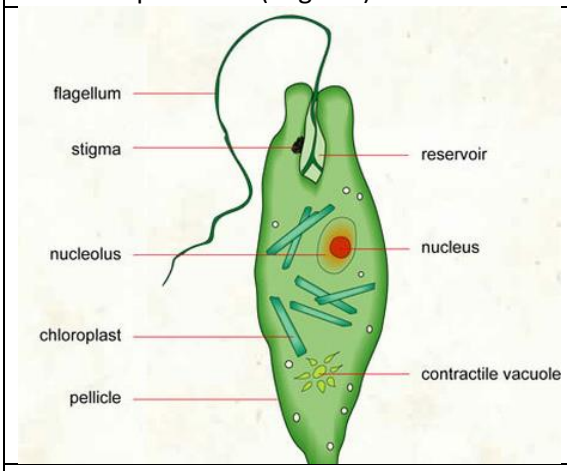
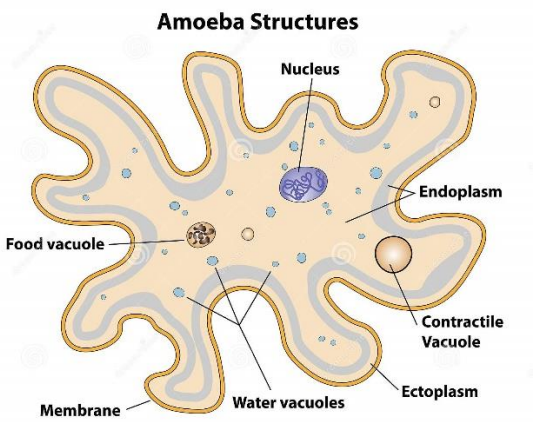
As multicellular organisms increase in size, they face the problem of maintaining a sufficient **surface area to volume ratio**. This is because a larger organism has a greater volume, but its surface area does not increase at the same rate. This can lead to problems with obtaining nutrients and removing waste. However, the development of specialized cells and tissues can help to solve this problem by increasing the surface area available for exchange.

Comparing Eukaryotes and Prokaryotes

Eukaryotes	Prokaryotes
Have a true nucleus containing genetic material	Lack a true nucleus and have genetic material scattered throughout the cytoplasm
Have membrane-bound organelles such as mitochondria, chloroplasts, and the endoplasmic reticulum	Lack membrane-bound organelles
Are generally larger in size	Are smaller in size
Can be single-celled or multicellular	Are single-celled
Include organisms such as animals, plants, and fungi	Include organisms such as bacteria and archaea
Can reproduce sexually or asexually	Can reproduce asexually through processes such as binary fission

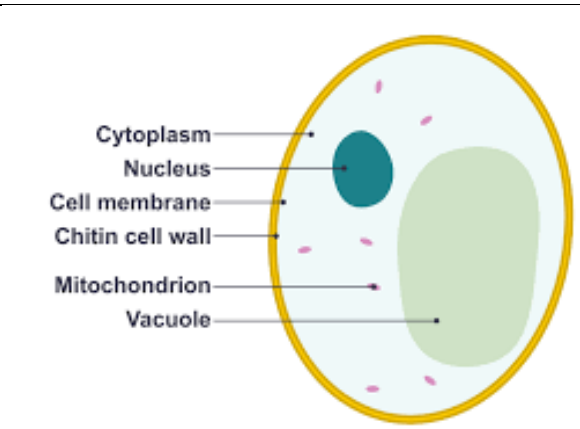
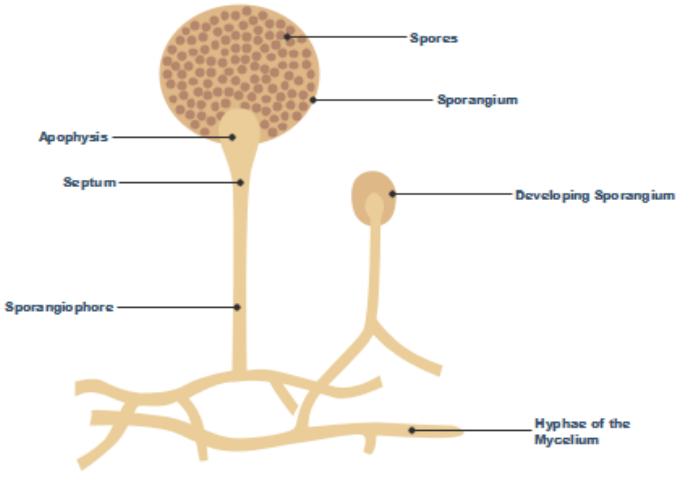
Protoctists

The first protoctists, which are **a diverse group of single-celled organisms**, appeared on Earth about 1 billion years ago. Protoctists include both plant-like and animal-like organisms and are believed to be the ancestors of modern plants, animals, and fungi.

Plant-like protoctist (Euglena)	Animal-like protoctist (Amoeba)
	
Similar to plant cells: - cell wall made of cellulose - chloroplasts for photosynthesis - large central vacuole	Similar to animal cells: - flexible cell membrane - cytoplasm - organelles such as mitochondria.

Fungi

Fungi are another group of **eukaryotic** organisms that colonized the Earth. They are characterized by their ability to **decompose organic matter** and are important for the cycling of nutrients in ecosystems. Fungi can be unicellular (eg: yeast) or filamentous (eg: mucor).

Yeast is an example of a **unicellular** fungus. It is a single cell with a cell wall and a cytoplasm containing organelles such as mitochondria and nuclei.	
Mucor is an example of a **filamentous fungus**. It consists of long, thread-like strands called hyphae that grow and branch out to form a network called a mycelium. The hyphae of a filamentous fungus have cell walls and contain cytoplasm with organelles such as nuclei and mitochondria.	

Worksheet [30 marks]

1. True or False? Write a reason in cases where the answer is "False" (10 marks)

    a. Natural selection is a process that can be easily seen as it occurs over a short period of time

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    _____

    b. Evolution is a linear process with one species evolving into another.

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    c. Mutations can be harmful or beneficial to the organism.

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    d. Fossil are the only evidence of common descent.

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    e. "Survival of the fittest" means that the strongest and fastest organism survive while others die.

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    _____

    _____

f. Mass extinctions can be beneficial for particular organisms.

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2. Answer the following questions:

a. What is extinction and what are the possible 2 reasons why it happens? (3 marks)

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b. Coelacanth is a species that hasn't evolved for millions of years. Suggest reasons for this. (2 marks)

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c. What is a gene pool? Choose a particular trait and explain how evolution works. (3 marks)

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d. Why are fungi important and what are the 2 types of fungi? (3 marks)

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3. Draw well labelled diagrams of a Euglena and an amoeba (6 marks):

Euglena:	Amoeba:

4. Complete the following table (3 marks)

	Prokaryotes	**Eukaryotes**	**Protoctists**
Cell type	Single cell		Single cell of multicellular
Size		Large	Small
Nucleus	Absent	Present	
Examples			