8.4 - Life on Earth:

Prerequisite Knowledge:

- *Discuss evidence that present-day organisms have developed from different organisms in the distant past:*
  - Comparison of the physiology of fossils to present day organisms have showed relationships between the organisms
  - The examination of the DNA structure of organisms has shown the development from past organisms.
- *Describe the conditions under which fossils form:*
  - Fossils are any remains of past life found in rocks of different ages
  - Fossilisation is a rare event
  - For fossilisation to occur, the following events must happen:
    - Quick burial in soil, sand or mud, or in tree sap or ice
    - Prevent decay
    - Organism lies undisturbed
  - Complete fossils are only very rarely found
  - Usually, only the hard parts, such as teeth and bones, are found as fossils
  - Footprints, trails, burrows and even animal poo (coprolites) are fossils
  - Fossils are only found in sedimentary rocks
- *Relate the fossil record to the age of the Earth and the time over which life has been evolving:*
  - The study of fossils shows that there has been a great diversity of living organisms since the Precambrian times
  - The types and abundance of organisms have changed over long periods of times
  - Using the fossil record and knowledge of present day diversity, the evolutionary pathways of organisms can be traced back
  - If we compare present-day organisms with those from the fossil record, we can see a history of change
  - An example is the evolution of the horse, whose fossil record has been excellent

1. Analysis of the oldest sedimentary rocks provides evidence for the origin of life:

- *Identify the relationship between the conditions on early Earth and the origin of organic molecules:*
  - Conditions of early Earth:
    - Massive oceans existed
    - Only small landmasses above the surface of the water
    - No ozone layer
    - Large amounts of radiation reached the Earth
    - No free oxygen in the air
    - Large amounts of volcanic activity; heat, ash, dust and gases into atmosphere
    - Violent electric storms common
    - Atmosphere contained some water vapour (H_2O), hydrogen (H_2), hydrogen cyanide (HCN), a lot of carbon dioxide (CO_2), nitrogen (N_2), possibly ammonia (NH_3) and methane (CH_4).
  - The chemicals of life are contained within the following basic organic compounds: water, carbohydrates, lipids, proteins, and nucleic acids.
  - These compounds are made up of hydrogen (H), oxygen (O), carbon (C), nitrogen (N) and some other common elements.
  - As you can see, the elements needed to create the basic organic compounds were already present in the atmosphere; i.e., H, O, C and N were already there.
  - The lack of an ozone layer, the frequent violent electric storms, and the volcanic activity of early Earth could have provided the energy for molecules to be formed.
- *Discuss the implications of the existence of organic molecules in the cosmos for the origin of life on Earth:*
  - For life to have originated, the following events need to have happened:
    - The required chemicals need to have been formed
    - These chemicals need to have come together in a self-replicating body
    - This body would need to have a form of protection for its contents
    - It had to be able to use an energy source to replicate itself

- The first step needed for life to be formed would be that the organic molecules needed for life would have to be present
- These organic molecules could have been formed here on Earth, or been sent to Earth from outer space (the cosmos)

- *Describe two scientific theories relating to the evolution of the chemicals of life and discuss their significance in understanding our origin of life:*
  - <u>Theory 1:</u> The chemicals for life came from outer space:
    - Before an atmosphere was formed, nothing stopped meteorites hitting the Earth
    - Scientists believe Earth was heavily bombarded with meteorites during formation
    - Certain types of meteorites, called carbonaceous chondrites, have been found, which contain organic molecules, like amino acids
    - This provided evidence of organic molecules somewhere else in the universe
    - This means that the chemicals for life could have come from outer space
  - <u>Theory 2:</u> The chemicals for life were formed on Earth:
    - Haldane and Oparin suggested that early Earth contained all the basic chemical components necessary for life
    - They hypothesised that complex organic molecules, like nucleic acids and carbohydrates, could have been created using inorganic molecules through slow reactions using energy from lightning or UV rays.
    - These complex organic molecules could have collected together on the surface of the oceans, forming a "soup", which later could have formed cells
    - The theory was untested until the 1950s, when Urey and Miller tested it in the lab

- *Discuss the significance of the Urey and Miller experiment in the debate on the composition of the early atmosphere:*
  - Urey and Miller performed the following experiment to prove Haldane and Oparin's theory:
    - A closed system was set up and powerful electrical sparks were passed through a chamber containing ammonia, hydrogen, and methane.

  - These chemicals were used because the scientists wanted to recreate the atmosphere of early Earth.
  - Steam was recycled and passed through the chemicals
  - After a week, the steam collected was red and turbid. When this water was tested, it was found to contain some amino acids.
- This experiment proved that, if early Earth did contain those chemicals, life could have formed from inorganic molecules.

- *Identify changes in technology that have assisted in the development of an increased understanding of the origin of life and evolution of living things:*
  - The Urey/Miller experiment has been improved using modern technology
  - UV radiation and carbon dioxide is used instead of electricity and ammonia and methane, to make the conditions in the closed chamber more like that of early Earth.
  - Advances in technology that has increased our knowledge of the origin of life and evolution are the changes in chemical analysis, biochemistry and molecular biology.
  - Other technological advances:

Technology	**Uses**
Microscope	Enabled the discovery or micro-organisms
Radiometric Dating	Can assign absolute dates to rocks/fossils Has established age of the Earth as 4.5 billion years old
Electron Microscopy	Remains of microbes and mineral nature of rocks can be studied in detail
Gas and Liquid Chromatography Radioactive Tracing Amino Acid and Nucleotide Sequencing Spectrophotometry	Enabled the comparisons between ancient organic material and biological material today

- *Gather information from secondary sources to describe the experiments of Urey and Miller and use the available evidence to analyse the:*
  - *Reason for the experiment:*
    - To test the hypothesis of Haldane and Oparin
    - i.e. organic molecules could have been created on the surface of early Earth, from inorganic molecules using energy from UV rays and lightning
  - *Result for their experiment:*
    - After a week of electrical discharge and recycling steam through their apparatus, they analysed the condensed liquid
    - It was found to contain amino acids, the building blocks of proteins
  - *Importance of their experiment in illustrating the nature and practice of science:*
    - It showed that hypotheses and theories are welcomed in science, but are only accepted when backed up with scientific proof, that is, experiments.
  - *Contribution to hypotheses about the origin of life:*
    - The results supported Haldane and Oparin's theory that early Earth contained the basic chemical components for life
    - It proved that complex organic molecules can be produced from basic chemical components or inorganic molecules

2. The fossil record provides information about the subsequent evolution of living things:

- *Identify the major stages in the evolution of living things, including the formation of:*
  - *Organic molecules*
    - The first stage of the evolution of life was the creation of organic molecules, either through synthesis from inorganic molecules, or from outer space
    - These organic molecules began to clump together in a "soup"
  - *Membranes*
    - A membrane had to be developed to protect the internal environment of the large organic molecule
    - The internal environment, i.e. the contents began to evolve into nucleic acids and the primitive cell could now replicate
    - RNA was thought to be the first genetic material
  - *Procaryotic heterotrophic cells*
    - The first and simplest types of cells, like bacteria
    - No membrane-bound nucleus or membrane-bound organelles
    - These consumed other organic molecules to provide energy (heterotrophic)
  - *Procaryotic autotrophic cells*
    - Some of the heterotrophic procaryotic cells developed pigments
    - These pigments allowed them to use the energy from the sun to create food
  - *Eucaryotic cells*
    - These cells had membrane-bound nuclei and organelles
    - Examples include animals, fungi, plants
  - *Colonial organisms*
    - Colonial organisms are groups or colonies of similar cells, eg, stromatolites
    - All the cells in the colony have the same function; no differentiation
    - They form when daughter cells from cell division become bound together

- *Multicellular organism*
    - These are groups of cells, where some cells have differing functions from others
    - Each cell has its own specialised function and all cells depend on each other
    - The organism functions as a coordinated whole

- *Describe some of the paleontological and geological evidence that suggests when life originated on Earth*
  - Fossils are found in sedimentary rocks, the oldest of which are 3800 million years old
  - The earliest fossils are of 2 types:
    - Microfossils, these are similar to present day unicellular, anaerobic (does not need oxygen) procaryotic organisms
    - Stromatolites, layered clumps or photosynthetic cyanobacteria
  - Modern stromatolites are found in Western Australia, Shark Bay
  - Microfossil and stromatolite fossils are found in 3 places:
    - 3400 – 3500 mya rocks from Warrawoona Group, Western Australia
    - 2800 – 3000 mya rocks from Fig Tree Group, South Africa
    - 2000 mya rocks from Gunflint Chert rocks, Lake Superior, North America
  - The first cells were heterotrophic, and obtained energy through consuming compounds
  - Then some cells developed pigments, which could be used to harness light energy
  - This development of photosynthesis meant a reduction in the amount of carbon dioxide in the atmosphere
  - Oxygen did not immediately begin to build-up in the atmosphere, but rather it was taken up by rocks.
  - Oxidised rocks can be seen in ancient banded iron formations and red bed rocks
  - The fact that anaerobic cells developed first, in an anaerobic environment, says that life could not have evolved in the presence of oxygen

- *Explain why the change from an anoxic to an oxic atmosphere was significant in the evolution of living things:*

- The conditions needed for life as we know it are:
  - Available liquid water
  - Protection from ultraviolet (UV) radiation
  - Free oxygen in the atmosphere
- Water was already readily available; it was everywhere
- When all oxidisable rock had been saturated with oxygen, due to the increase of photosynthetic organisms, the atmosphere began to fill with oxygen
- Firstly, the oxygen reacted with the UV radiation, and created ozone
- When enough ozone was created, it formed an ozone layer
- This protection from UV rays by the ozone layer enabled more sensitive organisms to develop on Earth
- Oxygen began to build up and the atmosphere was changed from anoxic (no oxygen) to oxic (has oxygen)
- The significance was that anaerobic organisms declined, and aerobic organisms thrived
- The number of photosynthetic organisms rose sharply
- Today, anaerobic organisms only live in places of low oxygen concentration; swamps and bogs, deep underground, etc.
- The protection provided by the ozone layer enabled organisms to live on land
- Aerobic organisms took advantage of the abundant oxygen by evolving a system of producing energy that lies on the presence of oxygen: respiration
- The energy efficiently produced in respiration enabled organisms to increase in size and in their complexity

- *Discuss the ways in which developments in scientific knowledge may conflict with the ideas about the origins of life developed by different cultures:*
  - **Science:** Evolution; all organisms are constantly changing, not created, but evolved.
  - **Christians:** They believe in Biblical creationism; all organisms created as they are by God, no change over time

- **Chinese:** Believe the first organism was P'an Ku, who evolved in a giant cosmic egg. All elements of the universe were in the egg, all mixed. In the egg, he separated the opposites, then 18,000 years later the egg hatched, and P'an Ku died from the effort of creation.
- **Aboriginals:** Dreamtime; great supernatural beings existed in the dreamtime and created the Earth and everything in it
- **Greek:** Aristotle's ideas that the whole universe had a hierarchy and that it started from rocks, up through plants and animals, to humans, and finally to God.
- **Romans:** Lucretius, a Roman philosopher believed there was no God, because the universe was so imperfect. It was made of particles all squeezing together.
- As you can see, science contradicts with the belief of many people.

3. Further developments in our knowledge of present-day organisms and the discovery of new organisms allows for better understanding of the origins of life and the processes involved in the evolution of living things:

- *Describe technological advances that have increased our knowledge of procaryotic organisms:*
  - Structural methods include differences in size and shape, general appearance; type of structures needed for movement; absence, presence or type of cell wall; spores and microscopic staining
  - These methods are useful for classification, but do not reflect on evolution
  - Two new technologies have enabled a new classification of procaryotes to emerge:
    - **Electron microscopes:** Shows the differences in the ultrastructure (fine details of cells)
    - **Biochemical techniques:** Studies of the metabolic pathways in procaryotes have revealed new similarities and differences. Sequencing the amino acids in the proteins and the nucleotides in the DNA and RNA is now possible. *These studies are based on the concept that the smaller the difference in the sequence of two organisms, the closer related they are.*
- *Describe the main features of the environment occupied by one of the following and identify the role of this organism in its ecosystem:*

Procaryotic Cell	**Environment Where Found**	**Role in the Ecosystem**
Archaeobacteria	Hostile environments such as salty brines (*halophiles*), boiling springs, ocean thermal vents.	Carry out inorganic reactions for chemical energy hydrogen + sulfur = hydrogen sulphide + energy carbon dioxide + hydrogen = methane + water + energy
Eubacteria Exist as spherical, rod-shaped and spiral forms	Are widespread including all habitats: Land, freshwater, marine and in a host. Well known for the diseases many	Single-celled organisms that are parasitic or decomposers. They play an essential role in recycling in ecosystems.

	of them cause, but many are used in industry.	
Cyanobacteria Including stromatolites (Belongs to Eubacteria)	Widespread, especially in marine environments. Ancient forms exist in stromatolites. Some are free-living and some exist in mutualistic association with fungi in lichens.	Photosynthetic, therefore produce oxygen, use carbon dioxide and are the basis of food webs. Many have nitrogen fixing abilities and so enrich soil where they live. They are key components in plankton
Nitrogen-Fixing Bacteria	Occur in nodules living mutualistically on the roots of legume (pea) plants. They are also associated with other plants including cycads and water ferns. Some types are found free living in the soil.	Convert nitrogen from the atmosphere into ammonium ions that can be converted in amino acids in plants. Enables plants to grow in low-nitrogen soils. In the long-term they enrich soils with nitrogen
Methanogens (Belongs to Archaeobacteria)	Anaerobic conditions such as the sediment at the bottom of lakes and ponds, sewerage lagoons and in the intestinal tracts of animals.	Uses hydrogen, or hydrogen-rich compounds and carbon-dioxide to produce energy and release methane as waste
Deep-Sea Bacteria *Thermophiles* (Belongs to Archaeobacteria)	The boiling undersea vents of volcanoes that are underwater	They are the basis of food webs in undersea vents, making use of sulfur compounds from volcanoes for energy.

- *Use the available evidence to outline similarities in the past and present for one of the following:* (Cyanobacteria chosen)

Past:	**Present:**
+ Cyanobacteria are among the most abundant fossils in PRECAMBRIAN ROCKS (3.5 billion years old). Some scientists think they were the *only* organisms present at this time. In Precambrian times: - There was more UV radiation than today - There was no free oxygen until the first cyanobacteria developed primitive photosynthesis - The environment would be warm and damp like a mineral water spring + Stromatolites (made of cyanobacteria) were more common than today and also wider spread. + Cyanobacteria; some were free-living + In the Pilbara region, WA, layered rocks 3.5 billion years old have been found. This was at North Pole Dome + Stromatolites were found in the layered rocks + These were very similar to the hot-spring stromatolites found. + Geologists find bacteria in the superheated vents of mineral waters up to 150ºC	+ Cyanobacteria are still common today: - Damp areas, ponds, streams - Warm conditions - Thrive in areas with dissolved calcium bicarbonate - No longer the only life form + Today, most are aquatic forms, some are free-living in the soil - Some are marine stromatolites - Some live in a mutualistic relationship with fungi (lichens) + Today stromatolites are found at Shark Bay, WA; Sea water there is really salty + They occur in those environments close to limestone and low in nutrients + Stromatolites have also been found in: - Antarctica - Hot Springs - High alkaline lakes - Lake Clifton WA + Stromatolites are now in danger of extinction due to rising nutrient levels due to fertilisation. Rise in competition + This possibly happened in Precambrian times

4. The study of present-day organisms increases our understanding of past organisms and environments:

- *Explain the need for scientists to classify organisms:*
  - Taxonomy, the science of classifying organisms, is needed because:
    - It enables organisms to be DESCRIBED quickly and accurately
    - It makes COMMUNICATION simpler and more precise
    - It lets newly IDENTIFIED organisms belong to particular groups
    - It enables TRENDS in groups to be observed
    - It helps to identify relationships and establish EVOLUTIONARY pathways
- *Describe the selection criteria used in different classification systems and discuss the advantages and disadvantages of each system:*
  - The 2 KINGDOM system, consists of PLANTS and ANIMALS:
    - Selection criteria:
      - PLANTS: autotrophic, no locomotion, no cell wall
      - ANIMALS: heterotrophic, locomotion, no cell wall
    - Advantages:
      - The oldest system that works well with familiar organisms
    - Disadvantages:
      - Some unicellular organisms possess plant and animal traits
      - Does not recognise differences in eucaryotic and procaryotic cells
      - Fungi is difficult to classify
  - The 3 KINGDOM system, consists of MONERA, PLANTS and ANIMALS:
    - Selection criteria:
      - MONERA: procaryotic
      - PLANTS: eucaryotic, photosynthetic, no locomotion, cell wall
      - ANIMALS: eucaryotic, heterotrophic, locomotion and no cell wall
    - Advantages:
      - Separating the eucaryotes is useful as their structure is different
    - Disadvantages:
      - Some unicellular eucaryotic organisms possess animal and plant traits

- The 5 KINGDOM system, consists of MONERA, PROTISTA, FUNGI, PLANTS and ANIMALS:
  - Selection criteria:
    - MONERA: Procaryotic
    - PROTISTA: Eucaryotic, unicellular
    - FUNGI: Eucaryotic, multicellular, heterotrophic, no locomotion, cell wall
    - PLANTS: Eucaryotic, multicellular, autotrophic, no locomotion, cell wall
    - ANIMALS: Eucaryotic, multicellular, heterotrophic, locomotion
  - Advantages:
    - Distinguishing fungi from plants is useful, as fungi have no chlorophyll and so are functionally different
  - Disadvantages;
    - Protista contains widely differing organisms and as such is a fairly meaningless group

- *Explain how levels of organisation in a hierarchical system assist classification:*
  - In the hierarchical system, the organisms are divided into the following groups: Kingdom, Phylum, Class, Order, Family, Genus, and Species.
  - Organisms are classified into the different levels according to the features they have.
  - Different levels of similarity of difference can be reflected as you go up or down the hierarchy. The lower down you go (from kingdom to species) the more features the organisms have in common.
  - Levels of organisation are very useful for storing and retrieving information, as much information is stored about an organism at each level. For example, all organisms in the Class: mammals have milk glands.

- *Discuss, using examples, the impact of changes in technology on the development and revision of biological classification systems:*
  - When organisms were classified just according to their external structure (Linnaeus' system) there were only 2 kingdoms: plants and animals

- The invention of the light and electron microscopes, and the discovery of cells and the discovery of micro-organisms increased the number of kingdoms to 5
- Advances in molecular biology and biochemistry revealed the two major groups within the procaryotic monera: the Archaeobacteria and the Eubacteria.
- Hence the number of kingdoms has increased to 6
- The advances in molecular techniques, like DNA and amino acid sequencing have revealed new relationships between organisms
- All these advances in technology have allowed taxonomists to continually change and refine the current classification systems.

• *Describe the main features of the binomial system in naming species and relate these to the concepts of genus and species:*

- Many organisms have many common names, that vary from place to place
- To overcome this, a binomial system of naming is used to give every organism just one name, consisting of two parts.
- This name is called the "scientific name" and this system was developed by Linnaeus in the 18th Century
- In this system, an organism is given a name consisting of 2 parts.
- The first word has a capital latter and represents the GENUS of the organism
- The second word represents the SPECIES of the organism and has no capitals
- Both words are either written in italics or underlined.

• *Identify and discuss the difficulties experienced in classifying extinct organisms:*

- We only know of many extinct animals from their fossils
- Fossils can be difficult to classify because they are often incomplete or may not show enough detail of the organism
- If the organism has been extinct for a very long time, there may be no other organisms to classify it with
- Fossils can be named even if they only have a part of the fossil
- If the same organism is given 2 or more scientific names due to incomplete fossils, the first name given is taken as the correct one.

- *Explain how classification of organisms can assist in developing an understanding of present and past life on Earth:*
  - Ordering: Grouping organisms together brings a sense of order to a vast range of organisms. Classification also simplifies the description of things
  - Communicating: All scientists throughout the world use the same names no matter what language they speak; this means there is no confusion
  - Relationships: Show relationships with other organisms present today. Some show evolutionary pathways (phylogenetic)
  - Conservation: Through classification and observing organisms in different environments, we can learn about endangered species and try to save them from extinction in the future.