TOPIC A2
UNITY AND DIVERSITY: CELLS

SUBTOPIC A2.1
ORIGINS OF CELLS (HL)

Index

The big picture (HL)

Higher level (HL)

? Guiding question(s)

- What plausible hypothesis could account for the origin of life?
- What intermediate stages could there have been between non-living matter and the first living cells?

Keep the guiding questions in mind as you learn the science in this subtopic. You will be ready to answer them at the end of this subtopic. The guiding questions require you to pull together your knowledge and skills from different sections, to see the bigger picture and to build your conceptual understanding.

About 4.5 billion years ago, the force of gravity pulled rock that had been scattered around our Solar System into the cohesive sphere that we live on today, our planet, Earth. As the Earth cooled, the water vapour in the atmosphere condensed, falling as rain to become our oceans.

We use the term ‘primordial soup’ to describe these early oceans, which were rich in simple carbon-based compounds. We think that this primordial soup was the source of the first primitive life forms between 3.5 and 3.9 billion years ago (**Figure 1**), which then gave rise to the billions of species existing since.

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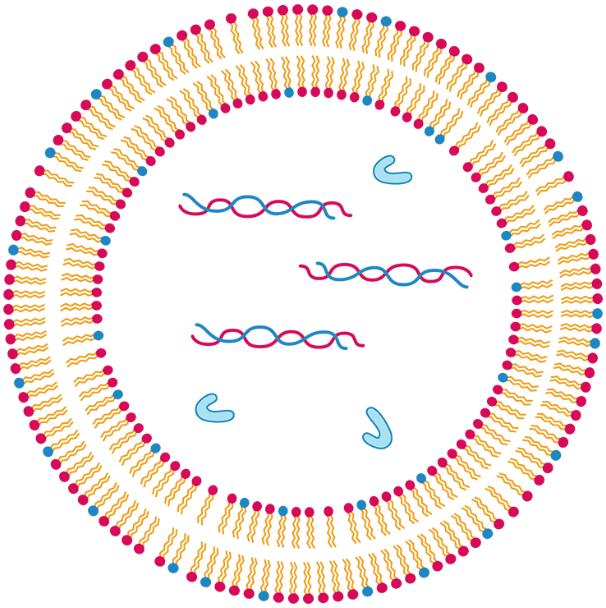

Figure 1. A primitive cell, consisting of a lipid membrane and genetic material, probably RNA, which can be passed onto offspring as the cell replicates.

More information for figure 1

The image is an illustration of a primitive cell. At the center, there is a circular structure, likely representing a lipid membrane. Within this, there are irregularly shaped blue elements, depicting genetic materials like RNA. The membrane appears as a thick orange ring enclosing the internal components. Thin lines emerge from the membrane, suggesting connections or interactions inside the cell. The interior structures are scattered randomly, filling the space within the membrane fairly evenly.

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International Mindedness

In some countries, the term 'billion' was previously used to denote 1 million million (that's 1 000 000 000 000). However, we now agree that **1 billion is equal to 1000 million** (1 000 000 000), and we use the term **1 trillion** to denote 1 000 000 000 000.

What are the benefits of everyone using the same term to denote the same amount?

When life first originated on Earth, the planet had a hostile environment (**Figure 2**). It was bombarded with asteroids and had widespread volcanic activity, with much higher temperatures than today. There was no ozone layer and the dusty atmosphere contained mostly methane, ammonia, water vapour, more carbon dioxide than exists today and no oxygen.

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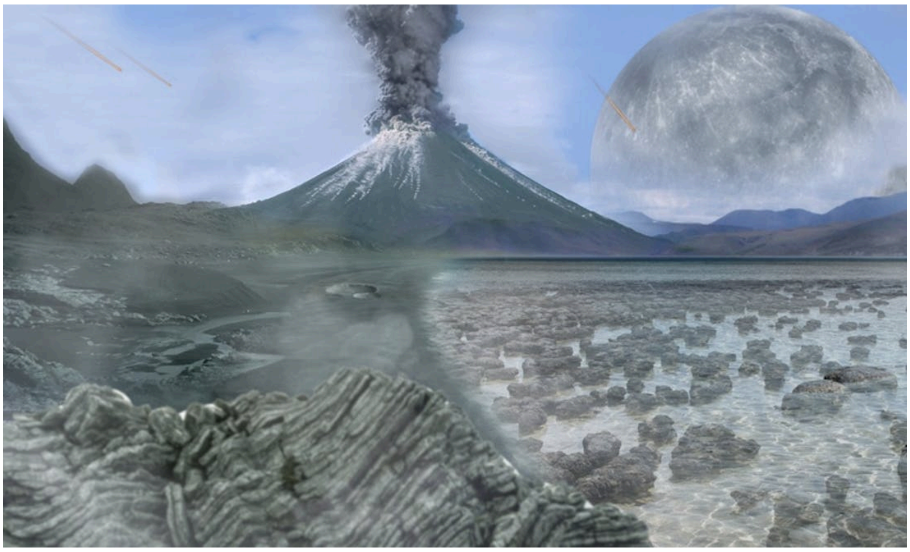

Figure 2. The hostile environment when life first originated on Earth.

Source: "Archean (https://commons.wikimedia.org/wiki/File:Archean.png)" by Tim Bertelink is licensed under CC BY-SA 4.0 (https://creativecommons.org/licenses/by-sa/4.0/deed.en)

But what conditions were necessary to support the development of life on Earth from inorganic molecules? What evidence do we have? And could life spontaneously form today?

Prior learning

Before you study this subtopic make sure that you understand the following:

- Cells are the building blocks of life.
- Cells divide and form new cells (see section D2.1.1 (/study/app/bio/sid-422-cid-755105/book/cytokinesis-id-44288/))

A2. Unity and diversity: Cells / A2.1 Origins of cells (HL)

Conditions on early Earth (HL)

A2.1.1: Pre-biotic formation of carbon compounds (HL)

Section Student... (0/0) Feedback Print (/study/app/bio/sid-422-cid-755105/book/conditions-on-early-earth-hl-id-44283/print/) Assign

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Higher level (HL)

Learning outcomes

By the end of this section you should be able to describe the conditions of early Earth and outline that these conditions may have led to the spontaneous generation of carbon compounds.

What is known about early Earth? When life originated between 3.5 and 3.9 billion years ago, the conditions on Earth were very different from the conditions today. Surface temperatures probably ranged from 75° to 95° C, and the surface of the Earth was covered in a single global ocean, with no solid land masses.

The early Earth was subject to bombardment by comets and asteroids, which brought water and other compounds to the planet. Methane and ammonia gases were released in these collisions and in the many volcanic eruptions that were occurring. As a result, these two gases formed the majority of the Earth's early atmosphere, which also contained water vapour (H_2O) and higher concentrations of carbon dioxide (CO_2) than exist today.

Because the early Earth's atmosphere lacked free oxygen, there was no ozone layer present in the atmosphere. The inner core of the Earth would have been much hotter, and a liquid rather than the solid inner core of today. The increased motion within the liquid core would have resulted in a smaller protective magnetic field than exists today, exposing the planet to much higher levels of cosmic and solar radiation.

These conditions on early Earth would have created extreme weather events, including electrical storms.

Use **Interactive 1** to compare the conditions on early Earth with those present today.

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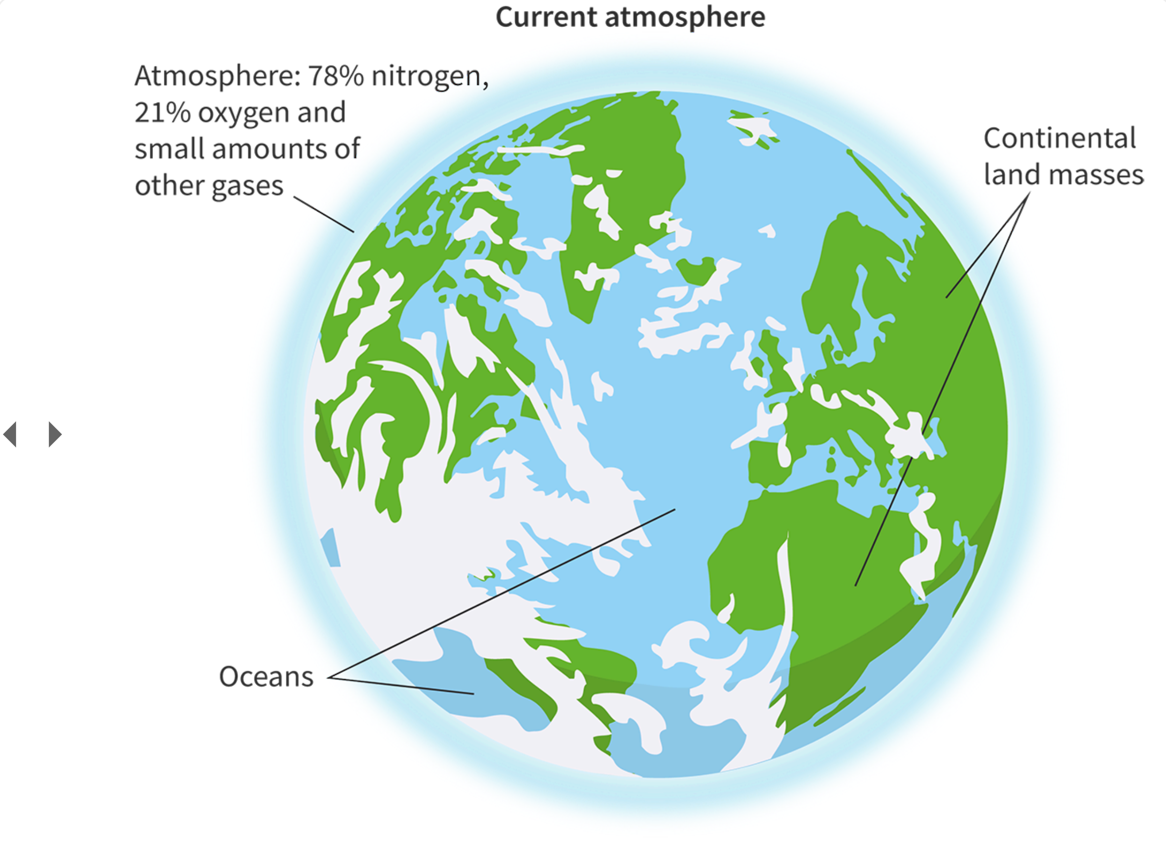

Interactive 1. A Comparison of the Conditions on Early Earth and the Conditions on Earth Today.

More information for interactive 1

An interactive illustration compares the early atmosphere and the current atmosphere of the Earth. Users can move a slider to view how the Earth has changed over time.

In the early atmosphere, ammonia and methane are present, and there is no ozone layer. The Earth's surface shows multiple scattered volcanoes, and a single global ocean covers the planet without any distinct land masses.

In the current atmosphere, the composition includes 78% nitrogen, 21 % oxygen, and small amounts of gases. The Earth's surface features oceans and continental land masses.

This illustration helps users understand how atmospheric gases have changed over time and recognize the development of features such as the ozone layer, continents, and diverse ecosystems.

The pre-biotic formation of carbon compounds

A necessary precursor to the origins of life is the formation of simple, carbon-based compounds. These simple molecules would be the precursors to more complex carbon compounds, organic molecules that provide the structural and functional components for cells to survive and replicate.

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Due to the lack of oxygen, and the high proportion of reducing gases, including methane and ammonia, the early Earth had a reducing atmosphere. The reducing gases in the atmosphere would have been able to donate electrons to other molecules, enabling chemical reactions to take place. These reactions resulted in the formation of more complex carbon compounds, including simple amino acids and hydrocarbons. These building blocks would have eventually joined together to form the building blocks of cells, including proteins, lipids and nucleic acids.

Some of these more complex carbon compounds would have developed the ability to self-replicate, and would have eventually become packaged into membranes. This would have enabled the molecules to exist within different conditions to the external environment, leading to the formation of what we call cells.

It is important to note that the conditions on Earth today are very different from the conditions on early Earth. Because of this, it is not possible for the spontaneous formation of biological molecules to occur today.

Try the activity below to bring together your understanding of the conditions on early Earth.

Activity

- **IB learner profile attribute**: Knowledgeable
- **Approaches to learning**: Communication skills - Clearly communicating complex ideas in response to open-ended questions
- **Time required to complete activity:** 20 minutes
- **Activity type:** Individual activity

A great way to learn new information is to transfer it from one format to another. In this activity, take the information provided in this section and use it to create an infographic that could be understood by a student one year below you who has no prior knowledge of this topic.

5 section questions

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A2. Unity and diversity: Cells / A2.1 Origins of cells (HL)

The origins of cells (HL)

Higher level (HL)

Learning outcomes

By the end of this section you should be able to:

- Explain why cells are the smallest units of self-sustaining life.
- Outline some of the challenges of explaining the spontaneous origins of cells.
- Outline and evaluate the Miller—Urey experiment.
- Outline how vesicles may have spontaneously formed by the coalescence of fatty acids into spherical bilayers.
- Explain the hypothesis that RNA was the first genetic material and catalyst in the earliest cells.

The world around you – your home, your school, what you eat – is composed of many things. How can we differentiate between living and non-living things? How do we classify something as living?

Cells as the smallest unit of self-sustaining life

Cells are the smallest unit of self-sustaining life because they contain all the components necessary to carry out all eight processes of life at some point in their life cycle (**Table 1**).

Table 1. The eight processes of life.

Life process	Definition	Example of how a cell carries out this life process
Metabolism	Chemical reactions that take place within the cell(s) of an organism	Cells contain catalytic molecules, such as enzymes to speed up chemical reactions within the cell

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Life process	Definition	Example of how a cell carries out this life process
Response to stimuli	Responding to changes in the external environment	Detecting changes in chemicals in the extracellular environment and moving towards or away from the chemicals
Homeostasis	The maintenance of constant internal conditions, despite changes in their external environments	Moving ions or other molecules into or out of the cell across the cell membrane to control the concentration of certain substances in the cell
Movement	Having some control over their place and position	Some cells have specialised structures, such as cilia, flagella and pseudopodia to help them move or change position
Growth	Increasing in size over a period of time. In multicellular organisms, growth can also refer to an increase in the number of cells that make up an organism	Cells can divide to produce more cells, and they can also increase in size over time
Reproduction	The production of offspring	Cells contain genetic material which contains the instructions for the cell to function and reproduce. During reproduction of a cell, this genetic material will be copied so it can be passed on to the offspring
Excretion	The removal of metabolic waste	Metabolic waste products are transported across the cell membrane, out of the cell into the external environment
Nutrition	The intake or production of nutrients. Heterotrophic organisms obtain their nutrients from the external environment, whereas autotrophic organisms can produce nutrients from inorganic material	Some cells can produce their own nutrients through processes such as photosynthesis; other cells obtain their nutrients by consuming other organisms or organic molecules. Cells can also obtain nutrients by diffusion of the molecules across the membrane into the cell and by endocytosis

Study skills

You can use the acronym MR HM GREN to help you to remember these eight

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life processes.

Viruses are considered non-living because they are unable to reproduce outside of the host cell. They rely on the host cell for many life processes, including nutrition and growth, and they do not possess a metabolism (see subtopic A2.3 (/study/app/bio/sid-422-cid-755105/book/big-picture-hl-id-43527/)).

The spontaneous origin of cells

Scientists believe that there were necessary steps for the evolution of the first cells:

1. Simple organic molecules such as amino acids and hydrocarbon chains were formed.
2. Chemical reactions were accelerated in the process of catalysis.
3. Larger organic molecules including RNA and phospholipids were assembled from smaller molecules.
4. Some of these molecules, including RNA were able to self-replicate.
5. Formation of a membrane-bound compartment (the cell surface membrane) allowed the internal chemistry of the cell to become different from that outside the compartment.

However, there are many reasons why scientists are not certain about how cells originated on Earth. Can you think of any explanations for this uncertainty?

- Cells spontaneously originated a very long time ago, which makes the evolution of cells difficult to study. For example, evidence may become destroyed or distorted.
- The very first protocells did not fossilise.
- It is thought that cells originated deep in the ocean, making it challenging to reach and collect samples for analysis.
- There is uncertainty surrounding the exact conditions on pre-biotic Earth, which means scientists cannot replicate the exact conditions that would have existed.

Nature of Science

Aspect: Hypotheses and Theories

Claims in science, including hypotheses and theories, must be testable. In some cases, scientists have to struggle with hypotheses that are difficult to test.

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How can scientists test and validate hypotheses on the origins of cells given the lack of fossil evidence and the inability to replicate the exact conditions on pre-biotic Earth?

Evidence for the origins of carbon compounds

In 1952, two scientists, Stanley Miller and Harold Urey, simulated Earth's pre-biotic atmospheric conditions to show that spontaneous formation of organic molecules could occur.

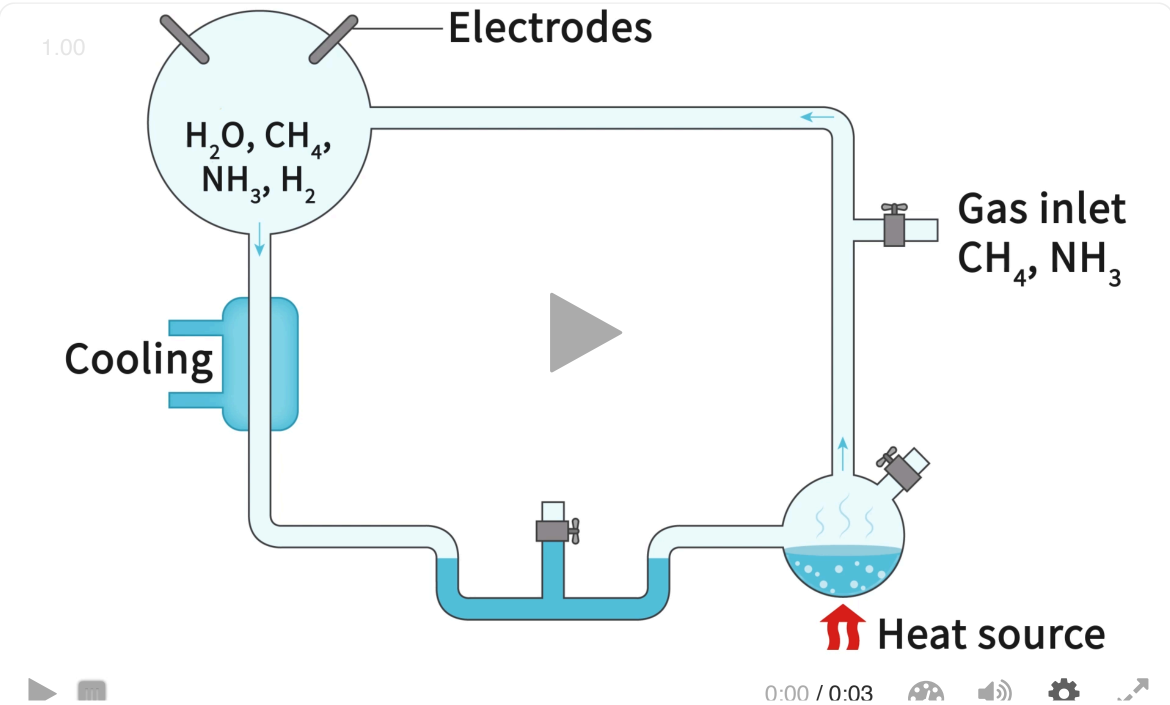
Miller and Urey set up a closed system. The system contained:

- water, which simulated the ocean
- a gas inlet with which to add the reducing gases methane, ammonia and hydrogen
- electrical sparks to simulate the electrical storms present on pre-biotic Earth.

The water was vaporised and run through the gases and electrical sparks, after which a cooling jacket was used to condense the water. The condensed water droplets formed on the side of the apparatus and collected at the bottom, representing the primordial soup of the early oceans. After a week of running the experiment, they showed that the primordial soup contained basic organic monomers, including amino acids.

This experiment proved that non-living synthesis of organic molecules was possible in the conditions existing on early Earth. It is important to note that this experiment did not *prove* that carbon compounds originated in this way, only that it *could* have happened this way.

Interactive 1 shows an animation of Miller and Urey's experiment.



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Interactive 1. The Equipment Used by Miller and Urey in Their 1952 Investigation.

More information for interactive 1

A labeled diagram illustrates the Miller—Urey experiment, designed to simulate early Earth conditions and test the formation of organic molecules. The setup includes:

A boiling flask containing water (representing early oceans), which is heated to produce steam.

- A connected chamber containing a gas mixture of methane (CH_4), ammonia (NH_3), water (H_2O), and hydrogen (H_2) simulating Earth's primitive atmosphere.
- Electrodes within the chamber emit electrical sparks to simulate lightning, providing energy for chemical reactions.
- The gases then pass through a condenser, where they are cooled and condensed into liquid.
- The resulting liquid collects in a trap at the bottom, containing newly formed organic molecules such as amino acids.

This experiment demonstrated that organic compounds essential to life could be formed from simple gases and energy sources.

Theory of Knowledge

Miller and Urey's investigation is still at the core of most origins of life theories today because it showed that organic compounds can be formed from inorganic precursor molecules.

However, because of new discoveries and advances in science, we now think that Earth's early atmosphere was different to the conditions they simulated in 1952, including that the atmosphere was not as reducing as Miller and Urey presumed.

To what extent should new evidence challenge the validity of previous accepted models?

Try this activity in pairs to evaluate the Miller–Urey experiment.

Activity

- **IB learner profile attribute:** Communicator
- **Approaches to learning:** Communication skills —Clearly communicating complex ideas in response to open-ended questions

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- **Time required to complete activity:** 15 minutes
- **Activity type:** Pair activity

In pairs, take it in turns to draw and explain the Miller—Urey investigation to each other. Discuss the extent to which this is a good model for how life originated on Earth, and the limitations of this model.

Spontaneous formation of vesicles by coalescence of fatty acids into spherical bilayers

An important step in the formation of the first cell was the formation of a membrane-bound compartment. This would have occurred when fatty acids spontaneously coalesced (merged) to form a spherical bilayer, a double layer of lipid molecules that encloses a space (**Figure 1**). Because of this physical separation, the interior of the vesicle would then have been able to provide a chemical environment with a different chemistry to the external environment.

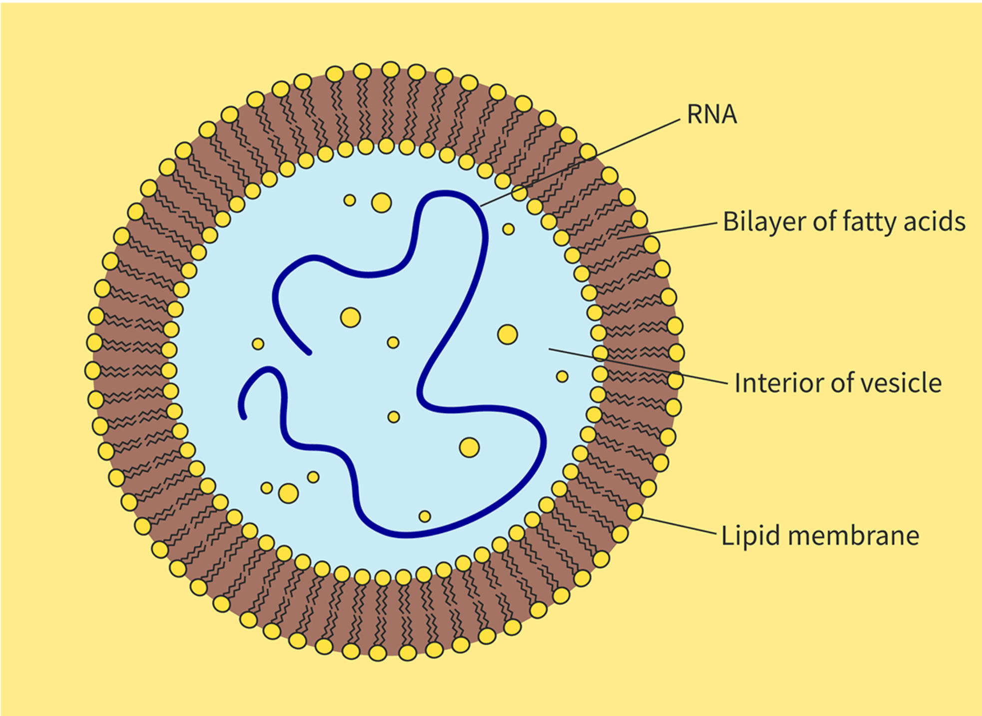

Figure 1. A necessary step in the evolution of the first cells was the spontaneous formation of vesicles by coalescence of fatty acids into spherical bilayers.

More information for figure 1

The image is a diagram illustrating the structure of a vesicle, a spherical compartment formed by bilayers of fatty acids. The diagram shows a circular arrangement of lipid molecules forming two layers (a bilayer), with their hydrophobic tails inward and hydrophilic heads facing outwards. This bilayer creates a membrane, marking the boundary of the vesicle. Inside this membrane, various components are depicted, including an irregular, free-form line labeled 'RNA,' which represents nucleic acids within the vesicle. Other parts of the

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vesicle interior have irregular yellow shapes. The exterior of the vesicle is labeled 'Lipid membrane,' indicating the entire boundary formed by the bilayer. The diagram conveys the fundamental structural components necessary for the compartmentalization seen in early cell evolution.

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This is an important step in the origins of cells, because this separation allows cells to control and maintain a precise set of conditions for proper cell functioning, including pH and solute concentration.

Membrane structure is covered in subtopic B2.1 (/study/app/bio/sid-422-cid-755105/book/the-big-picture-id-43205/).

RNA as the first genetic material

The 'RNA first' hypothesis posits that RNA was the basis for the formation of the first cell-like structure, acting as both genetic material and as a catalyst. This hypothesis suggests that:

1. RNA was formed from inorganic sources.
2. RNA was able to replicate using ribozymes.
3. RNA was able to catalyse protein synthesis.
4. Membrane compartmentalisation occurred.
5. Inside the cell, RNA was able to produce both protein and DNA.
6. DNA took over as the main genetic material because it is more stable.
7. Proteins took over as the catalytic form (enzymes) because they are more capable of variability.

Evidence to support the RNA first hypothesis includes:

- Short RNA sequences have been shown to be able to duplicate other molecules of RNA, demonstrating that RNA can self-replicate.
- RNA has some catalytic activity so it may have acted initially as both the genetic material and the enzymes of the earliest cells.
- Ribozymes in the ribosome are still used to catalyse peptide bond formation during protein synthesis.

However, this is not the only hypothesis on how cells originated. Other theories, none of which has been definitively proved or disproved, include:

- The Miller—Urey hypothesis: spontaneous generation of simple organic molecules such as amino acids, carbohydrates and lipids occurred in the conditions on pre-biotic Earth.
- The 'metabolism first' hypothesis: life began with simple metabolic reactions that led to the formation of simple metabolic pathways, which then formed more complex

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molecules which formed the basis of cells.

- The 'sulfur world' hypothesis: the first forms of life were based on iron—sulfur chemistry.
- The 'lipid world' hypothesis: lipid bilayers evolved before RNA, providing a protective layer to encapsulate the RNA.

Each hypothesis has strengths and weaknesses and scientists continue to gather evidence and explore models to test these hypotheses.

Study skills

In the context of molecular biology, the terms 'duplication' and 'replication' both mean to make an exact copy of something, and are often used interchangeably; however, they do have slightly different meanings.

Duplication means to make an exact copy of something, meaning that the original is copied once to make a second identical version. In contrast, the term replication does not specify the number of copies produced.

Try this activity to explain the steps of the RNA first hypothesis of how life may have originated on Earth.

Activity

- **IB learner profile attribute**: Thinker
- **Approaches to learning**: Thinking skills — Applying key ideas and facts in new contexts
- **Time required to complete activity:** 15 minutes
- **Activity type:** Individual activity

Draw a diagram that shows the following steps, outlining how life may have originated on Earth.

1. RNA was formed from inorganic sources.
2. RNA was able to replicate using ribozymes.
3. RNA was able to catalyse protein synthesis.
4. Membrane compartmentalisation occurred.
5. Inside the cell, RNA was able to produce both protein and DNA.
6. DNA took over as the main genetic material because it is more stable.
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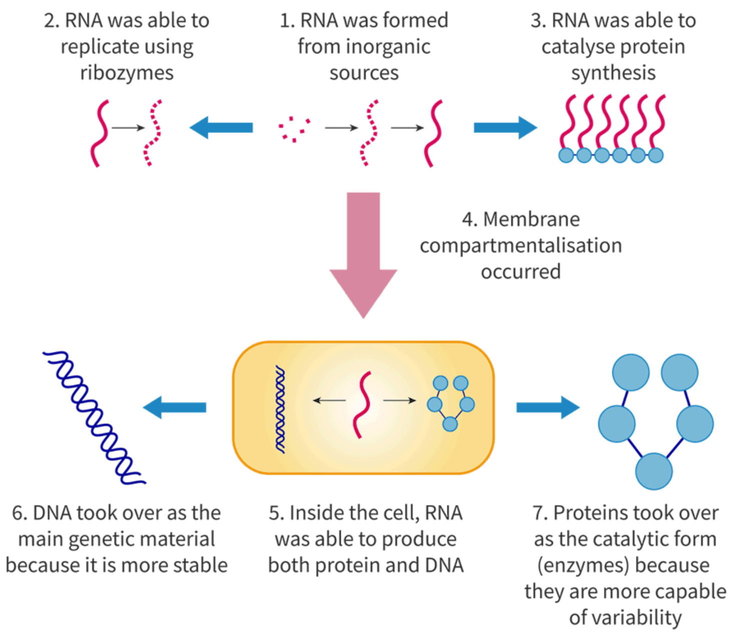

5 section questions

A2. Unity and diversity: Cells / A2.1 Origins of cells (HL)

The last universal common ancestor (HL)

A2.1.7: Evidence for a last universal common ancestor (HL) A2.1.8: Dating the first cells and last universal common ancestor (HL)
A2.1.9: Hydrothermal vents and evolution of last universal common ancestor (HL)

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Higher level (HL)

Learning outcomes

By the end of this section you should be able to:

- Describe how it is likely that other life forms evolved, but were outcompeted by a last universal common ancestor (LUCA).
- Outline approaches to estimate the time over which life has been evolving on Earth.

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- Outline the evidence that supports the existence of a LUCA.

Is there a definitive answer to where life started? If we traced evolution backwards, what type of organism would we find? It is likely that more than one life form spontaneously originated under the conditions present on early Earth, but only one of these life forms gave rise to all of the species existing since and today. This hypothetical life form is known as the last universal common ancestor (LUCA). Although the exact date of existence, nature and characteristics are still a topic of research and debate amongst scientists, it is thought that LUCA was a simple, single-celled autotrophic microbe with probably an RNA genome that existed between 2.5 and 3.5 billion years ago. Although there are arguments that LUCA had a DNA genome. The final decision has yet to be made.

Scientists think that LUCA, or descendants of LUCA, outcompeted the other life forms existing on early Earth, leading to the extinction of the other life forms.

Evidence for the last universal common ancestor

The genetic code is universal because it is shared by all living organisms and viruses on Earth. It uses the same nucleotide triplets, or codons, to code for the same amino acids in all organisms. For example, the codon AUG codes for methionine in bacteria, animals, plants and fungi.

The reason why the genetic code is universal lies in the common ancestry of all living organisms from one LUCA. Over time, this genetic code has been conserved as it is essential for the transmission of genetic information, with any change to this genetic code being likely to be highly detrimental to the organism. This universality and conservation means that scientists can use the genetic code as a tool to study when differences in the genome of groups of organisms evolved.

Scientists used to think that there were three domains of life that split from LUCA: bacteria, archaea and eukaryotes. Scientists looked for genes that were present in all three domains, inferring that these genes would also have been present in LUCA. However, in 1984 evidence from molecular phylogenetics, the comparison of genetic sequences, changed our understanding of the domains of life. Scientists now think that two domains, bacteria and archaea, arose from LUCA, with the third domain, eukaryotes, evolving much more recently by the process of endosymbiosis (**Interactive 1**).

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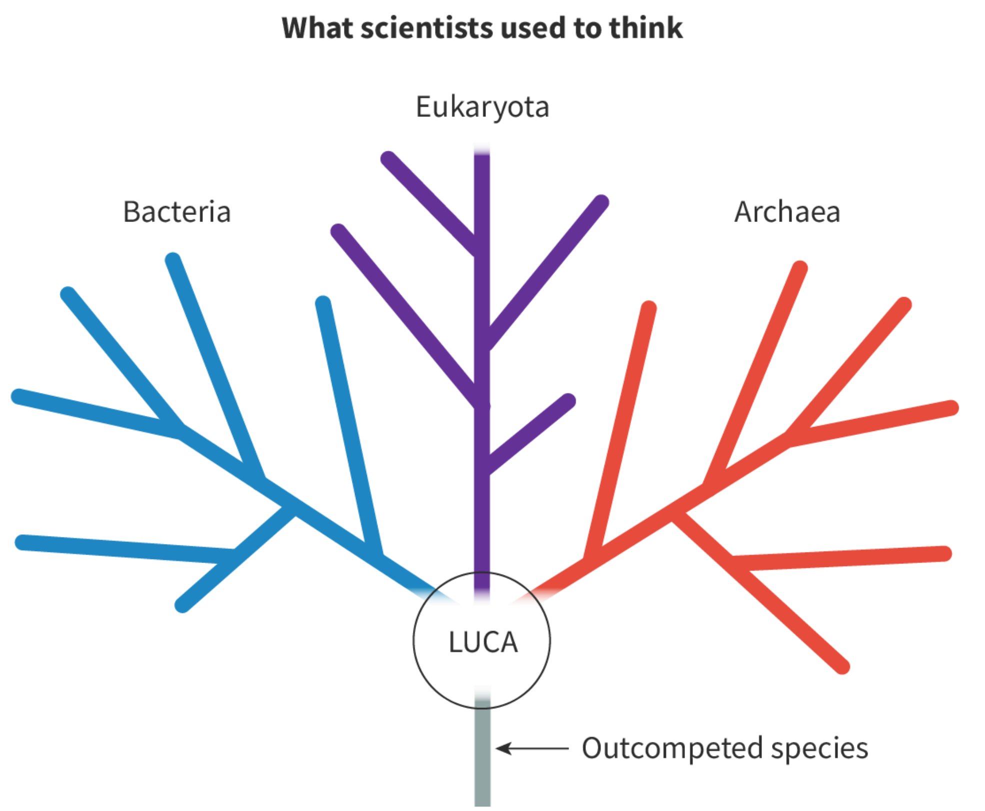

Interactive 1. The Evolution of Life: Revisiting the Three-Domain Tree.

More information for interactive 1

The interactive is a two-panel slider comparing past and current scientific understanding of life's domains. It explores the concept of the Last Universal Common Ancestor (LUCA), the hypothetical early organism from which all known life evolved. Outcompeted species are depicted using a grey line. They existed alongside LUCA's descendants but did not survive. The phylogeny diagram has many branches, with each domain represented using a different colour.

The first panel, labeled "What scientists used to think," shows LUCA splitting into three domains: Bacteria (blue), Eukaryota (purple), and Archaea (red).

The second panel, labeled "What is thought now," shows LUCA giving rise to two domains. They are Bacteria (blue) and Archaea (red), with Eukaryota (purple) evolving later through endosymbiosis.

The graphic illustrates the shift in thinking based on molecular phylogenetics.

With the knowledge that both bacteria and archaea arose directly from LUCA, scientists began searching for genes that were common to both these domains, inferring that they would have also been present in LUCA. Scientists found 11 000 common genes, which would have given LUCA much more advanced functionalities than any modern cell. Scientists realised this approach was confounded by a process called horizontal gene transfer, whereby genes can be transferred across species or domains. Because of this, scientists narrowed their focus to include only 'ancient'

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conserved genes present in bacteria and archaea that do not seem to have undergone horizontal gene transfer. Using this refined approach, they found 355 genes that can be presumed to have been present in LUCA.

Theory of Knowledge

How can confounding factors affect the validity of theories and hypotheses based on evidence? And how can these factors be taken into account when interpreting and evaluating such evidence?

Scientists have also studied stromatolites (**Figure 1**) to help understand the types of organisms that existed in the past, and the environments in which they lived. Stromatolites are fossils found within rocks that are thought to have been formed by layered communities of microorganisms.

Creativity, activity, service

Strand: Service
Learning outcome: Demonstrate how to initiate and plan a CAS experience

Preserving evidence is important because it allows us to gather information and gain insight into the past, understand current conditions and make informed decisions for the future.

What could you do in your local area to support the preservation of scientific or historical evidence?

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Figure 1. Stromatolites in Shark Bay, Australia.

Credit: Koradi, Getty Images (https://www.gettyimages.pt/detail/foto/stromatolites-shark-bay-australia-imagem-royalty-free/170075758)

From this fossil evidence and genetic analysis, scientists have inferred features and characteristics of LUCA, including that it:

- existed between 2.5 and 3.5 billion years ago
- existed deep in the ocean in alkaline hydrothermal vents. These hydrothermal vents would have been rich in hydrogen and dissolved minerals, including sulfur, methane and iron, which could have been used by LUCA as an energy source. Hydrothermal vents have high temperatures, which could have provided the energy necessary for the formation of complex organic molecules required for cellular formation
- was anaerobic, which fits with the lack of oxygen in the early atmosphere of the Earth
- was autotrophic, combining inorganic carbon with hydrogen, to produce carbon dioxide and formic acid, which could then be used for other processes.

Phylogenetic analysis and fossilised evidence suggest that LUCA evolved in hydrothermal vents – fissures in the ocean floor through which mineral rich water escapes (**Figure 2**). Hydrothermal vents are thought to have provided LUCA physical protection from the external ocean.

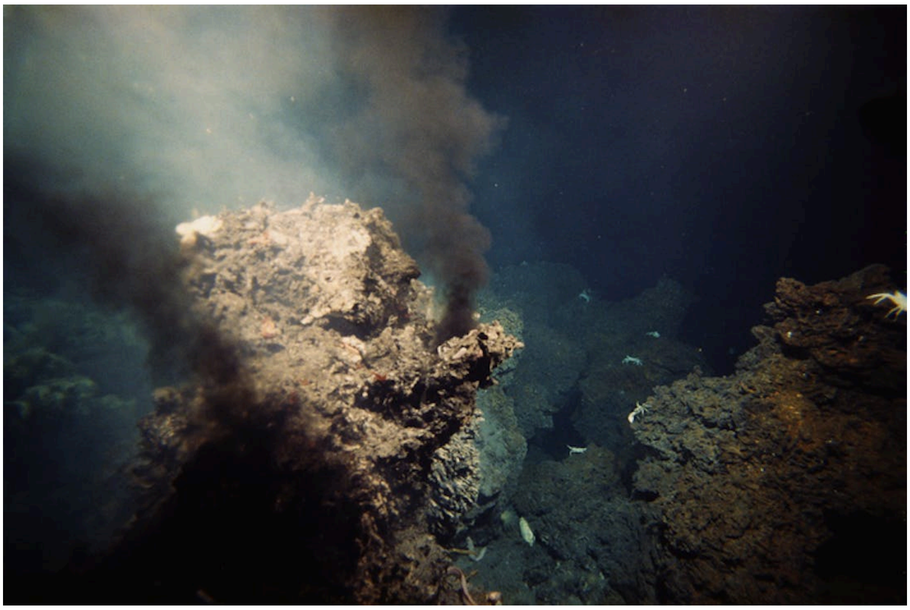

Figure 2. A hydrothermal vent.

Credit: Ralph White, Getty Images (https://www.gettyimages.pt/detail/foto/hydrothermal-vent-imagem-royalty-free/521194228)

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Try the activity below to help you appreciate the immense period of time over which life has been evolving on Earth.

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Activity

- **IB learner profile attribute:** Communicator
- **Approaches to learning:** Social skills — Working collaboratively to achieve a common goal
- **Time required to complete activity:** 30 minutes
- **Activity type:** Group activity

Materials: metre ruler, 5 m length of string, scissors, card, pens, sticky tape

1. Working in groups of three, use your metre ruler stick to measure and cut 4.6 metres of string. Each metre represents a billion years.
2. Tape a piece of card labelled 'present day' to one end, and a piece of card labelled '4.6 billion years ago' to the other.
3. Using your metre ruler stick, measure 0.5 m from 'present day', and use tape to attach an index card marked as '500 million years ago' to this point.
4. Continue measuring the string in 0.5 m increments and labelling the number of years represented.
5. Individually, read the following article: https://www.newscientist.com/article/dn17453-timeline-the-evolution-of-life/ (https://www.newscientist.com/article/dn17453-timeline-the-evolution-of-life/), or search for another article on the evolution of life, and then as a group, decide on between 10 and 15 notable events to mark on your timeline.
6. Make index cards for your chosen events, on one side marking the event and the time, and on the reverse of the card including a brief summary of that event.
7. Attach the index cards to your string at the appropriate locations.

Questions to discuss with your group:

1. If 4.6 metres of string represents 4.6 billion years, how much time is represented by:
(a) 1 metre
(b) 10 cm
(c) 1 mm
2. Why are many of these dates given as ranges, or approximations, rather than exact dates?
3. To what extent has this activity affected your appreciation of the immense time over which life has evolved on Earth?

Student
view

5 section questions

Summary and key terms (HL)

Higher level (HL)

- Before life evolved on Earth, our planet is thought to have had an atmosphere consisting mostly of reducing gases such as ammonia, methane and carbon dioxide. There were high levels of ultraviolet and solar radiation. Temperatures were much higher than today, probably exceeding 100 °C. These conditions would have resulted in extreme weather events, including frequent electrical storms.
- Cells are the smallest self-sustaining units of life. They are capable of carrying out all eight processes of life: metabolism, response to stimuli, homeostasis, movement, growth, reproduction, excretion and nutrition. Viruses are not considered to be living organisms because they cannot carry out these processes of life independently.
- Cells can only be produced by the division of pre-existing cells. Catalysis, self-replication of molecules, self-assembly and the emergence of compartmentalisation were necessary requirements in the evolution of the first cells.
- Under the conditions present on early Earth, it is thought that biological molecules formed from simple, inorganic molecules.
- Miller and Urey carried out an investigation to model the formation of biological models in the conditions they thought existed on early Earth, although we now think the conditions are different to the ones simulated in this investigation.
- The formation of a lipid bilayer was a necessary stage in the origin of the first cells, separating the cell's interior from the external environment.
- RNA is thought to have been the first molecule of life, exhibiting both a catalytic function and acting as the genetic material of cells. Proteins have taken over as the main catalytic molecule in cells because they are capable of more variability, and DNA has taken over as the primary genetic material because it is more stable.
- The last universal common ancestor (LUCA) is a hypothetical organism from which all organisms living on Earth today have evolved. Using phylogenetic analysis and fossil records, scientists think that LUCA was a simple single-celled microorganism that existed between 2.5 and 3.5 billion years ago in hydrothermal vents.

Overview
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Key terms

Review these key terms. Do you know them all? Fill in as many gaps as you can using the terms in this list.

1. are the smallest units of self-sustaining life. They are thought to have first around 3.5–3.9 billion years ago in the conditions existing on early Earth.
2. At that time in the Earth's history, the atmosphere contained many gases, the temperatures were much higher than those today and there was high ultraviolet and solar radiation, resulting in frequent electrical storms.
3. Under these conditions, it is thought that small, molecules were able to combine together to make molecules, which then became the building blocks of cells.
4. It is thought that was the first catalytic and genetic material, which then became separating the interior of the cell from the external environment.
5. Phylogenetic analysis and the records suggest that the last universal common ancestor existed between 2.5 and 3.5 billion years ago. This simple, single-celled organism is thought to have existed in vents deep in the oceans.

organic | inorganic | hydrothermal | originated | fossil | RNA | Cells | encapsulated | reducing

Check

Interactive 1. The Origin of Cells: Key Concepts and Terminology (HL).

A2. Unity and diversity: Cells / A2.1 Origins of cells (HL)

Checklist (HL)

Student view

Section Student... (0/0) Feedback Print (/study/app/bio/sid-422-cid-755105/book/checklist-hl-id-44286/print/) Assign

Overview
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Higher level (HL)

What you should know

After studying this subtopic you should be able to:

- Describe the conditions of early Earth and outline that these conditions may have led to the spontaneous generation of carbon compounds.
- Explain why cells are the smallest units of self-sustaining life.
- Outline some of the challenges of explaining the spontaneous origins of cells.
- Outline and evaluate the Miller—Urey experiment.
- Outline how vesicles may have spontaneously formed by the coalescence of fatty acids into spherical bilayers.
- Explain the hypothesis that RNA was the first genetic material and catalyst in the earliest cells.
- Describe how it is likely that other life forms evolved, but were outcompeted by a last universal common ancestor.
- Outline approaches to estimate the time over which life has been evolving on Earth.
- Outline the evidence that supports the existence of a LUCA.

A2. Unity and diversity: Cells / A2.1 Origins of cells (HL)

Investigation (HL)

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Higher level (HL)

- **IB learner profile attribute:** Communicator
- **Approaches to learning:** Communication skills — Presenting data appropriately
- **Time required to complete activity:** 30 minutes
- **Activity type:** Individual activity

Student
view

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Your task

Download the worksheet and complete the concept diagram. Use the information from this subtopic and any other lesson notes you have made or research you have gathered.

Worksheet
(https://d3vrb2m3yrmyfi.cloudfront.net/media/edusys_2/content_uploads/Biology A2.1.12 ACTIVITY.7ac86131f7695a34e164.pdf)

A2. Unity and diversity: Cells / A2.1 Origins of cells (HL)

Reflection (HL)

Section Student... (0/0) Feedback Print (/study/app/bio/sid-422-cid-755105/book/reflection-hl-id-46851/print/) Assign

Teacher instructions

The goal of this section is to encourage students to reflect on their learning and conceptual understanding of the subject at the end of this subtopic. It asks them to go back to the guiding questions posed at the start of the subtopic and assess how confident they now are in answering them. What have they learned, and what outstanding questions do they have? Are they able to see the bigger picture and the connections between the different topics?

Students can submit their reflections to you by clicking on 'Submit'. You will then see their answers in the 'Insights' part of the Kognity platform.

Higher level (HL)

Reflection

Now that you've completed this subtopic, let's come back to the guiding questions introduced in The big picture (/study/app/bio/sid-422-cid-755105/book/the-big-picture-id-43202/):

- What plausible hypothesis could account for the origin of life?
- What intermediate stages could there have been between non-living matter and the first living cells?

With these questions in mind, take a moment to reflect on your learning so far and type your reflections into the space provided.

You can use the following questions to guide you:

- What main points have you learned from this subtopic?

Student view

- Is anything unclear? What questions do you still have?
- How confident do you feel in answering the guiding questions?
- What connections do you see between this subtopic and other parts of the course?

⚠ Once you submit your response, you won't be able to edit it.

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Submit

Rate subtopic A2.1 Origins of cells (HL)

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