IB BIOLOGY | A2.1 | HL

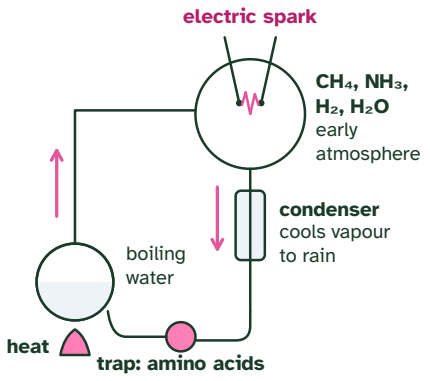
REVISION ON TWO PAGES

From chemistry to *cells*

What to know, what to draw and what to say. All nine statements are higher level.

THE ONE IDEA

Energy acting on simple molecules could make the compounds of life. A membrane and self-copying RNA could then make the first cells.



Draw it like this. Boil, spark, condense, collect: the loop runs for a week.

A2.1.4 START HERE

Miller and Urey: life's molecules *without life*

- **Set-up (1952):** water and a model early atmosphere of **methane, ammonia and hydrogen** were cycled past an **electric spark** (lightning) for a week.
- **Result:** the water turned brown and held **amino acids**, glycine and alanine most of all.
- **Evaluate** means weigh both sides: give a strength and a limit, each with its reason.

Strength what it showed
Organic compounds of life can form from simple molecules and energy, with **no life present**.

Limit the gases
The early air was probably mostly **CO_2 and N_2**, which give far fewer amino acids.

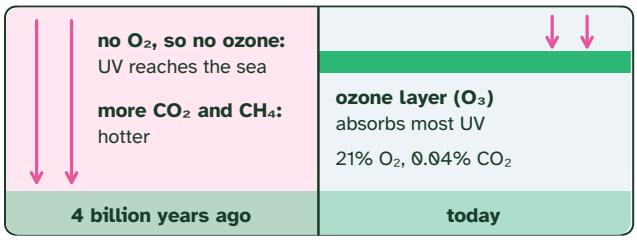
Strength later work
Miller's stored samples, reanalysed, held **more than 20** amino acids.

Limit far from a cell
It made **no proteins, nucleic acids or membranes**.

A2.1.1 CONDITIONS BEFORE LIFE

Early Earth: a world *without oxygen*

- **No free oxygen**, so **no ozone layer**: ultraviolet light reached the surface and the sea.
- Far more **carbon dioxide and methane**, greenhouse gases, so Earth was **hotter**.
- UV, lightning and heat could break simple molecules; the fragments joined into amino acids and sugars.
- Carbon compounds **formed spontaneously**, by chemistry that no longer happens: today oxygen breaks them down and organisms eat them.



A2.1.2 LIVING OR NON-LIVING

The cell: smallest unit of *life*

- A cell is the **smallest unit of self-sustaining life**: the smallest thing that carries out all the functions of life by itself.
- The functions: nutrition, respiration, excretion, growth, response, homeostasis and reproduction. DNA or an enzyme taken out of a cell does none of them.
- **The test is all of them, by itself.** One alone is not enough: a crystal grows and a flame feeds, but neither is alive.

Cell living
Has its own cytoplasm, ribosomes and metabolism. It grows and divides by itself.

Virus usually counted non-living
No metabolism, no cytoplasm, no ribosomes. Inert outside a host; **copied only by a host cell**. It has genes and evolves, but that is not enough.

A2.1.3

Why the first cell is *hard to explain*

- Today cells arise **only by division of pre-existing cells**. A cell is far too complex to assemble by chance in one step, so four things had to arise first.
- **Nature of science:** a hypothesis must be **testable**. This one is hard to test: early Earth cannot be recreated exactly and the first protocells did not fossilise, so scientists test the parts.

NEED 1
Catalysis
So that reactions happen fast enough.

NEED 2
Self-replication
Of molecules, so information can be copied.

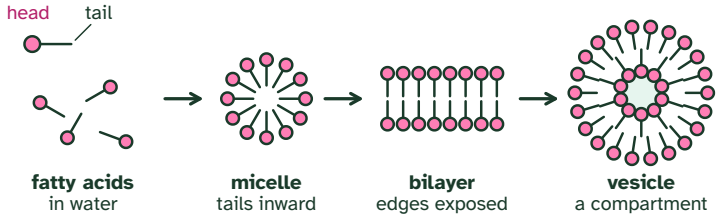
NEED 3
Self-assembly
Of structures, such as membranes, by themselves.

NEED 4
Compartmentalisation
So the chemistry inside differs from outside.

A2.1.5 VESICLES FROM FATTY ACIDS

The first *compartments*

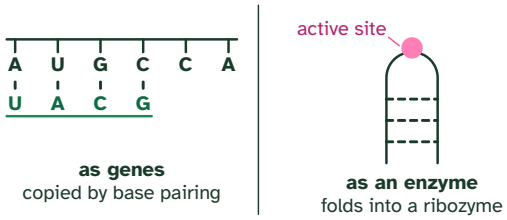
- A **membrane-bound compartment** lets the **chemistry inside differ** from outside. Without one, useful molecules drift away.
- Fatty acids are **amphipathic**: a hydrophilic head and one hydrophobic tail. In water they form micelles, then **coalesce into bilayers**.
- A flat bilayer exposes tails at its edges, so it **closes into a sphere**: a vesicle. In the lab these vesicles hold RNA, grow and divide.
- **Self-assembly:** no gene or enzyme is needed; the shape comes from the molecules alone.



A2.1.6 THE FIRST GENETIC MATERIAL

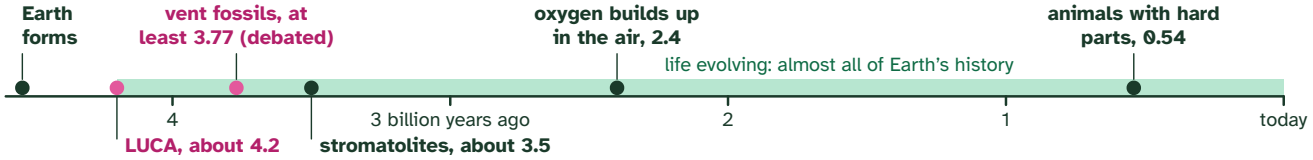
The *RNA world*

- **As genes:** RNA stores information in its base sequence and is **copied by complementary base pairing**.
- **As enzymes:** RNA folds into catalysts, **ribozymes**. So RNA may have been **both genes and enzymes** in the first cells.
- **Still in every cell:** in the ribosome, **RNA catalyses peptide bonds** in protein synthesis.



A2.1.7 to 9

LUCA, the *last universal common ancestor*



A2.1.7 EVIDENCE FOR LUCA

- A **universal genetic code**: the same codons give the same amino acids in all organisms.
- **Shared genes**, and DNA, RNA, ribosomes and ATP, in all life.
- Other early life probably **went extinct**, outcompeted by LUCA and its descendants.

A2.1.8 DATING IT

- **Fossils:** rock is dated by **radioactive isotopes**; stromatolites go back about 3.5 billion years.
- **Molecular clock: differences in shared genes**, with a rate calibrated on dated fossils, put LUCA near 4.2 billion years ago.

A2.1.9 NEAR HYDROTHERMAL VENTS

- **Genes: conserved sequences** traced to LUCA suit life with no oxygen, at high temperature, on H_2 and CO_2.
- **Fossils:** iron mineral threads and tubes in **ancient sea-floor vent precipitates**.

WATCH OUT

Six mistakes that *cost marks*

- ✕ **No ozone because no oxygen.** Ozone (O_3) is made from oxygen: one cause, not two separate facts.
- ✕ **Genes and evolution are not enough to be alive.** A virus has both, yet does nothing outside a host cell.
- ✕ **Miller and Urey did not make life.** They made amino acids: no proteins, nucleic acids or membranes.
- ✕ **A fatty acid vesicle is not a cell.** It has a boundary but no genes, no enzymes and no metabolism.
- ✕ **The RNA world is a hypothesis.** The evidence is what RNA can do today, not RNA from early Earth.
- ✕ **LUCA was not the first life.** It is the last ancestor that everything alive today shares.

COVER THE SHEET

Can you *answer these?*

1. Outline how early Earth let carbon compounds form.
2. Explain why viruses are usually considered non-living.
3. State four requirements for the evolution of the first cells.
4. Evaluate the Miller–Urey experiment.
5. Explain how and why fatty acids form vesicles.
6. Outline why RNA may have been the first genes.
7. Describe two pieces of evidence for LUCA.
8. Outline two approaches used to date LUCA.
9. State two pieces of evidence that LUCA lived near hydrothermal vents.

IN THE EXAM

Evaluate Miller–Urey with a strength and a limit, each with its reason: "amino acids formed with no life present, but the gases were probably not the real early atmosphere."

GO FURTHER

The Miller–Urey film, step-through figures and a marked Check are in the full guide online.