Unit 18 · Life and Its Origin

STUDY NOTES

WHAT NEB'S GRADE 11 EXAM ASKS

- **CDC's grid (2077):** Evolutionary Biology (Units 18–21 together): 9 of 75 marks; in one group with Faunal Diversity, Units 22–26 (28 marks)
- **The paper:** 11 MCQs × 1 · 8 short × 5 · 3 long × 8; 3 hours; 1 mark per expected point
- **CDC's model paper:** MCQ: the gases Miller and Urey used (ammonia, methane, hydrogen, water vapor)
- **MCQ (1 mark)**
  - elements of the core
  - where life comes from (biogenesis)
  - accepted theory today
  - stage making organic molecules; stage making nucleic acids
  - main energy of chemogeny (solar UV)
  - first autotrophs: chemosynthesis
  - Miller–Urey gases and main result
- **Short (5 marks, in parts)**
  - age of the Earth; conditions on the young Earth, why no life
  - special creation; biogenesis with two scientists
  - spontaneous generation and an experiment that disproved it
  - Oparin–Haldane theory, main ideas
  - steps of the Miller–Urey experiment (with the apparatus drawn)

Key terms

Nebular (dust-cloud) hypothesis: Sun, Earth, planets formed together from a turning cloud of gas and dust, the **solar nebula**.

Reducing atmosphere: no free O_2; gases that give hydrogen and electrons (H_2, CH_4, NH_3). Today's air: **oxidizing**.

Abiogenesis (spontaneous generation): life again and again from non-living matter.

Biogenesis: life only from **pre-existing life**.

Chemogeny: inorganic → complex organic molecules.

Biogeny: organic molecules → self-copying molecules → first cells.

Cognogeny: first cells → many kinds of life.

Hot dilute soup (Haldane): primordial or prebiotic soup; warm sea rich in organic compounds.

Coacervate (*coacervare*, to heap): droplet of large molecules held by water; takes in molecules, grows, splits.

Protobionts, eobionts: coacervate-like forerunners of cells.

Stromatolites: layered rocks built by microbial mats (cyanobacteria); oldest ~3.48 billion years (Pilbara).

Origin of the Earth

- age **4.54 billion years** (± 50 million): radioactive dating of meteorites, oldest rocks
- young Earth molten, too hot for life; elements as single atoms (C, Si, O, S, Cl, P, Na, Ca, K, Fe)
- cooled → **separated by density**
  - **core**: iron and nickel (densest)
  - **mantle, crust**: rock (O with Si, Mg, Al, Ca, Na, K)
  - **atmosphere**: H, He (mostly escaped), then volcanic gases: water vapor, CO_2, N_2; some CH_4, NH_3, H_2S, H_2
- vapor condensed → rain → first **oceans**
- **primitive atmosphere**: **no free oxygen** (O locked in H_2O, CO_2) → **reducing**; no ozone → UV reached the surface
- why no life then: molten, no O_2, no ozone (UV), asteroid impacts

Theories of the origin of life

Theory	Says	Who
Special creation	created by God, in present forms	a belief; not testable
Cosmozoic (panspermia)	spores or microbes came on meteorites	Richter 1865; Arrhenius 1903
Spontaneous generation	frogs, snakes from mud; worms from meat; aphids from plant juice; lice from sweat	Aristotle
Biogenesis	life only from life	Redi, Spallanzani, Pasteur
Biochemical	life arose once from non-living matter, slowly	Oparin 1924, Haldane 1929

Experiments against spontaneous generation

- **Redi** (1668): meat in open, sealed and gauze-covered jars → maggots only in open jars (flies laid eggs) → maggots from flies' eggs

- **Spallanzani** (1760s): broth boiled 1 hour, necks **melted shut** → clear; boiled briefly or open → microbes; Needham: "vital force" shut out
- **Pasteur** (1859–1862): broth boiled in **swan-neck flask**, neck **left open** → air enters, dust and microbes settle in the bend → clear for months; neck broken or broth tipped into the bend → microbes in days → microbes come from the **dust of the air**

Oparin–Haldane theory

- life arose **once**, from non-living matter, over millions of years, in a **reducing** atmosphere, before 3.5 billion years ago
- not today: O_2 would destroy the molecules; microbes would eat them

A. Chemogeny

- i. water, ammonia, methane, cyanamide: $2H_2 + O_2 \rightarrow 2H_2O$; $N_2 + 3H_2 \rightarrow 2NH_3$; $C + 2H_2 \rightarrow CH_4$; $N_2 + C + H_2 \rightarrow NH_2CN$
- ii. hydrocarbons (~100 °C): $CH + CH \rightarrow C_2H_2$ (acetylene); $CH_2 + CH_2 \rightarrow C_2H_4$ (ethylene); $CH_2 + CH_2 \rightarrow CH_4 + C$
- iii. oxy- and hydroxyl derivatives (with steam): $C_2H_2 + H_2O \rightarrow CH_3CHO$ (acetaldehyde); aldehydes, ketones
- iv. sugars, amino acids, fatty acids: $CH_4 + H_2O \rightarrow$ sugars; $CH_4 + H_2O + NH_3 \rightarrow$ amino acids (condensation, polymerization, oxidation, reduction)
- v. purines, pyrimidines → nucleotides
- energy: **UV** (most; no ozone), lightning, volcanic heat, radioactivity
- collected in Haldane's **hot dilute soup**: no O_2 to break them, nothing to eat them

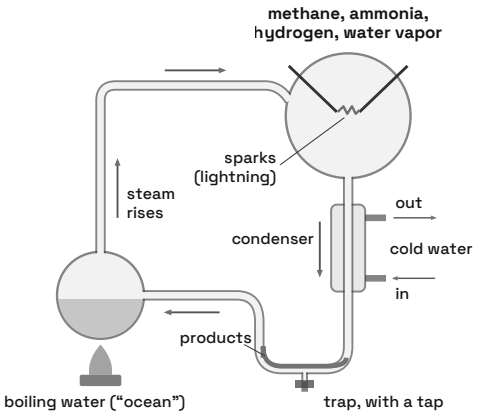
B. Biogeny

- (1) **nucleic acids**: sugar + phosphate + base → nucleotides → RNA, DNA; self-copying → can evolve
- (2) **coacervates** of proteins, nucleic acids, sugars; Oparin made them: take in, grow, split
- (3) first organisms (**protobionts, eobionts**): membrane + nucleic acids; **anaerobic chemoheterotrophs**; **prokaryotes**

C. Cognogeny

- diversified into protists, **metazoa**, **metaphyta**; parasites, saprophytes, chemosynthetic, photosynthetic
- **origin of autotrophs**: food ran short
  - **chemoautotrophs** first: energy from oxidizing chemicals (nitrifying bacteria)
  - sulphur bacteria, bacteriochlorophyll, **light**: $6CO_2 + 12H_2S \rightarrow C_6H_{12}O_6 + 6H_2O + 12S$
  - chlorophyll (porphyrin + Mg) → **cyanobacteria** split water, first to give **O_2**: $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$ (**photoautotrophism**)
- **origin of eukaryotes**
  - O_2 collected from ~2.4 billion years (**Great Oxidation Event**) → **oxidizing** air
  - → aerobic respiration, **ozone layer**, eukaryotes (true nucleus, membrane-bound organelles; oldest 1.6–1.8 billion years)
  - mitochondria, chloroplasts = engulfed bacteria (**endosymbiotic theory**, Margulis)
  - unicellular → multicellular; ozone → land (~470 million years)

Miller–Urey experiment (1952–1953)



Boiling water = ocean; $CH_4 + NH_3 + H_2$ = atmosphere; sparks = lightning; condenser = rain; U-trap collects products.

- **experiment**
  - sealed glass apparatus: small flask of **water**, large flask of **gases**
  - water **boiled** → vapor circulates
  - gases **methane, ammonia, hydrogen, 2 : 2 : 1**, + water vapor; **no oxygen**
  - energy: heat + **electric sparks** (tungsten electrodes) = lightning
  - **condenser** → drops → U-shaped **trap** → back to flask; ran about a **week**
- **observation**: water pink in a day, red-brown in a week; products in the trap
- **result**: **amino acids**: glycine, alanine, aspartic acid (paper chromatography); simple organic acids, urea
- **conclusion**: organic from inorganic without life → supports chemogeny

COMMON MISTAKES

✗ Zinc and sodium in the core
✓ core = **iron and nickel**; sodium is light (crust, sea salt).

✗ Pasteur closed the swan-neck flask
✓ neck **open**: air entered, dust trapped in the bend.

✗ Gases hydrogen : methane : ammonia = 2 : 2 : 1
✓ **methane : ammonia : hydrogen** = 2 : 2 : 1.

✗ Miller used UV light
✓ **sparks** and heat; no UV.

✗ Miller–Urey made sugars and ribose
✓ **amino acids** and simple organic compounds only.

✗ H_2S equation is chemosynthesis
✓ it needs **light**: photosynthesis of sulphur bacteria.

✗ Spontaneous generation = biochemical origin
✓ abiogenesis: again and again, today; biochemical: **once**, long ago.