29 Option D: Evolution

The origin of life

One of the tenets of the cell theory is that all cells come from pre-existing cells. Tracing back the ancestry of cells over billions of years, we must eventually reach the first cells to have existed. These were the first living things on Earth. For them to have arisen from non-living material, four requirements would have had to be met:

- simple organic molecules would need to be available
- the simple molecules would need to have been assembled into polymers
- these abiotically produced molecules would need to have been packaged into structures with a different internal chemistry from their surroundings
- a mechanism that makes inheritance possible would need to have developed.

A necessary precursor for life would be the **availability of simple organic molecules**. The experiments of Stanley Miller and Harold Urey illustrated that simple organic molecules such as amino acids can be produced in abiotic conditions. This was achieved experimentally by passing steam through a mixture of methane, hydrogen and ammonia. At the time of their experiment, this mixture was thought to be representative of the atmosphere of the early Earth. Electrical discharges were used to simulate lightning.

Another possible site for the origin of the first simple organic molecules is around deep-sea vents. These are cracks in the Earth's surface, characterized by gushing hot water carrying reduced inorganic chemicals such as iron sulfide. These chemicals represent readily accessible supplies of energy and raw materials for the creation of monomer organic chemicals. They are also a source of energy for the **assembly of these monomers into polymers**.

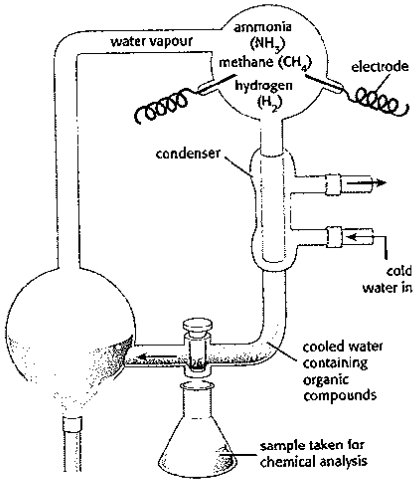

Figure 1 Miller and Urey's apparatus

Table 1

Amino acid	Murchison meteorite	Miller–Urey experiment
Glycine	•••••••••	•••••••••
Alanine	•••••••••	•••••••••
α-amino-N-butyric acid	•••••••	•••••••••
α-aminoiso-butyric acid	•••••••••	••••
Valine	•••••••	••••
Norvaline	•••••••	•••••••
Isovaline	••••	••••
Proline	•••••••	••
Pipecolic acid	••	•
Aspartic acid	•••••••	•••••••
N-ethylglycine	••••	•••••••
Sarcosine	••••	•••••••

Source: C. Mitchell, *Life in the Universe* (1995)

Data-based question: the Murchison meteorite

The theory of panspermia states that some of the first organic molecules may have been delivered to Earth by meteorites. Certain categories of meteorites are rich in the element carbon and some of these meteorites have been found to contain many of the same molecules observed in the Miller–Urey experiment.

A meteorite that struck near Murchison, Australia, was analysed for the presence of amino acids. Similar studies have been carried out on liquid samples taken from the Miller–Urey experiment. Table 1 summarizes the results from both sources. Each dot represents a relative amount of a particular amino acid, with one dot representing a small amount and eight dots representing a large amount.

1. Compare the amino acids found in the meteorite with those produced in the Miller–Urey experiment. Refer to named examples. [3]
2. Suggest a conclusion based on your comparison. [1]

Protobionts and the role of RNA

The packaging of abiotically produced molecules into structures with a different internal chemistry from their surroundings would have been a further necessary stage in the origin of cells. Such structures are termed protobionts. They exhibit some the properties associated with life, including response to the environment, simple reproduction and basic metabolism.

Inquiry
Protobionts can be modelled by adding a large droplet of vegetable oil to a beaker of water. Following the addition of the oil, add a drop of food colouring. Note how the water-soluble food colouring is excluded from inside the oil droplet.

A fourth requirement for the origin of cells would be a mechanism that makes inheritance possible. In modern biological systems, replication and catalysis require enzymes. However, for enzymes to be created, genetic material is necessary. RNA has two properties that make it the most likely original molecule of inheritance: it is self-replicating and it has catalytic properties. Ribozymes are enzyme-like RNA molecules. RNA also has a variable sequence, which means that it can store information.

Oxygen

"Life on earth consists of both chemistry and information"

J.L Bada

Early cells would have increasingly competed for energy sources and this probably provided the selection pressure necessary for the evolution of photosynthesis. Initially the oxygen produced would have dissolved in the oceans or would have been used up in chemical reactions. Eventually, it began to be released into the atmosphere. While these early prokaryotes contributed to significant rises in atmospheric oxygen, it is thought that the emergence of eukaryotes with chloroplasts was responsible for further significant increases in atmospheric oxygen. It is likely that rising quantities of oxygen led to the extinction of certain groups of prokaryotes, while other groups were able to adapt by developing mechanisms to deal with the oxygen. Cellular respiration is thought to be one of these mechanisms.

Thinking about science: the theory of endosymbiosis

Lynn Margulis is well known for her endosymbiosis theory. This theory advances that chloroplasts and mitochondria were once free-living organisms that gave up their independence to live inside other cells. Mitochondria and chloroplasts have their own circular DNA and their own ribosomes (which resemble prokaryotic ribosomes). Their size, their shape and their double membranes are typical of some groups of bacteria. Asked "what she believes but cannot prove", Margulis had this response:

1 What is the distinction between belief and knowledge?
2 To what extent is Margulis' belief falsifiable? In other words, to what extent is it a scientific claim?

I think the common ancestor of the cilium...was a free-swimming entity...This bacterium, who still has many live relatives, entered into symbiotic partnerships with other very different kinds of bacteria. Together this two-component partnership swam and stuck together and persisted. What kind of bacterium became an attached symbiont that impelled its partner forward? None other than a squirming spirochete bacterium.

The spirochete group of bacteria includes many harmless mud-dwellers but it also contains a few scary freaks: the treponeme of syphilis and the borrelias of Lyme disease. We animals got our exquisite ability to sense our surroundings to tell light from dark, noise from silence, motion from stillness and fresh water from brackish brine – from a kind of bacterium whose relatives we despise. Even though the concept that cilia evolved from spirochetes has not been proved, I think it is true. Not only is it true but, given the powerful new techniques of molecular biology, I think the hypothesis will be conclusively proved.