SPOTLIGHT

NSW

MODULES 5 To 8

Earth and Environmental Science

• David Heffernan • Rob Mahon •

Science Press

Using QR codes: QR (quick response) codes like this one allow users to access extra digital content quickly and easily without typing. The QR links in this book have been carefully selected to illustrate or elaborate on concepts covered in each unit, but they are not the work of the authors of this text. We therefore are not responsible for the contents, opinions or advertisements associated with any of these links. How to access QR links: Using your smart phone, tablet or laptop, download a QR code reader from your apps store. Activate the QR code reader by pressing the icon. It will activate your camera with a frame included in the view. Point the camera at the QR code image in this book. Some apps will require you to press a button at this stage, while others will automatically follow the link. If any link you try to follow is no longer available, or has been altered to include irrelevant or inappropriate content, please contact us at robwmahon@gmail.com and we will edit the link back to a suitable site.

Chapter vocabulary links

At the start of each chapter a QR link to a vocabulary list for that chapter has been included. These take the user to a Quizlet study set, which allows students to interact with the new vocabulary for this chapter in a variety of ways. At the top of the study set are a number of tabs to select from. These are explained below.

Note: Students can study either the full set of terms or they can select specific words to revise by selecting the star symbol next to each term.

Flashcards: The ideal starting point when being introduced to new terminology. The definition is shown and the student tries to guess the correct word (which is revealed by clicking/tapping on the card). Note that you can customise the settings to suit yourself.

Learn: Once you have been introduced to the terminology, practise typing in the terms when prompted. This helps with improving your spelling of these terms.

Match and gravity: These are single player games that challenge your recall of the terminology in different ways.

Live: This is an online team game using the vocabulary. Watch the introductory video, then play this during class.

Test: This is by far the most valuable interactive feature of Quizlet. This will autogenerate a test in a variety of question styles. You can include all terms or only the terms you select. It will then correct your answers and provide feedback. *Note:* The most valuable learning will come from from studying the terms you answered incorrectly, then immediately generate another test. You can keep doing this until you regularly score 100% in these tests.

First published 2019

Science Press
Private Bag 7023 Marrickville NSW 1475 Australia
Tel: +61 2 9516 1122 Fax: +61 2 9550 1915
sales@sciencepress.com.au
www.sciencepress.com.au

Contents

Words to Watch

account, account for State reasons for, report on, give an account of, narrate a series of events or transactions.

analyse Interpret data to reach conclusions.

annotate Add brief notes to a diagram or graph.

apply Put to use in a particular situation.

assess Make a judgement about the value of something.

calculate Find a numerical answer.

clarify Make clear or plain.

classify Arrange into classes, groups or categories.

comment Give a judgement based on a given statement or result of a calculation.

compare Estimate, measure or note how things are similar or different.

construct Represent or develop in graphical form.

contrast Show how things are different or opposite.

create Originate or bring into existence.

deduce Reach a conclusion from given information.

define Give the precise meaning of a word, phrase or physical quantity.

demonstrate Show by example.

derive Manipulate a mathematical relationship(s) to give a new equation or relationship.

describe Give a detailed account.

design Produce a plan, simulation or model.

determine Find the only possible answer.

discuss Talk or write about a topic, taking into account different issues or ideas.

distinguish Give differences between two or more different items.

draw Represent by means of pencil lines.

estimate Find an approximate value for an unknown quantity.

evaluate Assess the implications and limitations.

examine Inquire into.

explain Make something clear or easy to understand.

extract Choose relevant and/or appropriate details.

extrapolate Infer from what is known.

hypothesise Suggest an explanation for a group of facts or phenomena.

identify Recognise and name.

interpret Draw meaning from.

investigate Plan, inquire into and draw conclusions about.

justify Support an argument or conclusion.

label Add labels to a diagram.

list Give a sequence of names or other brief answers.

measure Find a value for a quantity.

outline Give a brief account or summary.

plan Use strategies to develop a series of steps or processes.

predict Give an expected result.

propose Put forward a plan or suggestion for consideration or action.

recall Present remembered ideas, facts or experiences.

relate Tell or report about happenings, events or circumstances.

represent Use words, images or symbols to convey meaning.

select Choose in preference to another or others.

sequence Arrange in order.

show Give the steps in a calculation or derivation.

sketch Make a quick, rough drawing of something.

solve Work out the answer to a problem.

state Give a specific name, value or other brief answer.

suggest Put forward an idea for consideration.

summarise Give a brief statement of the main points.

synthesise Combine various elements to make a whole.

Chapter 1
DEVELOPMENT OF THE BIOSPHERE

NSW EES HSC Chapter 1: Earth's Processes
https://quizlet.com/_4ash7t
http://qr.w69b.com/g/nPm1Up9hC

1.1 Origin of life

Eggs come from chickens. Chickens come from eggs. So which came first – the chicken or the egg?

This question and ones like it are often called **chicken-or-the-egg questions**. One such question regarding the origin of life on Earth challenged scientists last century. All living things are made of organic molecules and organic molecules are only produced by living things, so how could either of these things come into existence without the other one coming before it? This contradiction presented such a problem for scientists in a variety of fields that some suggested it could never be answered. The answer finally came from an unlikely source in a surprisingly easy way.

Urey-Miller experiment

In 1953 a 23 year old graduate student in chemistry at the University of Chicago, Stanley Miller (1930-2007), planned an experiment to reproduce conditions similar to those on Earth 4000 million years ago. He asked a glassblower to make a simple apparatus in which water and gases, representing the Earth's early sea and atmosphere, could be heated and circulated (Figure 1.1). He generated electrical sparks, simulating lightning, in the atmospheric chamber and let his apparatus run for a week.

After a while the water began to turn pink and then red. When Miller analysed the chemicals in the water, he found a large variety of **amino acids** – organic molecules that are the building blocks of **proteins**. Proteins are structural components in cells and they control the thousands of metabolic processes that take place in cells.

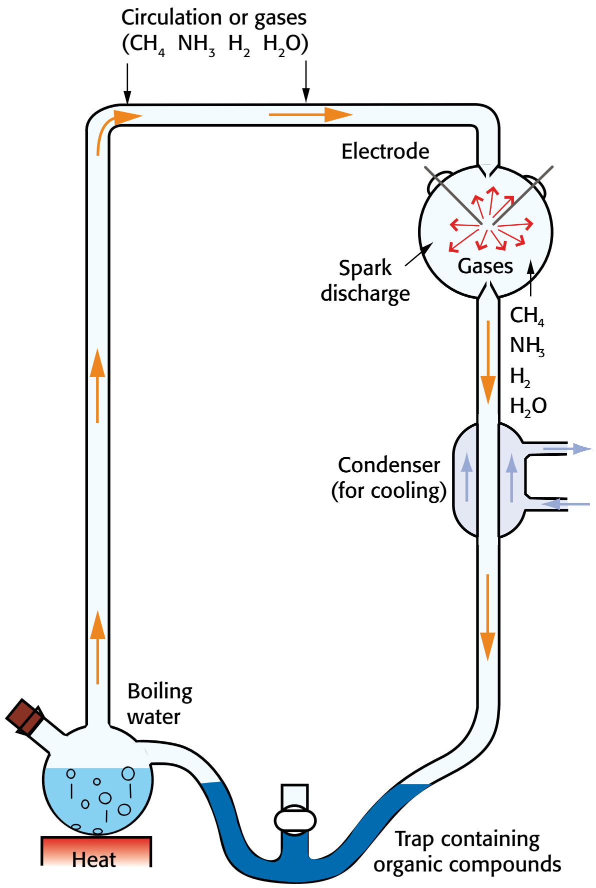


Figure 1.1 Urey-Miller experiment A mixture of chemicals was subjected to electrical sparks.

Figure 1.2 Volcanic lightning Massive lightning around an eruption.

News of this result electrified the scientific world and made Miller famous. He had solved this chicken-or-the-egg puzzle by demonstrating that, in the right conditions, organic molecules can form spontaneously from inorganic ingredients. It has since been shown that the building blocks of DNA, carbohydrates and other organic molecules can also be formed in this manner. Ultraviolet light and heat have been successfully used instead of sparks as the energy for breaking the chemical bonds of the gases in other versions of the Urey-Miller experiment (American chemist Harold Urey (1893-1981) was Miller's overseeing professor).

Urey-Miller Experiment Animation
http://qr.w69b.com/g/obCiicclW

Origin of life

While this experiment does not *prove* how life evolved, it does provide one plausible theory by which it *may* have occurred. Since the presence of oxygen would destroy life, conditions need to be found that are free of oxygen. We say they are **anoxic**. Since we are dealing with a time before the evolution of photosynthesis, the atmosphere would have been naturally anoxic.

A shallow water setting as a result of lightning strike

In the Urey-Miller experiment, electric sparks were used to provide energy. In the natural environment, sparks come mainly from lightning. The lightning can be that of a storm, but in the early Earth intense volcanic activity could also have produced intense lightning (Figure 1.2). American chemists recently examined some of the samples left by Miller and found evidence that volcanic activity was involved. Tidal pools or lagoons near active volcanoes on the young Earth would create conditions similar to the Urey-Miller experiment The first organic molecules such as amino acids would have been produced.

An ocean floor setting due to hydrothermal activity

Not all theories for the origin of life follow the Urey-Miller experiment exactly. What is needed is a source of energy that can allow organic molecules such as amino acids to form. One such theory from German and British molecular biologists proposes that life began on the ocean floor near hydrothermal vents (Figure 1.3). These sources of very hot water from deep in the Earth may carry sulfides which react with chemicals in sea water to produce 'black smokers'.

They also carry large amounts of methane (CH_4) and ammonia (NH_3) which in the right conditions can react to produce amino acids and other organic molecules. Clay particles also occur near these vents and we know that the surface of clay can catalyse the necessary reactions. This would need to be in a region between the very hot water from the vent and the very cold water on the ocean floor.

The Urey-Miller experiment highlights the value of using scientific models to reproduce conditions in order to learn more about them.

Figure 1.3 Black smokers Hot water from deep in the Earth can be rich in methane and ammonia.

Life in the Solar System

Another theory is that amino acids might have first been transported to Earth via collisions with comets or meteors, some of which are known to contain the necessary raw materials for building them. If this is true, it could be argued that all life on Earth, including us, is originally extraterrestrial.

The fact that life evolved on Earth means it could also have emerged elsewhere in the Solar System if environmental conditions were favourable. This is why the US National Aeronautic and Space Administration (NASA) and the European Space Agency (ESA) are so interested in some of Jupiter's and Saturn's moons. Jupiter's moon Europa has a thin atmosphere that contains oxygen and is covered by thick layers of water ice (Figure 1.4). Deep below the freezing surface, warmer conditions could allow for liquid water to be present and for life to have evolved in a similar way to that demonstrated by the Urey-Miller experiment. Another two of Jupiter's moons, Callisto and Ganymede, have also recently had traces of frozen water detected on them by spectroscopy.

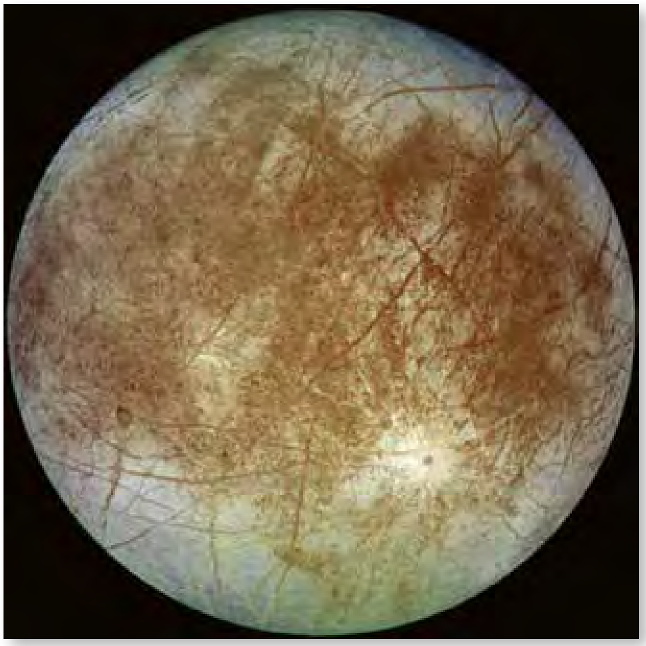


Figure 1.4 Europa Is there life on this moon of Jupiter? (NASA)

Recent visits by spacecraft to Saturn has revealed that its moon Enceladus may have conditions that allow life to survive. Enceladus has a layer of surface ice with salt water beneath. Even more interesting is that there are geysers emerging between cracks in the surface ice (Figure 1.5). Significant amounts of molecular hydrogen (H_2) has been found in these geysers. One way this hydrogen could be produced is around hydrothermal vents on the floor of the ocean.

Figure 1.5 Geysers on Enceladus Is there life on Enceladus, a moon of Saturn? (NASA)

The ongoing search for Martian life is predominantly bound up with Martian fossils because liquid water disappeared from the surface of Mars long ago. It is possible, however, that bacterial or other such life could still exist beneath the surface in any remaining water pockets. A Martian meteorite made world headlines in the late 1990s because it contained microscopic structures that were interpreted by one group of scientists as being deposited by bacteria. Subsequent analysis by other scientists was inconclusive. In other words, the structures may or may not be of biological origin.

In 2005 a Martian probe revealed higher than expected levels of atmospheric methane. Some scientists argue that since methane breaks down quickly when exposed to sunlight, its presence could be caused by bacteria living within the Martian soil. Others have offered alternative explanations. We are still looking for evidence of extraterrestrial life that is beyond doubt.

Panspermia

One controversial explanation for the origin of life is panspermia. It comes from a Greek word meaning ‘seeds everywhere’. Life did not originate on Earth but came from somewhere else in the Universe. Evidence that supports this idea include:

- Bacteria can survive the harsh environment from outer space.
- Carbon and amino acids are the building blocks of life and have been been found protected inside meteorites.
- Thousands of planets have been found around other stars, and life may have originated on at least some of them.
- Mars and moons such as Europa and Enceladus have conditions that may have supported life.

However, theories such as this do not really solve the problem of the origin of life. Rather, it just shifts the problem away from the Earth.

How the first cells, and therefore life, came to be is uncertain. What is certain is that the first cells to populate the Earth had a plentiful food supply in the form of the organic molecules floating on the ocean surface.

Early life

Trying to find fossils of the first forms of life is like trying to locate one specific quote in an unknown page within a unknown book kept at a library that has been mostly burnt down. The fossilisation of such organisms would have been a rare event, and few sedimentary rocks from this time remain unaltered by melting or metamorphism.

We do know from the few fossils greater than 3000 million years ago that early life was microscopic and soft bodied. These soft bodies rarely fossilise as they decompose so rapidly. Therefore they would need to be buried quickly. Only the finest grains of sediment could preserve the shape if such an organism was buried. Sand grains would be too coarse to show any outline. For any microfossils of the earliest life forms to survive until today, the rocks would have to be:

- Exceptionally old – greater than 3000 million years.
- Relatively unaffected by metamorphism.
- Sedimentary.
- Very fine grained.

Fortunately, such rocks do exist in a few rare localities, including the north-west of Western Australia (Figure 1.6).

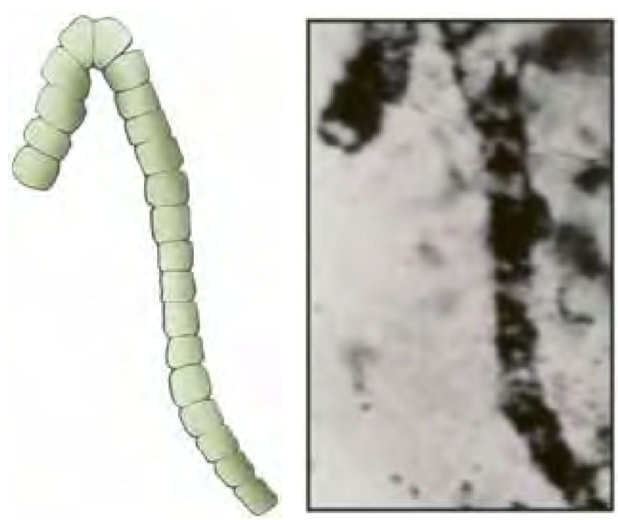


Figure 1.6 Archaeobacteria This bacterium is one of the earliest fossils found.

Currently, the oldest microfossils yet positively identified by Australian, British and American scientists come from around 3460 million years ago. Surprisingly, these fossils show considerable diversity. This strongly suggests even earlier and simpler life forms from which the different types of observed fossils evolved. Fossils of these earlier life forms might never be found.

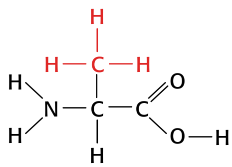
Despite existing so long ago, some of the earliest known fossils do have living relatives. Their modern day relatives survive in environmental conditions similar to those their ancestors endured (i.e. aquatic, mineral rich, oxygen poor and warm). Some of their modern relatives include stromatolites, cyanobacteria and archaeobacteria.

ACTIVITY 1.1
THE ORIGIN OF LIFE

1. It is believed the early Earth's atmosphere contained a mixture of methane, ammonia and hydrogen while water was present in the air and the oceans. The chemical formula for each is given in Table 1.1. Copy this table into your notebook and fill in the gaps. Use molecular modelling kits to construct one molecule of each gas and draw it in the right hand column.

2. All amino acids are made up of atoms of carbon, hydrogen, oxygen and nitrogen, but they are arranged differently from the inorganic substances shown in Table 1.1. What part of Miller's apparatus would be responsible for breaking the chemical bonds of the inorganic molecules, allowing them to re-form as organic molecules?

3. One example of an amino acid is alanine, as shown in Figure 1.7.



Alanine

Figure 1.7 The structural formula of alanine.

(a) Name how many of each type of atom is present in this amino acid.

(b) Create models of the atmospheric gases listed in Table 1.1, then deconstruct these in order to build one alanine molecule model.

4. Name the four most common gases in the Earth's early atmosphere.

5. Apart from any chemicals present, what other features of the environment contributed to the formation of organic molecules?

6. For comets to be a possible source of life on Earth, what chemical elements would have to be present in them?

7. If life on Earth did originate from comets, what are the implications of this regarding life elsewhere in the Solar System?

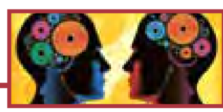
Table 1.1 Molecules and their shapes.

Gas	Chemical formula	Drawing of molecule
Methane	CH_4 (1 carbon atom joined with 4 hydrogen atoms)	
Ammonia	NH_3 (1 ______ atom joined with 3 _________ atoms)	
Hydrogen	H_2 (2 ________ atoms joined)	
Water	H_2O (_________________)	

SCIENCE SKILLS

1. 'Science is a global enterprise'. **Describe** the evidence in this unit and elsewhere that supports this statement.
2. Have we proved that life came from other parts of the Solar System? **Justify** your answer.
3. Development of complex theories such as the origin of life requires a wide range of evidence from many individuals and across several disciplines.
   (a) Suggest branches of science that would be interested in repeating or modifying the Urey-Miller experiment.
   (b) **Identify** the branch of science from which those who re-examined the material Stanley Miller produced came.
   (c) **Identify** the branch of science those who proposed the hydrothermal origin of life worked in.
   (d) **Identify** the branches of science that those who search for life on other planets and moons come from.
   (e) In the light of the above evidence, how accurate is the statement is at the start of this question? **Explain** your answer.

TO THINK ABOUT



Set 1

1. **Draw** a diagram of the apparatus used in the original Urey-Miller experiment. Label what is happening in each chamber.
2. The gases sealed inside the Urey-Miller apparatus were selected to simulate those in the early atmosphere. **Identify** the gases used by Miller and give the chemical formula for each.
3. All amino acids contain oxygen, hydrogen, carbon and nitrogen. **Identify** the source of these elements on the early Earth and in the Urey-Miller experiment.
4. Suggest a suitable energy source for early organisms.
5. Which part of the Urey-Miller apparatus was responsible for the breaking of chemical bonds. What types/forms of energy on the early Earth could have done this?

Set 2

6. (a) **Define** the term archaeobacteria.
   (b) In terms of a food chain, are archaeobacteria producers or consumers?
   (c) What would these earliest forms have fed on?
7. **Describe** how shallow pools near active volcanoes may have provided conditions for the origin of organic molecules.
8. **Outline** how the conditions near ancient hydrothermal vents might provide conditions for the origin of the first organic molecules.
9. **Explain** why scientists are keen to investigate conditions on other planets and their moons.
10. **Explain** why life could evolve in the Earth's early atmosphere but could not evolve in its atmosphere today.

1.2 Origin of photosynthesis

Evolution and oxygen
http://qr.w69b.com/g/n6dOU9Mxa

The origin of photosynthesis is one of the most important stages in Earth history. Before that time the composition of the atmosphere would not support life as we know it. Once oxygen became plentiful in the atmosphere the evolution of more complex life forms was possible.

First life

The first single celled organisms appear in early Archean rocks around 3500 million years ago and must have originated earlier. These fossils were found in the Pilbara region of Western Australia. These organisms were anaerobic, feeding on the organic molecules around them. Exactly when photosynthetic organisms first appeared is not known but the presence of oxygen is found around 2500 million years ago implying the presence of photosynthetic cells. Photosynthetic cyanobacteria are found in the geologic record around 2.1 million years ago.

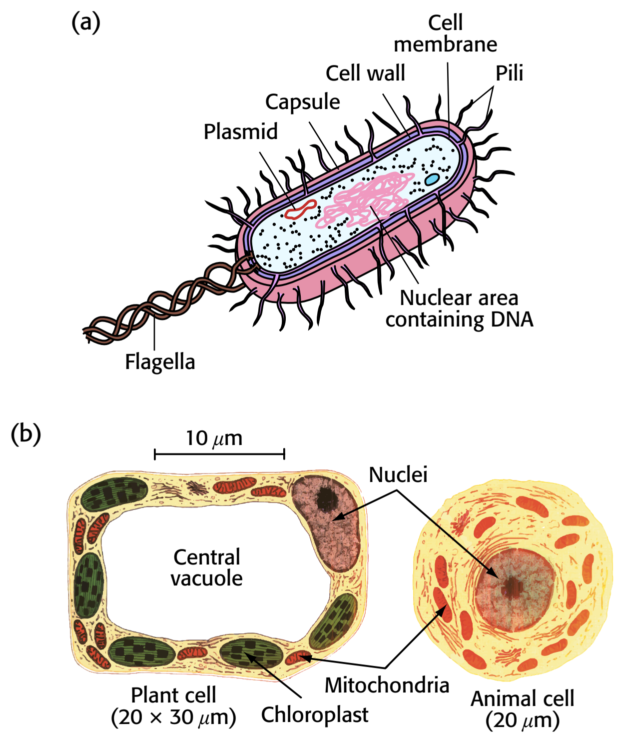


Figure 1.8 Cells (a) Prokaryotic cells such as bacteria do not have a nucleus. (b) Eukaryotic cells such as plant and animals cells do contain a nucleus.

Exactly when cells with a nucleus appear is not known, but appears to be around 2000 million years ago. We do not currently know how these cells acquired a nucleus, however. The origin of other internal structures such as mitochondria is better known. They may have originated when one cell **engulfed** another (Figure 1.9). Normally the engulfed cell would be digested for food. Instead the engulfed cell formed a symbiotic relationship with its host. Over time the engulfed cell becomes mitochondria, the energy producing part of a cell. These cells eventually give rise to the animals.

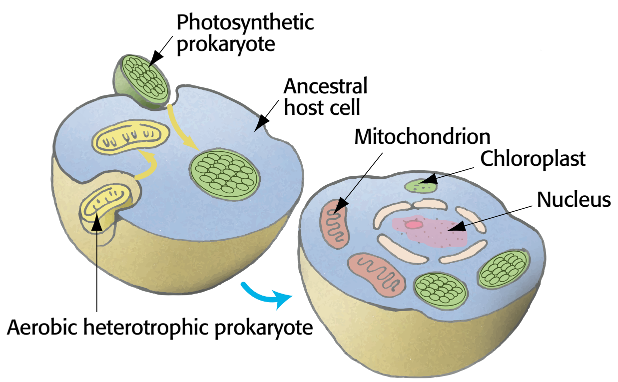


Figure 1.9 Engulfing cells Cells engulf other cells that in time evolve to become mitochondria.

Another symbiotic relation developed when these cells with a nucleus and mitochondria engulf photosynthetic bacteria. These bacteria eventually become chloroplasts and such cells give rise to the plants.

ACTIVITY 1.2
EXPLORING CELLS

1. Using information sources such as your library, biology textbooks or the internet, investigate the difference between:

(a) Heterotrophic and autotrophic cells.

(b) Prokaryotic and eukaryotic cells.

2. Explore some of the earliest evidence for life in this virtual field trip of the Pilbara.

Earliest evidence for life Virtual Field Trip http://vft.asu.edu/VFTDresser/panos/Dresser/Dresser.html http://qr.w69b.com/g/roiuZQL1m	

Cyanobacteria and the origin of photosynthesis

Figure 1.10 Microscopic plants Plants like these cyanobacteria brought about huge changes in the atmosphere.

Cyanobacteria, the first organisms capable of photosynthesis, appeared around 3500 million years ago (Figure 1.10). They had a tremendous advantage over simple organisms that obtained energy by anaerobic means. The earlier organisms obtained energy by ingesting naturally occurring organic and inorganic molecules. The photosynthetic cyanobacteria could actively produce their own fuel for respiration (sugars), making them much more efficient.

Initially, only a small number of photosynthetic organisms would have pioneered this new method of gaining food. Soon, however, they proliferated. This was accompanied by a rise in the production of oxygen gas, which the organisms produced as a waste product.

The early oceans contained abundant dissolved iron from the weathering of surface rocks. Any oxygen that was produced by photosynthesis would quickly react with iron to form insoluble iron oxide. It was not until the production of oxygen exceeded its loss by chemical combination in the oceans could it start to accumulate in the atmosphere. This became possible when the levels of dissolved iron in sea water began to be depleted. It took over 700 million years from the arrival of photosynthetic organisms before free oxygen began to accumulate in the atmosphere. This was the greatest environmental change ever brought about on the early Earth. The effects of photosynthesis dramatically and permanently altered the composition of the oceans and atmosphere. It changed the Earth forever and very nearly buried the life forms that caused it to occur in the first place. Scientists refer to this episode as the Great Oxygenation Event.

Stromatolites

Figure 1.11 Shark Bay Living stromatolites.

Easier to find are the stromatolites that still exist today in locations such as Shark Bay in Western Australia (Figure 1.11). These are the most common fossil found in rocks of the Precambrian. They are dome shaped structures built over time from layers of cyanobacteria and sediment. Much of Western Australia is covered by Precambrian rocks so that fossil stromatolites are relatively common (Figure 1.12).

Figure 1.12 Fossil stromatolites The many layers inside the stromatolite.

Figure 1.13 Strelley Pool formation Strata in the remote Pilbara region of Western Australia.

One location with a number of fossil stromatolites is the Strelley Pool formation of fine grained chert (Figure 1.13). This is where many of the most ancient of fossils were found by Australian, British and more recently by American palaeontologists. The Strelley Pool formation is located between two layers of volcanic rock that have been dated by radiometric means. One formed 3.43 billion years ago and the other 3.35 billion years ago. So the Strelley Pool Formation must lie between these two dates and is believed to be around 3.4 billion years old.

Since cyanobacteria could make their own food by photosynthesis, they were able to proliferate. The overall structure of stromatolites has not changed much over billions of years. However, their distribution has changed and they are now confined to a few coastal regions in Western Australia.

Shark Bay Virtual Field Trip.
http://vft.asu.edu/VFTSharkbay/panos/sharkbay/sharkbay.html
http://qr.w69b.com/g/nrWA3Y9JC

Fossil stromatolites Virtual Field Trip
http://vft.asu.edu/VFTEnoramaH5/panos/tf1h5main/tf1h5main.html
http://qr.w69b.com/g/qBrP2RSfK

SCIENCE SKILLS

1. Construct a 4 billion year timeline for early life on Earth. Use the data above to add stages to the timeline. Keep your timeline for future work.
2. Once life evolved on Earth, it diversified into more and more species. Sketch a line graph (i.e. no numbers) with 'Time' on the horizontal axis and 'Number of Species' on the vertical axis. Draw in what the line would look like if:
   (a) New species evolved at a regular rate.
   (b) New species evolved at an increasing rate.
   (c) New species evolved at an increasing rate, but were then greatly and rapidly reduced by the Great Oxygenation Event, before continuing to evolve again.

TO THINK ABOUT

Set 1

1. **Explain** why the evolution of photosynthesis is so important to life on Earth.
2. **Identify** where the first known fossil life has been found. **Describe** the nature of this life.
3. **Suggest** how the first cells gained mitochondria which supplies energy for cell functions?
4. **Identify** the advantage of symbiosis to living things.
5. **Identify** the first organisms capable of photosynthesis.

Set 2

6. **Compare** how energy was obtained by the first cells and cyanobacteria.
7. **Contrast** prokaryotic and eukaryotic cells.
8. Where would you find living stromatolites?
9. How were the fossil containing rocks of Strelley Pool dated?
10. **Discuss** the significance of stromatolites in the early fossil record.

1.3 Origin of multicellular life

Photosynthesis and multicellular life
http://qr.w69b.com/g/kFLkNh86A

We humans are multicellular organisms. How did life change from being single celled to having many cells – often billions of cells. This development resulted in the evolution of many organisms, some being very strange looking.

The first multicellular organisms

It is hard to determine when multicellular organisms first evolved from single celled organisms:

- Early forms **lacked hard tissues** such as bone, shell or cellulose and so rarely fossilised.
- Older fossils are likely to have been **distorted or destroyed** over time.
- It is difficult to tell the difference between cells living as groups (**colonial living)** from **true multicellular** organisms based only on fossils.

The further back in time we go the less reliable much of the fossil evidence becomes. The tube-shaped fossil *Grypania* (Figure 1.14 (a)) is thought to be a primitive alga and is found in rocks that are 2.1 billion years old. At the time of writing a number of other very early fossils were being discovered.

Figure 1.14 First multicellular organisms (a) Grypania formed long chains of cells more than 2 billion years ago. (Wiki) (b) This fossil algae is at least 555 million years old, dated to the Ediacaran period. (University of Wisconsin-Milwaukee)

There are very few fossils preserved until we get to around 600 million years ago. A complex multicellular fossil has been found showing many modern features (Figure 1.20). This spherical multicellular specimen of the *Megasphaera* fossils shows dividing cells in its interior. The peripheral cells on the outside of the cell are slightly elongated, suggesting cell differentiation.

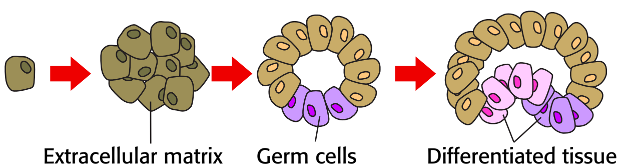


Figure 1.15 The colonial theory Over millions of years cells begin to specialise producing multicellular organisms.

How did single cells change to being multicellular? There are many theories, but we will only present one (Figure 1.15). It has been observed that in some single celled organisms the cells remain attached after cell division. Perhaps in the distant past this took place and over time and the cells formed into a hollow ball. Some of the cells in the ball then began to specialise, producing reproductive cells. The cells then began to fold inwards to produce a variety of tissues.

For evolution such as this to occur, there must be some biological advantage. Single cells had successfully survived for billions of years. There are, however limitations to their size. If the cell becomes too large it has a reduced surface to volume ratio and has difficulty absorbing sufficient nutrients and transporting them throughout the cell. Living as a group where some cells specialise does confer some advantage as it is not limited in size this way. They can have longer life spans as they can continue living when individual cells die. A multicellular structure also permits increasing complexity by allowing specialisation of cell types within one organism.

ACTIVITY 1.3
THE ORIGIN OF MULTICELLULAR LIFE

This unit is at the forefront of scientific research. Using the internet and any other sources at your disposal, research to see if there are any new fossil discoveries to update the material in this unit.

Ediacaran fauna

The earliest known occurrence of recognisable multicellular animals is the Ediacaran fauna, named for the Ediacara hills north of Adelaide in South Australia (Figure 1.16). Dated to around 565 million years ago, during the Precambrian, these organisms lived in a shallow marine environment. Some of these Ediacaran animals resemble modern jellyfish and segmented worms, found in great numbers in the seas today. Others are unlike any known organisms and cannot be classified with certainty. All these early creatures lack the rigid, supporting skeletons and protective shells that are found in the first fossils of the Cambrian period.

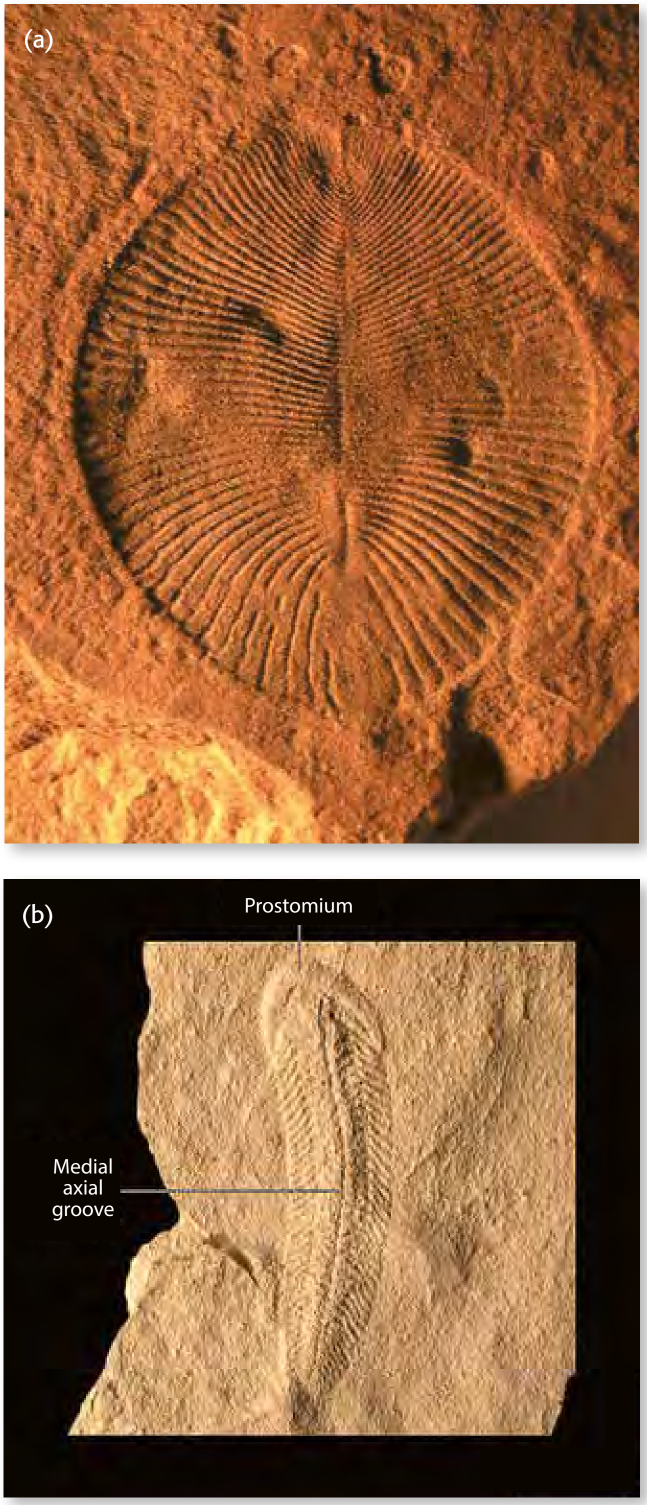


Figure 1.16 Ediacaran fauna (a) *Dicksonia* is around 50 cm long and seems to be a large flat sheet worm; (b) *Spriggina* is about 4 cm long and was thought to be a segmented worm, but may be an early type of arthropod.

Virtual field trip to the Ediacaren Hills. http://vft.asu.edu/iVFTLocations/Nilpena/NPoptions.html http://qr.w69b.com/g/t7YqiPQTm	

Cambrian fauna

One of the great puzzles in the fossil record is the appearance of a large number of new organisms at the beginning of the Cambrian, around 530 million years ago. Called the **Cambrian explosion**, the fossil record is dominated by organisms with hard parts, including trilobites and brachiopods (Figure 1.17). There also soft bodied animals such as worms and jellyfish. There are also many organisms that have no modern counterparts. There are three main sites where these fossils appear. In Australia they are found at Emu Bay on Kangaroo Island. The other locations are the Burgess Shale in Canada and at Chengjiang, in Southern China.

Figure 1.17 Cambrian explosion Some of the organisms in Cambrian seas after the Cambrian explosion. (Wiki)

The puzzle facing geologists may have several answers. Evidence shows that oxygen levels had risen in the atmosphere prior to the Cambrian and that some of this oxygen had slowly reached the bottom of the oceans where most of these animals lived. Plate tectonics saw large areas of shallow seas appear that were suitable for life. Another reason may be the appearance of hard parts such as shells and exoskeletons that are more readily fossilised. Perhaps there were many soft bodied organisms prior to this period that were never fossilised.

All fossils from this period were marine – as far as we can tell there was no life on land. Most of these Cambrian animals were extinct by the end of the Permian, including the famous trilobites.

Brachiopods reached a peak in the Devonian but relatively few species survived the Permian extinction and today survive in polar regions and at great depths. There are also a number of unusual fossils of strange animals that have all become extinct.

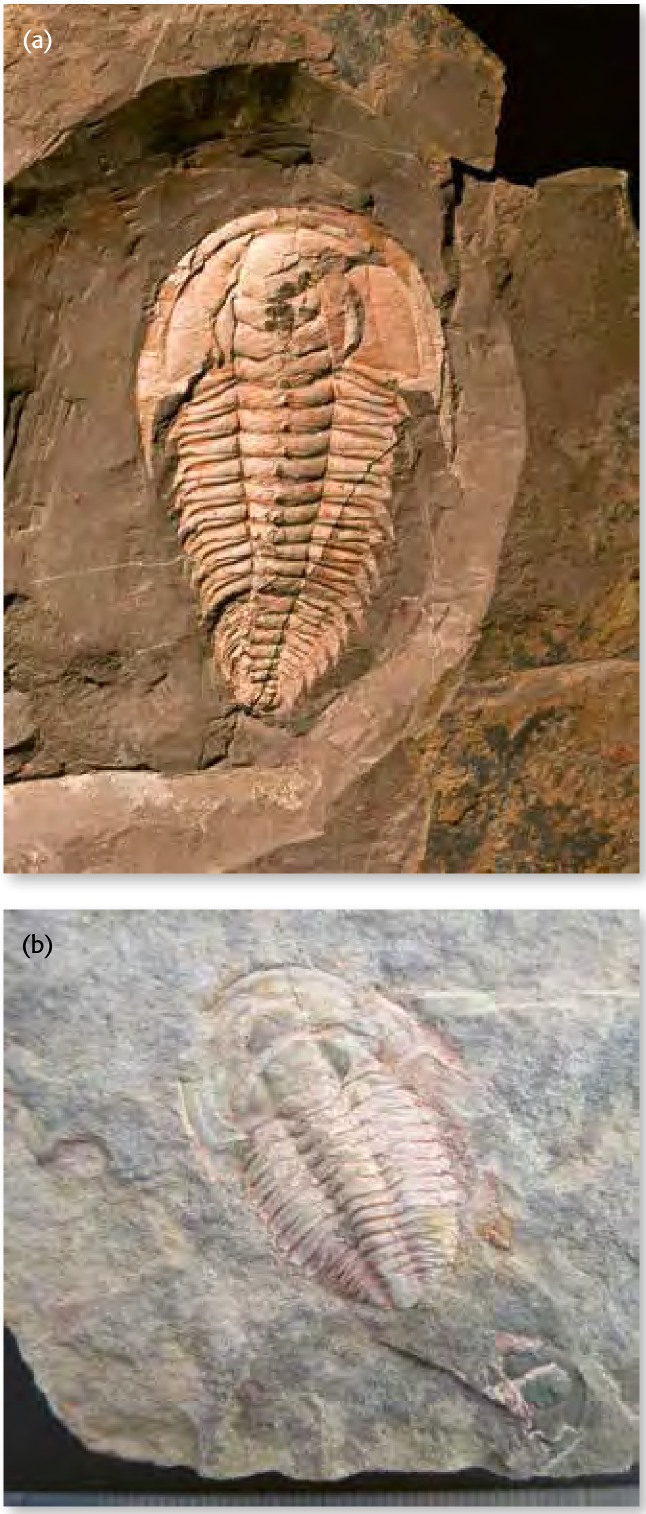


Figure 1.18 Emu Bay trilobites These trilobites found on Kangaroo Island are several centimetres long. (Palaeocast/ Fossil forum)

Trilobites are one of the most famous of fossils even though they are extinct at this time (Figure 1.18). These crustaceans were some of the most prevalent organisms during the Cambrian. They had many segments that were covered by a shield-like structure and used their segmented legs to crawl or swim. Many trilobites crawled along the floor of ancient oceans preying on worms and other organisms. Others were able to swim to seek their prey. Some trilobites seem to feed on detritus, particles of organic material on the ocean floor. Still others were filter feeders using net-like structures to filter food particles from the water.

In Australia, one place where these fossils are found in abundance is Emu Bay on Kangaroo Island, off the south coast of South Australia (Figure 1.18). These fossil beds are dated from 520 million years ago. The Australian examples lived in shallow seas and are found in very fine grained shales so that their anatomy is well preserved. The fine grained rocks allow 'soft parts', such as eyes, appendages and intestines to be preserved. Animals in all stages of life have been found, ranging is size from a centimetre or two up to 25 cm long giants.

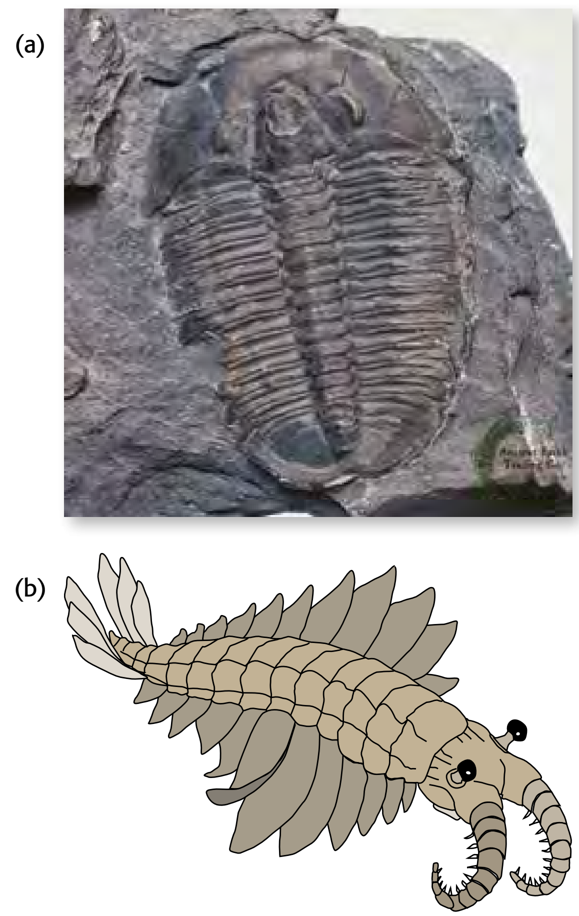


Figure 1.19 Trilobites (a) Trilobite with bite on left side. (b) The predator *Anomalocaris*.

Fossil evidence indicates that the trilobites were being fed on by at least one other crustacean called *Anomalocaris* (Figure 1.19). This 60 cm long predator with large claw-like structures was able to attack and kill trilobites. One trilobite fossil was found with a chunk missing from one side that matched the size and shape of an *Anomalocaris* claw. A coprolite, fossilised dung, about 43 mm long and 28 mm wide has been found that contains trilobite fragments from an animal estimated to have been about 4 cm long. There are many other fossilised animals present including brachiopods (a type of shellfish), hyoliths (have a long conical shell), a variety of worms including some with segmented bodies and spider-like crustaceans. Also present are a variety of algae and sponges.

ACTIVITY 1.4
COMPARATIVE ANATOMY

1. If possible, obtain a whole sample of either a 'Balmain bug' or 'Moreton Bay bug' (both are small native slipper lobsters) from a seafood supplier. These are both crustaceans, but have structural similarities to trilobites as they occupy a similar niche in similar habitats.

(a) Examine the specimen carefully, noting its main features. In particular, take note as to how its armour plating behaves as it moved in different ways.

(b) Take a photo then sketch a scientific diagram of the specimen (above view). Sketch a diagram of a named species of trilobite next to it.

(c) Construct a data table to compare the 'bug' features with the trilobite features.

(d) Research and describe the habitat and diet of both your 'bug' and your trilobite.

2. If possible, get specimens of chiton shells and/or living slaters (woodlice).

(a) Classify which phylum of the animal kingdom each belongs to.

(b) Describe and explain the behaviour of the slaters when they are touched (look for a video if live specimens are unavailable).

(c) What inferences might we make about trilobites based on the behaviour seen above?

(d) In written form, compare each of these modern organisms with your trilobite.

(e) Search online for curled trilobite images. How does this evidence effect your inference from Question 2 (c) above.

Cambrian explosion fossils http://www.fossilmuseum.net/museum-cambrian-explosion-fossils.htm http://qr.w69b.com/g/q58Xp4EfK

SCIENCE SKILLS

1. Below is a description of fossils believed to be that of a 600 million year old multicellular organism (Figure 1.20). **List** the evidence for and against that the fossil is an example of multicellular life. What is your conclusion?

'Spherical microfossils from the Ediacaran (630 to 542 million years ago) have been found in central China. Called Megasphaera, the fossil shows evidence for cell differentiation and cell division – qualities of complex multicellular eukaryotes such as animals and plants.'

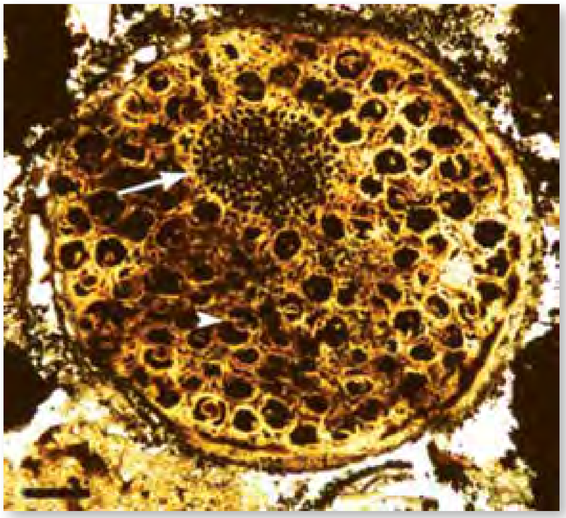


Figure 1.20 Multicellular life Are we looking at an early multicellular organism? (Lei Chen et al)

'The large arrow appears to show a boundary between two types of cell. The arrowhead appears to show cell division. The cells around the outside seem to be larger and of different shape than those towards the centre. The specimen is microscopic in size.'

2. Use the data in this unit to add stages to the timeline you prepared in Unit 1.1. Keep your timeline for future work.

TO THINK ABOUT

Set 1

1. **Explain** why it is hard to find fossils of the first multicellular organisms.
2. **Identify** the sorts of features used to determine that a structure in rocks is an early multicellular organism.
3. **Describe** the colonial theory for the origin of multicellular organisms.
4. **Outline** the advantages that multicellular organisms have over single celled organisms.
5. **Identify** two major advantages that Ediacaran fauna have over earlier life forms.

Set 2

6. **Explain** why the fossil record around 500 million years ago is called the 'Cambrian explosion'.
7. **Outline** why there is such a proliferation of fossils during the Cambrian explosion.
8. **Describe** the advantage of fine grained sediments in preserving fossils.
9. **Describe** the lifestyle of trilobites.
10. **Outline** the evidence of predation during the age of trilobites.

1.4 Conquest of the land

Animals evolved in the sea and that is where they remained for at least 600 million years. This is because without a protective ozone layer, the land was bathed in lethal levels of UV radiation. Once photosynthesis had raised atmospheric oxygen levels high enough, some oxygen atoms could recombine as ozone (O_3) and form an ozone layer in the stratosphere. This meant that it was then possible for living things to venture onto land without being exposed to lethal doses of UV radiation.

Animals conquer the land

Figure 1.21 Arthropod tracks These tracks were produced by arthropods during the Cambrian. (Wiki)

The earliest invertebrates

Animals continued to diversify in the Ordovician seas (505 to 440 million years ago). They were mostly invertebrates, including brachiopods (a shellfish), trilobites, cephalopods, corals and crinoids (Figure 1.22). In terms of number of species, invertebrates were by far the most common Ordovician animals.

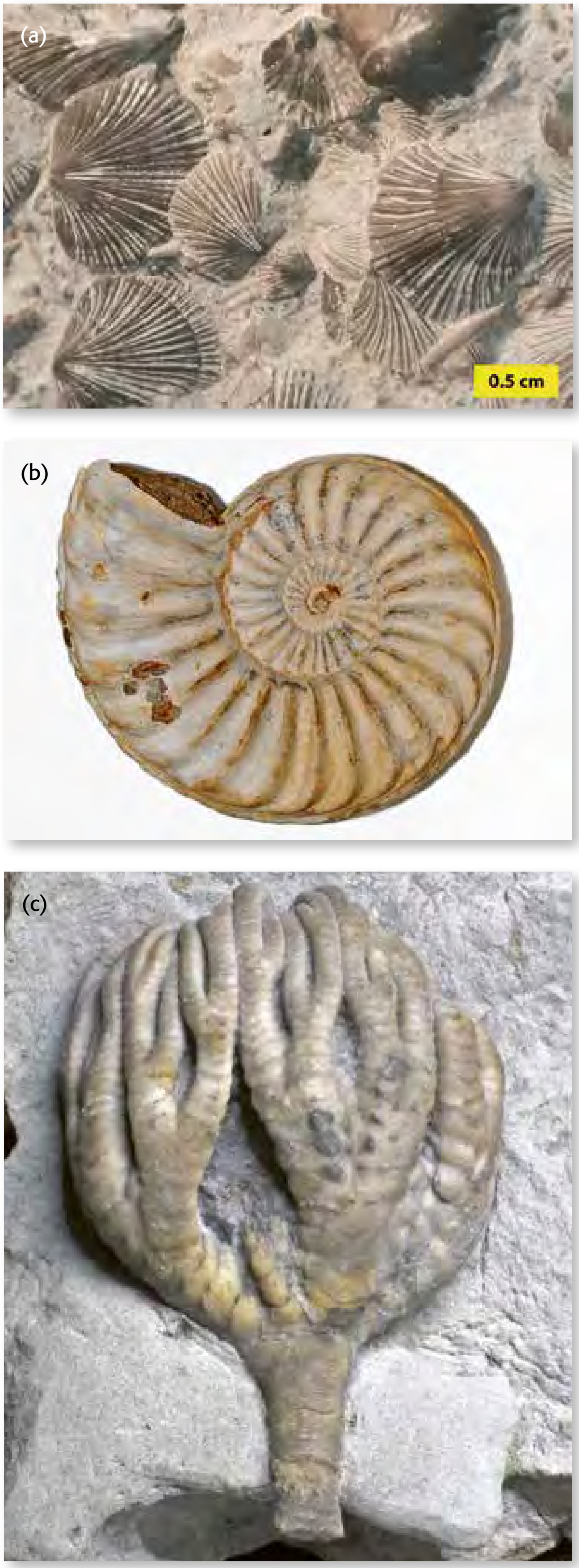


Figure 1.22 Early invertebrate fossils (a) Brachiopods. (b) Cephalopod. (c) Crinoid. (Wiki)

Appearance of the fish

The fish were also evolving in the Ordovician seas. Fish are placed in the subphylum Vertebrata, because they show the development of skeletal features such as a backbone, skull, and limb bones.

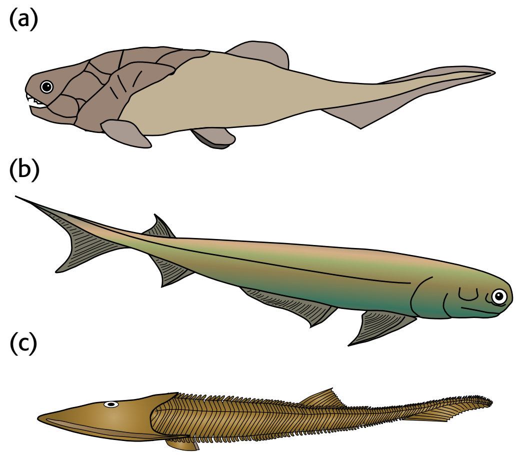


Figure 1.23 Early fish (a) Placoderm. (b) Acanthodians. (c) Agnathans or jawless fish.

Not all the modern groups of fish were represented in the Ordovician oceans. At this time only the jawless fish had evolved. The sharks and their relatives along with two extinct groups, the placoderms (which had bony plates covering their heads) and the acanthodians (the first known jawed vertebrates, with a skeleton of cartilage) made their appearance in the Silurian (Figure 1.23). Neither the sharks nor the jawless fish became common until the Devonian. The other two living lineages, the ray finned (e.g. carp and kahawai) and the lobe finned fish (e.g. lungfish and the coelacanth), evolved during the Devonian period. The lobe finned fish had a series of flesh covered bones to which the fins are attached. Ray finned fish have a system of smaller bones closer to the body to which the fins are attached.

Agnathans, or jawless fish, were some of the earliest fish – an excellent fossil of *Haikouichthys* dates back about 530 million years, to the Cambrian (Figure 1.23). Jawless fish have traditionally been placed with the vertebrates due to the presence of a skull, despite modern forms such as hagfish lacking a vertebral column. The earliest jawless fish were bottom feeders that ate either decaying organic matter that has sunk from the ocean above, or on other animals living on the ocean floor. For protection they were almost entirely covered in armour plates. When the sharks and bony fish began to evolve, around 450 million years ago, only the lineage that produced the modern hagfish and lampreys survived.

Answers

Chapter 1 Development Of the Biosphere

1.1 Origin of life

1. Urey-Miller experiment (Figure A1).

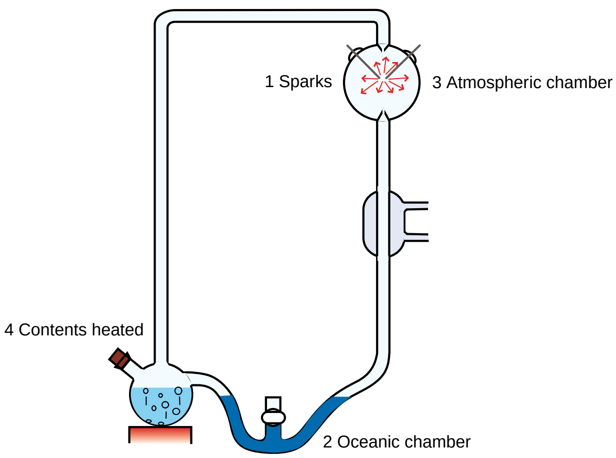


Figure A.1 Urey-Miller experiment.

2. Methane (CH_4), ammonia (NH_3), hydrogen (H_2), water vapour (H_2O).
3. Oxygen was present as part of carbon monoxide (CO) and carbon dioxide (CO_2). Hydrogen formed a part of both methane (CH_4) and water vapour (H_2O). Carbon was abundant as a component of carbon monoxide (CO), carbon dioxide (CO_2) and methane (CH_4). Nitrogen was abundant as a gas (N_2) in the early atmosphere as it is today.
4. Since photosynthesis had not yet evolved, alternative sources of energy were needed so that organisms could evolve. Sparks were used in an early version of the Urey-Miller experiment. Perhaps volcanic lightning provided energy for chemical reactions in pools located in volcanically active regions. Or perhaps hydrothermal activity provides energy for such reactions near vents and carry hot water from deep in the crust.
5. The atmospheric chamber where the sparks occurred. Lightning, UV rays from the Sun or heat from molten rocks could all have been responsible for breaking chemical bonds.
6. (a) Archaeobacteria are ancient and primitive micro-organisms which have no nucleus or specialised organelles within them.
   (b) Mainly consumers.
   (c) The early archaeobacteria may have had abundant organic molecules in the oceans (resulting from reactions between the atmosphere and lightning or UV rays).
7. Sparks were used in an early version of the Urey-Miller experiment. Perhaps volcanic lightning provided energy for chemical reactions in pools located in volcanically active regions thus producing molecules such as amino acids.
8. Hydrothermal vents carry hot water from deep in the crust where it has been heated by magma. Perhaps this provides energy for reactions between methane and ammonia found near vents.
9. Conditions in other parts of the Solar System approximate what it might have been like on the early Earth. By studying conditions in these locations it may be possible to find simple life forms, or obtain other clues as to how life originated here on Earth.
10. Scientists think that the first life on Earth was likely to be the result of reactions like those observed in the Urey-Miller experiment. The Urey-Miller apparatus has produced organic molecules from a range of inorganic gases present, with the exception of oxygen. Oxygen gas is highly reactive and organic molecules will not form if it is present. Earth's early atmosphere had little or no oxygen in it, so was agreeable to the formation of organic molecules and life. Earth's current atmosphere has abundant oxygen and so would not allow the formation of organic molecules and life in this manner.

1.2 Origin of photosynthesis

1. While a number of living things can function on anaerobic sources of energy they are severely limited in their mobility and many other life processes. Aerobic respiration that uses oxygen allows much greater mobility so that both plants and animals can survive in many different environments including, oceans, deserts, alpine and other cold regions and the air.
2. The first known fossil life has been found in Western Australia. These are single celled organisms.
3. A cell is engulfed with it and is taken into the host cell. Normally it would be digested as a source of food. However at some time in the distant past it remained inside the host and evolved over millions of years to become mitochondria.
4. During symbiosis an association between different organisms is mutually beneficial to both.
5. The first organisms capable of photosynthesis were the cyanobacteria.
6. There was no oxygen in the atmosphere for the first cells. They used anaerobic methods to digest organic molecules to obtain their energy. The development of photosynthesis and the slow addition of oxygen to the atmosphere allowed the development of aerobic respiration as we know it.
7. Prokaryotic cells have no separate internal organelles, and do not have a nucleus separated by a membrane from the rest of the cell's contents. Eukaryotic cells do have internal structures such as mitochondria and chloroplasts, as well as a membrane bound nucleus.
8. Living stromatolites can be found along the coasts of Western Australia.
9. The sedimentary rocks containing stromatolites fossils at Strelley Pool are located between layers of volcanic rocks that can be dated using radiometric means.