Environmental Studies
FACT SHEET
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Conditions for life on Earth

Planet Earth is about 4.5 billion years old. About 3.9 billion years ago, life evolved and has continued to evolve. Life exists in the oceans, in the soil, on the surface, in rocks extending to several kilometres below the surface and (at least temporarily) in the air to an altitude of several kilometres. The question is: Why is Earth the only planet in our Solar System with life on it ?

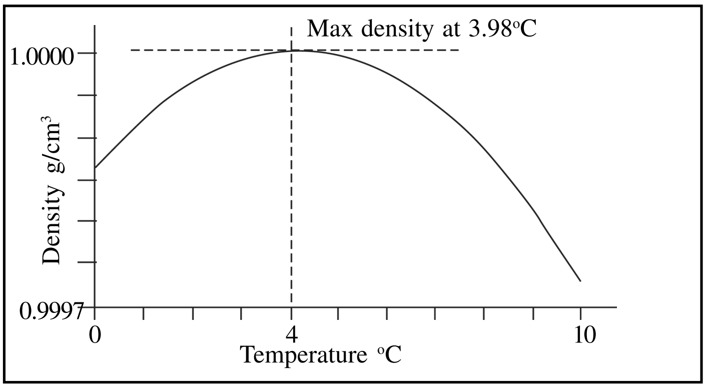
The key factors are:
- liquid water near the surface;
- an atmosphere that filters incoming radiation, allowing just the right amount through;
- a stable planetary orbit around the Sun;
- our current position relative to the Sun, which provides our heat and energy;
- enough internal heat from the planet's molten core to allow plate tectonics (which are important for maintaining the balance of the carbon cycle);
- having Jupiter as a neighbour which protects us from comets and asteroids;
- the presence of a large moon that stabilizes tilt (keeping the seasons mild) and the tides;
- the evolution of photosynthetic microbes that released oxygen into the atmosphere

Water

Liquid water exists on Earth because we are just the right distance from the Sun and the natural greenhouse effect maintains a moderate surface temperature. Water acts as the solvent for all metabolic reactions in living organisms and is essential for internal transport.

Water has the very unusual property that its solid form (ice) floats on the liquid (Fig 1).

Fig 1 Density of water



This is because it is most dense at about 4°C - so ice is less dense than cold water. Thus water freezes from the top down. The ice crust that forms on a body of water insulates the water beneath from cooling and allows life to survive.

Water has a high specific heat capacity i.e. it takes a lot of energy to raise the temperature of water or conversely, a lot of energy can be lost before the temperature of water starts to fall. This is crucial for living organisms which need to maintain particular temperatures in order to optimise enzyme activity. The high water content of cells and tissues helps them to maintain a constant temperature. In this way water acts as a **temperature buffer**.

Conversely, when water molecules do escape from the water surface during evaporation, a lot of energy is released with them. As a result, evaporation (e.g sweating or panting) is an efficient cooling mechanism, allowing living organisms to maintain a constant body temperature. The biological importance of water is summarized in Table1.

Table 1 Biological importance of water

Function	Examples/Explanations
Transport	Uptake of minerals by plants from soil Transpiration stream and water-based movement of sugars and amino acids, hormones etc. in phloem occurs in solution. All transport fluids used in animals (e.g. cytoplasm, blood, plasma and tissue fluid) are water-based.
Chemical reactions (metabolism)	Combination of thermal stability and excellent solvent properties makes water an ideal environment for chemical reactions. All enzyme reactions of photosynthesis, respiration, excretion etc. occur in solution.
Temperature control	High specific heat capacity allows water to act as a buffer; essential in endothermic organisms that need to maintain a constant body temperature in order to optimise enzyme activity and thereby regulate metabolism. High incidence of hydrogen bonding also makes at it difficult for water molecules to evaporate. When they do so, much energy is released and this is involved in cooling mechanisms. Water remains a liquid over a huge temperature range - essential for metabolism and useful for aquatic organisms which avoid freezing.
Support & movement	In plant cells water confers turgidity. This is essential for example, in: 1. Maintaining maximum leaf surface area, hence light absorption, hence photosynthesis. 2. Maintaining aerial parts of the plant to maximise seed dispersal or pollination. Loss of water in very hot conditions may lead to leaves wilting. This decreases their surface area, hence light absorption, temperature and water loss. In animals, water-filled tissues also contribute to skeletal support. In organisms which possess a hydrostatic skeleton (e.g. annelids), water is the major component of the fluid in the coelom against which muscles can act. For aquatic organisms, water provides support through buoyancy. Organisms such a earthworms and leeches use their hydrostatic skeletons to move around. Longitudinal and circular muscles are able to contract against the incompressible watery fluid of the coelom.
Reproduction	Organisms which employ sexual reproduction use water to bring the male and female gametes together in the process of fertilisation.

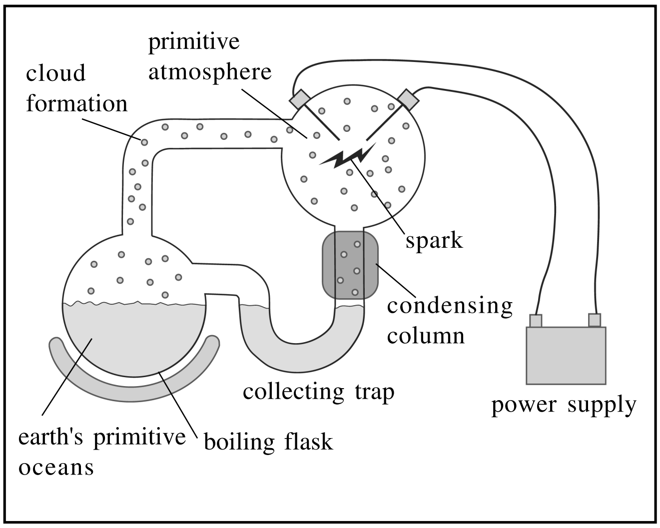
Water vapour in the atmosphere contributes to the greenhouse effect and helps raises the average surface temperature of the planet. Both atmospheric clouds and surface snow and ice are highly reflective; without them the Earth would absorb much more of the sunlight that strikes our planet, and this would raise the temperature even without a greenhouse effect. Water also plays a key role in the energetics of the atmosphere, since it can store or release energy as it changes from vapour to liquid (clouds) and back again.

The beginning of Life on earth

In the 1950s many scientists were trying to work out how the building blocks of life –amino acids, simple sugars etc – could have formed in the first place. Stanley Miller, an American scientist carried out an ingenious experiment. He put the gases that were believed to have made up the Earth's early atmosphere - methane (CH_4), ammonia (NH_3), hydrogen (H_2), and water (H_2O) and zapped them with an electric current to simulate lightning (Fig 2)

He used chromatography to identify the products. At the end of one week, 10% of the carbon was now in the form of organic compounds. Two percent of the carbon was in the form of amino acids which are used to make proteins. Thus, Miller showed that organic compounds such as amino acids, which are essential to cellular life, could be made easily under the conditions that scientists believed to be present on the early Earth.

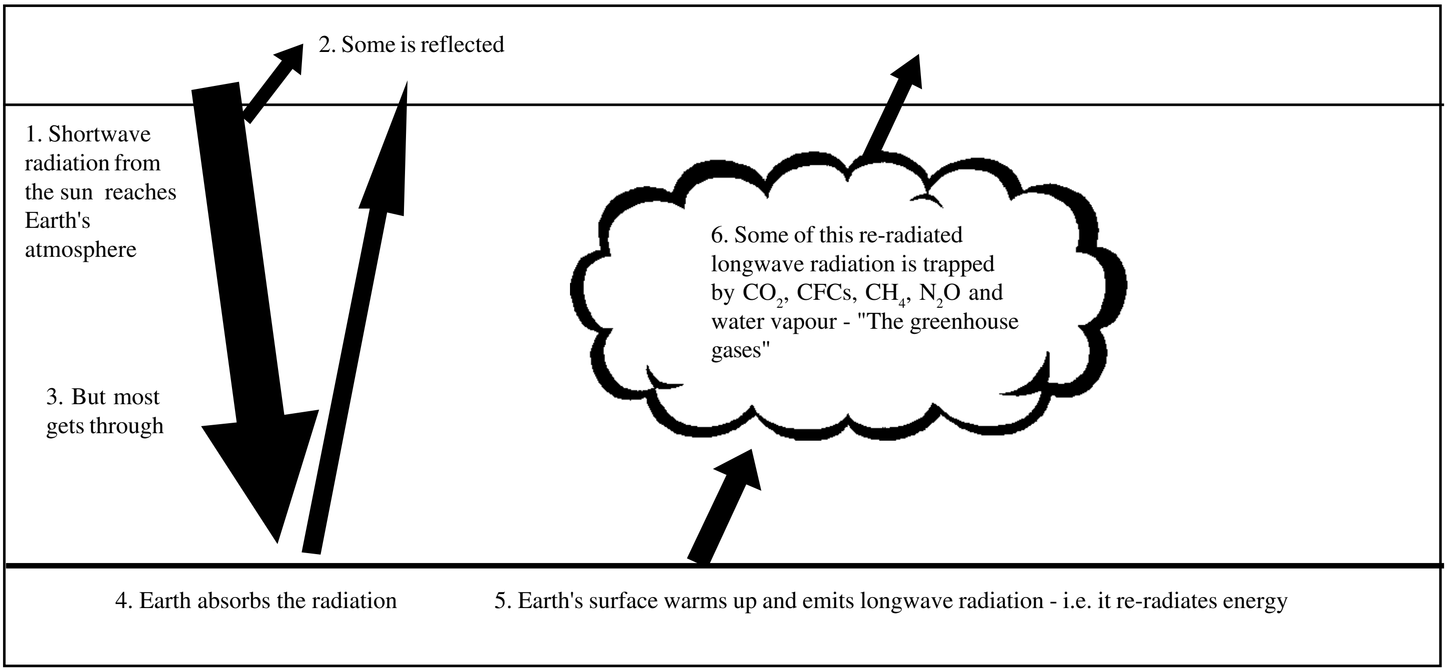
Fig 2 Miller's How did Life begin? experiment



The atmosphere

The greenhouse effect – the trapping of heat in the lower atmosphere – is a natural process and is essential for life on Earth. Without it, temperatures would be below 0°C (Fig3).

Fig 3. The Greenhouse Effect



The greenhouse effect ensures that most of our planet has a temperature range that permits life. These temperatures also ensure that the gases that all life depends upon – oxygen and carbon dioxide – exist in a gaseous state.

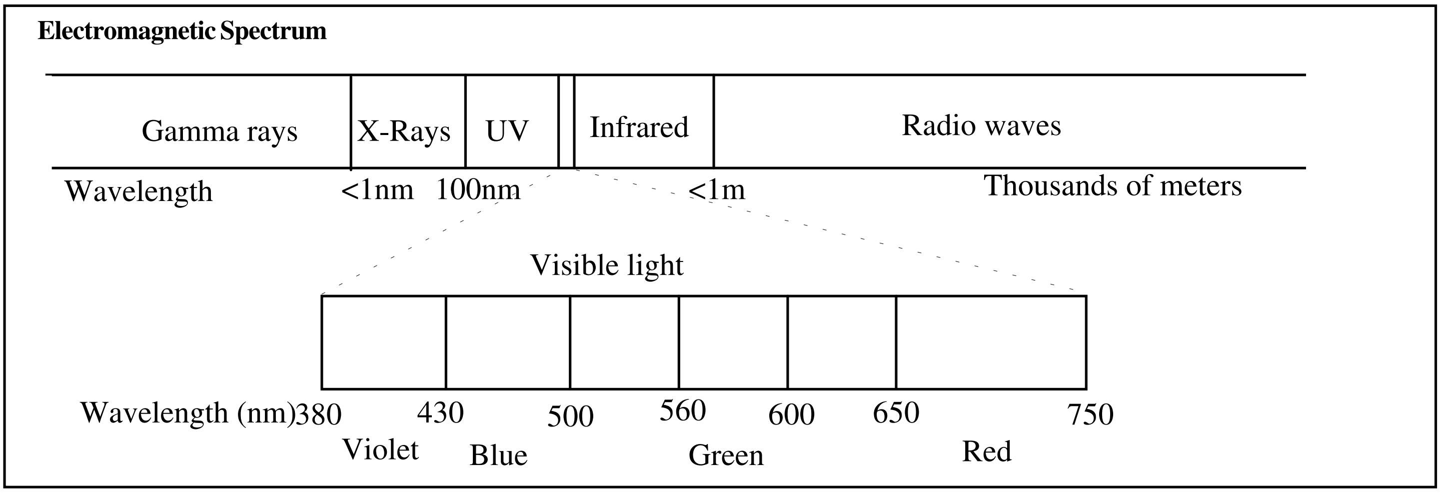
The gaseous composition of our atmosphere allows photosynthesis and aerobic respiration, two processes that actually help to maintain that composition. Although there is only 0.035% carbon dioxide, that is sufficient for photosynthesis and, if that percentage was higher, we would run the risk of a runaway greenhouse effect. The 21% of the atmosphere that is oxygen allows plants and animals to carry out aerobic respiration – the efficient release of energy from chemical stores.

The ozone layer in the stratosphere absorbs UV radiation which would otherwise destroy living organisms by causing mutations and cancers.

Photosynthesis

Green plants are the basis of almost all food chains. Plants trap light energy in the pigment chlorophyll. This light energy is converted into chemical energy – carbohydrates,fats, proteins etc. Plants use only a small part of the electromagnetic spectrum – the part that is visible light (Fig4).

Fig 4. The Electromagnetic Spectrum

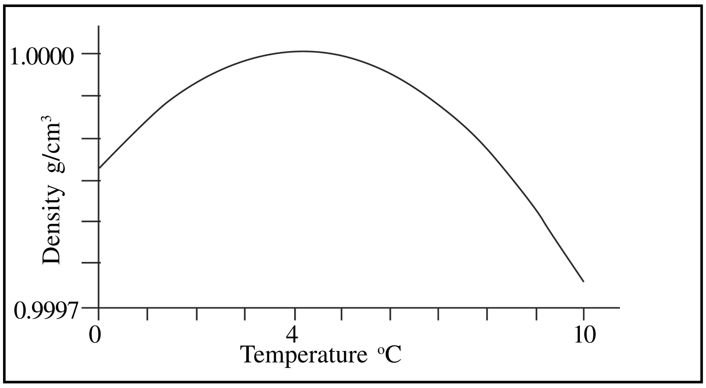


Chlorophyll is actually a mixture of different pigments, each of which absorbs a slightly different part of the visible spectrum. The two wavelengths that are most useful in photosynthesis are those that correspond to red and blue light – most green light is reflected from leaves, which is why they appear green to us. No animal is capable of converting light energy into chemical energy in this way – so the animal Kingdom depends upon the plant Kingdom, and both depend upon the Sun!

As far as we know, no other planet supports life.

Practice Questions

1. The graph shows the effect of temperature on the density of water.



(a) State the temperature at which water reaches maximum density; 1 mark

(b) Outline the environmental significance of the relationship between water temperature and density. 4 marks

2. Outline the importance of each of the following for life on Earth:
(a) the ozone layer; 2 marks

(b) the natural greenhouse effect. 4 marks

Answers

1. (a) 4°C;
(b) water most dense at 4°C;
ice forms at 0°C;
so ice is less dense than the water;
and floats on top/water freezes from the top down;
allowing organisms to survive beneath the ice;

2. (a) absorbs UV radiation;
which is a carcinogen/mutagen/damages DNA;
(b) named gases/carbon dioxide/methane/tropospheric ozone/water vapour/NOx;
absorb outgoing radiation/longwave radiation;
warming lower atmosphere/troposphere;
maintaining moderate temperature;
allowing enzyme function;
maintains gaseous state of carbon dioxide/oxygen etc;

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