Energy and change

A project funded by the Nuffield Foundation

Theme J

Flows of matter and energy

Teaching notes

Theme J - Flows of matter and energy

What is this theme about?

What thoughts and feelings does the phrase 'Spaceship Earth' conjure up in you? The term was coined to encapsulate and encourage a certain attitude to the planet, based on the idea that the Earth is essentially a closed system - no matter gets in and none gets out. Nothing can be 'used up' in the sense that it disappears completely - matter flows around the planet, sometimes 'spread out', sometimes concentrated in one place, but always conserved.

These changes to matter do not happen 'just by themselves'. They need to be driven - with nothing to drive them, flows of matter would stop and the chemicals on Earth would reach an equilibrium. While matter does not enter or leave 'Spaceship Earth', energy flows continually through it. Energy flows from the hot Sun to warm Earth and into cold space. It is this 'spreading' out of energy which drives these changes.

This theme begins by looking at 'steady states' and how they are kept going. Later activities look at how temperature differences create energy flows , and at how flows of matter are maintained. The final activity is about what happens if flows of matter and energy are interrupted.

The activities

J1 Keeping moving to stay where you are

J2 Going up and coming down

J3 Keep it hot

J4 Earth, Sun and space

J5 Convection currents

J6 Wind, waves and water

J7 The Earth's energy balance

J8 Flows and cycles

J9 Matter matters

J10 Using sunlight to pull a rock uphill

J11 If ...

Activity J1 - Keeping moving to stay where you are

This activity introduces the idea of a 'steady state system', i.e. a system which is maintained in the same state by a constant flow of energy or matter or both.

There is more than one way of 'staying the same'. One important way is by being kept in a 'steady state', by a constant flow of energy or matter or both. There are many examples including simple domestic situations, biological systems, and large-scale phenomena, such as a centrally-heated room, a flame, a saucepan kept boiling, a living organism, an ecosystem, a tornado, the maintenance of the Earth at a constant temperature.

Sheet 1 is an OHP which introduces different ways of staying the same, focusing on two particular examples. (Note that the pictures of changes involving water flow were introduced in Theme D 'Life', and the pictures of changes involving warming and cooling were introduced in Theme E 'Energy from hot to cold'.)

In the first example, the steady state system involves a flow of water and can be illustrated with the 'steady state bottle' shown in Figure 1. (Another illustration would be a bath with the plug out and the tap on maintaining a constant water level.) In the second example, the steady state system involves a flow of energy to keep something hotter than the surroundings. This can be illustrated by a thermostatically-controlled water bath, or by the 'steady state box' described in the next activity.

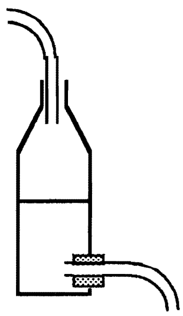


Figure 1 - A 'steady state bottle'

Another more direct example could be used as an analogy - a person standing still on the ground compared with a person walking up a 'down escalator'. This is literally 'keeping moving to stay where you are'. The point of these demonstrations at this stage is simply to introduce the idea of a system staying the same with the input balancing the output - the idea that changing the input or output leads to a different steady state is left until the next activity.

Sheet 2 is another OHP which introduces some further examples of things that do not change, things that do change, and things that are kept in a steady state.

Sheet 3 is the pupil activity. There are 14 situations which pupils should match to the pictures. They should write their explanations for some of the situations. The focus of class discussion in this activity should be on pupils' explanations, rather than on getting the 'right answer' in every case - some are more clear-cut than others. Possible answers are shown below.

Answers
1 C H K
2 A D I L
3 B E F G J M N

For some of the examples, pupils could also be asked to say whether energy or matter (or both) was flowing in or out (or both), and to say how this was happening. It would be worth re-visiting this activity after pupils had looked at other activities in this theme.

Activity J2 - Going up and coming down

This activity looks at how a steady state system changes when the input in increased or decreased.

There are two demonstrations - the first showing a system with a flow of matter and the second showing a flow of energy. Both are about how the rate at which matter or energy flows affects the amount in the system, and how this in turn affects the rate at which matter or energy leaves the system.

Sheet 1 is an OHP which relates to the 'steady state bottle' as described in activity J1. Now, the emphasis is on paying attention to how the height is affected by changes to the rate of water flowing in. It would be useful to experiment with the bottle and encourage pupils to make suggestions and answer questions before looking at the OHP. For example, starting with an empty bottle, pupils could be asked to predict what will happen if the tap is turned on a little (the water level rises, the output of water increases, and eventually it reaches a steady state with a low level of water at which the input balances the output). Or they could predict whether the bottle will necessarily overflow if the if the input is increased a little - and if it does not, why not? (Finding the right rate for input and input to give desired results will need a little practice.) Though this is not mentioned on the OHP, pupils could also be asked to predict what might happen if the water flow at the bottom is reduced by putting a clip on the tube (the water level rises again until the output balances the input again).

Sheet 2 is an OHP with similar ideas about energy flow. These can be illustrated using the 'steady state box', as shown in Figure 2. This consists of a small cardboard box with two holes. Into one hole is inserted a lamp (12V 24W would be suitable) connected to a variable power pack, and the other hole is covered with temperature sensitive film. (The most useful kind is film which changes colour over the temperature range 25°C to 30°C. This can be obtained on small cards from the Science Museum Shop in London or in larger quantities from George Eliott, Stone Cottage, Tickerage Lane, Blackboys, East Sussex, TN22 5LX.)

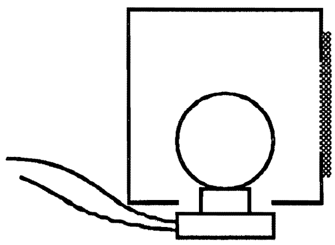


Figure 2 - A 'steady state box'

As before it would be best to experiment with this before looking at the ideas on the OHP. Before looking at the box, another piece of temperature sensitive film should be used to demonstrate how the temperature sensitive film behaves - pupils could note how the colour changes as it warms up in their hands (black to orange to yellow to green to blue) and as they let it cool down. They could then be asked to predict what will happen when the lamp is turned on - will the temperature keep rising and if not, why not? What will happen if the lamp is on a higher setting? (Finding the right settings will again need a little practice.)

The box can also be discussed as a model of a central heating system (the lamp representing the radiator) or the human body (the lamp representing the body's metabolism and the film showing surface temperature of body). In all these cases an object is being kept at a different temperature to that of the surroundings by a constant flow of energy. (In both the central heating system and in the human body there is also a constant flow of matter.)

The OHPs on sheets 1 and 2 can be shown to pupils side-by-side so that they can draw the similarities between the flow of water in the 'steady state bottle' and the flow of energy in the 'steady state box'. (Again, pupils could be asked to think about systems in which a steady state is maintained by a flow of both energy *and* matter.)

Sheet 3 is the pupil activity, in which they are asked to match different changes to graphs which represent the changes. The three changes in each question of this activity are similar to the three kinds of changes shown on the OHPs ('coming down', 'going up' and 'coming down again'), and pupils should be encouraged to refer to the pictures on the OHPs when explaining what is happening in each of the changes. They should be encouraged to talks about rates of input and output.

Answers:

1	a) 2	b) 1	c) 3
2	a) 1	b) 3	c) 2

Activity J3 - Keep it hot

This activity looks at various factors which can affect the temperature of something which is being kept hotter than its surroundings.

Many things are kept warmer than their surroundings - for example, a centrally-heated room, the human body, the Earth. These reach a steady state when the energy flowing in balances the energy flowing out. If there are changes to the system which affect the rates at which energy is flowing in or out, then the temperature will change.

Sheet 1 is an OHP which illustrates the effects of changing the conditions of the 'steady state box'. This should be set up with lamp at lowish setting, and a hair dryer blowing cold air onto film so that it is kept at intermediate temperature (green). The changes shown on the OHP can be carried out as follows:

Changing energy input:
A1 Increase the voltage on the power pack - the film should turn blue.
A2 Decrease the voltage to the original setting - the film should return to green.

Changing insulation:
B1 Put a cloth between the hair dryer and the box - the film should turn blue.
B2 Remove the cloth - the film should return to green.

Changing outside temperature:
C1 Turn on the heater on the hair dryer - the film should turn blue.
C2 Turn off the heater on the hair dryer - the film should return to green.

Sheet 2 is the pupil activity. In the first question, pupils are asked to match various situations to the pictures shown on sheet 1 and to explain what is happening when the steady state changes. The second question is concerned with the controlling the energy input way in order to balance changes in energy output so that the steady state is maintained.

Answers:

1 a) B2 b) B1 c) A1 d) C1

2 a) The energy output increases due to a bigger temperature difference so the energy input is increased.
   b) The energy output decreases due to more insulation so the energy input is decreased.
   c) The energy output decreases due to a smaller temperature difference so the energy input is decreased.

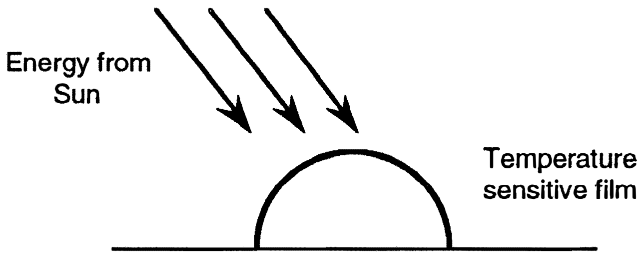
Activity J4 - Earth, Sun and space

Temperature differences lead to energy flows and other changes happening. This activity is about how temperature differences arise on Earth.

There are different ways in which temperature differences occur on Earth due to the energy flow from the Sun. There are temperature differences between night and day, between equator and poles, between land and sea, and between the air and the surface.

Sheet 1 is an OHP which outlines how these various temperature differences arise. Overall, the Earth is kept at the same average temperature because of a flow of energy from the hot Sun to the warm Earth to cold space (see activities J2 and J3). Differences in temperature in different parts of the Earth arise because of different rates of energy flow from the Sun to the Earth and from the Earth to space.

One common misunderstanding is that the difference in temperature between equator and poles arises from the Sun being closer to the equator than to the poles. A useful demonstration is to bend a large piece of temperature film in a semi-cylindrical shape, and to put near the window exposed to the Sun. Pupils can clearly see that the part of the surface directly facing the Sun is warmer than the part of the surface which is at an angle to the Sun.



Note that the story told about the atmosphere is a little simplified here in that the temperature does not keep decreasing with height. In the first 15km or so (the troposphere which contains the major part of the air in the atmosphere), the air does get cooler as you go up, because little radiation from the Sun is absorbed and the air is warmed mainly by infra-red radiation from the Earth's surface. Above the troposphere, however, is the stratosphere, whose temperature increases with height since the Sun's radiation is absorbed by ozone which is present at this height. (Above the stratosphere there are also other variations of temperature with height.)

Sheets 2 and 3 are for the pupil activity. Pupils are asked to match the situations on sheet 2, which are about changes involving various temperature differences on earth, with the pictures on sheet 3.

Answers:

A 5	B 4	C 6	D 8
E 1	F 3	G 9	H 2

Note that picture number 7 shows the 'impossible change', and that the reason it is impossible is because it shows a flow of energy from cool to warm which 'does not just happen by itself'. It is worth pointing out to pupils that all the other pictures of changes show energy flows from hot to cold and that these all 'just happen by themselves'. Some pupils may wonder whether the Sun is 'running down' and that if energy is flowing from it to cold space why it does not cool down. How the Sun is maintained at an approximately constant temperature is discussed in activity J11.

Activity J5 - Convection currents

Temperature differences can drive other changes. Energy moving from hot to cold can make something move.

This is the first example in this theme of a change which 'just happens' driving a change which does not 'just happen'. In this case, a change in which energy flows because of a temperature difference is coupled to a change in which something is started moving (a convection current). The previous activity (J4) looked at how temperature differences arose on the Earth, and this activity about how convection currents arise leads into the next activity (J6) in which the effects of the Earth's temperature differences are considered.

Sheets 1 and 2 are OHPs which introduce the idea of a convection current as being driven by an energy flow from hot to cold. The example used is that of a beaker of water being warmed - if a small crystal of potassium permanganate is dropped down by the side into a beaker of water, and this part is then warmed by a low Bunsen flame, the convection currents can easily be seen as the purple dye dissolves. Another way of making the currents visible is to project a shadow onto a screen using a point source of light (for example, a car headlight). The beaker could be warmed in the middle with an electrical heater - with no potassium permanganate to worry about, there is no constraint on where the heater is placed. The emphasis of the OHPs pictures is on the idea that a change which 'just happens' can drive a change which does not 'just happen'.

What happens in a warmed beaker of water is very similar to the way in which convection currents arise in a centrally-heated room. Sheets 3 and 4 are for the pupil activity, in which they are asked to match situations concerned with a radiator being switched on and off (on sheet 2) to the pictures shown on sheet 4. (Note that the pictures of changes involving moving things slowing down and stationary things starting to move were introduced in activity H1 'Things that just happen and things that don't'.)

Answers:

A 1	B 4	C 9	D 8
E 5	F 2	G 3	H 6

Note that picture 7 is impossible, since it shows a temperature difference being created which is too big (one part becoming hotter than the source and the other colder than the surroundings. Picture 10 shows a change in which something slowing down drives a change in which something becomes warmer than the surroundings. This is indeed possible (friction) and is, in fact, involved in the centrally-heated room (though it is not mentioned on the sheets). As the circulating air slows down it has a tendency to warm up the room.

Activity J6 - Wind, waves and water

The temperature differences which exist on Earth drive many kinds of changes, such as winds, wave, ocean currents, rain and rivers.

Temperature differences on Earth arise for a number of different reasons and these were explored in activity J4. These differences are responsible for many changes occurring on the Earth. Temperature differences give rise to convection currents (see activity J5) which are responsible for winds and ocean currents, and waves are produced by winds blowing over the sea. The temperature difference which exists between the surface of the Earth and the air high in the atmosphere is responsible for 'pumping' water around the water cycle.

Sheet 1 is an OHP which introduces some of these ideas. Note that the story about winds arising from the temperature difference between the equator and the poles is simplified. The OHP shows just one 'convection cell', with a current of warm air going directly to the pole, and a current of cold air going directly to the equator. This is in fact what would happen if the Earth had a uniform surface and if it did not rotate. In reality, the behaviour of these winds is more complex, but the overall effect is the same, with energy being transferred by moving currents of air from the warmer equator to the cooler poles. A similar thing applies for the ocean currents. Note that what we experience as wind is the movement of air in the *lower* part of a convection cell in the atmosphere, whereas what we experience as an ocean current is the movement of water in the *upper* part of a convection cell in the sea.

The water cycle is also driven by a temperature difference (between the warmer surface and the cooler atmosphere). Energy is carried by the warm water vapour from the surface to high in the atmosphere where vapour condenses and energy spreads out into space. This energy flow tends to reduce the temperature difference, and so the presence of water keeps the surface of the Earth cooler than it would be if there was no water. This energy flow from hot to cold also drives the change in which water is continually 'pumped uphill' before flowing back down again as rain.

Sheets 2 and 3 are for the pupil activity. Pupils are asked to match the situations on sheet 2, which are about changes resulting from various temperature differences on earth, with the pictures on sheet 3. (Note that the pictures of changes involving 'springs' being stretched and released - real springs or gravitational 'springs' - were introduced in activity H2 'Springs and things'.)

Answers:

1 E F	2 B
3 A C G H I	4 J
5 D L	6 K

Activity J7 - The Earth's energy balance

This activity takes a quantitative look at the energy flows on Earth which have been discussed in previous activities.

Sheet 1 contains the instructions for pupils. It starts by introducing the meaning of the exajoule, giving a feel for its size, and then asks some quantitative questions about the energy flow diagram on sheet 2. It would be useful to relate the energy flows on this diagram to the changes that drive them, referring back to earlier work in this theme.

Most of the changes shown are driven by the temperature differences between the Sun, Earth and space. These are shown on the left of this diagram. However, it also includes two other causes of changes which are shown on the right of the diagram. The first is the difference in temperature between the Earth's surface and its core due to radioactive decay in the Earth. This temperature difference causes volcanoes to erupt and continental plates to drift due to the convection currents in the mantle. The second is the slowing of the Moon's orbit and the rotation of the Earth which is responsible for tides.

Answers:

1 a) 5 400 000 eJ of energy radiates from the Sun onto the Earth. The same amount radiates from the Earth into space.

b) The average temperature of the Earth stays about the same, because the amount of energy radiating from the Sun onto the Earth is the same the amount radiating from the Earth into space.

2 a) About 35% of energy arriving at the Earth is reflected into space.

b) About 30% of the energy not reflected is absorbed by the atmosphere.

c) About 45% of the energy arriving at the Earth reaches the surface.

d) About 50% of the energy reaching the surface is carried away by water vapour.

e) About 1% of the energy absorbed by the atmosphere is transferred to currents of moving air.

f) About 0.05% of the energy reaching the surface is stored by plants.

3 1 eJ is stored in the fossil fuels made in one year. It would take 300 years to make enough fossil fuel for the world's requirements for one year.

Activity J8 - Flows and cycles

There are many different flows of energy and matter on Earth. While energy enters and leaves the Earth, matter does not - energy flows through the system but matter is cycled within it.

Most of the previous activities in this theme have been concerned with flows of energy. In this activity, we now pay attention to flows of matter, and the way in which it is cycled between organisms and the environment. One point that will be developed in later activities is that such flows of matter do not 'just happen by themselves' - they need to be driven by changes which *do* 'just happen'. Ultimately, these cycles are driven by the flow of energy from the hot Sun to the warm Earth to cold space.

Sheets 1 and 2 could be used as OHP or as the basis for activities for pupils. The first panel shows flows of energy, and the remaining three panels show flows of matter in cycles (the water cycle, the carbon cycle and the nitrogen cycle). The diagrams have been drawn in the same way in each panel, in order to make comparisons easier. Each flow is indicated by a number, and a key identifying the changes is shown below. Thus, the identification of changes could form the basis of a class discussion of a pupil activity. Note that a selection of the more important flows has been made - it is not practicable to include all. Some of the changes included will be taken up in later activities in this theme.

An important point which pupils can be asked to look for is whether there are flows both in and out of each of the parts of these systems. For example, are there flows of water both in and out of plants? Are there flows of carbon both in and out of the air? In every case, there are flows both in and out - a steady states can be maintained when the flow in is balanced by the flow out (see activity J1 'Keeping moving to stay where you are'). This is one consequence of the conservation of matter (which is taken up in activity J10 'Using sunlight to pull a rock uphill').

The main point for pupils in this activity is that, while energy enters and leaves the Earth, matter does not - energy flows through the system but matter is cycled within it. If it were not for this energy flow, then the cycles of matter would stop. This can be compared to the way in which winds are maintained on Earth (see activity J6 'Wind, waves and water') by a flow of energy from the hot Sun to cold space. Without this temperature difference there would be no energy flow, and the winds would stop moving. This point will be taken up in more detail in the later activities.

A Energy flows

1	land warmed by radiation	2	plants photosynthesising
3	sea warmed by radiation	4	energy reflected and radiated from plants
5	plants eaten by animals	6	energy radiated from animals
7	plant remains decomposed	8	animal remains decomposed
9	energy radiated from decomposers	10	energy reflected and radiated from land
11	radiation, reflection, evaporation from sea	12	energy radiated from atmosphere into space

B Water cycle

1	water evaporates from land	2	rain falls onto land
3	plants take up water through roots	4	water evaporates from plants
5	animals eat plants	6	animals lose water by evaporation
7	animals take in water directly, e.g. drinking	8	water in plants used by decomposers
9	water in animals used by decomposers	10	decomposers lose water by evaporation
11	water evaporates from sea	12	rain falls onto sea
13	water runs off land into rivers and seas		

C Carbon cycle

1 carbon dioxide used in photosynthesis
2 carbon dioxide given off by respiration
3 plants eaten by animals
4 formation of fossil fuels
5 combustion of fossil fuels
6 carbon dioxide given off by respiration
7 organic remains used by decomposers
8 organic remains used by decomposers
9 carbon dioxide given off by respiration
10 carbon dioxide dissolves (sea acts as 'sink')
11 carbon dioxide comes out of solution

D Nitrogen cycle

1 nitrates absorbed by roots of plant
2 plants eaten by animals
3 plant remains decayed by decomposers
4 animal remains decayed by decomposers
5 nitrates returned to soil
6 denitrifying bacteria produce nitrogen
7 action of nitrogen-fixing bacteria
8 lightening / manufacture of fertilisers

Sometimes there may be disruptions to the maintenance of a steady state. For example, because of leaching of nitrates from agricultural land, fertilisers are used. In this case, human activity is attempting to maintain a steady state.

In the water cycle, most of the water is transferred unchanged between organisms and the environment. However in the carbon and nitrogen cycles, changes often involve chemical reactions in which small molecules are being built up into larger ones or large molecules are breaking down into smaller ones (see activity G8 'Building up and breaking down molecules'). So another activity would be to identify some of these changes on the diagrams of the cycles.

Activity J9 - Matter matters

Living things are kept in a steady state by flows of matter. Particles take part in various kinds of changes - 'building up', 'breaking down', 'joining', 'splitting', etc..

The ideas in this activity can be introduced by thinking about a car. To keep a car going we need to service it regularly, replacing parts that are worn or broken, and we need to fill it with petrol from time to time. In other words, we need to maintain its structure and we need to maintain its *fuel supply*. Living things are like this, too.

Sheets 1 and 2 are OHPs which introduce the ideas. Sheet 1 is about how a living thing maintains its structure (see also Theme G 'Up and down in complexity'). Sheet 2 is about how it maintains its fuel supply (see also Theme H 'Fuels and food').

Sheets 3 and 4 are for the pupil activity. They are asked to find pictures on sheet 4 which match the changes on sheet 3. Unlike other activities, there may be more than one picture needed to represent the change, for example, one picture to show the driving change and one to show the change that is driven. On sheet 4, pictures 1 to 5 are introduced in the OHPs. Pictures 6 and 7 represent 'spreading out' and 'bunching together' (see Theme D 'Life'). Picture 8 is intended to show energy flowing from very hot to very cold, and has been used in earlier activities in this theme to represent the Sun.

Possible answers:

A A building up' change (2) - which must be driven by fuel (4).

B A 'breaking down' change (1) followed by a 'spreading out' change (6) which both 'just happen by themselves'.

C Maintaining a steady state by both 'breaking down' and 'building up' changes (3).

D A 'spreading out' change (6) which 'just happens by itself'.

E Photosynthesis involves a 'splitting' change (5) in creating a fuel and oxygen. Also, taking in carbon dioxide from the air and concentrating it in glucose in the plant is a 'bunching together' change (7). The process is driven by energy spreading out from the hot Sun (8).

F Oxygen 'spreads out' (6) - this 'just happens by itself'.

G Oxygen passes from higher concentration to lower, so it is a 'spreading out' change (G) which 'just happens'. (It also involves oxygen bonding to haemoglobin (4).)

H Respiration is a 'joining' change which 'just happens' - it can be used to drive others changes which do not happen such as the 'building up' changes (2) involved in the synthesis of complex molecules.

I Making fat molecules involves a 'splitting' change (5) in which oxygen atoms are 'pulled off' (rather like oxygen atoms are 'pulled off' water during photosynthesis). It is a change which does not just happen by itself, so a fuel needs to be used (4).

J Glucose is used as a fuel by the plant, 'joining' with oxygen, and releasing energy (4).

Note that picture 4 which represents using a fuel *could* apply to the oxidation of a hydrogen-containing compound such as glucose - as discussed in Theme H 'Fuels and food' - in which a 'hydrogen-oxygen spring' is released. It could also represent the use of ATP - the energy released is due to the attraction between the end phosphate group and the water molecules surrounding it - a phosphate-water spring'. The energy is not located in a 'high-energy bond' in the ATP molecule as is often implied. Similarly picture 5 could represent photosynthesis in which hydrogen and oxygen are 'pulled apart' (and the hydrogen joined with carbon dioxide to form glucose) or phosphate and water being 'pulled apart' (and the phosphate joined with ADP to form ATP).

Activity J10 - Using sunlight to pull a rock uphill

This activity discusses a simple example of a system which, like the Earth, has a flow of energy through it and matter cycling within it.

Energy enters and leaves the Earth, but matter does not. An example which can be used to illustrate this idea is storing energy by electrolysing water to produce hydrogen and oxygen, and then reacting these to release the energy. This example was discussed in Theme H 'Fuels and food' activities H4 and H5. This example is significant because the two changes are fundamentally the same kind of change as photosynthesis and respiration (discussed in activity

H7). In Theme H, the focus was essentially on the energy flow. In this activity, we are concerned with both energy and matter flows, and the changes are now treated quantitatively.

Sheet 1 is an OHP which introduces the example, illustrating how in each case a change which 'just happens' drives another which does not. It might be worth discussing that rocks *are* sometimes pulled uphill by the Sun - temperature differences create winds which create sand dunes with little rocks (sand grains) going uphill. On a smaller scale, the temperature differences in a room are responsible for lifting up tiny 'rocks' (dust) which make the dirty marks on the ceiling above a radiator. On a bigger scale, temperature differences within the Earth are responsible for making mountains.

Sheet 2 is also an OHP which shows some values for the amounts of energy and matter involved. These relate to using a solar cell about the size of an exercise book. In half an hour, about 100 kJ of energy would arrive at it from the Sun. A solar cell is only about 20% efficient. This means that for every 100 kJ of energy from the Sun, only 20 kJ of energy is used to make hydrogen fuel. This is stored and can be used later. The rest of the energy (80 kJ) escapes. With 20 kJ of energy we can split 1.5 g of water into 0.2 g of hydrogen and 1.3 g of oxygen. (0.2 g of hydrogen would almost fill a large plastic lemonade bottle.)

We can react the hydrogen and oxygen together in a fuel cell to make electricity. We could use the electricity to drive an electric motor. This could pull the rock up the hill. We would get back our 1.5 g of water. But a fuel cell is only about 60% efficient. So we would only get 12 kJ of energy to drive the electric motor. The rest (8 kJ) escapes.

Pupils can be asked to add up the amounts of energy and matter flowing - an important thing to notice is that both energy and matter are conserved. Also, energy flows into and out of the system, but matter cycles within it. Panel E on Sheet 2 summarises this idea.

Sheet 3 is the pupil activity. It is very similar to the example discussed above, but is about photosynthesis and respiration. Pupils are asked to fill in values from the information given. They could also produce a summary picture as shown on Sheet 2. What is shown here is really a 'mini-ecosystem' with energy flowing through it maintaining a cycle of matter. In this system there is a single 'food chain' - some energy passes along the chain but most escapes.

Activity J11 - If ...

The Earth is a steady state system maintained by flows of energy and matter. What would happen in these flows were interrupted?

The first activity in this theme looked at steady state systems, in which there are continual flows of energy and matter. This activity looks at what might happen if the Earth's flows of energy and matter were stopped. The Earth is maintained in a steady state by a flow of energy through the system (from Sun to earth to space) and by flows of matter cycling within the system (for example, the water cycle). The flow of energy would be stopped if there was no Sun, and a flow of matter such as the water cycle would be stopped if there was no water.

Sheet 1 is an OHP which is intended to follow up a brainstorming activity in which pupils are asked to think about what would happen if the Sun suddenly went out, or if all water suddenly disappeared. Sheet 1 shows lists of possibilities. It is very likely that pupils will come up with many ideas about things that will happen which are not on these list (both correct and incorrect) and it is unlikely that they will think of all the examples on the lists. However, the possibilities shown on sheet 1 are intended to tie together some of the ideas developed in this theme. An additional activity would be to think about the time scale of the changes - what would happen immediately, after a day or after a year?

Sheet 2 is also an OHP just to make the point that the Sun is not simply a hot object cooling down, but is maintained at an approximately constant temperature by using its nuclear fuel. In fact, since the formation of the Earth, the Sun has actually been getting hotter. Estimates of the Sun's age made in the last century before a knowledge of radioactivity and nuclear reactions gave a result which was much too young, and conflicted with the theories of geologists. Similar estimates of the Earth's age based on its cooling without taking into account the internal radioactivity also conflicted with the geologists' estimates.

The last picture on sheet 2 illustrates the idea that the Sun's temperature is maintained by the running down of a 'nuclear spring'. This is similar to the running down of a 'chemical spring' when a fuel burns in oxygen (see activity H4 'Ways of storing energy'). Both kinds of fuel are similar in that they involve 'pulled-apart' particles joining together and releasing energy. It is this release of energy which maintains the temperature difference between the Sun and space, which in turn drives nearly all of the changes discussed in this theme. Were it not for the Sun's nuclear fuel, then it would cool down. Indeed when the fuel runs out, it will do so.

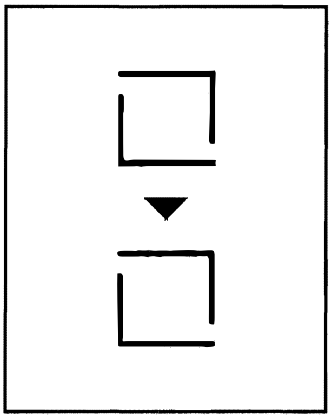
Keeping moving to stay where you are

Sheet 1

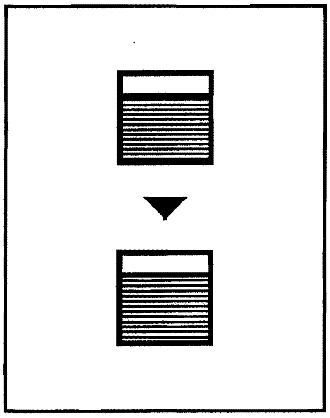
There are different ways in which things can 'stay the same'.

A Water and a leaky bottle

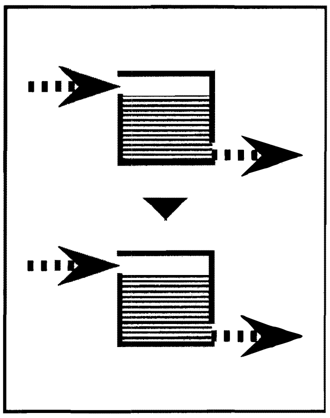
Three ways of staying the same:



have no water in the bottle



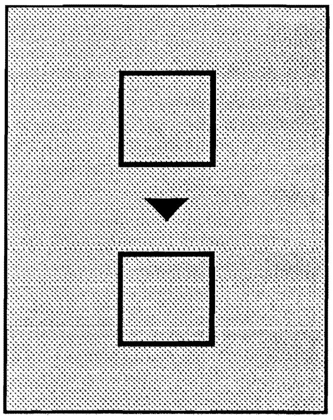
seal the bottle so the water cannot escape



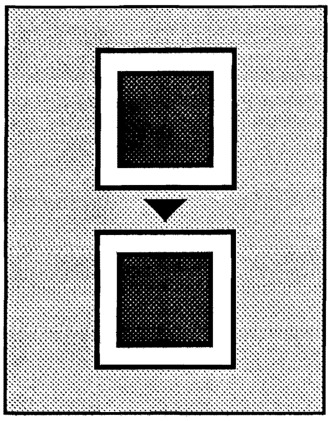
keep adding water to replace the water which escapes

B Keeping something at the same temperature

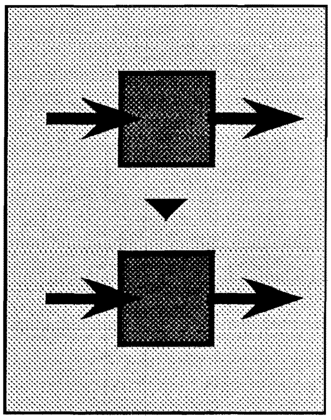
Three ways of staying the same:



let it stay at the same temperature as the suroundings



insulate it perfectly so the water cannot escape

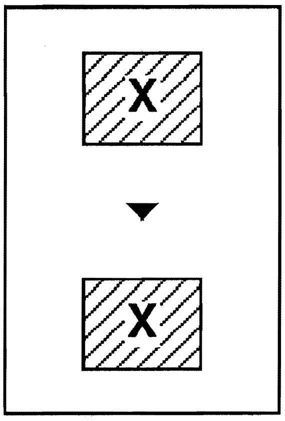


keep adding energy to replace the energy which escapes

1 Things that don't change

Some things do not change at all. They stay as they are because there are no changes in matter or energy.

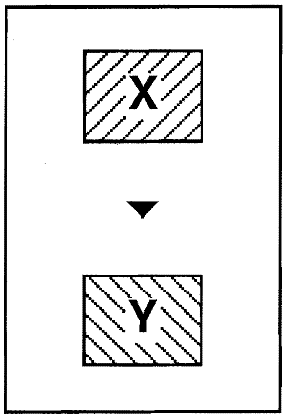
E.g. a spoon
a statue



2 Things that change

Some things change because of changes in matter or energy or both. They may change into different substances or may change their temperature.

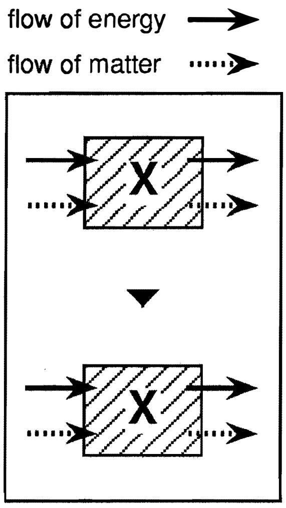
E.g. a car rusting
a cup of tea cooling down



3 Steady states

Some things stay the same but only because of a constant flow of matter or energy or both. This is like 'keeping moving to stay where you are'.

E.g. an oven kept hot
a flame
a tree



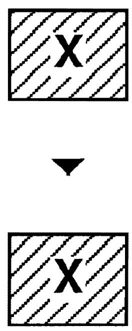
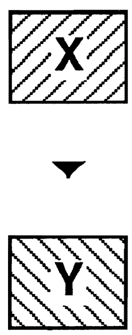
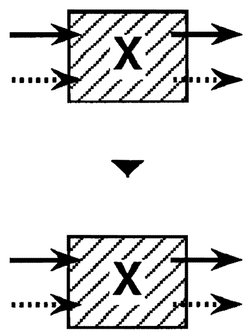
Keeping moving to stay where you are

There is more than one way of staying the same. Some things stay the same because there are no changes. Some things stay the same because of a continual flow of matter or energy or both. These are 'steady states'. A steady state is a bit like 'keeping moving to stay where you are'.

1 Cut up the list of situations at the bottom of the page.

2 For each one decide:
    Is it changing or is it staying the same?
    If it is staying the same, is there no change or is it a steady state?
  Match it to one of the pictures below.

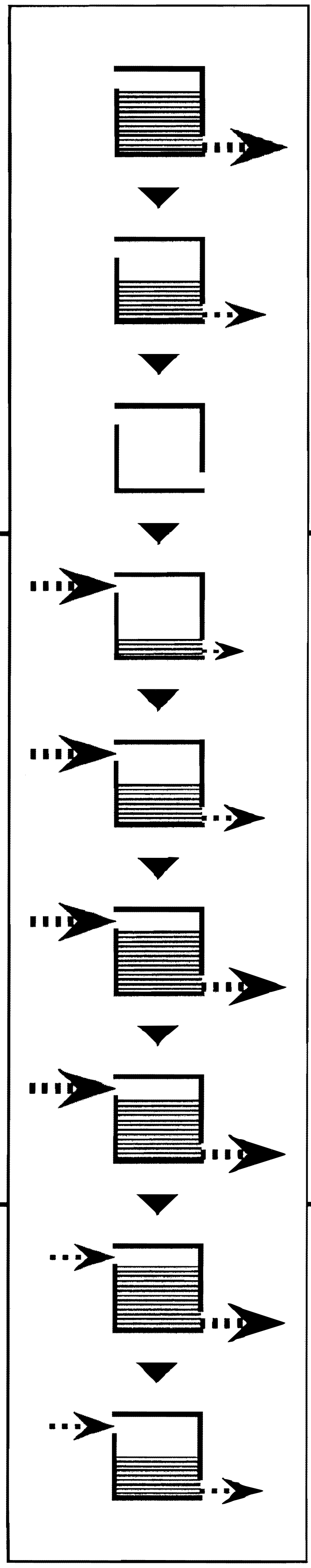
3 Choose one example of each kind of change, and explain why you matched it to the picture.

1	2	3
		
Things that don't change	Things that change	Steady states

A	an explosion	B	a river
C	a tin of soup at room temperature	D	a hot bowl of soup cooling down
E	a rabbit	F	a field of grass
G	a car going down a motorway	H	a pen resting on a table
I	sugar dissolving in water	J	a light bulb after being turned on
K	ice in a fridge	L	ice in a warm room
M	a population of owls	N	the Earth's atmosphere

Going up and coming down

Sheet 1



1 Coming down

Water does not stay in leaky containers - it escapes and the water level drops.

Water escapes more slowly when the water level is lower.

Eventually, the level falls to the bottom. It now stays the same.

2 Going up

If you start putting water in, the level rises. Some of the water escapes.

As the level gets higher, more water escapes.

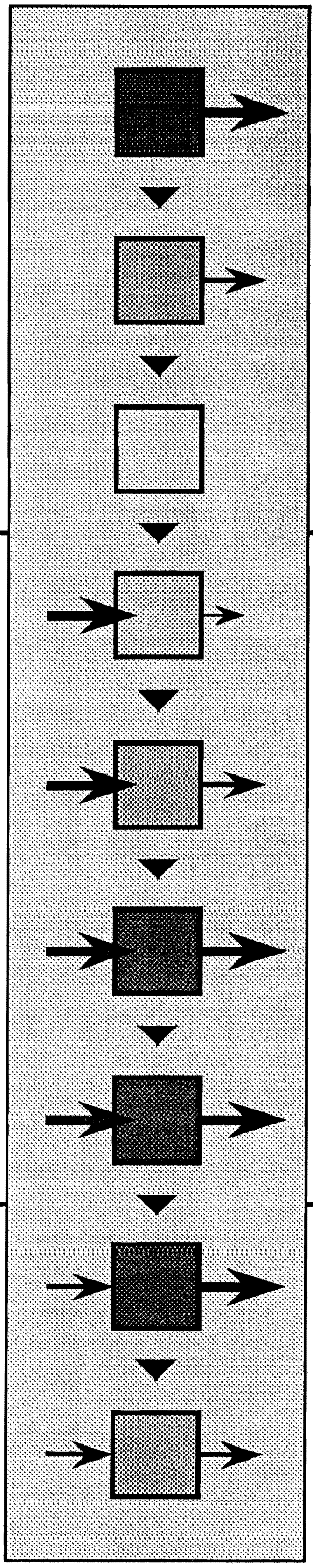
Eventually, the water escaping balances the water going in.

The level now stays the same. This is like 'keeping moving to stay where you are'.

3 Coming down again

If you lower the water input, water still escapes.

The level drops until it reaches a new steady state.



1 Coming down

Hot things don't stay hot - energy escapes and they cool down.

Energy escapes more slowly when it is nearer to room temperature.

Eventually, it becomes the same as room temperature. The temperature now stays the same.

2 Going up

If you start to heat something, energy flows in and makes it hotter. Some of the energy escapes.

As it gets hotter, more energy escapes.

Eventually, the energy escaping balances the energy going in.

The temperature now stays the same. This is like 'keeping moving to stay where you are'.

3 Coming down again

If you lower the energy input, energy still escapes.

It cools down until it reaches a new steady state.

Going up and coming down

Sheet 3

This activity looks at flows of water and of energy. How much water or how much energy is in something depends on how much flows in and out.

1 These situations all involve flows of water. Match the three situations to the three graphs below, which show how the water level changes.

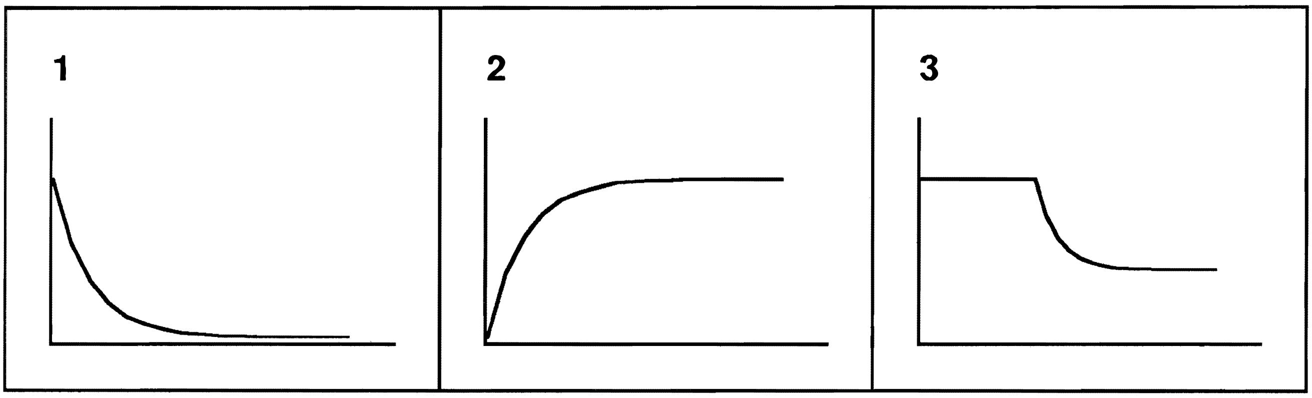
a) In a heavy storm, a road becomes flooded.
b) The plug is pulled out of a bath full of water.
c) The level of a lake changes during a dryer spell of weather.

For each example, describe what happens to the level of water. Explain why this happens in terms of the rates of water input and water output. (The pictures on sheet 1 may be helpful.)

2 These situations all involve flows of energy. Match the three situations to the three graphs below, which show how the temperature changes.

a) A hot car engine is turned off at the end of a journey.
b) An oven kept at one setting, is put onto a lower setting.
c) Cold, wet washing is put onto a hot radiator to dry.

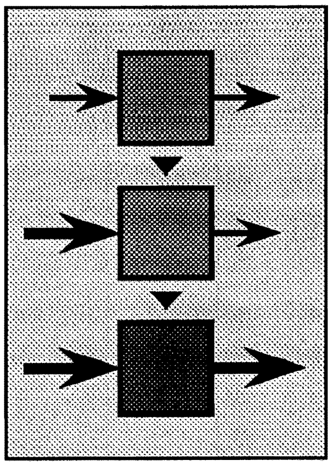
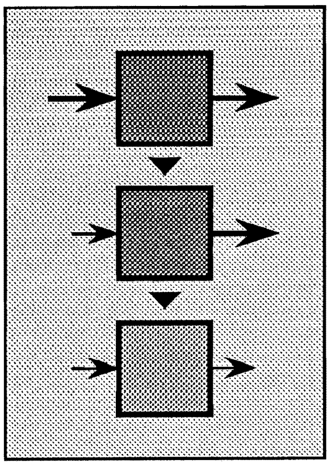
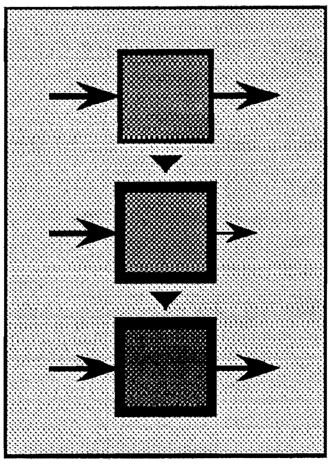
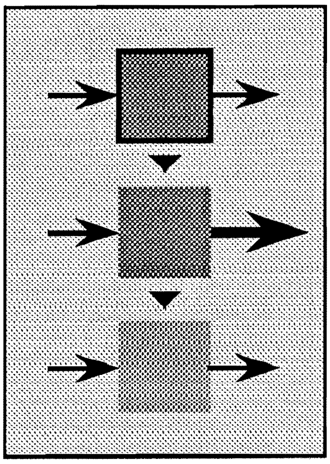
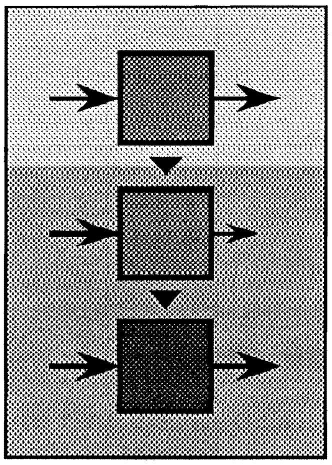
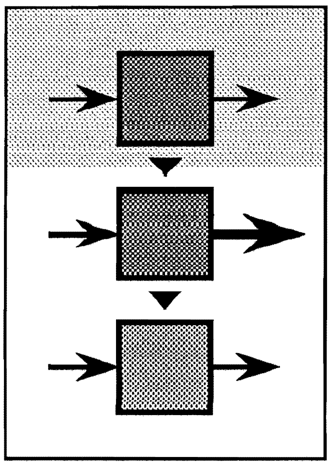
For each example, describe what happens to the temperature. Explain why this happens in terms of the rates of energy input and energy output. (The pictures on sheet 2 may be helpful.)



Keep it hot

Sheet 1

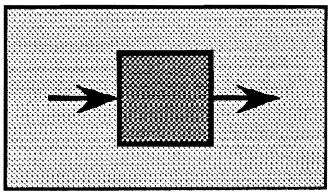
When something is in a steady state, what can affect its temperature?

It becomes **warmer** ('energy in' **bigger** than 'energy out').	It becomes **cooler** ('energy in' **smaller** than 'energy' out).
A1 more energy input 	**A2**  less energy input
B1 less energy escapes (more insulation) 	**B2**  more energy escapes (less insulation)
C1 less energy escapes (outside temperature rises - smaller temperature difference) 	**C2**  more energy escapes (outside temperature falls - larger temperature difference)

Keep it hot

Sheet 2

There are many examples of things which are kept hotter than their surroundings because of a constant flow of energy.



The temperature of a centrally-heated room stays about the same. This is because the energy flowing from the radiators is balanced by the energy escaping to the colder air outside.

The average temperature of the Earth stays about the same. This is because the energy flowing from the Sun is balanced by the energy escaping to cold space.

Your body temperature stays about the same. This is because the energy from 'burning' food is balanced by the energy escaping to the colder air outside.

1 Each of the following is about changing the conditions of something kept hotter than its surroundings. For each situation, match it to one of the pictures shown on sheet 1. Explain what is happening in terms of temperature changes and energy flows.

a) If you open a window in a heated room, it will get colder (though not as cold as outside).

b) Increasing carbon dioxide in the atmosphere may lead to global warming, because of the 'greenhouse effect'.

c) When we have a fever, our bodies 'burn' food faster and we have a high temperature.

d) A heated room gets colder when the weather turns colder (but still stays warmer than outside).

2 In the examples above, the temperature changes when the conditions change. Sometimes the energy input is controlled to keep the temperature the same. Explain what is happening to the energy input and output in these situations.

a) In a cold room, our bodies need to 'burn' food faster to stay at 37°C.

b) Our bodies need to 'burn' less food if we put on more clothing.

c) In hot weather, a central heating system uses less fuel.

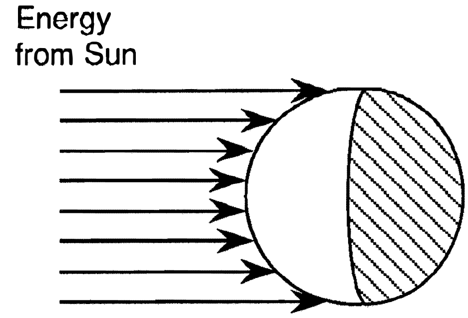
Earth, Sun and space

Sheet 1

Energy flowing from the Sun keeps the Earth warmer than space. But the Earth is not all at the same temperature - there are temperature differences here too.

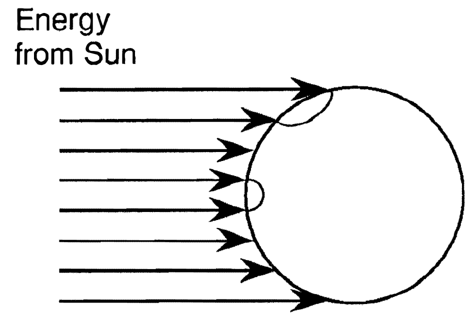
A Night and day

As the Earth rotates, the energy from the Sun only falls on one half of the Earth. No energy falls on the other half. Thus, it tends to be cooler during the night than during the day.



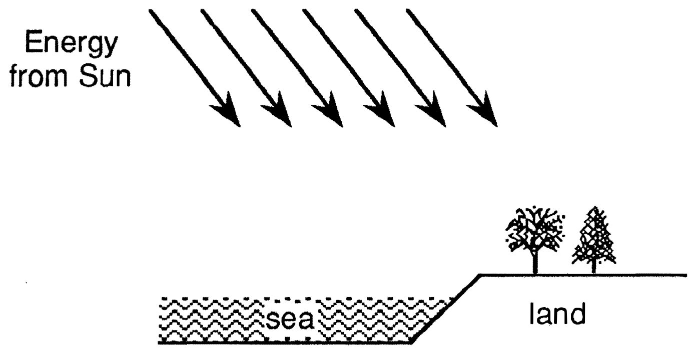
B Equator and poles

Because of the shape of the Earth, energy is spread over a larger area nearer the poles than the equator. Thus, it is warmer at the equator than at the poles.



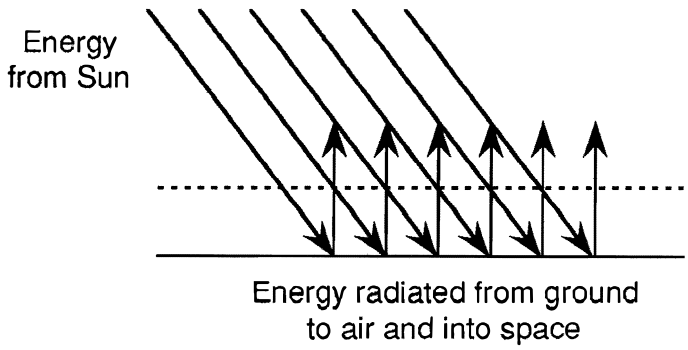
C Land and sea

During the day, the temperature of the land rises faster than that of the sea. At night, the land cools quicker. (Water gets less warm than the ground, for the same energy input.)



C Air and surface

The Sun warms the Earth's surface, and this is turn warms the air above it. From here, energy escapes into cold space, so the atmosphere is colder than the Earth's surface.

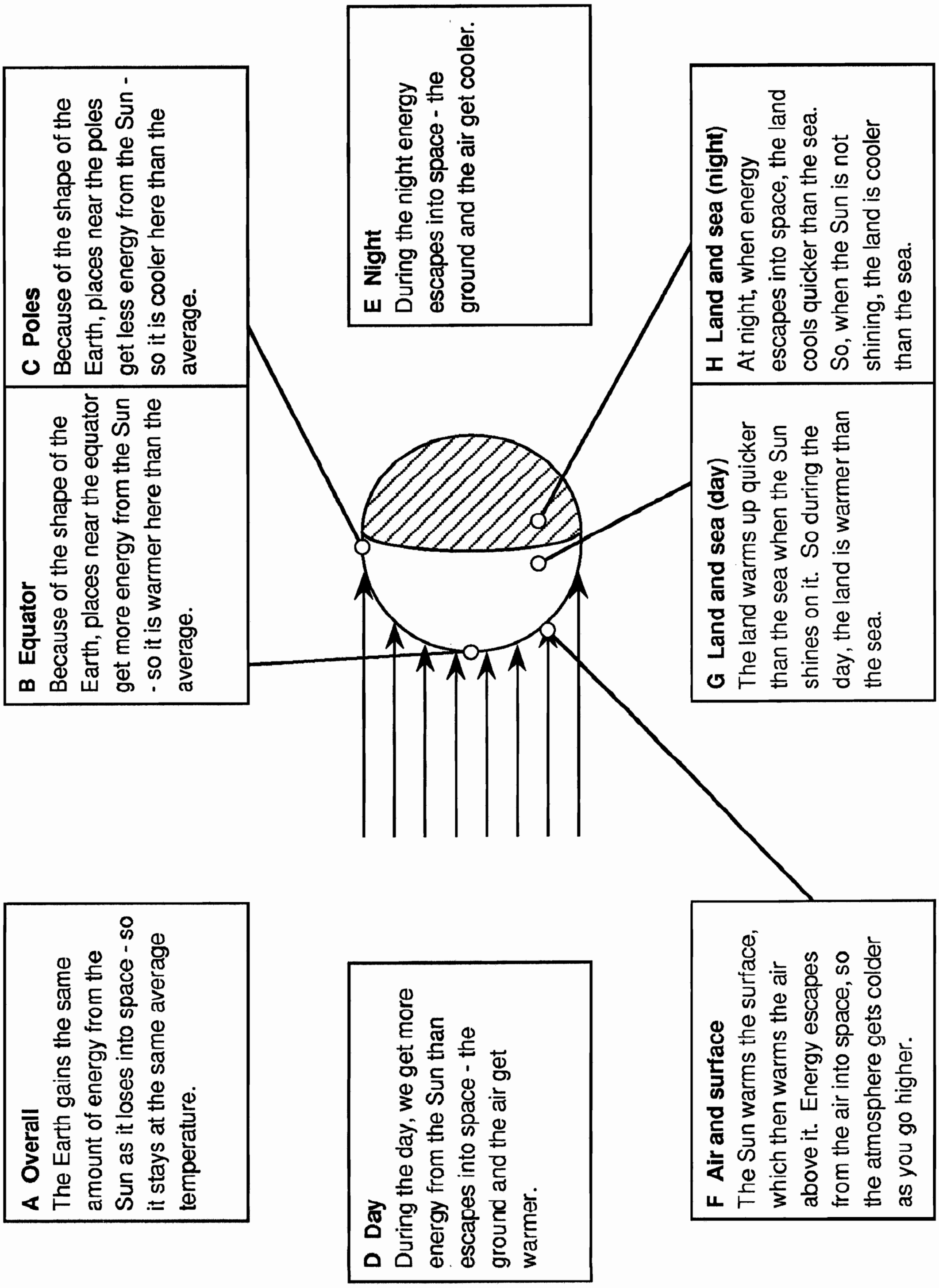


Earth, Sun and space

Sheet 2

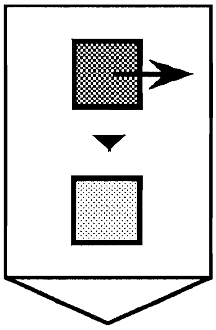
Energy flowing from the Sun keeps the Earth warmer than space. But the Earth is not all at the same temperature - there are temperature differences here too.

Look at the changes below. Match each change to one of the pictures on sheet 3. (Note that one of the pictures on sheet 3 shows an 'impossible change'.)



Match these pictures to the changes on sheet 2. (Note that one of these pictures shows an 'impossible change'.)

1



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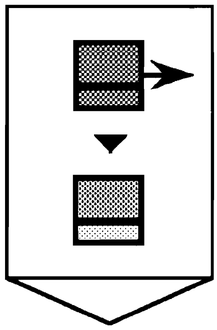
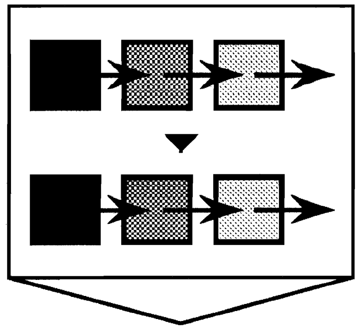
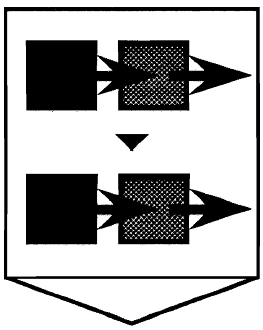


3



4



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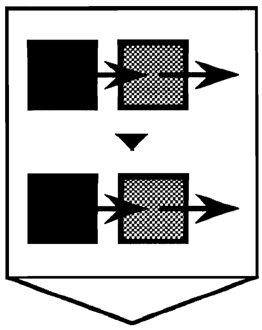

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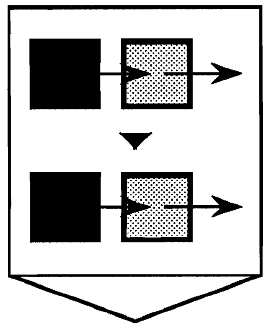

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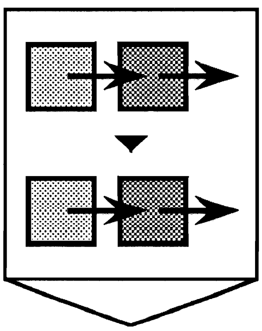

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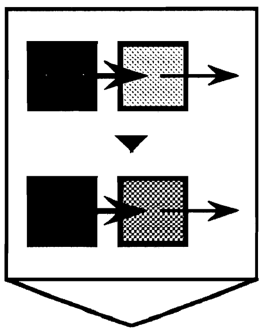
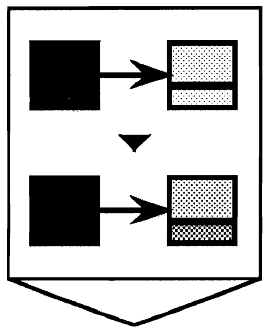


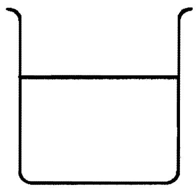
9

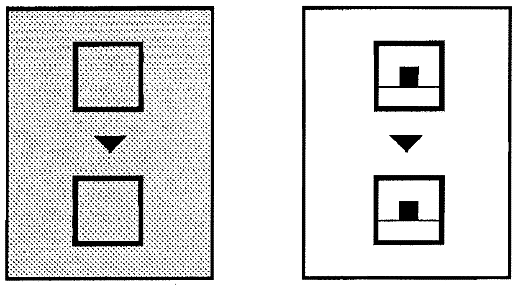


Convection currents

A A beaker of water

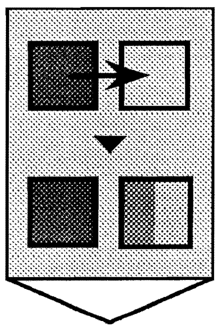
The beaker is at the same temperature as the air in the room. The water is not moving.





B Making it hot

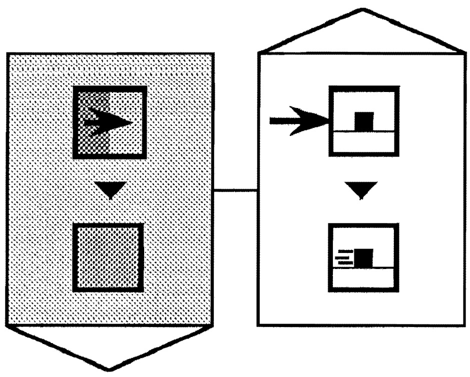
You start warming the water with a Bunsen flame. The flame is hot - energy goes from the flame to the beaker. More energy goes to some parts of the beaker than others, so some parts get hotter.



C Convection currents

Different parts of the beaker are at different temperatures. Energy flows from hot to cold parts, and this makes the water move. The temperature of the water in different parts of the beaker tends to become the same.

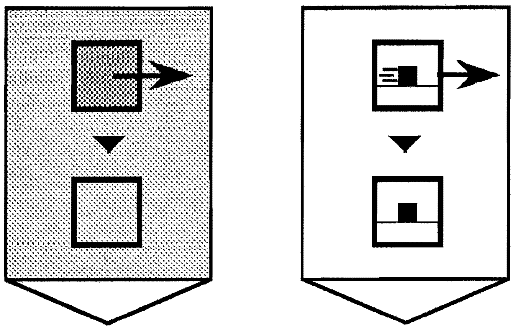
A change which 'just happens' drives one that does not.



D Letting the beaker cool down

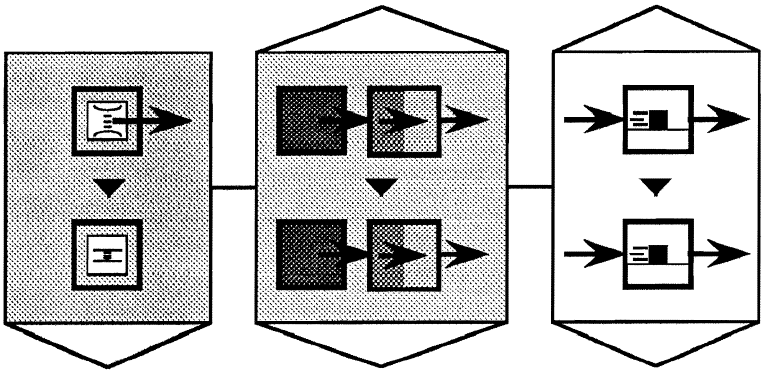
If you take the flame away, energy escapes from the warm water until it is at the same temperature as the air in the room.

With no temperature differences, the water stops moving.

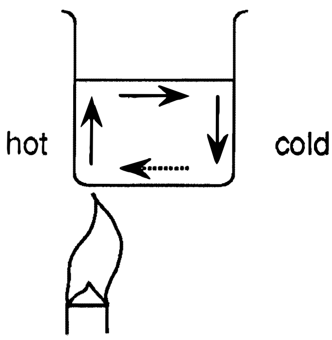


E Keeping it going

If you keep warming the water with the flame, then the water will keep moving. It is kept moving because the temperature difference is kept going. The temperature difference is kept going by burning fuel.



F Convection currents in a beaker of water



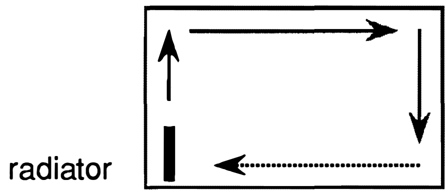
The flame keeps one part of the beaker hotter than another.

Energy is carried by the water from where it is hot to where it is not.

The hot water is less dense that the cold water. The cold water sinks and pushes the hot water up.

Convection currents

In a centrally-heated room, convection currents are started because of the temperature difference created. Energy flows from hot regions of the room to cold and is carried by moving currents of air.



The situations below explain what happens when a radiator is switched on in a cold room. Match each situation to the picture on sheet 4 which you think is best.

A When the radiator is off, the air in the room stays the same temperature as the air outside.

B The air in the room does not move when the radiator is off (since there are no temperature differences to drive this change).

C When the radiator is switched on, a temperature difference is created - some of the air becomes warmer than the rest of the air in the room.

D Because of this temperature difference, air starts moving. Energy moving from hot to cold drives this convection current.

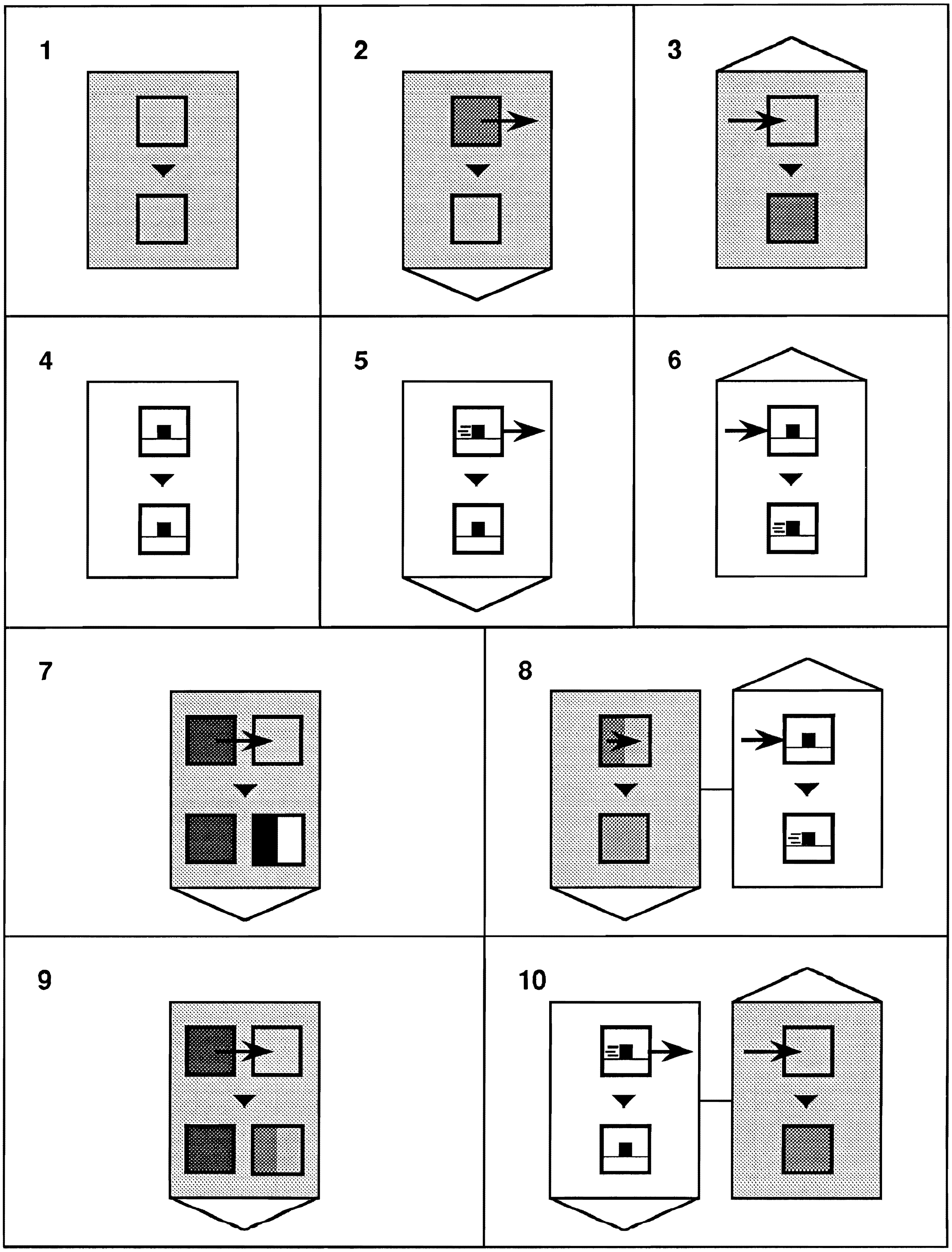
E When the radiator is switched off, the convection currents slow down and eventually the air stops moving.

F The temperature of the room drops until it is the same temperature as the air outside.

G Now that the radiator is off, the room cannot get warmer 'just by itself'.

H With the radiator off, the air cannot start moving 'just by itself'.

Match these pictures to the changes on sheet 3.

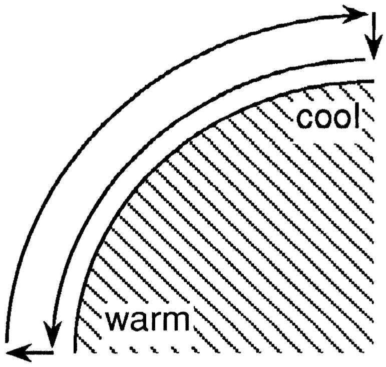


Wind, waves and water

Sheet 1

Temperature differences arise on Earth for a number of different reasons. These temperature differences can drive other changes.

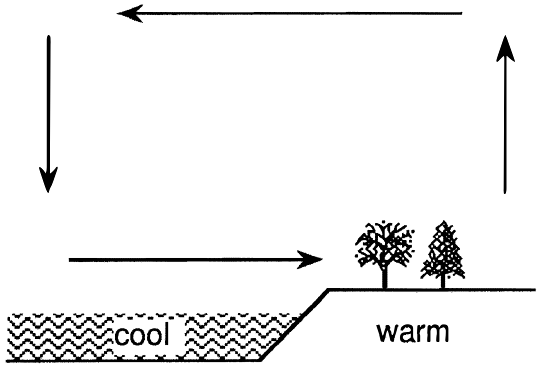
A Equator and poles



The equator is warmer than the poles. This temperature difference creates convection currents. Energy is carried by warm air from the equator to the poles.

At the surface, cooler winds tend to blow from the poles to the equator.

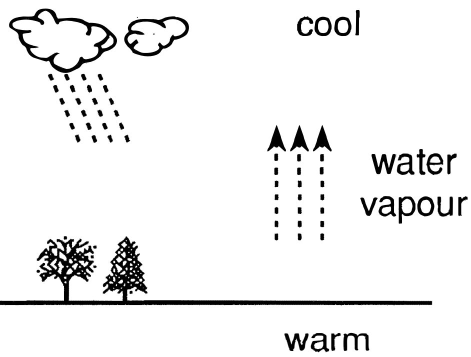
B Land and sea



During the day, the land tends to be warmer than the seas. This temperature difference creates convection currents. Energy is carried by warm air from the land to the sea. At the surface, cooler winds tend to blow from the sea to the land (sea breeze).

At night, the opposite tends to happen.

C Air and surface



The surface of the Earth tends to be warmer than the air high in the atmosphere. Water evaporates from the warm surface, and the vapour rises carrying energy away from the surface. In the cooler air, the water condenses and the energy escapes.

In this way, water is 'pumped uphill'.

Wind, waves and water

Temperature differences arise on Earth for a number of different reasons. These temperature differences can drive other changes.

Look at the changes below. Match each situation to the picture on sheet 3 which you think shows the change best.

A **Winds**
Some parts of the Earth are warmer than others. These temperature differences cause energy to flow, and create *winds.*

B **No winds without the Sun**
If there were no temperature differences, there would be no winds - winds do not happen 'just by themselves'.

C **Equator and poles**
The equator is warmer than the poles. This temperature difference creates convection currents, with warm air carrying energy from the equator to the poles.

D **Waves**
As winds blow over the sea they create waves.

E **Winds slow down**
Without anything to keep them going, winds will slow down and stop.

F **Waves slow down**
Without anything to keep them going, waves also slow down and stop.

G **Sea breezes**
During the day, the land tends to be warmer than the sea. Because of this temperature difference, energy flows from hot to cold, creating a sea breeze.

H **Land breezes**
At night, the sea tends to be warmer than the land. This temperature difference causes energy to flow from hot to cold, and creates a land breeze.

I **Ocean currents**
Some parts of the sea are warmer than others. Cold water sinks and warm water floats, causing ocean currents which carry energy from hot to cold.

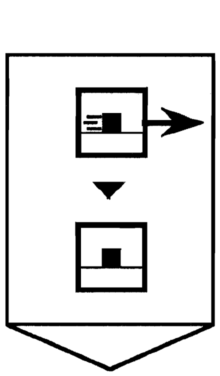
J **Clouds**
Water evaporates from the warm surface of the earth, and condenses as clouds in the cooler air higher up. In this way, water is 'pumped uphill'.

K **Rain and rivers**
After water has been 'pumped uphill', it falls down again. Droplets of water form in clouds, falling as rain. Some of this flows down to the sea in rivers.

L **Erosion by rivers**
As a river flows, it erodes its bed and banks, carrying material along with it.

Match these pictues to the changes on sheet 2.

1



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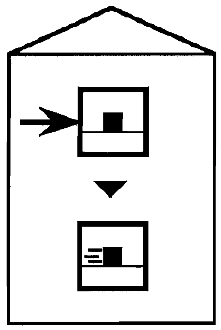

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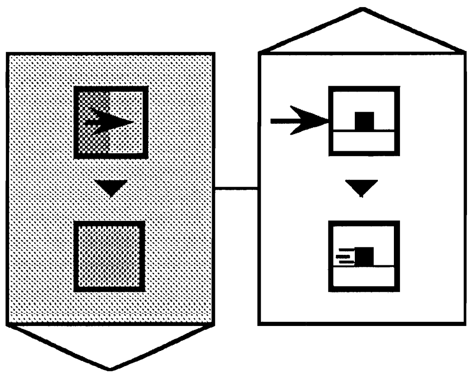
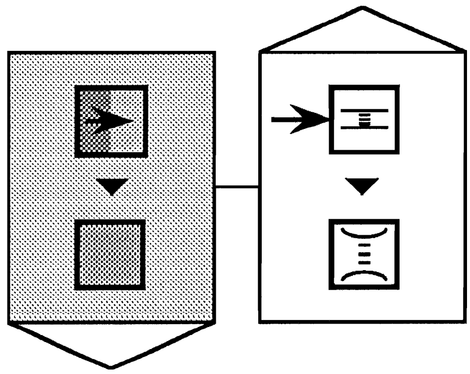


4



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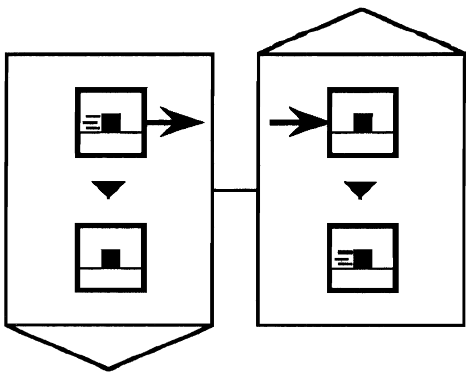

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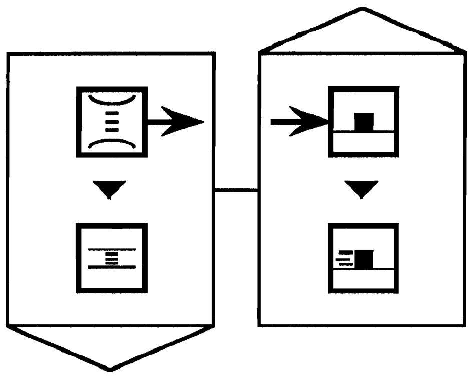
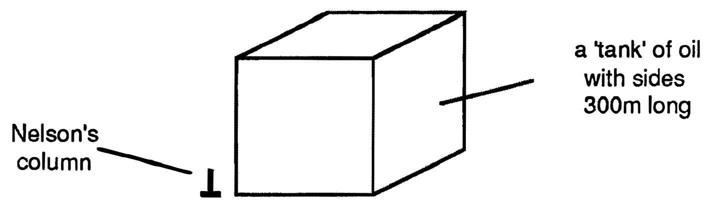


The Earth's energy balance

Sheet 1

The picture on sheet 2 shows the amounts of energy flowing into and out of the Earth in one year. It is measured in units of exajoules (eJ). For small amounts of energy, the kilojoule (kJ) is a convenient unit. For very large amounts of energy we need a bigger unit - one exajoule is one thousand million million kilojoules (or 1 eJ = 1 000 000 000 000 000 kJ).

It is difficult to 'get a feel' for such a lare amount of energy as an exajoule. An example may help. The whole population of the world uses 300 eJ per year. This is the energy produced when burning about this much oil:



Questions

1 a) How much energy radiates from the Sun onto the Earth? How much energy in total is radiated from the Earth into space? Which is bigger, or are they the same?

b) Why does the average temperature of the Earth stay about the same?

2 a) What proportion of the energy arriving at the Earth is reflected into space?
(About: 1% 5% 10% 35% 65%)

b) What proportion of the energy not reflected is absorbed by the atmosphere?
(About: 5% 10% 30% 70% 90%)

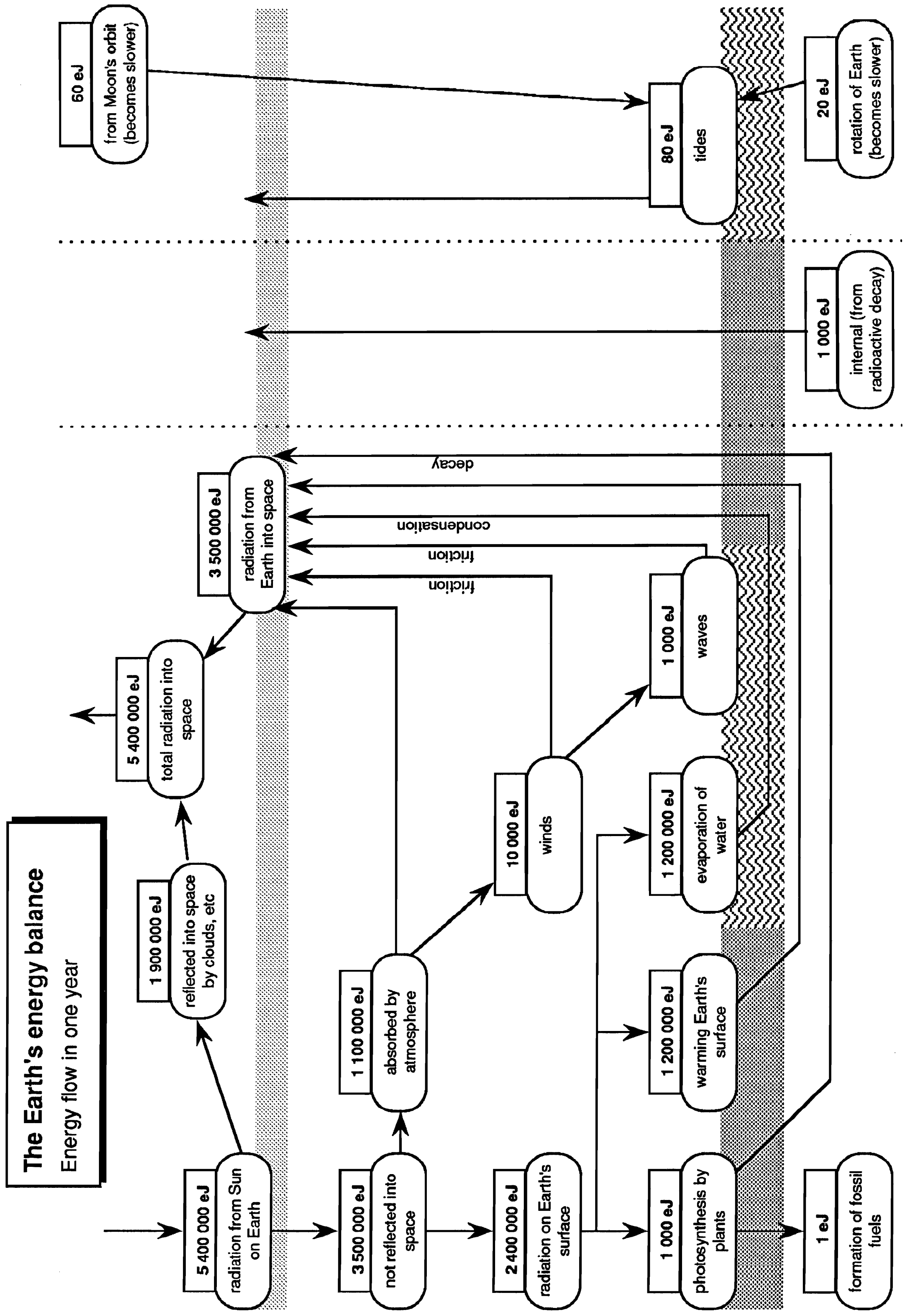
c) What proportion of the total energy arriving at the Earth reaches the Earth's surface?
(About: 1% 10% 25% 45% 90%)

d) What proportion of the energy reaching the surface is carried away by water vapour?
(About: 5% 10% 20% 50% 70%)

e) What proportion of the energy absorbed by the atmosphere is transferred to currents of moving air?
(About: 1% 10% 25% 50% 90%)

f) What proportion of the energy reaching the surface is stored by plants?
(About: 0.01% 0.05% 0.1% 0.5% 1%)

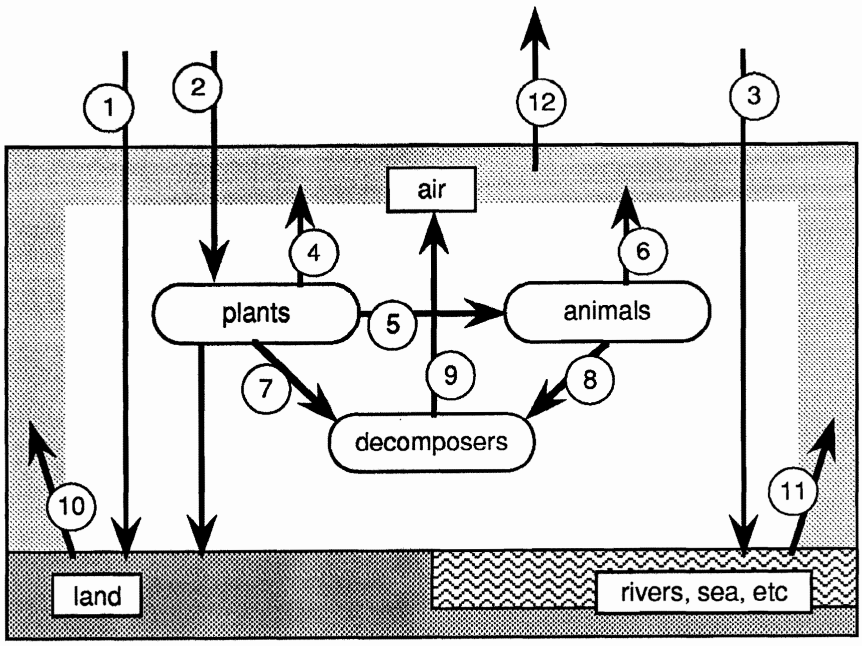
3 How much energy is stored in the fossil fuels made in one year? How many years would it take to make enough fossil fuel to meet the world's requirements for one year?


The Earth's energy balance
Energy flow in one year
5 400 000 eJ
radiation from Sun on Earth
1 900 000 eJ
reflected into space by clouds, etc
5 400 000 eJ
total radiation into space
3 500 000 eJ
not reflected into space
1 100 000 eJ
absorbed by atmosphere
3 500 000 eJ
radiation from Earth into space
2 400 000 eJ
radiation on Earth's surface
10 000 eJ
winds
1 000 eJ
waves
friction
friction
condensation
decay
1 200 000 eJ
evaporation of water
1 200 000 eJ
warming Earth's surface
1 000 eJ
photosynthesis by plants
1 eJ
formation of fossil fuels
1 000 eJ
internal (from radioactive decay)
60 eJ
from Moon's orbit (becomes slower)
80 eJ
tides
20 eJ
rotation of Earth (becomes slower)

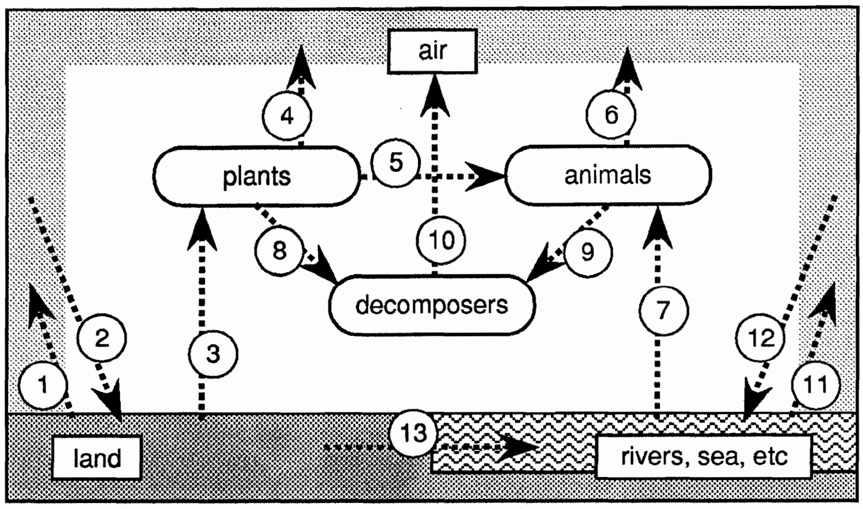
Flows and cycles

Sheet 1

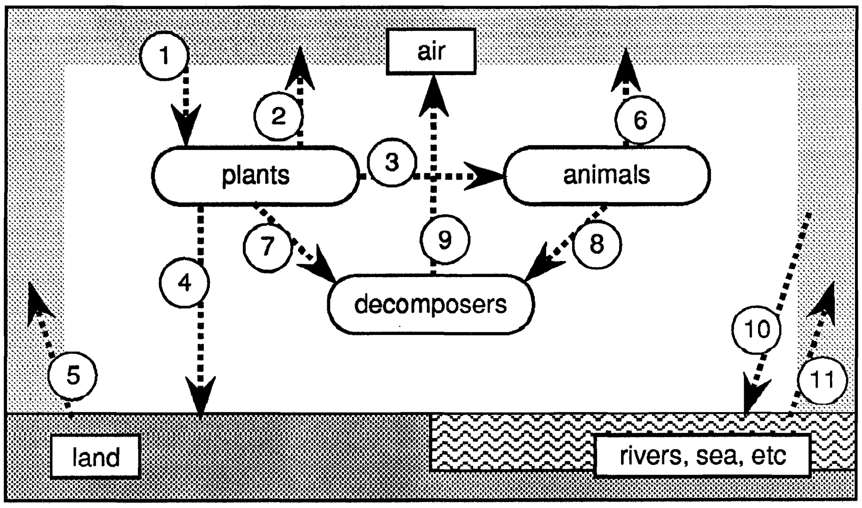
A Flows of energy



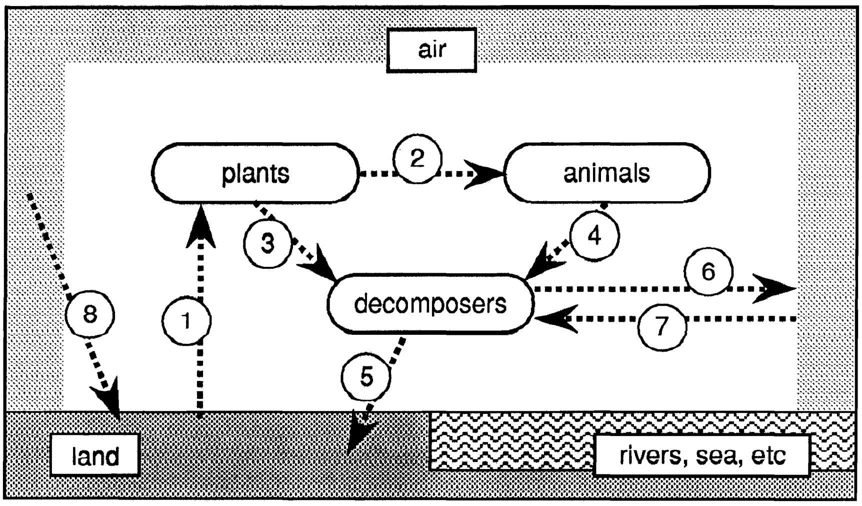
B Water cycle



C Carbon cycle



D Nitrogen cycle



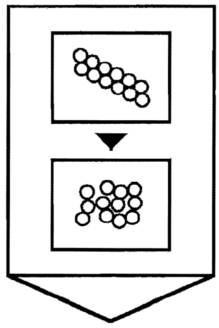
Matter matters

Like a car, a living thing needs to maintain its structure.

A Breaking down

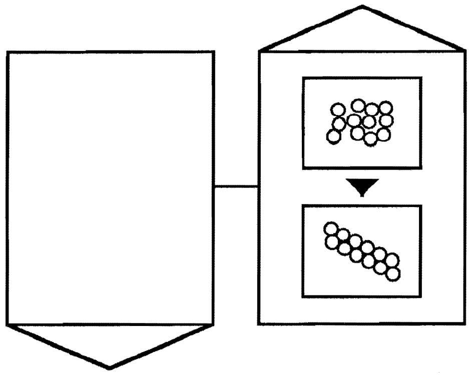
Living things are made of complex molecules, such as cellulose and proteins. These complex molecules tend to break down.

When an organism dies, the complex molecules may be broken down by bacteria. Simpler substances are returned to the environment and may then be used by other living things.



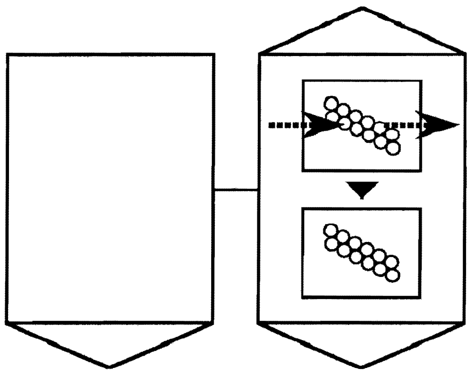
B Building up

In order to grow, a living thing needs to build up complex molecules. This is not a change which 'just happens by itself' - it needs another change to make it happen. Plants and animals need to use fuels to manufacture complex molecules.



C Maintaining a structure

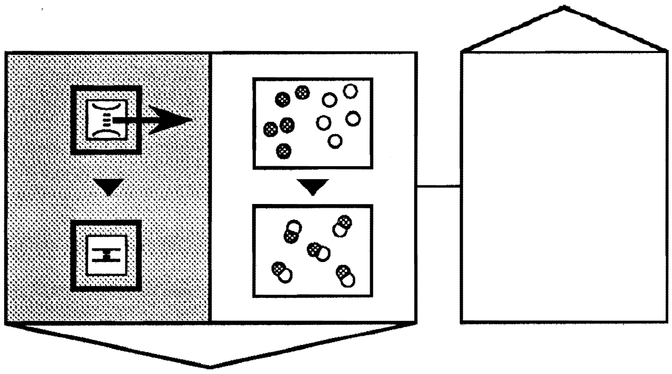
In a mature plant or animal, both of these changes are happening. Large molecules constantly break down, and new molecules must be constantly manufactured to maintain its structure. Its structure is being kept in a 'steady state'.



Like a car, a living thing needs to maintain a fuel supply.

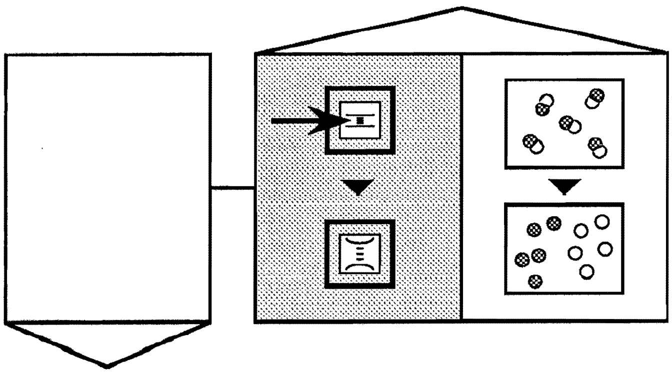
D Using a fuel

All living things need fuels. Some changes happen just by 'themselves', though others do not. Fuels need to be used up in order to drive all the changes in the organism which do not 'just happen by themselves'.



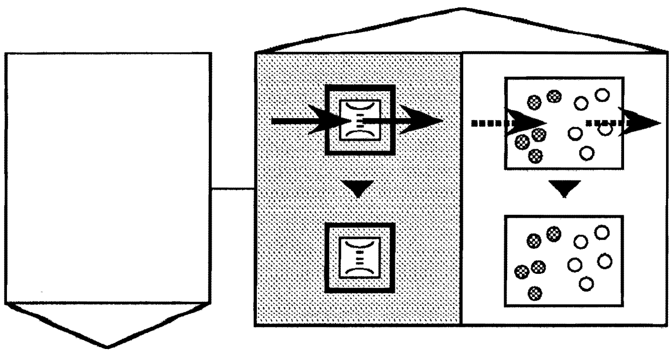
E Creating a fuel

Creating a fuel is a change which does not 'just happen' by itself. Plants are able to manufacture their own fuels; animals get their fuels from other living things. In both cases, the change is driven by another which 'just happens'.



F Maintaining a fuel supply

In a living thing, both of these changes are happening. Fuel is constantly being using up and replaced. Because it maintains a fuel supply, a living thing is always 'ready for action'. Its fuel supply is being kept in a 'steady state'.



Matter matters

Sheet 3

In living things there is a constant flow of matter - to and from the surroundings. Some of this is used as a 'building material' to maintain the structure of the living thing. Some is involved in the making and using of fuels.

The situations below all involve changes to matter in living things. For each change, think about which pictures on sheet 4 are involved in the process (more than one may apply for each change).

Some changes happen 'just by themselves' other need to be driven by another change. For changes that do not happen by themselves, think about what drives them.

A Plants contain a great deal of cellulose particularly in their cell walls. It is made by linking many glucose molecules together into a long chain.

B In the human intestine, starch is broken down into smaller sugar molecules (maltose), which are then able to pass into the bloodstream.

C Proteins are used to make human cells. As cells die, proteins are broken down into amino acids, while new proteins are built up from amino acids.

D In the leaves of a plant there are pores called stomata. Water escapes from these pores into the air by evaporation.

E A plant needs to take in carbon dioxide and water as raw materials for making glucose by photosynthesis.

F The oxygen produced during photosynthesis escapes into the air through the stomata in the leaves.

G In a human, oxygen passes from the air in the lungs through the alveoli into the bloodstream.

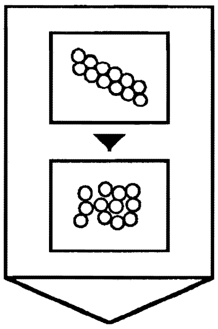
H A human can use glucose as a 'fuel' by 'burning' it with oxygen (respiration), driving changes such as moving around or synthesising molecules.

I Fat is a more efficient way of storing fuel in a human than by using sugars. Sugars are converted into fats by 'pulling oxygen away from the sugar'.

J Glucose cannot be made in the roots of a plant - there is no light for photosynthesis. In fact, glucose is used up in the roots by respiration.

Match these pictues to the changes on sheet 3.

1



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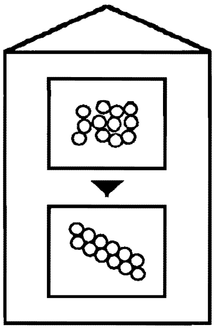

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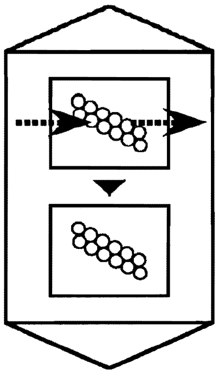

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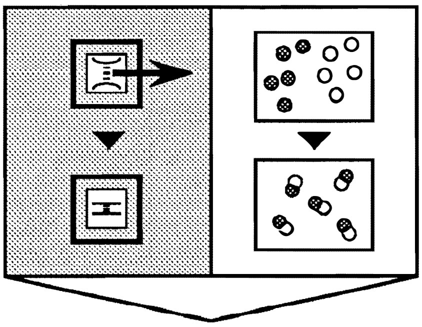

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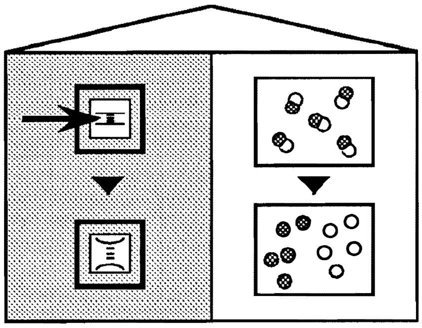

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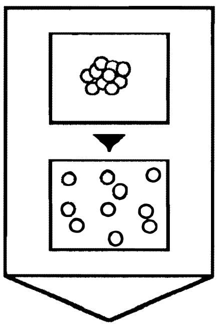

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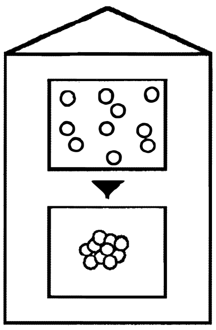
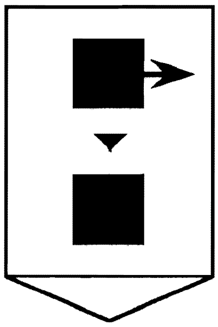


8

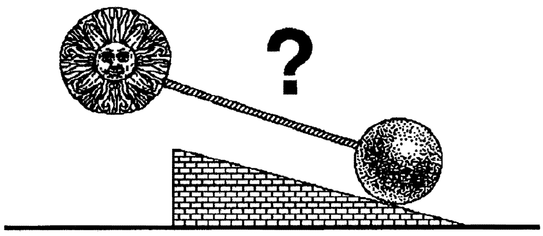


Using sunlight to pull a rock uphill

Sheet 1

A Using the sunlight directly?

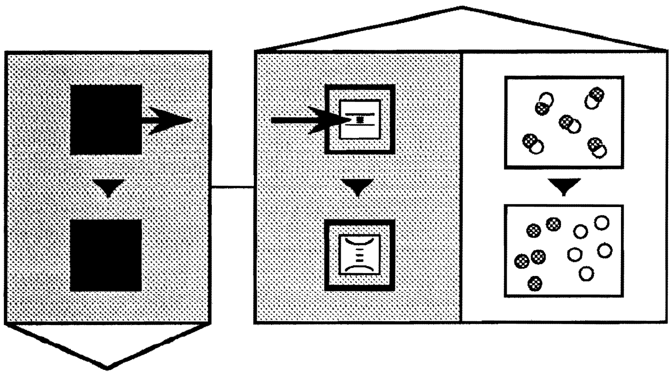
Suppose we wanted to use sunlight to pull a rock uphill. Just letting the Sun shine on the rock will not work.



One way we could do it is to use the sunlight to make a fuel. We could then use the fuel to drive a motor to pull the rock up the hill.

B Making hydrogen

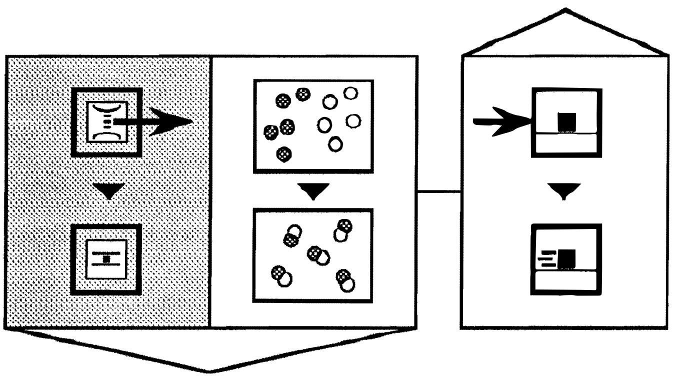
Hydrogen can be made by electrolysing water.



The electricity can be generated by letting sunlight shine on a solar cell. This drives the 'splitting' of water into hydrogen and oxygen.

C Using hydrogen as a fuel

The hydrogen could later be reacted with the oxygen.

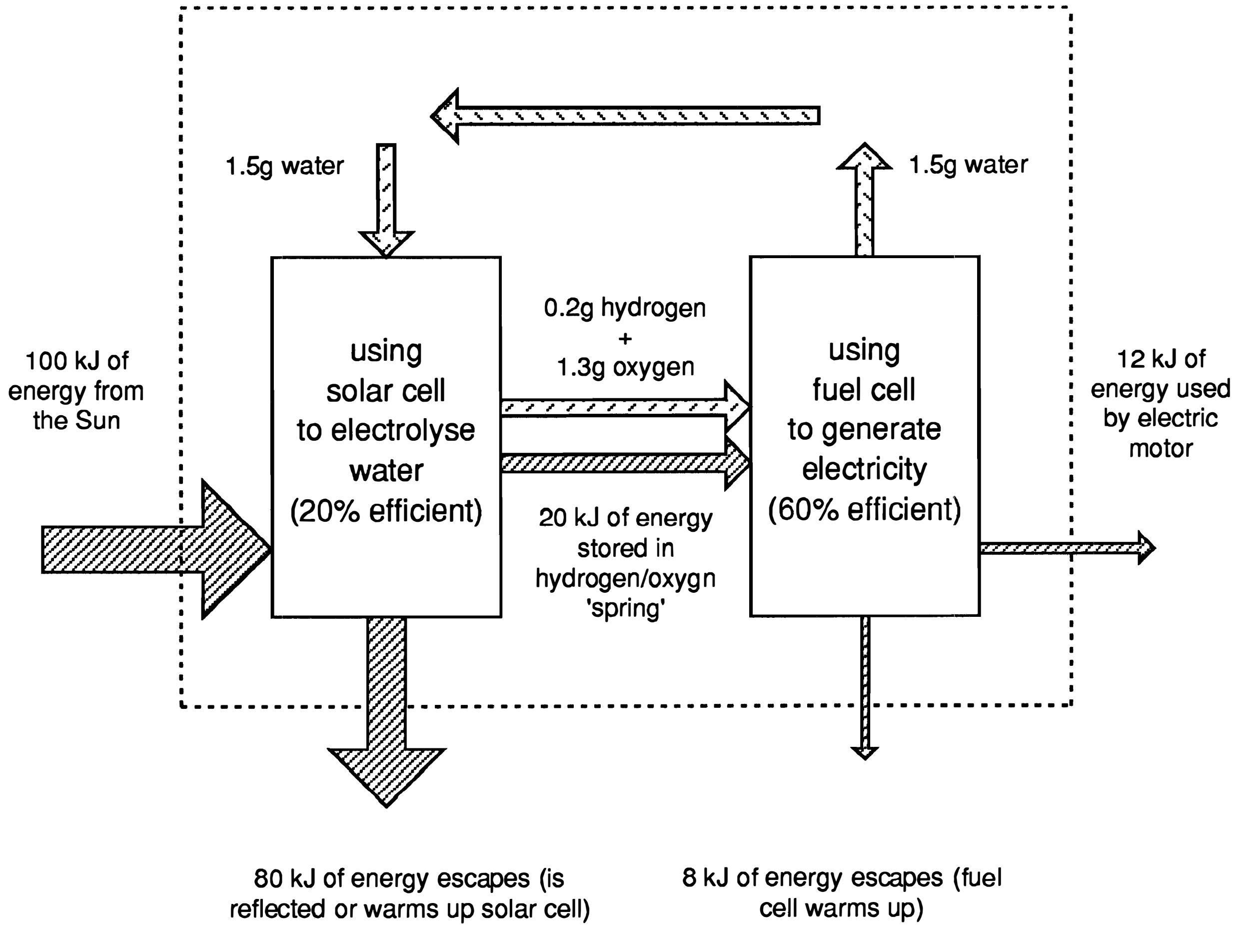


This can be done in a fuel cell to generate electricity. This can run a motor to move the rock. The 'joining' of hydrogen and oxygen drives this change.

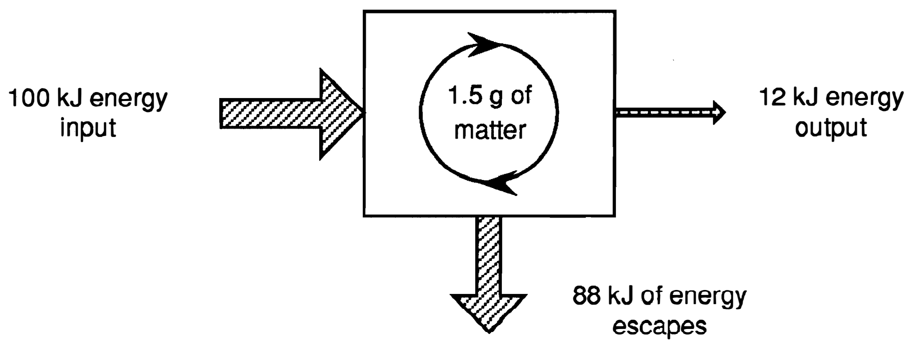
D How much energy flows? How much matter?

This is how much energy and how much matter would flow if you used:

- a solar cell the size of an exercise book
- let it run for half an hour



E Overall



Using sunlight to pull a rock uphill

Sheet 3

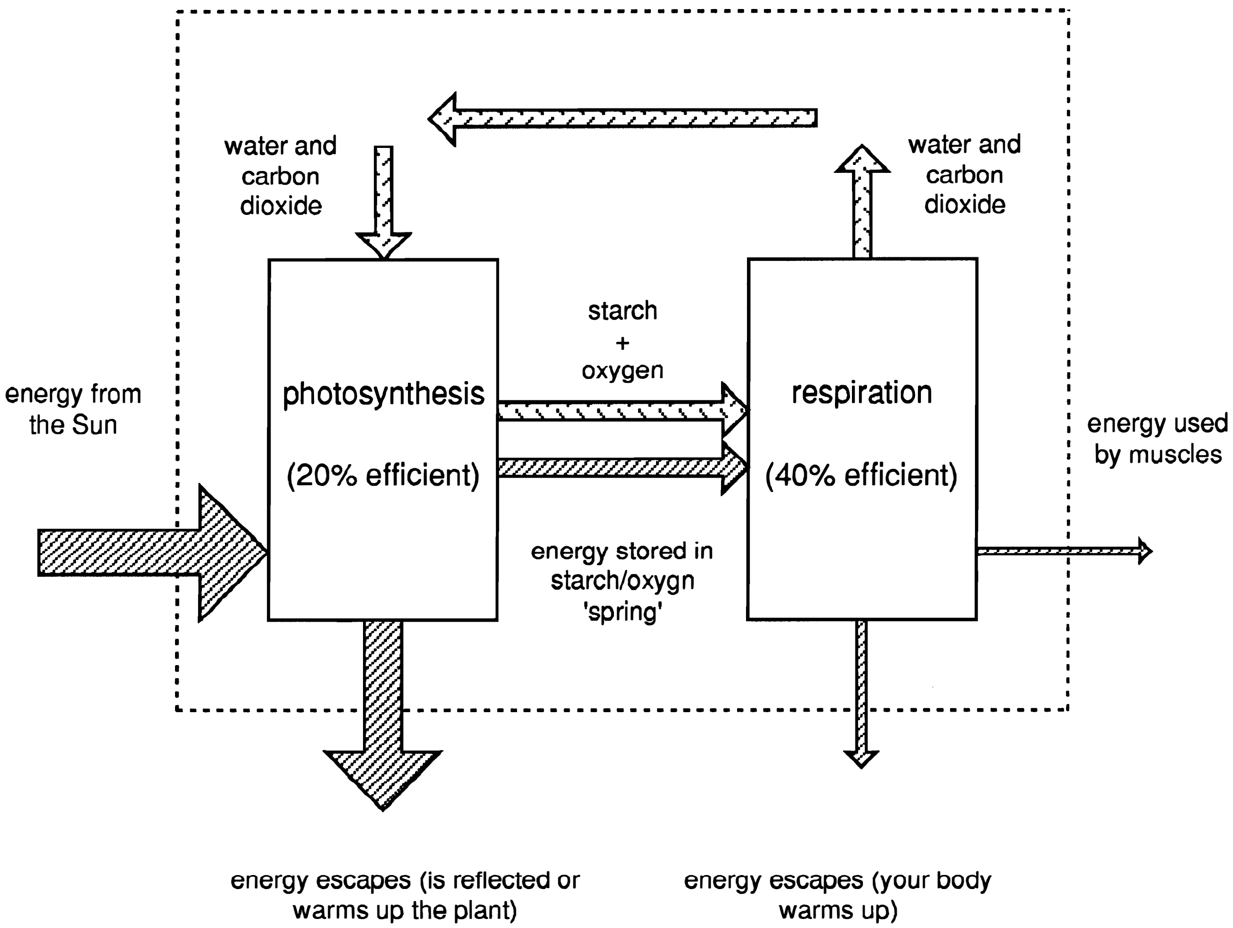
Use this information to fill in the values on the diagram.

Making starch

Plants make starch by photosynthesis. Suppose we had a plant about the size of an exercise book. In half an hour, about 100 kJ of energy would arrive at it from the Sun. Photosynthesis is only about 20% efficient. This means that for every 100 kJ of energy from the Sun, only 20 kJ of energy is used to make starch. This is stored and can be used later. The rest of the energy (80 kJ) escapes. With 20 kJ of energy the plant makes about 1.2 g of starch It also gives off about 1.3 g of oxygen. To make this amount of starch it would use up about 0.7 g of water and 1.8 g of carbon dioxide.

Using starch as a fuel

We could eat the starch and use it as a fuel (respiration). It reacts with the oxygen we breathe in. We could then use our muscles to push the rock up the hill. We would get back our 0.7 g of water and 1.8 g of carbon dioxide. But respiration is only about 40% efficient. So we would only get 8 kJ of energy to use in our muscles. The rest (12 kJ) would escape.



A What would happen if the Sun suddenly went out?

There would be no night and day - it would always be dark.

Everywhere would start to become colder.

With no temperature differences, winds would stops blowing

With no winds, waves would stop.

Ocean currents would stop.

Clouds would not form and there would be no rain.

Plants would stop making sugars by photosynthesis, and die..

The amount of oxygen in the air would decrease.

The amount of carbon dioxide in the air would increase.

Animals would die because they would have no food

Water in the sea and in the ground would freeze.

Even if there was food, it would become too cold for animals to live.

B What would happen if all water suddenly disappeared?

There would be no oceans, no lakes, no clouds, no rain, no rivers

Living things are mostly water - they could not exist.

The Sun's radiation would not be reflected by ice at the poles

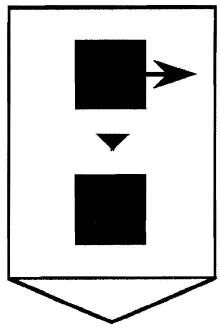
The energy from Sun would not be reflected by clouds.

There would be no water cycle which cools the Earth's surface.

The Earth would get hotter.

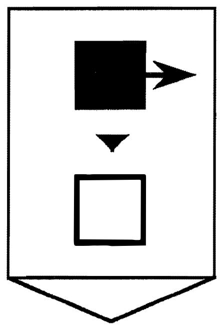
1 Why doesn't the Sun run down?

So far, we have treated the Sun as though it constantly stays at the same temperature. Energy radiates from the hot Sun into cold space.



2 Cooling down

But if energy constantly escapes from the Sun, then why does it not cool down?



3 The Sun's fuel

The Sun is maintained at an approximately constant temperature by using nuclear fuel. Hydrogen nuclei join together to form helium nuclei and energy is released.

When the fuel runs out, then the Sun will cool down.