CXC Integrated Science

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Contents

Contents

Living and non-living things

Look around you in the classroom and outside. Think about what you can see, hear, smell, touch and feel. How are the things similar and different? What are the things made of? How do they work? How can we use them …? These are some of the questions you will be answering as you go through this course.

As you look at the things around you, the most important differences you will notice are those between living and non-living things.

Activity | *Living and non-living things*

1 Look carefully at the photograph below. Make a list of all the things you can see.

2 Make a table in your notebook with two columns. Use the headings **Living things** and **Non-living things**. Write the names of the things into the correct columns.

3 Discuss your completed table with a friend. Have you put the same things in the same columns? Discuss any differences you notice.

Let's look at the characteristics of living things, which distinguish them from non-living things.

Living things make or eat food (nutrition)

All living things need food. Food is the fuel they use for all their activities.

Plants can make their own food from simple substances: carbon dioxide, water and mineral salts. They are 'self-feeding' or **autotrophic**. They contain **chlorophyll** (a green pigment) and carry out photosynthesis. This means that they use energy from the sun to make their own food (pages 66–7).

Animals cannot make their own food. They need complex compounds that contain energy. They eat plants, or animals which have eaten plants (pages 74–5). They are 'other feeding' or **heterotrophic**.

Living things respire

The food which an organism makes or eats is taken into the cells of its body. As energy is needed, for example for movement or response, some of the food is broken down by respiration to release the trapped energy. At the same time carbon dioxide and water are produced.

All living cells of plants and animals carry out respiration all the time. Respiration is similar to burning: the combination of oxygen with a fuel to release energy. In living things respiration is brought about by special substances called **enzymes** and can happen without high temperatures.

Non-living things like cars and machines cannot make their own food, nor do they go around eating other things! Humans have to put fuel, such as diesel and gasoline, into them. The fuel does not become a part of their 'body', it just stays in the engine. The fuel is burned to release energy for the movement of the car or the work of the machine. This burning involves high temperatures and is not brought about by enzymes.

Living things excrete

A living organism is a bit like a chemical factory. Different raw materials arrive (such as carbon dioxide and water in plants, and foods in animals) and they are changed or processed in a variety of chemical reactions to make new products. At this very moment there are millions of chemical reactions going on inside you!

These chemical reactions take place inside the cells. In plants, for example, photosynthesis occurs in the chloroplasts which contain chlorophyll, while respiration occurs in very small structures called mitochondria. Not all of the products of these reactions are useful, and some of them may be harmful if they accumulate. Living things therefore get rid of, or **excrete**, these waste materials. Excretion is the removal of waste products made by the activity of living cells. Cars also get rid of exhaust gases, but the fuel has never been part of the car's body.

Living things respond

Living things are affected by changing conditions around them and inside them. These changing conditions are called **stimuli**. Organisms have to **respond** correctly in order to stay alive.

Plants growing in the soil have to grow their roots near to sources of water and mineral salts. They have to grow their leaves so that they can catch the rays of the sun. Some plants, such as the sensitive plant, also respond to touch, and sunflowers twist each day to face the sun.

Animals respond to their surroundings, for example by looking for food, while also avoiding being eaten themselves. They usually have special sense organs to help them pick up stimuli, and muscles with which to respond.

(a) A praying mantis

(b) Fish

(c) Sunflowers facing the sun

(d) A pig with her litter

Living things move

Within plant and animal cells the material or protoplasm moves continually. The main way in which living things respond to stimuli is by the movement of parts of themselves. In contrast, a car moves when we make it move, it cannot move *on its own*.

Movement in living things may be easy to see, for example, you move your hand away from a hot object, or an animal moves around in search of food. The movement may also be inside you, for example, the movement of your jaw or of your stomach as it churns up your food and helps to digest it.

Plants have roots and they do not move around from one place to another. But they can move parts of themselves. A plant's movements are usually very slow and they are brought about by growth. A plant's stem bends towards the light because it grows more on one side of the stem than on the other.

Living things grow

Living things can grow if they make or eat more food than is needed for staying alive. New substances are built up in the body, and the organism grows: it becomes bigger or more complex and increases in mass, length or width.

Cars certainly do not grow, but we can say that crystals grow (page 16). Crystals are non-living and they 'grow' in the sense that extra substances of the same kind are just added to the outside. However, this is not at all like the growth in living things.

Living things reproduce

New organisms are formed by **reproduction**. To *reproduce* means to 'make again'. It means that another organism, similar in many ways to the parent, is made and can live separately. It would be very convenient if cars could also reproduce, but unfortunately this is *only* a characteristic of living things.

Organisms need to grow before they can reproduce. They have to become mature. We have seen that growth is a characteristic of living things. For example, flowering plants grow flowers which produce pollen and eggs before they can reproduce. Animals, such as ourselves, have to reach puberty before they are able to produce the sperm and eggs necessary for reproduction. This is called sexual reproduction (page 38).

Some organisms reproduce asexually. A part of the organism grows and becomes a new, separate organism (pages 39 and 73).

Questions

1. What is meant by (a) a living thing and (b) a non-living thing? Give an example of each.
2. What are the seven characteristics of living things? How is a non-living thing, such as a car, different from a living thing for each characteristic?
3. What characteristics of living things are shown in pictures (a) to (d) above? (*Note*: each picture may show more than one characteristic.)

What are the units of measurement?

A system of measurement

There is a system of measurement which is used by most of the leading nations of the world. The system is called the Système International d'Unités or SI (metric) system and its units are meant to replace all other types of units of measurement. These measurements include measurements of mass, length (distance), time, force, pressure, energy, temperature and electricity. The table below gives the different types of measurements with their units and symbols which you are likely to find in the text. These units have been adopted by all scientists and are essential for accuracy in the recording, transfer and interpretation of data.

SI units

Measurement	Quantity	Unit	Symbol
length, mass and time	length	metre	m
	area	square metre	m^2
	volume	cubic metre	m^3
	mass	kilogram	kg
	density	kilogram per metre cubed	kg/m^3
	time	second	s
	frequency	hertz (= per second)	Hz
force and pressure	force	newton	N
	weight	newton	N
	moment of force	newton metre	Nm
	pressure	pascal (= newton per square metre)	Pa
energy and heat	energy	joule	J
	work	joule (= newton metre)	J
	power	watt	W
	temperature absolute temperature	degree Celsius Kelvin	°C K
electricity	electric current	ampere	A
	electromotive force	volt	V
	potential difference	volt	V
	resistance	ohm	Ω
	electrical energy	joule	J

There are certain prefixes that can be used to change the standard unit of measurement. For example, the term *kilo* is used with *metre* to derive the term *kilometre*. Since kilo stands for 1 000, *a kilometre* = one thousand metres.

Often scientists use short forms of mathematical expression to deal with very large or very small numbers. Numbers are expressed as *powers of ten*. For example, one hundred is ten to the power two (or ten squared): $100 = 10 \times 10 = 10^2$.

The table below gives a few examples of the powers of ten of large numbers and shows how the prefixes are used.

Multiple	Prefix	Symbol	Example
10^9	giga	G	gigawatt
10^6	mega	M	megajoule
10^3	kilo	k	kilometre

One metre can be divided into smaller units, for example into one thousand parts, each of which is called a *millimetre*. The prefix *milli* means that the particular unit to which it is attached is divided by one thousand. In the short form of mathematical expression, one hundredth is ten to the power minus two:

$$\frac{1}{100} = \frac{1}{10^2} = 10^{-2}$$

This table gives a few examples of the powers of ten for smaller numbers and shows how the prefixes are used.

Multiple	Prefix	Symbol	Example
10^{-1}	deci	d	decimetre
10^{-2}	centi	c	centimetre
10^{-3}	milli	m	millimetre
10^{-6}	micro	µ	micrometre
10^{-9}	nano	n	nanosecond

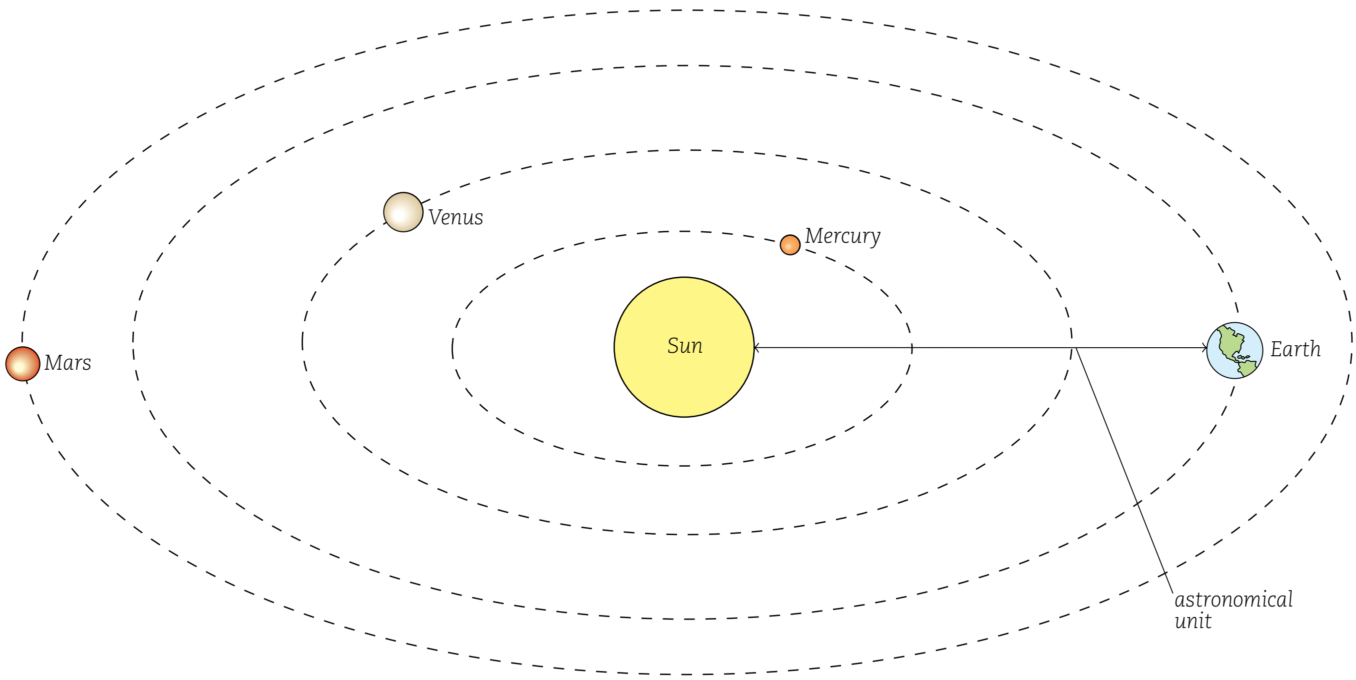
Are there other measurements in general use?

A visit to the local grocery store or market place will soon reveal that many things are still sold in *pounds* and *pints*. Tailors still use *inches*, cloth is sold in *yards* and *gallons* of paint can be bought from the hardware store. Racehorses still run *furlongs*, weather reports often give wind speeds in *miles per hour* and ships travel in *knots*. While these units are no longer taught in our schools, they remain part of our every-day experience and we still need to know how they relate to the new units we use more often. Here is how some of the older units relate to the metric system (SI units).

Unit	How used	Metric equivalent
Inch	Length measure	2.54 cm
Foot	Length measure	30.48 cm
Yard	Length measure	0.9144 m
Furlong	Length/distance measure	201.18 m
Mile	Length/distance measure	1.6093 km
Mile per hour	Speed measure	1.61 km/h
Knot	Speed measure	1.85 km/h
Pint (US)	Volume measure	0.473 l
Gallon (US)	Volume measure	3.79 l
Gallon (Imperial)	Volume measure	4.55 l
Ounce	Weight/mass measure	28.38 g
Pound	Weight/mass measure	0.454 kg
Pound/square inch	Pressure measure	7.038 kPa
Ton	Weight/mass measure	1016.05 kg

Astronomical distances

Light year = 9.45×10^{15} km
(The distance light travels in a year.)
Astronomical unit = 149.6×10^{6} km
(The average distance of the Earth from the sun.)

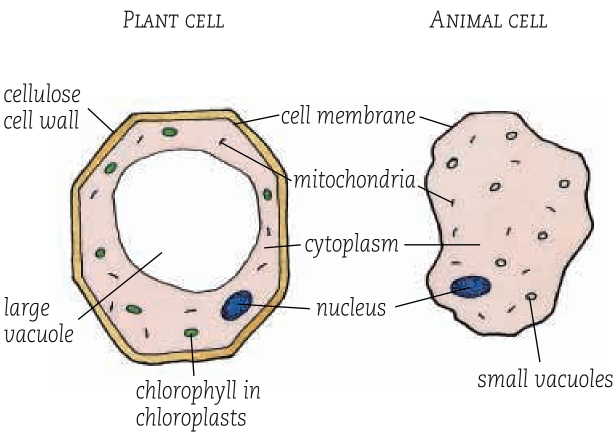


How are living things built up?

What are living things like inside? How do the various parts carry out the processes of life? On pages 8–9 you saw how we measure in science. The **cells** which are the building blocks of living things are very small. We need to use a microscope to see them.

Activity | *Looking at plant and animal cells*

1. Pull away a little piece of the purple skin from the lower side of the long, green and purple leaf of Moses-in-the-bulrushes (*Rhoeo*).
2. Put it onto a microscope slide with a drop of water and cover it with a cover-slip (see page 34).
3. Examine your slide under the low power of the micro-scope (see page 35) and see how many of the features shown in the plant cell below, you can see. Notice also how the cells are fitted together to make a **tissue**, in this case the lining skin of the plant.
4. Your teacher will give you a slide with animal cells on it. Examine your slide under the low power of the micro-scope and see how many of the features shown in the animal cell below, you can see.

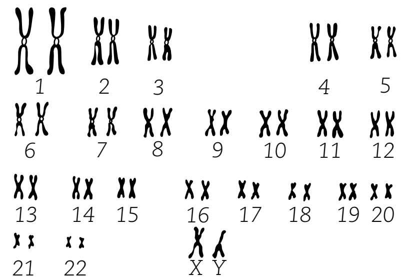


Similarities between plant and animal cells Both have a nucleus, cytoplasm, cell membrane and mitochondria.
Differences Copy the table into your practical notebook and fill in the right-hand side by looking at the pictures above.

Typical plant cells	Typical animal cells
1 Have a cellulose cell wall outside cell membrane	
2 Contain chlorophyll in chloroplasts	
3 Have large vacuoles with cell sap	

Inside the nucleus

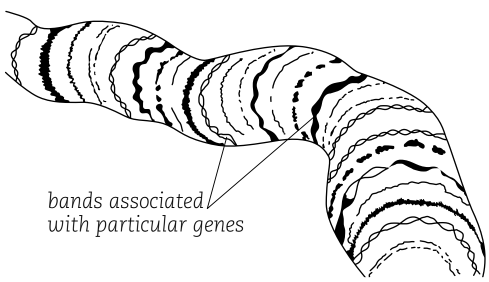
Each cell has a dark area – the nucleus. The nucleus controls the activities or processes of the cell. When we magnify the nucleus we see thread-like **chromosomes**. Below is a diagram of human chromosomes.



The diagram shows the chromosomes in the cells of a male. There are 22 pairs (the ordinary chromosomes) and two chro-mosomes left over, one of which is larger than the other. These last two chromosomes are called the **sex chromo-somes** which are responsible for the differences between the sexes. The long one is called an **X** chromosome, and the shorter one is called a **Y** chromosome. All males have 22 pairs of chromosomes plus XY. All females have 22 pairs of chro-mosomes plus two X chromosomes, or XX.

Inside the chromosome

When scientists look at some chromosomes under greater magnification they see dark bands called **genes**. It is the genes which have the instructions for giving us our various characteristics. The picture below shows some genes on the chromosomes of the fruit fly, *Drosophila*.



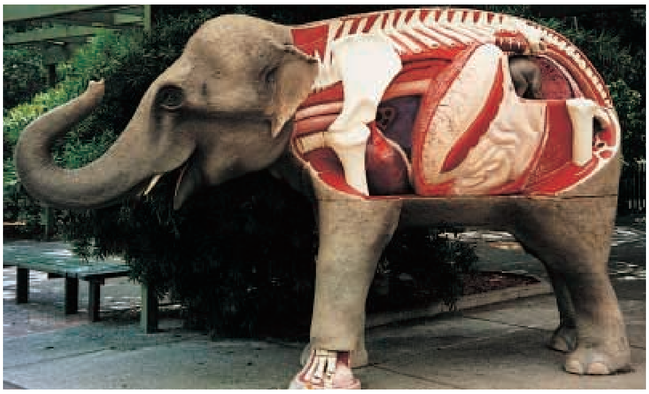
Building up

- Genes are found on chromosomes inside the nucleus of cells.
- Living cells are grouped together to make tissues, such as packing tissue in plants, and muscles in animals.
- Tissues are grouped together to make organs such as leaves in plants, and the stomach in animals.
- Organs working together make up the whole organism.

Organs and systems in a mammal

The photograph below shows a model of an elephant, cut away to show the inside. The **organs** (complicated structures made up of many tissues) carry out one or more jobs or functions. Examples of organs are the heart (pumping blood) and the stomach (digesting food).

- Identify as many parts of the model as you can and talk with a partner about their functions.



Several organs also work together to make **systems,** such as the digestive system, the circulatory system, the nervous system and the reproductive system. In this course you will learn more about organs and systems, and their functions.

- With a partner list the systems you know in a mammal, the organs which make them up, and the functions.

Organs and systems in a flowering plant

When we look at plants we can identify important organs, such as flowers, leaves, stems and roots. The organs working together above ground are sometimes called the shoot system – these are shown below in the photograph of Cassia (also known as the Pride of Barbados). The organs working together underground are called the root system.

- With a partner list the organs in a flowering plant and the functions of each one.

Matter, energy and living things

Matter and energy make up our whole universe and make it possible for things to work.

Matter Matter is the material of which everything is made – both living and non-living things. Matter makes up the *things* around us. We can see matter, even though we need to use special microscopes to look at cells, chromosomes and genes, or to investigate the chemicals of which things are made. Matter has mass – though this mass may be very, very small. We will be introduced to what matter is made of on pages 16–19 and 22–5, and learn more throughout the course. Matter is the chemicals which are the building blocks that are put together in various ways to make living and non-living things.

Energy We cannot *see* energy; we can only see or feel what it does. Energy also does not have mass. We see or feel the effect of different forms of energy, such as light, heat, sound, electricity and the energy of movement. Energy allows things to work. We will be introduced to the forms of energy on page 20, and learn more throughout the course.

Activity | *Matter and energy*

1. Look around you in the classroom and outside. Look for things made of matter – living and non-living. Search for different forms of energy that you cannot see, but know are there because they are having some effect, such as the wind blowing the trees.
2. Copy this table into your notebook. A few examples of matter and energy have been filled in for you. Find other examples and put them in the correct columns.

Matter (material, things that have mass)		**Energy** (the power to do work of some kind)
Living things	Non-living things	
Yourself	Your desk	Sound from a CD
Birds	Your clothes	Light from a bulb
Flowers	Clouds	Warmth and light from the sun
Trees	Stones	

Living things Living things have a special ability: they are able to take their own energy from their surroundings – either by photosynthesis, or by taking in ready-made food. They then use this energy for all their activities, and for growth and reproduction. When living things lose this ability, they die. The variety of living things is introduced on pages 12–15, and you will learn more about the life processes throughout the course.

Who's who among living things?

Living things have basic characteristics which make them different from non-living things (pages 6–7). All but the simplest of living things are also built up from cells, tissues and organs (pages 10–11). But living things show a great variety in their appearance and structure. These differences allow us to separate or **classify** them into many different groups.

We will first look at the important similarities and differences between a plant (Pride of Barbados, which is a flowering plant) and an animal (a fish, which is an example of a vertebrate).

Activity | *Comparing a plant and an animal*

1 Look back at the characteristics of living things (pages 6–7). Describe in your notebook why you think the plant and animal shown below are living.

2 Write down the different ways in which the plant and animal carry out the characteristics of living things. For example, how does each carry out nutrition? How do their differences in appearance and structure affect how they carry out the characteristics of living things?

A typical plant	A typical animal
Uses simple inorganic substances (page 66) to make its own food	Feeds on complex organic substances (page 66) containing trapped energy
Has chlorophyll and can carry out photosynthesis	Does not have chlorophyll and cannot photosynthesise
Does not digest food	Has structures to digest food
Usually rooted in the ground	Not rooted in the ground
Does not usually move from place to place	Moves around to get food
Has no nerve or muscle cells	Has nerve and muscle cells
Does not have special senses	Has special sense organs

Classifying living things

- *Viruses*
- *Bacteria*
- *Protists*
- *Fungi*
- *Plants*
  - *Algae*
  - *Mosses*
  - *Ferns*
  - *Conifers*
  - *Flowering plants*
- *Animals*
  - *Invertebrates*
    - *Coelenterates*
    - *Roundworms*
    - *Flatworms*
    - *Ringed worms*
    - *Molluscs*
    - *Echinoderms*
    - *Arthropods*
  - *Vertebrates*
    - *Fish*
    - *Amphibians*
    - *Reptiles*
    - *Birds*
    - *Mammals*

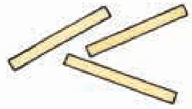
Plants and animals make up a large part of the living things around us. There are also many other organisms which we cannot see unless we use an ordinary microscope or a microscope which uses electrons instead of light rays.

Instrument	Magnification	Can see
Naked eye	Life size (× 1)	Many multicellular organisms
Hand lens	× 10	Cell as a dot
Low power microscope	× 100	Nucleus in a cell
High power microscope	× 400 to × 1 000	Some cell structures
Electron microscope	× 40 000 to × 500 000	Internal structure of mitochondria

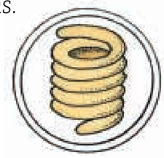
100 cm = 1 m　　1 000 µm (micrometres) = 1 mm
10 mm = 1 cm　　1 000 nm (nanometres) = 1 µm

Part 1

Viruses *about 100 nm, seen only with electron microscope, no cell structure, can only reproduce inside living organisms.*

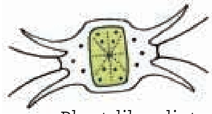


Tobacco mosaic disease virus



Influenza virus

Protists *about 10 µm–1 mm, some seen with low power, single-celled, with nucleus. Plant-like with chlorophyll, or animal-like.*

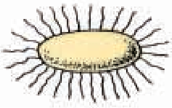


Plant-like: diatom

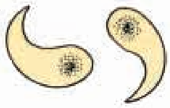
Animal-like: Entamoeba

Bacteria *about 0.001 mm, seen under high power, single-celled or joined in chains, no nuclei.*

Streptococcus *(sore throat)*

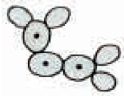


Bacillus typhosus *(typhoid fever)*



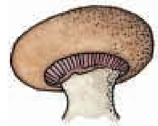
Vibrio *(cholera)*

Fungi *about 5 µm–20 cm, mostly many-celled with nuclei. No chlorophyll.*



Yeast

Pin mould on a banana

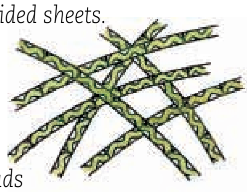


Mushroom

PLANTS

Small to very large, visible to the naked eye (i.e. without a microscope), many-celled with nuclei, chlorophyll, mostly stationary and rooted in the ground.

Algae *about 5 mm–100 cm, mostly small, no roots, stems or leaves. Threads or divided sheets.*

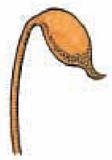


Spirogyra *green threads*

Sargassum *brown seaweed*

Mosses *about 5 mm–15 cm, simple roots, stems and leaves, reproduce by spores.*

Moss 'leaves'



Spore case

Ferns *about 5 cm–10 m, small to tree-like, roots, stems and leaves, reproduce by spores.*

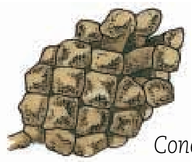
Fern

Spore cases

Tree fern

Conifers *about 5 m–30 m, mainly tree-like, roots, stems and leaves, reproduce by seeds inside cones.*

Pine tree

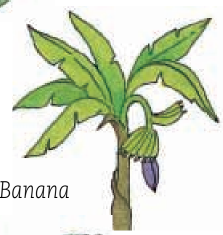


Cone

Flowering plants *5 cm–30 m, small to tree-like, roots, stems and leaves, reproduce by seeds inside flowers.*

Monocotyledons	*Dicotyledons*
Narrow leaves with parallel veins. *Bunch of small roots (fibrous roots).* *One seed leaf (cotyledon) in seed, for example, grass, banana, coconut palm.*	*Broad leaves with branching veins.* *Main (tap) root with many branches.* *Two seed leaves (cotyledons) in seed, for example, balsam,* Hibiscus, *mango tree.*

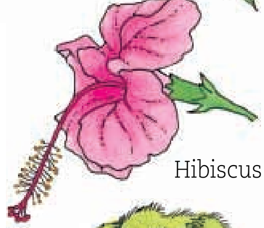
Grass



Banana

Coconut palm

Balsam



Hibiscus

Mango tree

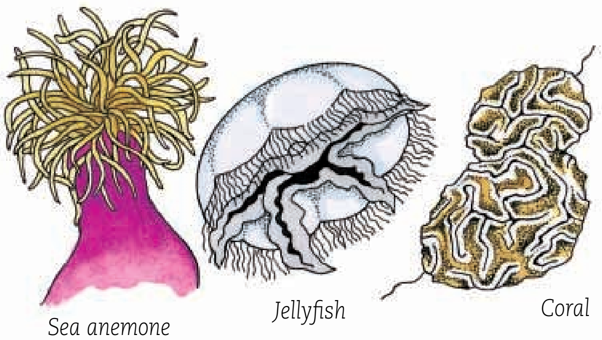
Who's who among living things?

ANIMALS

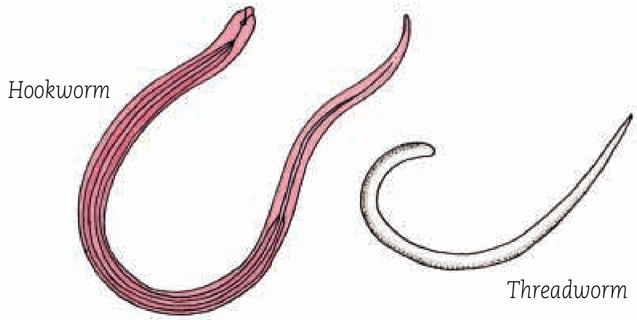
Small to large, visible to the naked eye, many-celled with nuclei, no chlorophyll, usually move around and feed on other organisms.

INVERTEBRATES Animals without backbones. Mostly small. Either soft-bodied or with a hard outer case (exoskeleton).

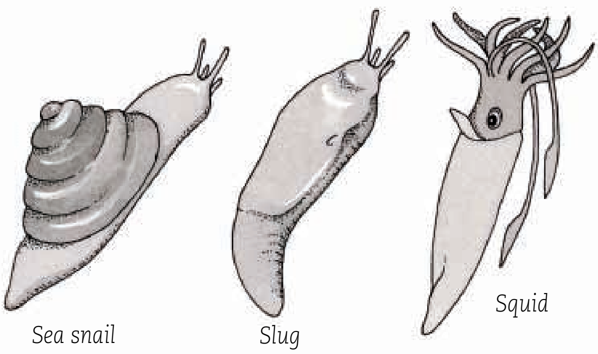
Coelenterates *about 1 cm–many metres. Bag-like with tentacles around mouth, no legs. Live singly or in groups (coral). Most live in the sea.*



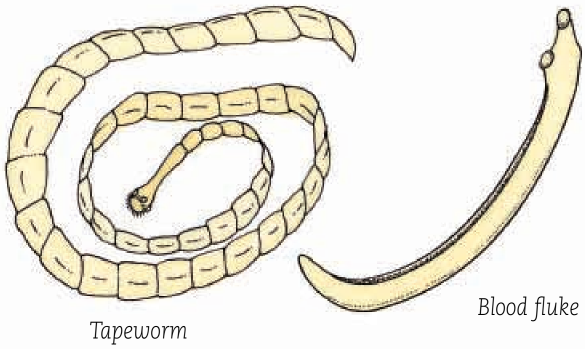
Roundworms *(nematodes) about 100 mm–30 cm. Body long and thin, round in cross-section, no legs, no rings. Most are parasites, others live in the soil.*



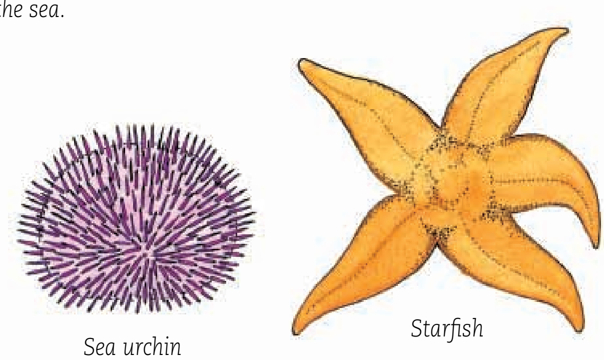
Molluscs *about 3 cm–30 cm. Soft body, undivided and often inside a shell, no legs. Some with tentacles. Most live in water, a few on land.*



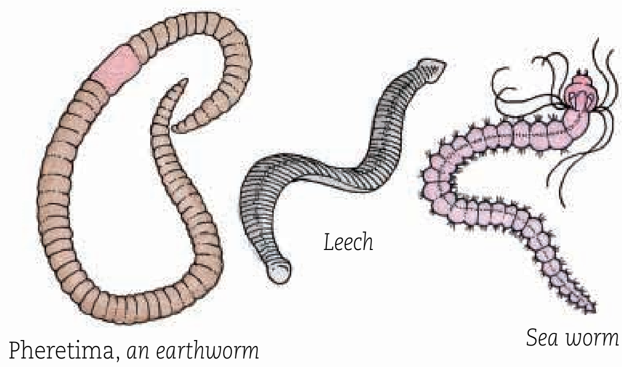
Flatworms *about 10 mm–5 m. Body long and thin, flat in cross-section, no legs, no rings. Have hooks and suckers. Most are parasites of animals.*



Echinoderms *about 10 cm–15 cm. Ball-shaped or star-shaped based on a five-part pattern, no legs, tough outer skin with spines. Live in the sea.*



Ringed worms *about 5 cm–1 m. Body long and divided up by rings, round in cross-section, no legs. Most aquatic, others live in the soil.*

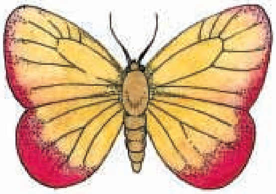


Part 2

INVERTEBRATES (continued)

Arthropods *Mainly small, crawling animals with a hard outer case (exoskeleton). The only invertebrates with jointed legs.*

Insects *3 pairs of legs, body divided into head,thorax, abdomen, 2 pairs of wings. Live on land, for example, butterflies, roaches, beetles, termites and lice.*

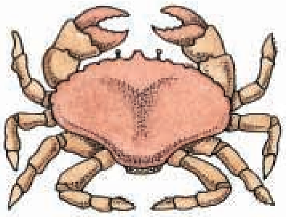


Butterfly

Arachnids *4 pairs of legs, head and thorax joined, no wings. Some are parasites. Live on land, for example, spiders, ticks and mites.*

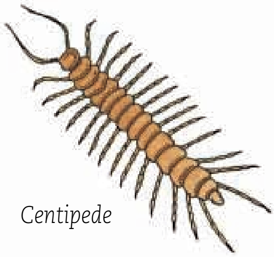
Spider

Crustacea *4–10 pairs of legs, usually with shield over front of body, no wings, breathe with gills. Mostly live in water, for example, crabs, shrimps, woodlice.*



Crab

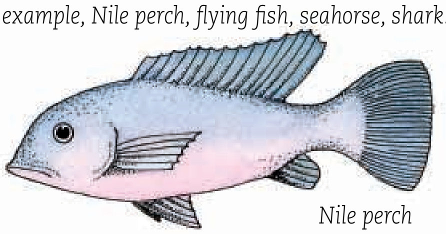
Myriapods *More than 10 pairs of legs, body long and divided into segments, no wings. Live on land, for example, centipedes and millipedes.*



Centipede

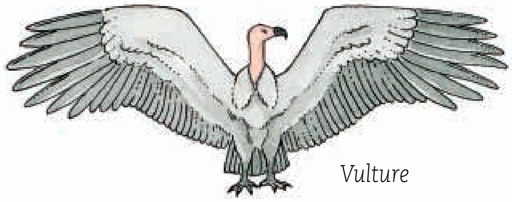
VERTEBRATES *Animals with backbones. Skeleton inside the body (endoskeleton). Mostly large. Some live in water and have gills. Others live on land or in the air and have lungs. Land forms have four limbs.*

Fish *Covered in scales. Live in water and breathe with gills. Streamlined body and fins for swimming. Eggs laid and develop in water, for example, Nile perch, flying fish, seahorse, shark.*



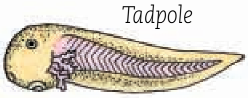
Nile perch

Birds *Covered in feathers. Breathe with lungs. Live on land and in the air. Have wings for flying. Eggs laid inside a hard shell in nests, for example, vulture, egret, chicken, owl.*



Vulture

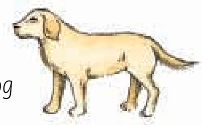
Amphibians *No skin outgrowths. Young stage (tadpole) lives in water, breathes with gills. Adult lives on land and in water, has 4 limbs and breathes with lungs. Eggs laid and develop in water or moist places, for example, toads and frogs.*



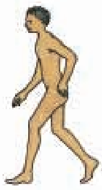
Tadpole

Adult toad

Mammals *Covered in hair. Breathe with lungs. Most live on land, some live in water. Either walk (dog) or swim (whale). Eggs develop inside female, and the young are born. The young are fed on milk.*

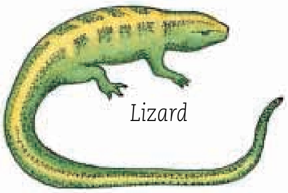


Dog

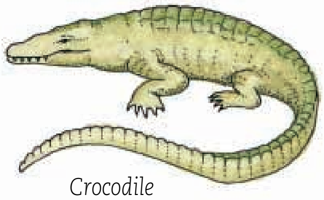


Human

Reptiles *Covered in scales. Breathe with lungs. Most live on land, others in water. Either slide (snakes), swim (turtles), or walk (lizards). Eggs laid inside a leathery shell on land.*



Lizard



Crocodile

Activity | *Classifying organisms*

Look at pages 13–15. Read through the descriptions and look at the pictures of the organisms belonging to each of the groups.

1. Your teacher will give you some pictures or diagrams of living things. You should try to find out which of the groups each one belongs to.
2. Collect pictures of living things and prepare some classification charts to stick on your classroom wall.

What is matter made of?

Why do we need to know about matter?

The world around us is made up of a vast number of different substances. Scientists want to know *what* both the similarities and the differences between substances are. They also want to know *why* there are these similarities and differences. They search for patterns in the behaviour of these substances. For example, there may be substances which behave in the same way – this may suggest that these contain matter that behaves in the same way. To find out about this we need to investigate the substances in more detail to find out what they are made of. This may help us to explain the properties we observe.

Quartz crystals which have grown naturally. Note the regular shapes

Activity | *Growing crystals*

1 Make up some *very* concentrated solutions of copper sulphate and potassium aluminium sulphate (potash alum) in warm water.
2 As the warm solutions cool, use a glass rod to put a few drops of each solution onto a glass slide and observe them using a microscope (page 35).
3 Allow the solutions to cool and observe them every day for 4 to 5 days. You may need to use a seed crystal to encourage crystal growth.
4 Record your observations.

Activity | *Diluting a solution*

1 Dissolve a small crystal of potassium manganate(VII) (potassium permanganate) in a small volume of water – about 10 cm^3.
2 Pour 1 cm^3 of the diluted solution into a small measuring cylinder. Make this up to 10 cm^3 by adding more water.
3 Pour 1 cm^3 of the diluted solution into the measuring cylinder and dilute that to 10 cm^3 by adding water.
4 Repeat step 3 until the colour of the solution has disappeared.

Questions

1 Do the crystals you have seen all have regular shapes?
2 What happens to the potassium manganate(VII) as the solution becomes more and more diluted?

Activity | *A crystal in water*

1 Pour about 200 cm^3 of water into a 250 cm^3 beaker. Very carefully add one crystal of blue copper(II) sulphate. Leave the beaker for a few days.
2 Record your observations.

Activity | *Looking at bromine*

1 Your teacher will place a drop of bromine at the bottom of a gas jar, and place another gas jar upside down on top of the first.
2 Record your observations.

Activity | *Hydrogen chloride gas and ammonia gas*

1 Your teacher will clamp a long glass tube horizontally and place one piece of cotton wool at each end of the tube. One piece of cotton wool is soaked in concentrated ammonia solution and the other in concentrated hydrochloric acid.
2 The pieces of cotton wool will each give off a vapour – either ammonia gas or hydrogen chloride.
3 Record your observations. Do you think there has been a reaction?

The white substance, ammonium chloride, is formed by the reaction of ammonia and hydrogen chloride.

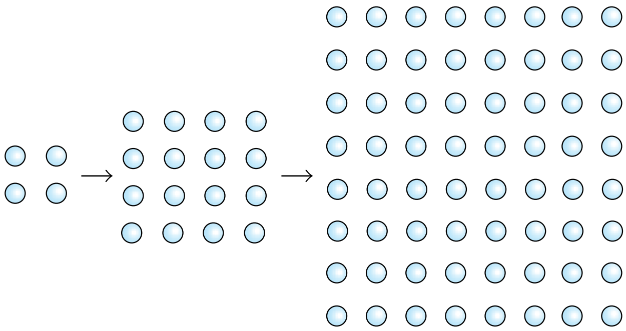
These different Activities help us to think about matter. We can summarise as follows:

Solid crystals form in regular shapes. When a coloured crystal dissolves, the solution becomes less coloured (fainter) as it is diluted. The colour of a solid crystal spreads very slowly through water if it is left without stirring. However, gases seem to move very quickly.

One way to explain these observations is to suggest that matter is made up of very small **particles**. We can try to build up a picture of what is happening with these small particles. We shall think further about what these particles might be in Part 2.

Part 1

Solid crystals We can imagine that crystals are built up from particles arranged in regular patterns. As more and more particles are joined together, the crystals get bigger and bigger. The crystals grow until we see the regular shapes which are formed.



This is how a crystal grows

Diluted solutions Any one crystal of a solid such as potassium manganate(VII) may contain a large number of particles. As the solutions are made more and more dilute, there are fewer and fewer particles in each successive 10 cm^3. This may explain why the colour of the solution gets fainter and fainter.

Liquids Particles in a liquid seem to move more slowly than those in a gas. The colour of the blue copper sulphate spreads slowly through water.

Gases The colour of the bromine spreads quickly through the gas jar. This rapid spread suggests that the particles in a gas move quickly.

The white ring of ammonium chloride is formed where the ammonia particles collide and react with the hydrogen chloride particles.

Activity | *What are the states of matter?*

1 Put a small cube of ice in a small beaker. Heat gently until the solid becomes liquid. Now heat more strongly until the liquid boils. Stop heating and allow the liquid to cool.

When ice (solid water) is heated, liquid water is formed. When water is boiled, steam is formed. Ice is a solid, water is a liquid and steam is a gas (vapour). We can summarise the changes you see in the states of matter in a diagram like the one in the next column.

HEAT →

Solid (ice) → Liquid (water) → Gas (steam)

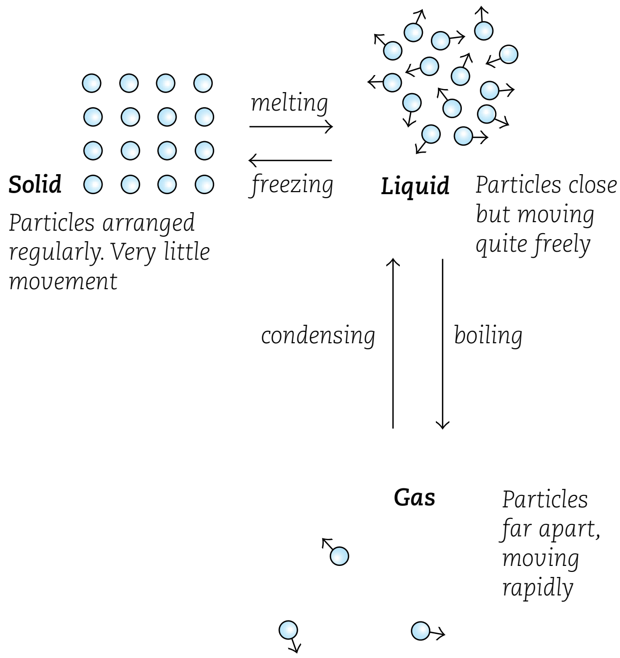
We should also include what happens when steam is cooled to form water and water is frozen to form ice.

HEAT →

Solid (ice) ⇄ Liquid (water) ⇄ Gas (steam)

← COOL

Solid, **liquid** and **gas** are called the three states of matter. We know that we have to supply heat energy to change a solid into a liquid and a liquid into a gas. We can use this information to help us think about the way the particles are arranged in each of the three states of matter.



Particle arrangements in solids, liquids and gases

Question

3 How would you define (a) a solid (b) a liquid and (c) a gas?
4 What kind of energy is needed to change a solid into a liquid and a liquid into a gas?

What is matter made of?

What are the particles in matter?

In the previous two pages we have looked at some of the evidence for the existence of particles in matter. We have seen that the idea of particles can be used to explain our observations. At this stage, even if we assume that there are particles in matter, we cannot say anything about what these particles are. Scientists always search for explanations of observations, and a more detailed examination of matter shows that we need to go beyond the simple idea of particles.

The idea of a basic building block in nature is very strong, and the first complete theory of matter was put forward by John Dalton in the early 19th century. He proposed that the smallest particles found in matter were **atoms**. *An atom may be thought of as the smallest particle of an element which can take part in a chemical reaction*. This definition assumes that you know about **elements**. *An element is a substance in which all of the atoms are the same*.This means that the properties of the atoms of any one element should be the same, as well as different from the properties of the atoms of any other element. Examples of some common elements are hydrogen, copper, oxygen, carbon, iron, nitrogen, aluminium and silicon.

We can consider a very simple reaction of two elements, iron and sulphur. If these two elements are heated together strongly, a new substance, iron sulphide, is formed. We can display this information in the form of a **word equation**. Word equations tell us what we start with and what new substances are formed. Here the **reactants** are on the left-hand side and the **product(s)** are on the right. In this case we have:

iron + sulphur → iron sulphide

The particles which take part in this reaction are atoms of iron and atoms of sulphur. The elements carbon and oxygen react together to form the new substance, carbon dioxide:

carbon + oxygen → carbon dioxide

Atoms of carbon react with molecules of oxygen to form molecules of carbon dioxide. In the Activities you carried out in Part 1, the particles are mostly **molecules**. *A molecule is the smallest part of a substance which can exist by itself and still show all the properties of that substance. Molecules may contain atoms of the same element* (an oxygen molecule contains two atoms of oxygen) *or atoms of different elements* (a carbon dioxide molecule contains one atom of carbon and two atoms of oxygen).

Activity | *What happens when elements combine?*

We can examine the reaction between iron and sulphur as one example. The elements iron and sulphur contain atoms. When the elements react, as we have seen, a new substance, iron sulphide, is formed. This new substance has properties which are different from those of either iron or sulphur.

1 Make a list of the obvious physical properties of both iron and sulphur.
2 Examine a sample of iron(II) sulphide.
3 How would you try to test whether the properties of iron(II) sulphide are different from those of iron and sulphur?

Iron(II) sulphide contains two elements combined in some way. It is a **compound**. *Compounds are substances in which two or more elements are combined in definite proportions by mass.*

You should notice that this definition does not tell us anything about the nature of the particles when a new substance (compound) is formed by the reaction of two or more elements. In many cases, these may be molecules.

4 Consider the reactions of the following elements:
(a) Carbon and oxygen
(b) Hydrogen and oxygen
(c) Aluminium and iodine
(d) Iron and chlorine.
5 What would you expect to be the name of the new substance (compound) formed in each case?
6 Write a word equation for each reaction.

Many of the common gases are elements, such as oxygen, nitrogen and chlorine. In these elements, the particles found are molecules, in which two atoms are combined.

Questions

1 How would you define (a) an atom (b) an element and (c) a molecule?
2 Name as many elements as you can that exist as gases at room temperature.
3 Hydrogen chloride and ammonia are gases. Each is a compound containing hydrogen. What would you expect to be the nature of the particles in these gases?
4 When sodium reacts with chlorine, sodium chloride (common salt) is formed. Write a word equation for this reaction.

Part 2

What are atoms made of?

Atoms were thought of as very small particles once Dalton's theory had been accepted. However, towards the end of the 19th century, there was evidence to suggest that there might be smaller particles still. A series of key experiments was carried out early in the 20th century by Rutherford. In one of these, he started with a very, very thin piece of gold foil and directed a stream of radioactive particles at the foil. There were some very interesting observations:

1 Many of the particles passed through the foil without being deflected at all.
2 A very small number of the particles (which were positively charged) were reflected back in the direction from which they had come.

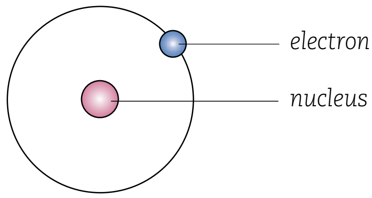
Rutherford needed to find an explanation of these observations and he developed a model of the atom which is still the basis for much of our understanding of basic chemistry. Firstly, he assumed that most of the mass of the atom consists of a small, dense nucleus. (If the nucleus is positively charged, this would account for the reflection of a small number of positively charged particles – like charges repel.)

This small, dense nucleus is surrounded by much smaller particles, mostly at a considerable distance from the nucleus. (This would leave a good deal of empty space, and could account for the fact that most particles passed through the foil.) This model is often called the **solar system model** of the atom, since it is similar to the model of our solar system in which the sun can be thought of as the 'nucleus' of the system of planets.

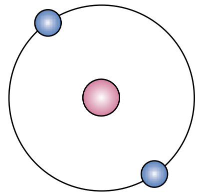
One of the problems with the early Rutherford model was that no-one was sure what would happen to the very small, negatively charged particles outside the nucleus. Common sense suggested that these should be attracted towards the small positively charged nucleus – unlike charges attract – and then the atom would collapse!

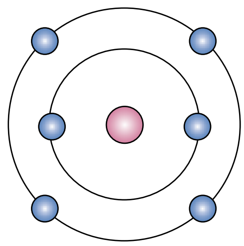
Further development of the model involved the following ideas:

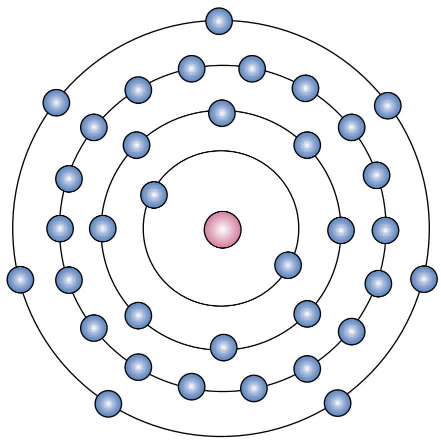
1 The small, positively charged nucleus contained two different particles:
(a) Protons, with a single positive charge and a mass of 1 on a given scale.
(b) Neutrons, with no charge and a mass the same as that of the proton.
2 The particles outside the nucleus were very light (mass very much less than that of the protons and neutrons) and had a single negative charge. These electrons were found at fixed distances from the nucleus, such that successive shells of electrons were built up as atoms became heavier. (There are now at least 115 known elements, some of them found only in a laboratory.)



hydrogen atom


helium atom


carbon atom


bromine atom

Electron arrangements are often represented by diagrams. These are not meant to be like photographs, showing exactly what real atoms look like. Instead, they are intended to help us understand the structure of the atom

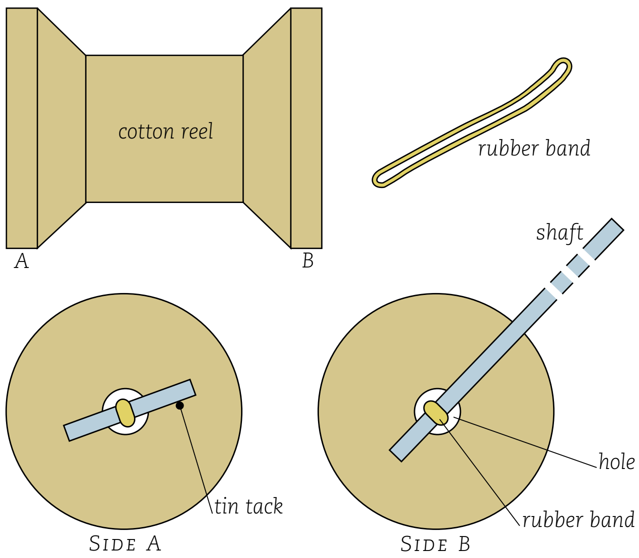
What is energy?

It is very difficult to find a precise yet complete definition of the term **energy**. Energy is described in terms of what it can do, like the purchasing power of money, so energy may be defined as *the capacity for doing work*.

You may know that there are different forms of energy, such as **potential or stored energy,** and **kinetic energy** which is energy in the motion of a body.

Activity | *How can energy be stored?*

1 Build a toy tank like this, from a cotton reel, a rubber band made from an old bicycle inner tube and some spent matches.



Making a cotton reel tank

The length of the rubber band should be less than that of the reel. Insert and pull one end of the band through to side B and insert the shaft. The shaft must be about two to three times the diameter of side B.

2 Hammer small tacks into side A to prevent the stick at A from spinning. Lubricate side B with paraffin wax (candle wax).

3 Hold the tank in one hand with side B uppermost. Turn the shaft in a circle several times. This twists the rubber band. Place the tank on the ground. It will move forward as the rubber band slowly untwists.

Energy is stored in the rubber band as it is twisted. The energy is made to do the work of moving the toy tank along as the rubber band untwists. Potential energy is converted into kinetic energy.

Similarly, energy is stored in a spring when a clock is wound up. This energy keeps the mechanism of the clock running.

The head of a match is made of chemicals, which store **chemical energy**. When the chemicals are activated, the chemical energy can be converted into **heat energy**.

Activity | *Chemical energy*

Heat the tip of a pin until it is red-hot. While it is still red-hot, touch it quickly to a match head. Observe what happens. Do you think the energy released by the match is more than that in the red-hot pin?

Paper, wood, gas and oil can all be considered as stores of chemical energy. Under the right conditions this energy can be released and used. The electrochemical cell is also a store of chemical energy. Here chemical energy is converted mostly into electrical energy (pages 172–3).

In raising a weight up to a height, work is done on the weight. If the weight is allowed to fall it gives up its energy mainly as heat when it falls to the ground. Similarly, water is raised from the sea by evaporation to form clouds. Water vapour condenses and falls as rain, which may produce streams and rivers. In many foreign countries outside the Caribbean, for example Canada, water on high ground is collected into a dam. The large amount of potential energy due to the height of the water is used to power water turbines, which generate electricity.

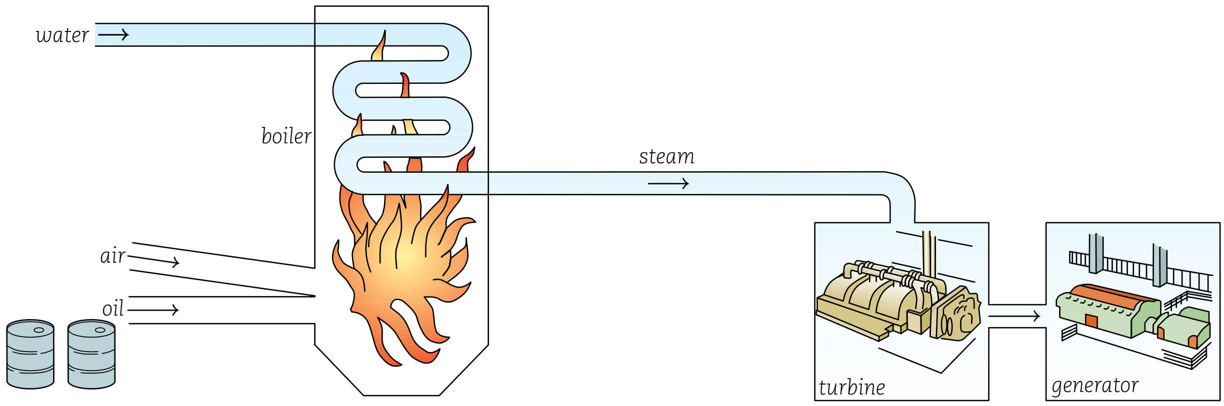
What are the forms of energy?

Energy appears in different forms, such as in the vibration of particles of matter, causing a temperature increase (heat); in the production of electromagnetic radiation such as light, heat and radio waves; in the movement of electrons through matter (electricity) and in the displacement (movement) of matter (mechanical energy). Other forms of energy include magnetic energy and sound energy.

Sometimes we produce certain forms of energy from others that may be more abundant, for example chemical energy in oil is changed to heat energy by burning, then into electrical energy for us to use as shown at the top of page 21.

How is energy measured?

Energy is measured by the amount of **work** it can do. Work may involve producing motion, overcoming gravitational force, a change of state (for example, water into steam), radiation (for example, production of light), overcoming frictional forces, or countering motion. The unit of work and energy is the **joule**. *The joule is the work done when a weight of one newton is raised to a height of one metre.*



Generating electrical power from oil

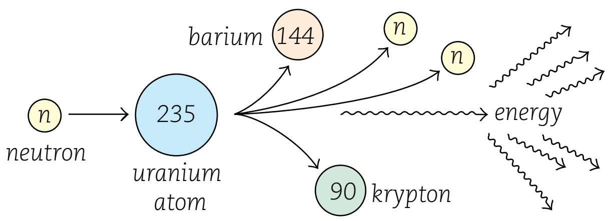
What is nuclear energy?

In the late 19th century and the early part of the 20th century, scientists found that some elements emit light and other types of radiation. These elements are called **radioactive substances**. Furthermore, some of these substances change into other new elements because they emit **alpha** and **beta** particles. This process is called **radioactive decay**. Some elements are naturally unstable and these slowly break down, losing energy in the radiation emitted.

One of the denser metals, uranium, exists mainly in two forms, called isotopes. Isotopes are forms of the same element. They have identical chemical properties but their **nuclei** have different numbers of particles in them.

The lighter isotope of uranium has an atomic mass of 235 and the denser isotope has an atomic mass of 238. The lighter isotope can be made to disintegrate by bombarding it with neutrons. When this happens the uranium splits up into lighter elements such as barium and krypton, and releases two neutrons and an enormous amount of energy. This is the energy that binds nuclear particles together and is called **nuclear energy**.

Nuclear energy is the most concentrated form of energy known. In this type of energy matter is directly converted into energy according to Einstein's equation $e = mc^2$ where e = energy, m = mass, c = universal constant (speed of light).



Where nuclear energy comes from

An extremely large amount of energy is produced from a relatively small amount of matter.

The type of nuclear reaction described above is called **nuclear fission**, because matter is disintegrated. The other type of nuclear reaction known is called **nuclear fusion** and this gives a much higher output of energy. The nuclear reactions in the sun (page 194) are of the fusion type. Many of the nuclear weapons stockpiled during the Cold War also used nuclear fusion. For fusion reactions to occur continuously, a temperature of 60 million °C or higher is required. These temperatures exist typically in the centre of stars.

What are the dangers of nuclear energy? One gram of nuclear fuel is over a million times more powerful than one gram of any other ordinary fuel. It therefore has a tremendous power output, which can be used destructively in war, or usefully in nuclear power plants to help solve the world's energy problem.

However, some major problems remain to be overcome. When nuclear energy is produced in nuclear power stations, radioactive waste materials are also produced. These waste materials send out harmful radiation, which is damaging to all living organisms. There is a serious problem in finding adequate means of getting rid of this waste because it will remain harmful for hundreds or even thousands of years.

Questions

1 Trace the energy that lights an electric bulb from its source, namely the sun.
2 Are sea waves powered by the sun?
3 Would you recommend the introduction of nuclear power plants in the Caribbean?

How can matter change?

How can matter be changed?

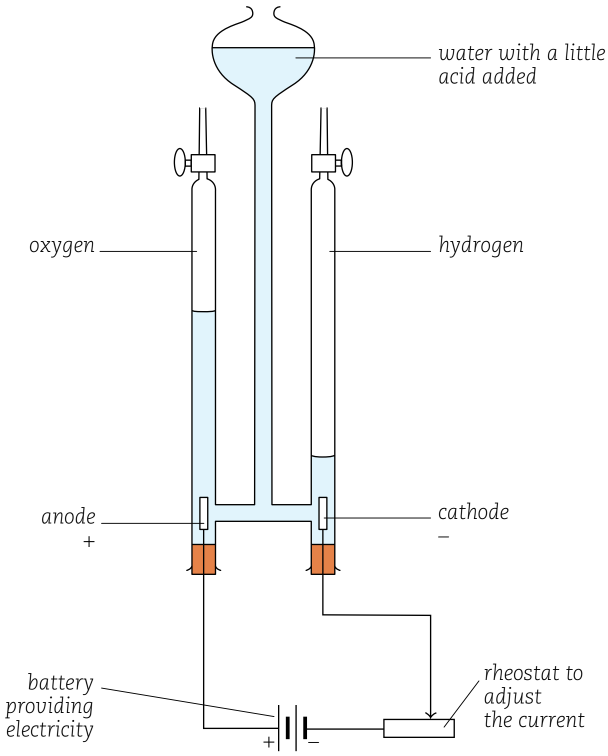
In the first few years of your school science course you will almost certainly have seen experiments in which matter has been changed. These changes usually involve one of the forms of energy – see page 20.

The most obvious way of causing a change in matter is to *heat it*. If you heat blue copper sulphate crystals, water is driven off, and a solid white substance (anhydrous copper sulphate) is left. If magnesium is heated, it burns, giving out very intense white light. A great deal of heat is given out too.

If *electricity* is passed through dilute hydrochloric acid, bubbles of gas are given off at each electrode. The electrical energy supplied causes this change.

We can also cause changes by *mixing* solutions together. These must contain chemical substances which react with each other. If iodine solution is added to starch solution a very striking blue-black substance is formed. This is a good test for the presence of iodine.You can also add a solid to a liquid, such as water or an acid. Magnesium metal will react with dilute acid and hydrogen is formed.

We can try to summarise this as follows. *Matter can be changed by supplying energy or by the chemical reaction of one substance with another. In each case, we start with one or more substances and we end up with one or more new substances.*



Electricity is used to break water down into its elements: oxygen and hydrogen

How can we show changes in matter?

When crystals of blue copper sulphate are heated, a white solid is formed. The gas given off condenses on the cool part of the tube and a colourless liquid is formed. The original blue crystals are hydrated copper sulphate; the white solid is anhydrous copper sulphate. The liquid formed is water.

When a piece of magnesium ribbon is held in a Bunsen flame, it begins to burn rapidly as soon as it is hot enough. Intense white light can be seen and heat energy is given out. The magnesium combines with the oxygen in the air to form a new substance, magnesium oxide. We can summarise the information we get from our observations by writing a **word equation**, but now we also say something about the energy involved.

(1) blue copper sulphate $\xrightarrow{\text{heat}}$ white copper sulphate + steam

(2) magnesium + oxygen $\xrightarrow{\text{heat}}$ magnesium oxide + energy

Magnesium and oxygen are called the **reactants**, and magnesium oxide is the **product**. In reaction 1, what is the reactant and what are the products?

State symbols tell us about the *physical state* of each reactant and product. Blue copper sulphate is a solid, so we can write this as copper sulphate (s). Steam is water in the gas state so we write this as water (g). Water itself is a liquid, so we write this as water (l). We can show changes in matter by writing more complete word equations, including the state symbols.

(1) blue coppper sulphate (s) $\xrightarrow{\text{heat}}$ white copper sulphate (s) + water (g)

(2) magnesium (s) + oxygen (g) $\xrightarrow{\text{heat}}$ magnesium oxide (s)

If you include the energy involved you have added a little more information and the equation may be more useful.

If a substance is dissolved in water, we say that it is **in aqueous solution**. We write the symbol (aq) after the substance to show this. When ammonia gas is dissolved in water we write this as ammonia (aq). When starch solution reacts with iodine solution, we write the word equation as:

starch (aq) + iodine (aq) → blue-black substance (aq)

When you investigate chemical reactions, you should always try to write word equations for the reactions.

How can we classify substances?

On page 18 an element was defined as a substance in which all of the atoms are the same. We can define elements more simply. When substances break down into two or more simpler substances we say that they **decompose**. These simpler substances can sometimes be broken down into even simpler substances. At some stage it will not be possible to break the substances down any further. When this happens we say that the substances are elements: they cannot be broken down any further by chemical means. *An element is the simplest substance which can be obtained by decomposition.*

The substance magnesium oxide contains two elements – magnesium and oxygen. Blue copper sulphate contains four elements – copper, sulphur, oxygen and hydrogen. White copper sulphate does not contain water, so there is no hydrogen present. It contains three elements – copper, sulphur and oxygen. Both magnesium oxide and copper sulphate are examples of substances called **compounds**. Compounds consist of two or more **elements**. *The elements in compounds are combined together in fixed proportions by mass.* Compounds such as blue copper sulphate can be broken down into simpler substances by heat energy.

Elements are joined together chemically in compounds. Water is a compound containing the two elements, hydrogen and oxygen, in fixed proportions. It is possible to mix the two gases, hydrogen and oxygen, together, and obtain a mixture of the two gases. The properties of the mixture are not the same as those of the compound. The mixture can contain the gases in any proportions, and the gases are not combined chemically.

Mixtures can contain elements or compounds or some combination of the two. The substances in a mixture are not chemically combined.

Questions

1. Define the following terms and provide an example: (a) decomposition (b) element (c) mixture and (d) compound.
2. Which of the following are compounds: (a) water (b) carbon dioxide (c) rum (d) air and (e) sodium chloride?

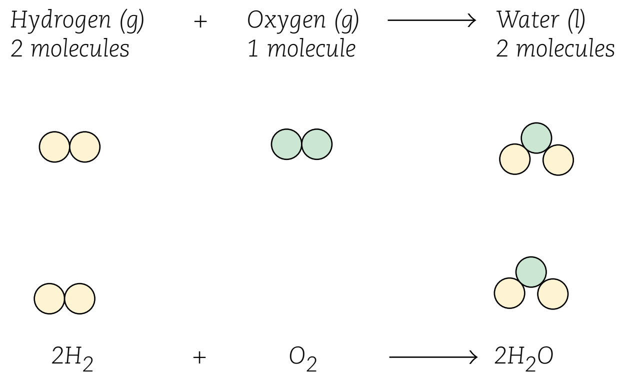
How do substances combine?

When hydrogen reacts with oxygen a new substance is formed – water. The properties of this new substance are not the same as those of either hydrogen or oxygen. We can try to explain this by suggesting that there are new particles formed when the particles of hydrogen and oxygen react. These 'compound particles' are called **molecules**. On page 18 we defined a molecule as the smallest part of a substance which can exist and still show the properties of the substance. Water is formed when *two molecules* of hydrogen react with *one molecule* of oxygen to form *two molecules* of water.

The word equation is:

hydrogen (g) + oxygen (g) → water (l)

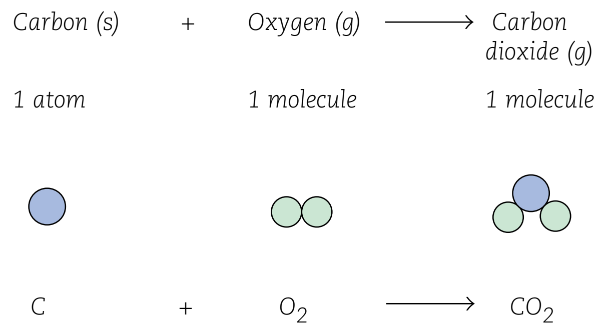
We can show this in a diagram like this:



Carbon reacts with oxygen to form carbon dioxide. Carbon is a solid and oxygen is a gas. The word equation is:

carbon (s) + oxygen (g) → carbon dioxide (g)

One *atom* of carbon reacts with one *molecule* of oxygen to form one *molecule* of carbon dioxide gas.



Most of the common gases are found as molecules. Each molecule of oxygen contains two atoms. Ammonia gas contains nitrogen and hydrogen. Each molecule of ammonia contains one atom of nitrogen and three atoms of hydrogen. When new substances are formed, new particles are formed. The new particles may be molecules but this is not always so.

Why is carbon so important?

What do you think the following things have in common: sugar, cheese, kerosene, gasoline, a compact disc and a plastic cup? The answer is that they all contain carbon. Carbon is a very important element in all living things, as well as in foods, fuels and plastics. Carbon is an element and it may be found in forms as different as diamonds (which are very hard and shiny) and graphite (which is soft and used as a lubricant). Charcoal is an impure form of carbon.

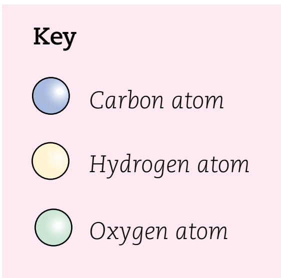
Activity | *Where can we find carbon?*

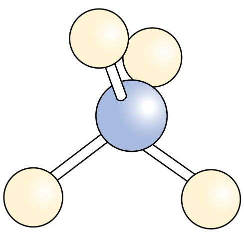
1. Heat a small piece of wood in a test-tube until there is no further change. What do you see remaining in the test-tube?
2. Hold a clean test-tube or tin lid in the yellow part of a Bunsen flame or a candle flame. What is formed on the outside of the test-tube or on the lid?
3. Your teacher will put a small quantity of white sugar in a small beaker and *carefully* add a few cm^3 of concentrated sulphuric acid. What happens to the sugar? What is left?
4. Put some kerosene in a bottle top, and then light it. Hold a test-tube or lid over the flame. What is formed on the outside of the test-tube or on the lid?

In each case, a black substance is formed, and it is reasonable to guess that this may be carbon. Most of the substances containing carbon are called **organic compounds**. You have looked at some of the properties of a few compounds – but there are many others containing carbon.

How can carbon form so many compounds?

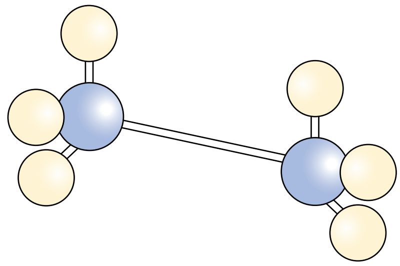
Methane is an example of a simple compound of carbon. It contains carbon and hydrogen. One molecule of methane contains one atom of carbon and four atoms of hydrogen. Turn back to page 18 to remind yourself about the meaning of the terms atom and molecule. The diagram shows a model of a **methane** molecule.





Methane

Now look at the diagram of an **ethane** molecule.

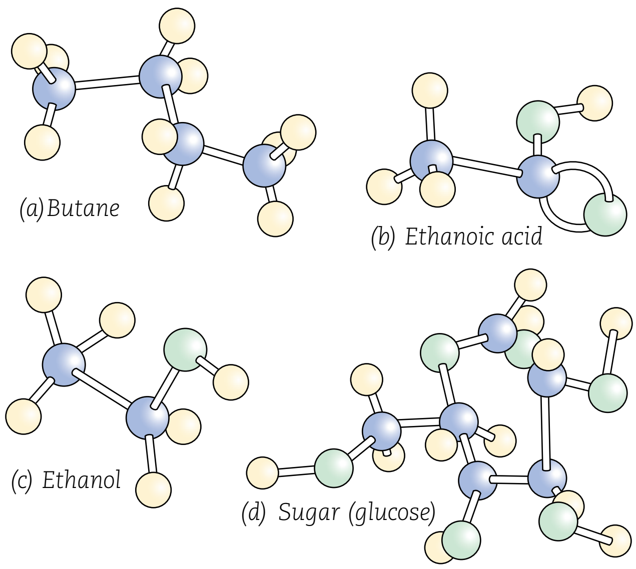


Ethane

Questions

1. How many carbon atoms are there in an ethane molecule?
2. How many hydrogen atoms are there in an ethane molecule?
3. How many hydrogen atoms are joined to each carbon atom?
4. Are the carbon atoms joined together?

Methane and ethane are examples of compounds which contain carbon and hydrogen only. These are called **hydrocarbons** (see pages 188–9). There are many carbon compounds in which the molecules contain carbon atoms joined to *four* other atoms. This is one reason why there are so many carbon compounds. The molecule of a carbon compound may be quite small – methane, for example – or larger, for example, the sugars. There are also very large molecules called **polymers** (see pages 204–5).



Look at the diagrams at the bottom of the previous page again. Each diagram represents a molecule of a different carbon compound. For each molecule, count the number of carbon atoms. Then work out how many atoms are joined to *each* carbon atom in the molecule of the compound.

The molecule shown in (a) is a hydrocarbon – it contains hydrogen and carbon only. There are three other compounds shown in (b) to (d). Each of these compounds contains *oxygen* as well as carbon and hydrogen. You can check this by looking at the key at the bottom of the previous page. Many of the compounds containing carbon, hydrogen and oxygen only are called **carbohydrates** or **fats**. Another important element found in many compounds of carbon is *nitrogen*. This is found in **proteins**, for example. You need to know about proteins, fats and carbohydrates when you are thinking about eating a healthy diet (see pages 74 and 76).

What are some of the important groups of carbon compounds?

We have used a number of different names for groups of carbon compounds. Although there are many groups, we shall concentrate on three in particular.

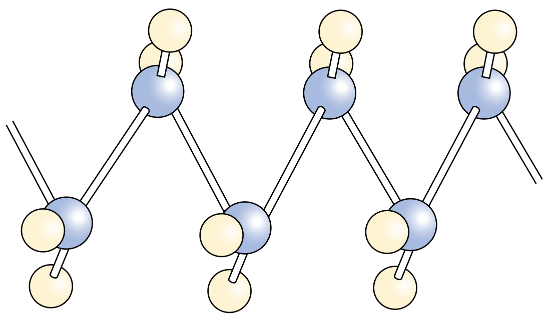
Fuels Fuels are compounds which burn in air. When fuel burns, energy is given out. Gasoline and charcoal are both examples of common fuels. Can you think of a few other examples of fuels?

When a fuel is burned new substances are formed and energy is given out. We have to think about where this energy comes from. It obviously has something to do with the chemical composition of the fuel, since different fuels burn in different ways – some give out a great deal of energy, and others less. You should remember that when new substances are formed, energy is either given out or taken in. When a fuel such as kerosene is burned, the new substances formed include compounds of carbon and hydrogen – as you might expect. Look at pages 188–91 for more information on fuels.

Foods There are three classes of foods: carbohydrate, protein and fat. Each of these contains carbon. Sugar is a carbohydrate, and therefore contains carbon, hydrogen and oxygen only. Proteins contain the same elements but also contain nitrogen. Some proteins contain sulphur as well. Plants can make food during **photosynthesis** (see pages 66–7). Energy is taken in as the new compounds are formed. This energy can be released during respiration in plants and animals – see pages 104–7. Foods act like fuels for living things.

Polymers These are compounds which contain very large numbers of atoms in their molecules. For example, the substance known as polythene – or more correctly, polyethene – contains very large numbers of carbon and hydrogen atoms. There are two hydrogen atoms for every carbon atom.

The diagram below shows a very small *part* of a model of a polyethene molecule. It shows how the atoms are joined together (see also page 204).



There are many polymers in nature, as well as polymers prepared industrially (synthetic polymers). Examples of natural polymers are cotton, silk and wool. There are now many synthetic polymers, such as plastics (see pages 204–5).

Objects made from a common polymer: plastic

Questions

5 What is meant by (a) a hydrocarbon and (b) a carbohydrate?
6 Which fuel is used for (a) aeroplanes (b) trucks and (c) heating?
7 Name three common plastics.