Introduction

Science in Focus is a series designed for pupils studying science at GCSE/Standard Grade level which will support both classroom and laboratory work.

The individual programmes are largely independent of one another (although in this **Materials** unit Programmes 1 and 2 are complementary) in terms of their subject matter. Students are encouraged to question the science they see on the screen and to contribute their own views. The problems and issues associated with these scientific ideas and their applications in the real world are also illustrated.

In this way we hope that these programmes will stimulate the interest of students in areas of the curriculum where the material is sometimes difficult to access.

This Study Guide provides support material for the problems and issues developed in the programmes and contains a brief summary of each programme, additional relevant background information and a series of possible student activities.

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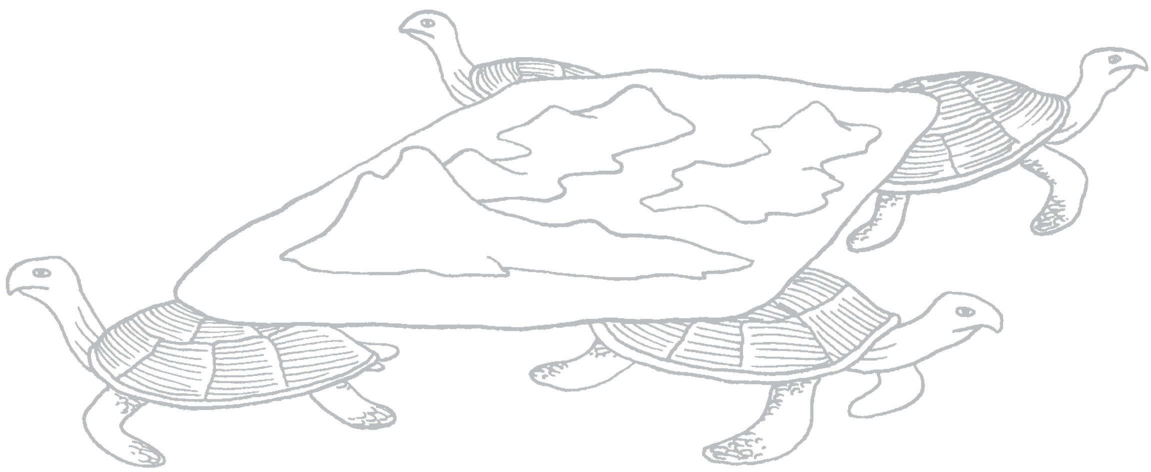


Rock Sculptures

Programme summary

The stunning background of Arizona's Painted Desert is used to explore the variety of rock types. The startling colours are explained in terms of their mineral content and the elements that colour them. The formation of different types of rock such as sedimentary and metamorphic rocks is beautifully illustrated. Computer graphics are used to demonstrate the forces of erosion and the ultimate destruction of the famous Three Sisters. The programme provides a useful summary of this wide-ranging topic.

Background information

What is a rock? We have names for the different kinds, such as pebble, boulder, stone – but what do they all have in common?

We need a working definition to help us identify a real rock when we see it. **A rock is made up of individual mineral particles that are cemented together or crystallised to form an interlocking mass.** So, rocks can be of any size and shape, they might be smooth or rough, heavy or light. Rocks found naturally on earth contain different types and quantities of minerals. Minerals are naturally occurring chemical elements or compounds that have a definite crystalline structure. They can be recognised by their appearance and other characteristics. For example, the mineral galena is found as large cubic crystals embedded in rock. The shape of the crystals is merely reflecting the way in which the atoms in galena are arranged.

Figure 1a: Galena in rock

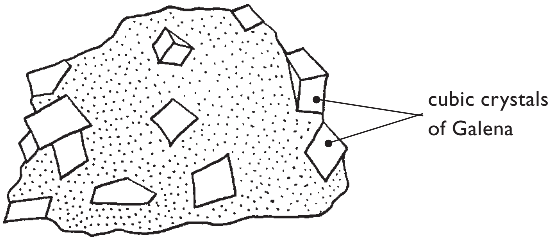
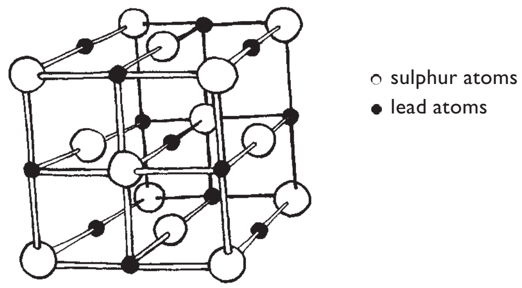


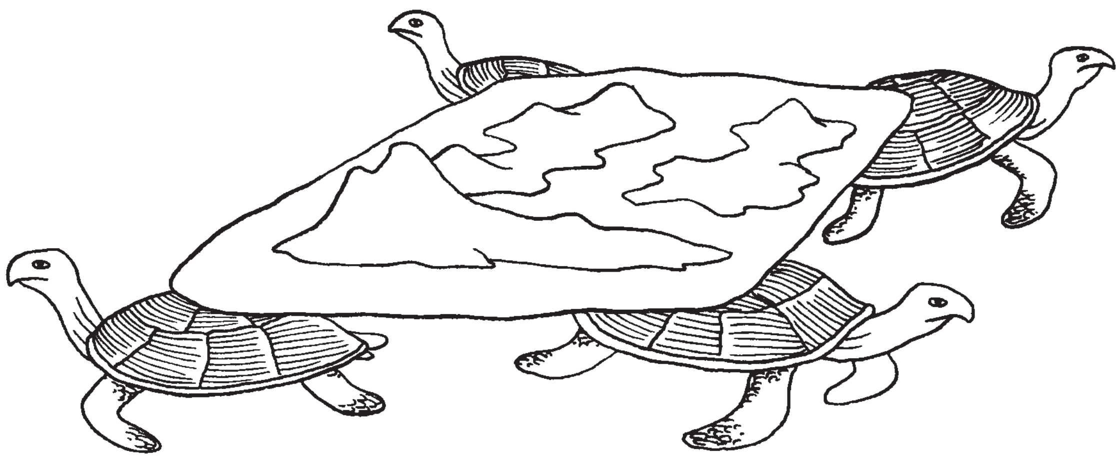
Figure 1b: Drawing of atomic structure of galena showing the arrangement of lead and sulphur atoms



The different types and quantities of minerals found in a rock are not just random, but are directly related to the way in which the rock was formed.

This leads us to our next big question: where do rocks come from? There always seem to be plenty around, but are rocks being made continuously or are we seeing the same ones over and over again? To find the answers we need to know a little bit about the structure of the Earth itself. Over the centuries there have been lots of theories about how the Earth was formed and of what it is made. Ancient civilisations had their own ideas, like the one below.

Figure 2: Four turtles carrying a flat Earth



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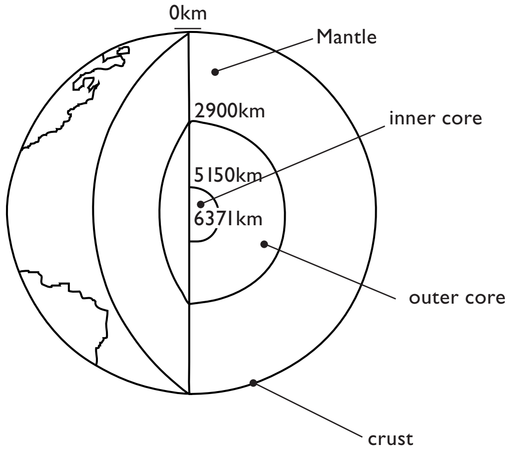
Elegant though such ideas were, they had little in the way of evidence to support them. Today we prefer theories based on observation and experiment. We know that the Earth is only one of many millions of planets in the universe, and it was probably formed around the same time as the other planets in our solar system.

Finding out about the Earth's internal structure has been a long and difficult process.

However, we now think we have a reasonable picture of what the centre of the Earth looks like.

Figure 3: Model Earth showing main layers in cut-away



It is the mineral-containing rocks that are the building blocks of the Earth's crust and new rocks are being formed all the time from the molten (liquid) layer beneath that crust.

Four main types of rock have been identified. Their names are linked to the processes that form them and each type of rock has recognisable characteristics.

Igneous rocks

Figure 4a: Intrusive igneous rock with large crystals

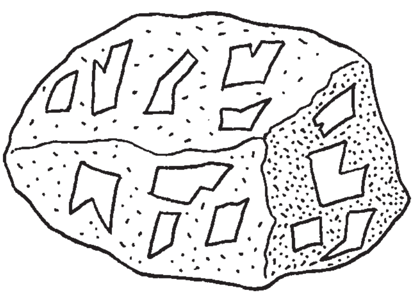
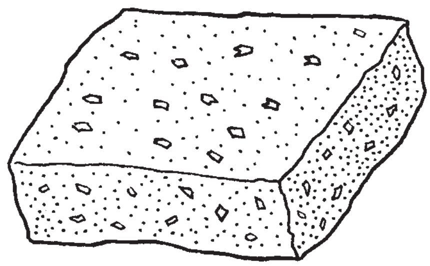


Figure 4b: Extrusive igneous rock with small crystals



Formed from liquid rock (magma). A uniform texture composed of randomly arranged interlocking crystals. Usually hard and do not scratch easily.

Extrusive igneous rocks (for example, basalt) have small crystals which form when the molten rock cools quickly in air or water. This can happen when magma is thrown out or expelled from a volcano.

Intrusive igneous rocks (for example, granite) have large crystals because the magma has been able to cool more slowly within the Earth's crust before being brought to the surface.

Sedimentary rocks

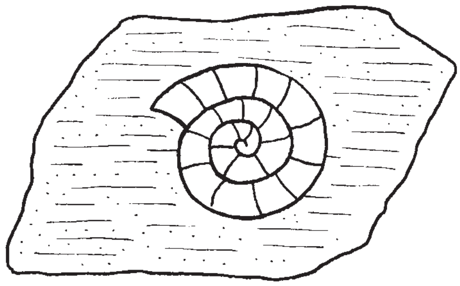


Figure 5: Sedimentary rock with fossil shell

Formed from fine particles of rock that have been worn (eroded) away on the surface of the Earth. The particles are deposited in layers (bands) that become cemented together by the weight of material above them. May contain fossils.

Metamorphic rocks

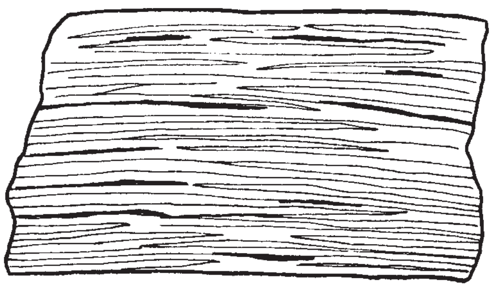


Figure 6: Metamorphic rock

Sedimentary rock that has been deeply buried becomes changed by heat and pressure. However, it does not melt and still retains the banding seen in typical sedimentary rocks.

Tasks and activities

True or False?

1 Sandstone is a sedimentary rock composed of fragments or grains derived from the weathering of pre-existing rocks.

2 Basalt is a fine-grained igneous rock that cooled from magma relatively quickly when compared with granite.

3 Granite and basalt are both examples of extrusive igneous rocks.

4 Sedimentary rocks crystallise from rocks melted at temperature below 100°C.

5 Igneous rocks are usually formed by the crystallisation of molten rock or magma.

Rock hard

It is the mineral content of rocks that gives them many of their recognisable characteristics. For example, the green colour of **malachite** is typical of copper-containing minerals. Hardness of rocks is also a valuable guide to their mineral content. A scale of hardness was devised by a German mineralogist, Frederick Mohs, in 1822. It uses a ten-point scale where 10 is the hardest and 1 the softest. The mineral with the higher number can scratch anything softer or equal to it in hardness. The Mohs scale is still in use today:

The Mohs Hardness Scale

1 Talc	**6** Feldspar
2 Gypsum	**7** Quartz
3 Calcite	**8** Topaz
4 Fluorite	**9** Corundum
5 Apatite	**10** Diamond

Substance X can scratch fluorite but not feldspar. Quartz can scratch X. Using the Mohs scale, what hardness is X? What mineral substance might it be?

Material questions

So far we have concerned ourselves only with natural materials, but these are becoming harder to find and more expensive. Material scientists spend a lot of time trying to find artificial materials to replace the use of natural ones. They also design new materials for specific tasks that are unsuitable for natural materials. For example, when the Space Shuttle made its first flight it had a covering of specially designed tiles made from a unique material. The tiles had to withstand the enormous temperatures and extreme conditions that the spacecraft would encounter on its long flight and on its re-entry to the Earth's atmosphere. Natural materials alone could not meet the demands of such a specialist job. In the home we have many artificially created materials that have been devised to make our day-to-day lives easier and cleaner.

Consider the following example:

An architect is designing a modern kitchen for a family with three young children; she knows that the cost and durability of the design are going to be important.

1 Think about the requirements for the kitchen design. Make a list of the characteristics that are going to be needed for the work surfaces.

2 Name four natural materials, for example marble, that you might use for the work surfaces. For each material give the advantages and disadvantages of its use.

3 If you could invent your own material for the work surfaces, what characteristics would it have and why?

In the programme we see an artist selecting from a range of materials. She has been asked to make a number of statues for a film set.

1 Marble was described as being too hard for this job. Why is this a problem?

2 Sandstone is much softer then marble and so relatively easy to shape. Why was it also rejected for the sculpture?

3 Alabaster was finally chosen to make the statues. What are the advantages of alabaster over the other two types of rock suggested?

Are you a petrographer?

Described below are some simple tests you might carry out for yourselves when trying to identify rocks. Your teacher will supply you with samples of different types of rocks and a range of chemicals and equipment. Remember to follow all safety instructions and to make careful observations. Identify each of your samples with a letter or number so that you can keep track of your results.

- Try to scratch each of the samples with a nail. Using the Mohs Hardness Scale put your samples in order of hardness.
- Using a hand lens look closely at the softest of your samples. Can you see crystals and/or fossils? Is it sedimentary, igneous, or metamorphic rock?
- Certain types of sedimentary rock contain calcium carbonate which reacts readily with dilute hydrochloric acid. Write the chemical equation for this reaction. Test a small part of each of the samples with a couple of drops of dilute acid and note your results.
- Some metamorphic rocks also react with dilute acids. What type of metamorphic rock would react in this way? Why would the reaction be similar to that with some sedimentary rocks?

Grand Canyon

Programme summary

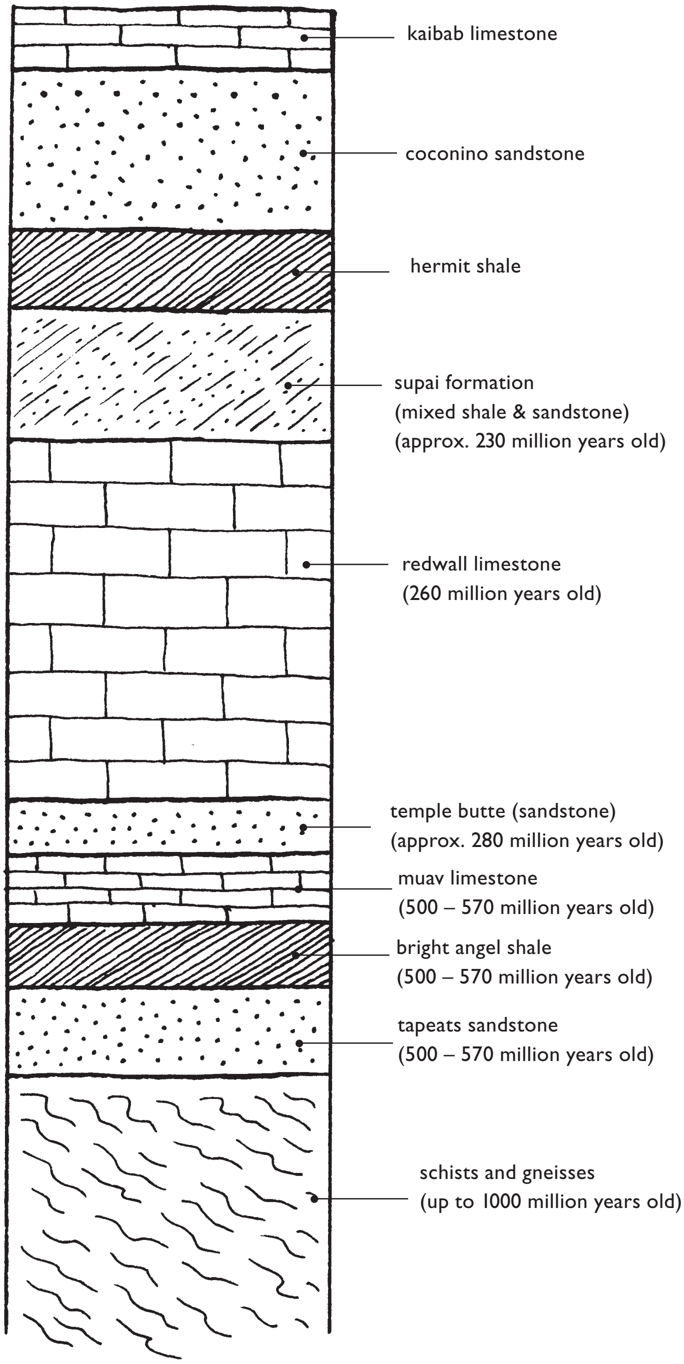
The effects of erosion are dramatically demonstrated by film of the beautiful Grand Canyon in north-western Arizona. The Canyon provides a stunning historical record of the region within its exposed rocks. The processes that produced its remarkable architecture are discussed and demonstrated using computer graphics.

Background information

The Grand Canyon is perhaps the most spectacular example of the effects of erosion to be seen anywhere on Earth. It is more than 1.6 kilometres deep, 349 kilometres long and varies in width from just 6 kilometres to 29 kilometres, However, the Grand Canyon itself is relatively young, having been formed by the action of the Colorado River about six million years ago.

At that time, the fast flowing water of the river cut into the rock by dissolving some of the minerals in the rock and carrying stones that scoured and abraded the river bank and bed. Along with the additional effects of weathering and extremes of temperature, an ever deeper and deeper channel was cut into the land. Although the Colorado River has now lost much of its original force these eroding actions are still going on today.

Figure 1: Typical section of Grand Canyon wall



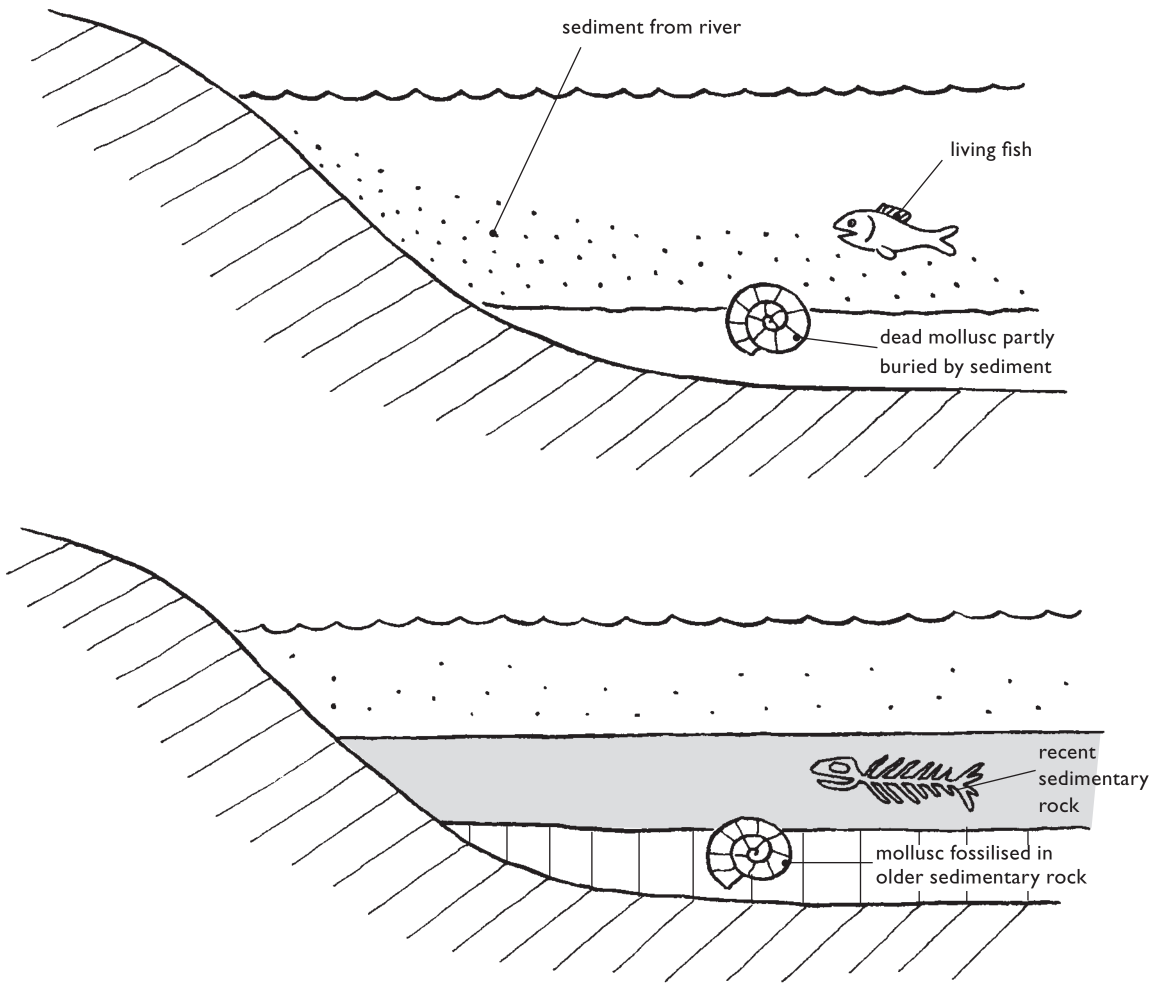
In the programme, as the camera looks down the steep sides of the canyon, many different coloured layers can be seen. These exposed rocks range in age from about 200 million years old, in the upper layers, to those in the bottom of the Canyon that are more than 1,000 million years old.

Most of the rock strata are sedimentary rocks containing numerous fossils which indicate that for a long period of time the Canyon area formed the floor of a shallow sea. The walls of the Grand Canyon provide what is known as a 'stratigraphic record of time'. This means that the order of the different strata or layers of rock can be used to calculate the time period over which those layers were formed. In the Grand Canyon nine main sedimentary rock layers can be seen, stacked on top of each other like giant pancakes.

The fossils found within these layers of rock provide clear evidence of the rocks' ages and origins. Many of the fossils are formed from the remains of sea creatures whose bodies have been preserved through time.

These days we do not have to rely solely on this comparative evidence to date the rocks. Indeed, since 1913 it has been possible to use radioactive decay methods to date rocks more accurately. This was a technique pioneered by Arthur Holmes who used **radio-dating** to confirm the ages of fossils whose stratigraphic ages had already been established. From then on we have been able to put absolute dates on the geological time scale. As will be seen later, this was not the only contribution that Arthur Holmes made to the science of geology.

Figure 2: Summary of fossil formation



Earth sculpture?

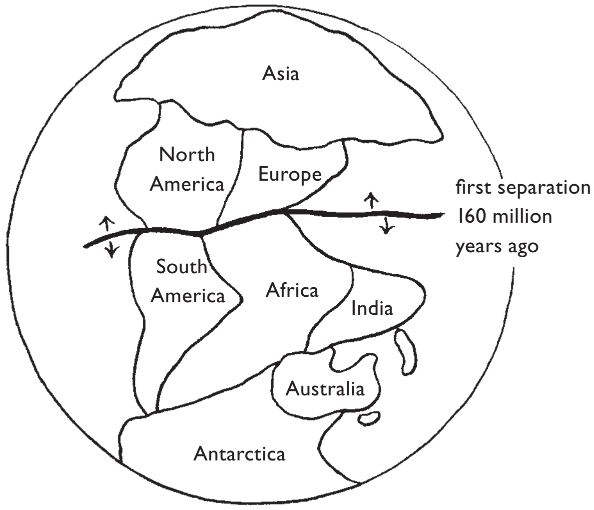
The Grand Canyon has provided us with a spectacular example of the power of erosion – but is that the only force at work in shaping the surface of the Earth? Parts of the wall of the Canyon indicate that some major upheavals of the land have also taken place in the distant past.

By studying other great geological features, and events such as earthquakes, we know that the surface of the Earth is not a rigid outer skin. Evidence indicates that the Earth's crust is in a state of continuous motion with some sections moving apart and others crushing together. These ideas were first proposed by Alfred Wegener in 1912, as **The Theory of Continental Drift**. Wegener proposed that the Earth originally had one super-continent that he called **Pangaea**.

This continent then split, eventually to give rise to the continents we have today. It was Arthur Holmes who, in 1928, proposed a mechanism for Wegener's Continental Drift theory.

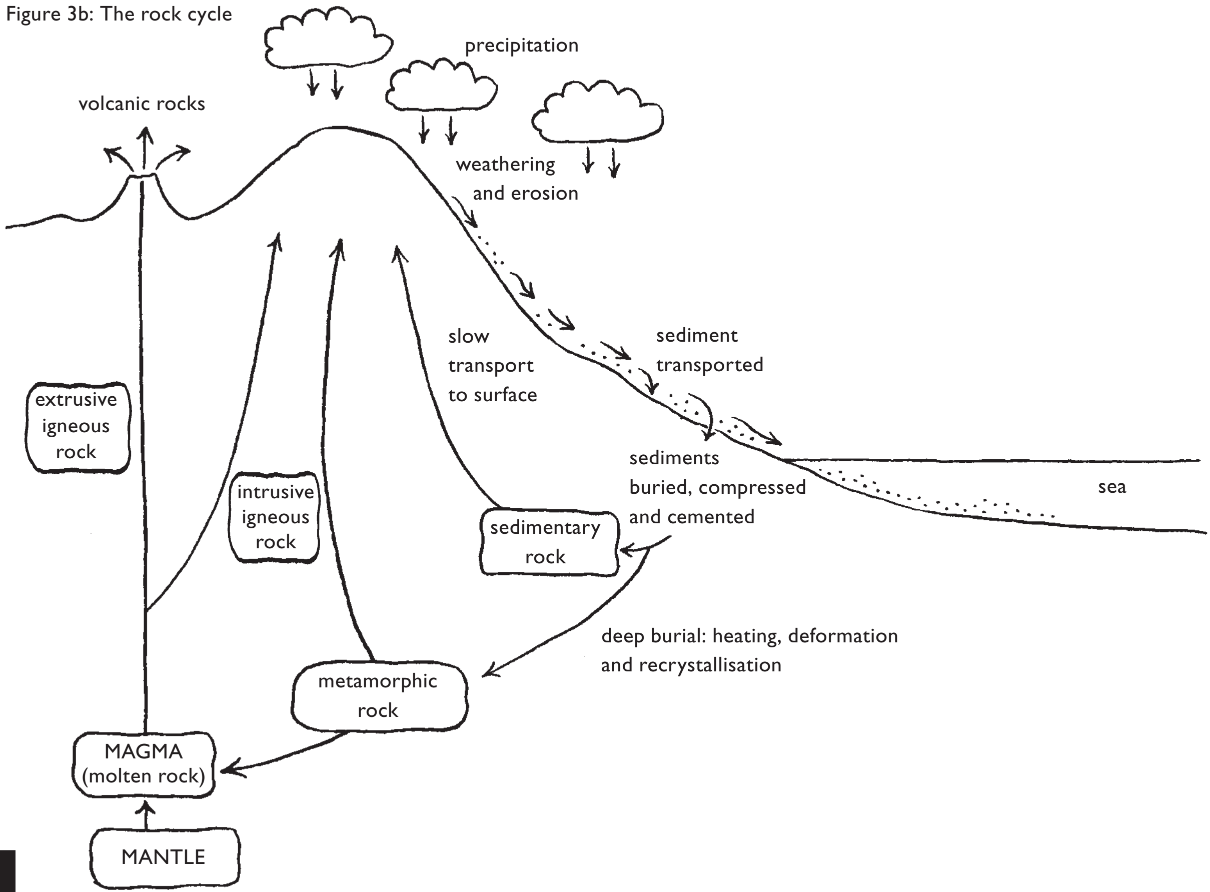
Holmes suggested that there are convection currents in the Earth's mantle that are the driving force for the movements of the huge surface plates

Figure 3a: Wegener's view of the 'super-continent' Pangaea. Gradual continental drift separated the super-continent into the arrangement we know today.



on which the continents rest. He believed that the heat for this convection came from the decay of radioactive elements deep within the Earth. Since that time, a great deal more evidence has accumulated that further supports Wegener's theory. **Plate Tectonics** is the name given to the modern theory now used to explain Continental Drift and other related processes. These processes are summarised below:

Figure 3b: The rock cycle



Tasks and activities

1 The rocks found at the base of the Grand Canyon, schist and gneiss, are both metamorphic rocks. Describe, with appropriate diagrams, how this type of rock is formed.

2 Explain why earthquakes and volcanoes are most commonly found along plate margins.

3 Where does the energy for the Earth's plate movements come from?

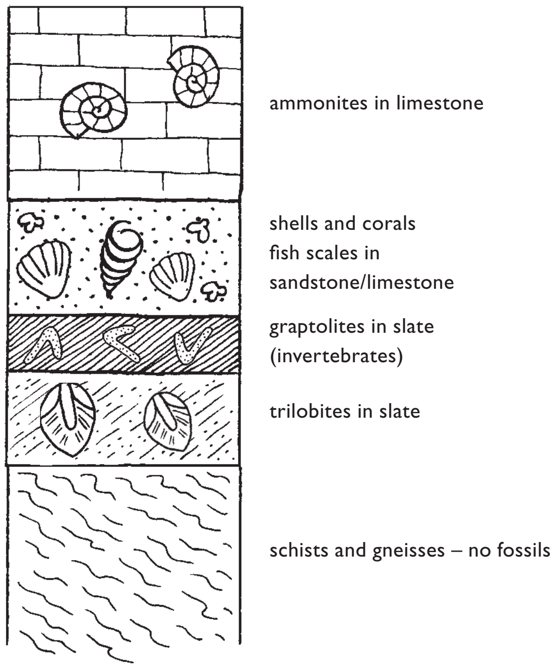
4 Figure 4 shows a section through sedimentary rock, such as that found in the Grand Canyon.

a How can we tell that this section of rock once formed part of a sea floor?

b Which section is the oldest and which is the youngest?

c The earliest forms of marine animals were............... They had soft bodies and no shell. Why are there no fossils present in the rock for this period?

Figure 4: Simple section through rock with fossils



5 Find out about the work of Alfred Wegener. Produce a poster that shows his vision of how the Earth looked when it had only one super-continent; and the progressive changes that have resulted in the arrangement of the continents we have today.

6 Work in small groups of three or four. Your task is to choose one of the following topics and explain it simply to others in your class.

a How different types of rock are formed

b The plate tectonic theory

c How the Grand Canyon was formed

Your presentation must include clearly labelled diagrams/photographs/pictures; headlines of the main points; and suggestions for getting further information.

7 Radioactive decay processes have been used for dating rocks A commonly used isotope (element) is uranium 235 that has a half life of 704 million years. Using the axes shown in Figure 5, draw a graph to show how much uranium 235 will be left after 2,000 million years.

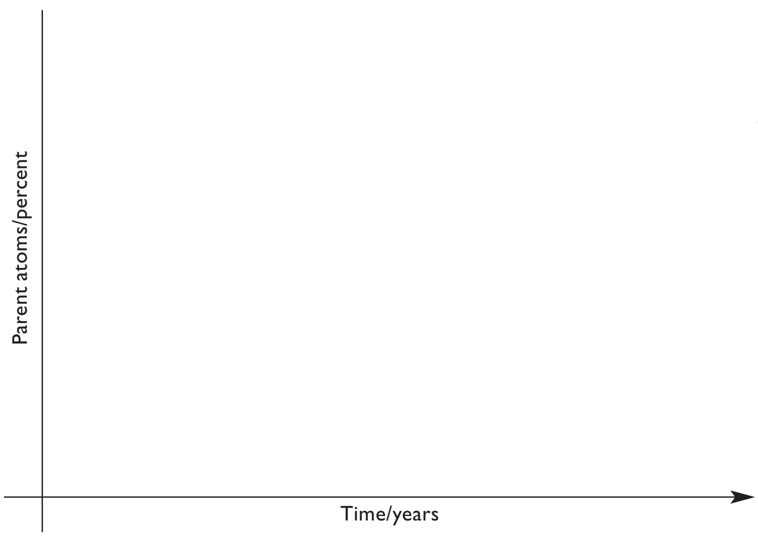


Figure 5: The process of radioactive decay

Periodic Table

Programme summary

The basic nature of why elements combine is explored using a familiar television-show format. Some of the properties of both metals and non-metals are shown in action, and the relationship between the electronic structure of elements and their capacity to react are clearly demonstrated. *(It would be helpful if you have a copy of the periodic table to which you can refer during the programme. You might also need to revise atomic structure in order to complete some of the written tasks.)*

Background information

Chemistry is all about the study of elements and compounds; to most people it seems to have little to do with everyday life. Nothing could be further from the truth! In fact, everything our world is made of – including computers, books, flowers, plum pudding, hair gel and even our own bodies – is composed of elements. All the living and non-living things on this planet, and beyond, are made up from a collection of about 90 stable elements. Complex living things, like us, consist chiefly of only two elements, hydrogen and oxygen (mainly as water). We contain less than 30 elements in all, most of these in minute quantities. The nature of everything around us is entirely the result of the properties of those individual elements and the compounds that they can make.

So where did the idea of elements come from? Who discovered the first one? How many are there? What are elements? What makes them fundamental to all materials? Are they just a random and haphazard collection of matter or is there some order to them?

Order from Chaos – a brief history of the Periodic Table

- 1661 Robert Boyle (Irish), began modern chemistry when he rejected the alchemist view that there are only the four elements of air, earth, fire and water. Instead he proposed that the elements are 'perfectly unmingled bodies' and that they can combine to make compounds.
- 1789 Antoine Lavoisier (French), published his Elementary Treatise on Chemistry. His work was based on experiment, for example, that air is a mixture of gases and that metals combine with oxygen. In his book he gave a list of elements, and a definition of a chemical element as 'the last point which analysis can reach'. Unfortunately Lavoisier was guillotined during the French revolution.
- 1860 Stanislao Cannizzaro (Italian), provided a consistent set of atomic masses that chemists could use to develop their ideas.
- 1864 John Newlands (English), showed that if elements are arranged in order of their atomic mass, then every eighth element has similar properties. He called this the Law of Octaves. Using this method, the halogens are in one group and the alkali metals in another. However, his law was not entirely accurate and he did not develop his idea further.
- 1868–70 Dmitri Mendeleyev (Russian), prepared the first periodic table of the elements. Taking the chemical properties of the known elements into account he arranged elements in order of their increasing atomic weight. The vertical columns in the table were called groups and the horizontal rows were called periods. Elements in the same group had similar properties. Mendeleyev was sufficiently confident of his work that he left 'gaps' in his table for elements that he said had yet to be discovered.
- 1913 Henry Moseley (English) demonstrated the link between an element's chemical behaviour – and therefore its position in the periodic table – with its atomic number. Using this information, he was able to predict the existence of a further six elements, which have since been discovered.

LEARNING

Table 1: Mendeleyev's periodic table of the elements

Group I	Group II	Group III	Group IV	Group V	Group VI	Group VII	Group VIII
H=1							
Li=7	Be=9	B=11	C=12	N=14	0=16	F=19	
Na=23	Mg=24	A1=27	Si=28	P=31	S=32	C1=35.5	
							Fe=56
K=39	Ca=40	?=44	Ti=48	V=51	Cr=52	Mn=55	Co=59
							Ni=59
Cu=63	Zn=65	?=68	?=72	As=75	Se=78	Br=80	
							Ru=104
Rb=85	Sr=87	Yt=88	Zr=90	Nb=94	M0=96	?=100	Rh=104
							Pd=106
Ag=108	Cd=112	In=113	Sn=118	Sb=122	Te=128	I=127	
Cs=133	Ba=137	Di=138	Ce=140				
							Os=195
		Er=178	La=180	Ta=182	W=184		Ir=197
							Pt=198
Au=199	Hg=200	T1=204	Pb=207	Bi=208			
			Th=231		U=240		

By knowing an element's position in the periodic table, chemists and other scientists find out about its likely characteristics. They can predict the types of reaction that a particular element will make and what compounds it is likely to form. Scientists can also use the periodic table to predict the existence of new and as yet undiscovered elements. Mendeleyev used his own periodic table to do this. For example, he predicted the existence of the element **gallium** long before its actual discovery. These days new elements are created rather than discovered, such as element 109 **unnilennium**, but they exist for only fractions of a second. Notice also that the periodic table has a group of elements known as the **'transition elements'**. One of their more unusual properties is that many of their compounds are brightly coloured. This is because they can absorb visible light, the colour depending on the frequency of light that they absorb. So in water, some chromium salts are violet; some manganese salts are pale pink or purple; and copper salts, like copper (II) sulphate, are usually bright blue. Knowing the colour associations can help you to identify transition metal compounds.

Tasks and activities

1 Table 1 above represents one of the periodic tables that Mendeleyev produced. Compare this with the modern periodic table in use today. Elements that Mendeleyev predicted, but at that time unknown, are marked with a question mark. Identify the missing elements.

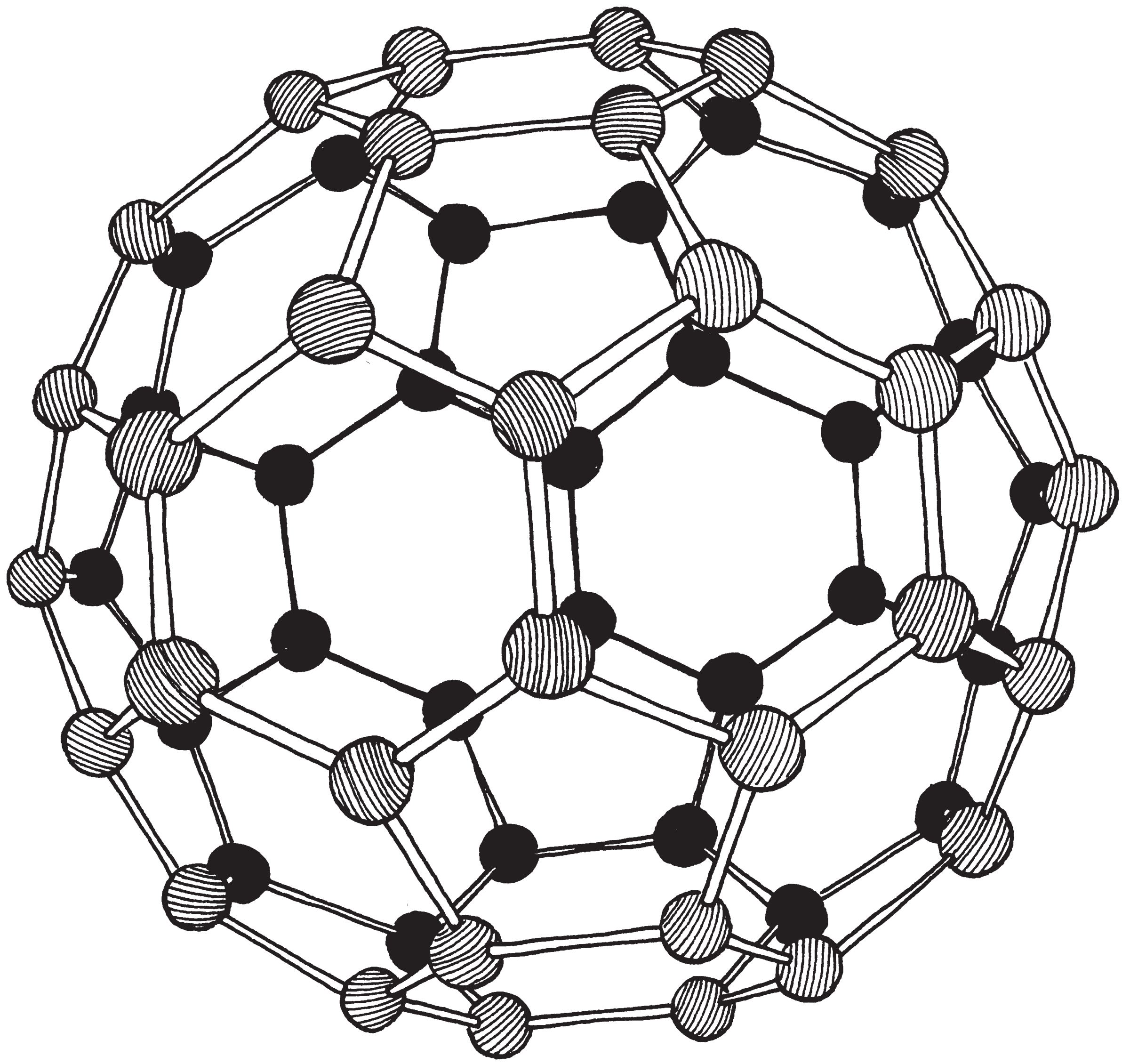
2 Look at Group 1 in Table 1 and compare it with Group 1 in a modern periodic table. Which elements appear in both tables? In which group is silver and gold now placed?

3 Identify the noble gases in the modern table. Why are there no noble gases in Mendeleyev's periodic table?

4 Which element is named after Mendeleyev? What other elements are named after famous scientists?

5 Some elements can exist in more than one form, for example, oxygen. This is most familiar as the colourless gas 0_2, but it can also exist as 0_3, the gas ozone. Carbon also exists in more than one form. Figure 1 shows carbon in one of its most recently identified forms: a carbon cage molecule known as **'buckminsterfullerene'**. This discovery, published in 1990, was the result of years of work by **Kroto, Smalley,** and others, for which they were awarded the 1996 Nobel Prize for Chemistry.

Figure 1: C60 Buckminsterfullerene. A modern soccer ball has the same symmetrical pattern.



This molecule was named after the architect Buckminster Fuller, whose 'dome' designs provided a clue to the molecule's shape.

Name two other forms (allotropes) of carbon. Use your text book to find diagrams of the molecular structures. Explain what you can about the physical properties of each form of carbon from looking at the structures.

6 It is often said that royalty have blue blood – they don't of course! However, there are some creatures that do have bluish blood – lobsters, for example. Using the background information given earlier, what metal ion do you think lobsters have in their blood? What is the metal found in human blood that gives its characteristic red colour? What other common red/brown compound does this metal make? (Clue – it is often seen on old cars.)

7 The noble gases were so called because it was believed that they would never form chemical compounds. However, in 1962 Neil Bartlett, an inorganic chemist, isolated a compound of xenon and fluorine '$Xe(PtF_6)$'. We now know of hundreds of other noble gas compounds. Noble gases are in Group 8 of the periodic table.

What do all the noble gases have in common that makes them less reactive than other elements?

Models

Programme summary

Live action film and computer graphics are used to demonstrate how models can be used to represent reality. Our understanding of how the world works depends upon our ability to grasp difficult ideas and concepts. Models help us to do this. Their uses are diverse – from aircraft design to the behaviour of elements during chemical reactions.

The programme shows numerous examples, ranging from everyday life to high science.
It explains how scientific and technical information can be represented symbolically in useful ways to enhance communication and understanding.

Background information

What is a scientific model? Why are they useful? Are they a true representation of reality?

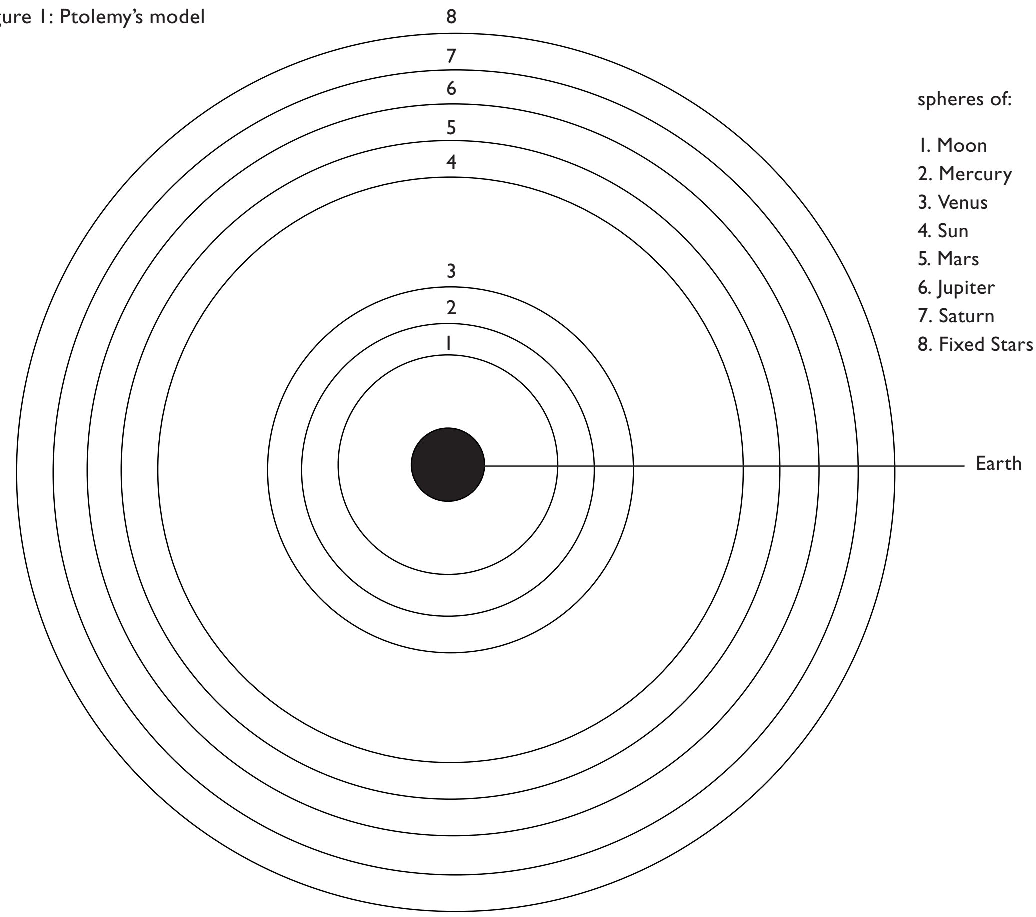
Let's start by defining a model. The Oxford English Dictionary defines a model as **a simplified or idealised description of a system, situation or process, often in mathematical terms, devised to facilitate calculations and predictions.** In other words, models are a way of representing an object or process in such a way that it makes it easier to understand.

What is our earliest recording of a scientific model being used? Not surprisingly, early research was centred on what could be seen around us – the Earth, Sun, and Stars. So, models of the universe and solar system were some of the earliest models used.

Remember, that the purpose of a scientific model is to explain an observation or theory. The model must fit all the information known at that time. Much of early scientific study occurred in ancient Greece. Ptolemy (c. 90–170) was an Egyptian–Greek astronomer who was very influential in shaping our early ideas. His observations about the Earth and heavens dominated astronomy for fourteen centuries.
He believed in an Earth-centred or **geocentric universe**, with the Sun and other planets attached to spheres revolving around us. He represented his ideas using a model.

Ptolemy's model was a useful one because it fitted all the facts known at that time and allowed a framework for further study. This model was changed, in the light of new information, initially by Copernicus who, in 1514, visualised the Sun-centred or **heliocentric solar system** that we know today. Copernicus's model has been modified many times to incorporate new knowledge.

Figure 1: Ptolemy's model

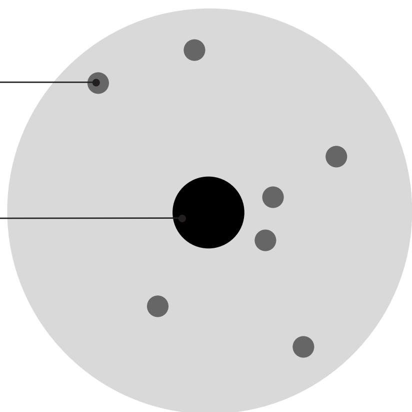


Astronomical research is, of course, still going on today, but we are now also concerned with things closer to home and on a much smaller scale. We know from the programme that we can, for example, use representations of the underground transport system to make it easier to use. Can we use similarly simplified models to understand things that are much less solid and tangible? The answer, of course, is yes. We shall now look at a few of the great advances in the sciences where models have played a significant part.

Seeing the invisible

Atoms are invisible to the naked eye, so how do we know that they exist? By experiment of course! Early experiments, such as those by Boyle, Lavoisier and Dalton indicated that atoms existed. It was left to others to come up with an idea of what an atom 'looks' like. Amongst the earlier models was Rutherford's. He depicted the atom as a miniature solar system.

Figure 2: Rutherford's atom



This model was satisfactory for a while, but could not explain all the phenomena produced by experiments, so further models were created.

Figure 3: Bohr model

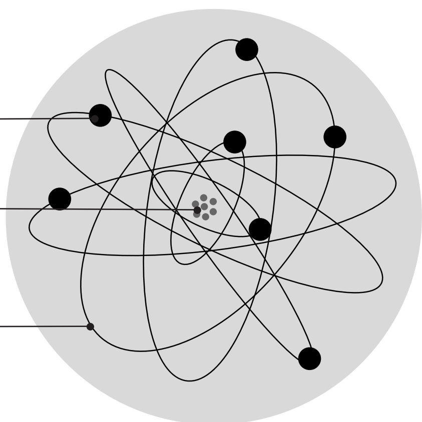
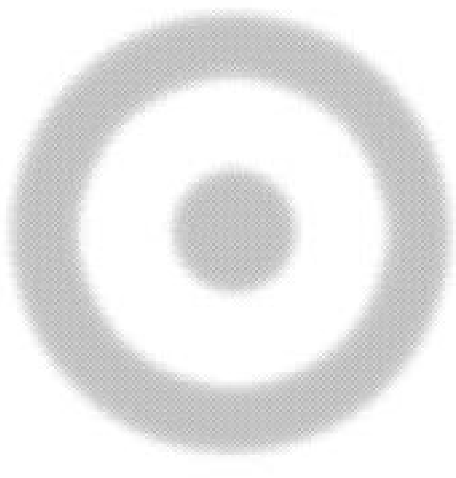


Figure 4: Schrödinger model (abandoned the idea of precise orbits, replacing them with a description of the region of space where electrons were most likely to be found).

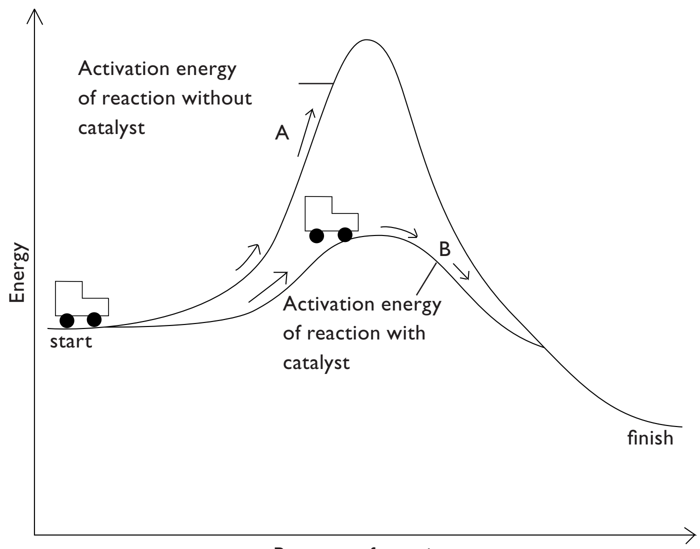


Even this latest version does not answer all our questions about the atom, but it is sufficient for most purposes.

Over the hill chemistry!

The action of catalysts and their ability to speed up chemical reactions was one of the most puzzling aspects of chemistry. The effects of catalysts have been observed for centuries but it was only when we understood the importance of the energy balance of chemical reactions that we were able to establish how catalysts work. A simple model is now used to explain this:

Figure 5: Action of catalysts

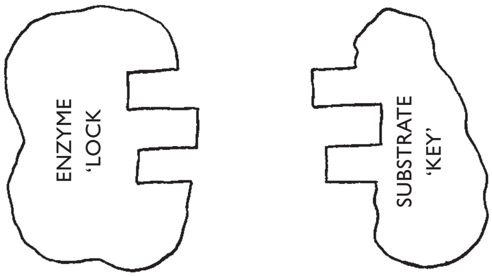


A – car has too little 'power' to get over hill.
B – 'Tunnel' through the hill means the car needs less power to reach the finish.

LEARNING

Enzymes are a special type of catalyst found in living things. One of their properties is that they can select the chemicals for reaction from a mixture of many different chemicals – i.e. we say they are specific. How do they do this? We explain it by saying that they have a shape that is complementary to the reactants – commonly called the lock-and-key hypothesis.

Figure 6: Enzyme lock and key



Again a model is useful in helping us to understand how something works – but it is not meant to be a true likeness of these very complicated molecules!

What's in a name?

In the programme we see carbon represented by not one, but two models – a graphite model and a diamond model. Both materials are made of carbon and yet we know just by looking at them that they have very different properties. Properties that can be explained by looking at the way in which the carbon atoms are arranged. Water can also take different forms, with many different properties and uses. We can visualise the different types as molecular models. We know how the elements are arranged because we know what the lengths of the bonds are; and how the elements interact with each other. From this we can construct a working model – but it is not the real thing.

Figure 7a: Water molecules in liquid water

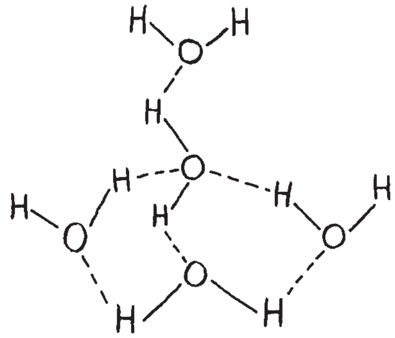
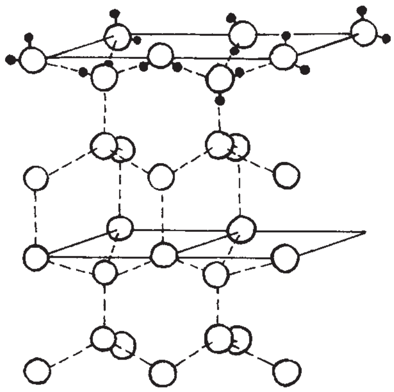


Figure 7b: Water molecules forming the lattice structure of ice



● oxygen (shown in first layer only)

◠ hydrogen

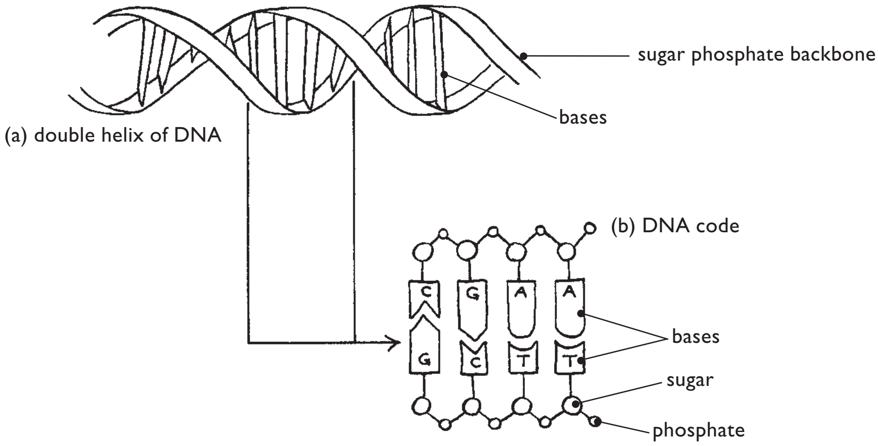
Molecular models make it much easier to understand chemistry and to be able to predict the results of chemical reactions – but like all models they have their limitations.

A model of life itself

In conclusion, we will consider perhaps the most significant model to date, the one that explains the secret of life itself – **the model of DNA**.

Watson and Crick provided an answer to one of our most fundamental questions – is there a blueprint for living things? Their model of DNA fitted all the requirements. A chemical that could produce almost infinite variety and yet also produce identical copies – one that could be made up of simple substances found in the most primitive and the most advanced organisms – **The Double Helix**.

Figure 8: DNA



This model of DNA has been the basis of one of our most powerful sciences, that of genetic engineering. With its implications for the manipulation of all life forms, including the creation of new ones, it has implications that we can only just begin to understand.

Tasks and activities

1 A chemistry student built a molecular model of hydrogen(H_2). Her brother became very frightened when shown the model because he knew that hydrogen gas could be explosive and thought that he was in danger. How would you explain to the brother the difference between a model and the real thing?

2 In the programme you see a map of the London underground system.

a Is this a true representation of the underground rail network?

b Would this be a useful model to use for driving around London? Explain your answer.

3 Look up an experiment that you have done or a demonstration that you have seen where a model has been used. For example, a model lung to explain breathing; wave models in physics; models of industrial processes in chemistry.

a Explain how the model works.

b What it explains.

c How it differs from the real thing.

d What the limitations of the model are.

4 A computer modelling system of the weather is shown on the programme. Find out why a computer model is more useful than a conventional model for explaining weather effects. In what ways are computer models superior to conventional models?

5 Working in a group of three or four, devise a simple model to explain one of the following processes:

a the action of the enzyme **amylase** on starch;

b the transmission of energy by waves;

c the difference between direct current and alternating current;

d the replication of DNA;

e continental drift.

Credits

Produced by: **Prospect Television**

Producer/Director: **Lambros Atteshlis**

Assistant Producer: **Hazel Graham**

Consultant: **John Holman**

Study Guide written by: **Christine Ryan**

Study Guide edited by: **John Austin**