Earth
Earth structure *and* Universe

Ideas you have met before

Rocks have properties which can be studied

Rocks can be grouped together based on their appearance, such as whether they have grains or crystals.

Different kinds of rock can be compared and grouped together on the basis of their physical properties.

Formation of rocks

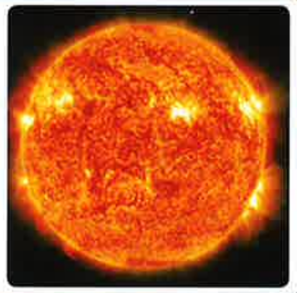
Fossils are formed when organisms are trapped within the layers of sedimentary rock.

Soils are made from rocks and organic matter.

The Earth in space

The Sun, the Earth and the Moon are approximately spherical objects.

The Sun is our nearest star but there is an unimaginable number of other stars.



The Earth and other objects in space move

The movement of the Earth, and other planets in the solar system, can be described relative to the Sun.

The Earth's daily spinning motion explains day and night and the apparent movement of the Sun across the daytime sky.

The movement of the Moon can be described relative to the Earth.

In this chapter you will find out

The rock cycle

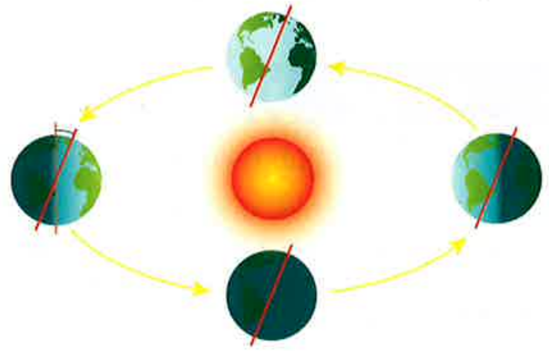
- Sedimentary, igneous and metamorphic rocks can be inter-converted over millions of years, through weathering and erosion, heat and pressure, and melting and cooling.
- Magma from volcanoes solidifies to form igneous rock.
- There is a relationship between the shape of a volcano and the type of magma it produces.
- There are different ways that fossils can form in sedimentary rock.
- Rocks are continually being broken down and new rocks are formed. This is described by the rock cycle.
- The constant movement of the Earth's crust causes rocks deep underground to be brought to the surface and mountain ranges to form.

The Earth in the Universe

- Distances in space are so vast that special units are used to measure them.
- Our solar system is a tiny part of a galaxy, one of many billions of galaxies in the Universe.
- Light takes minutes to reach Earth from the Sun, four years from our nearest star and billions of years from other galaxies.

The movement of objects in space

- The solar system can be modelled as planets rotating on tilted axes while orbiting the Sun, moons orbiting planets, and sunlight spreading out and being reflected.
- This explains day and year length, the seasons, and how we see objects from Earth.



Understanding the structure of the Earth

We are learning how to:

- Name the layers of the Earth.
- Describe the characteristics of the different layers.
- Explain how volcanoes change the Earth.

The Earth has various layers, some of which are constantly moving. What are the different layers of the Earth called? What are their features?

The Earth's layers

The Earth is made up of different layers:

- **core** (part solid and part liquid);
- **mantle** (semi-liquid and solid);
- **crust** (solid).

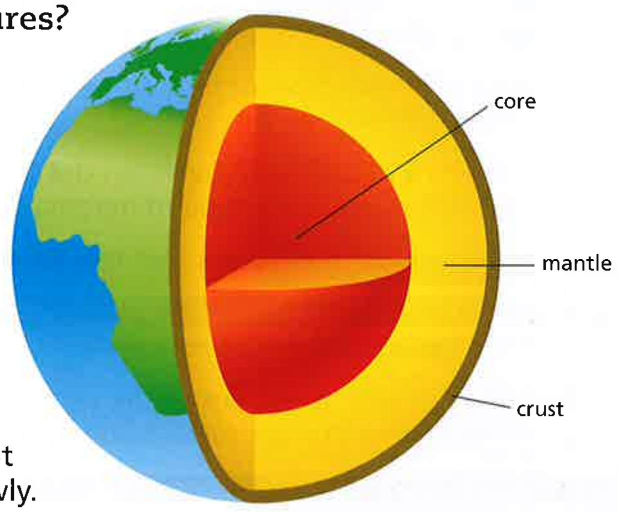


FIGURE 1.7.1a: The crust is the outer layer of the Earth – it is the land on which we live.

The crust and the outer (solid) part of the mantle are called the **lithosphere**. This consists of pieces of rock called **tectonic plates** that float on the semi-liquid mantle and move about slowly.

It is difficult to study the structure of the Earth directly because the crust is too thick to drill right through. However, scientists can study how waves made by earthquakes and explosions travel through the Earth. This gives them evidence of the different types of material in the different layers.

1. Suggest a kind of fruit which, when cut open, might look rather like a sectional view of the earth.
2. Why do scientists have earthquake sensors all over the world?

Features of the layers

The Earth's core is very hot. It consists of nickel and iron.

The mantle is the very thick middle layer (about 3000 km thick). It contains silicon, magnesium and iron, in the form of oxides. The flowing mantle material transfers heat outwards from the core.

The crust is relatively thin (5 km to 100 km thick) and rocky. There are two types – the dense, thinner oceanic crust (made of basalt) and the less dense continental crust (which is granite).

The Earth's lithospere is a relatively cold part of the Earth. It is made up of about 20 tectonic plates. These move at a rate of about 2.5 cm per year on average. Over millions of years this has allowed whole continents to shift thousands of kilometres apart. This process is called 'continental drift'.

3. Explain the difference between the two types of crust.
4. How do continents move?

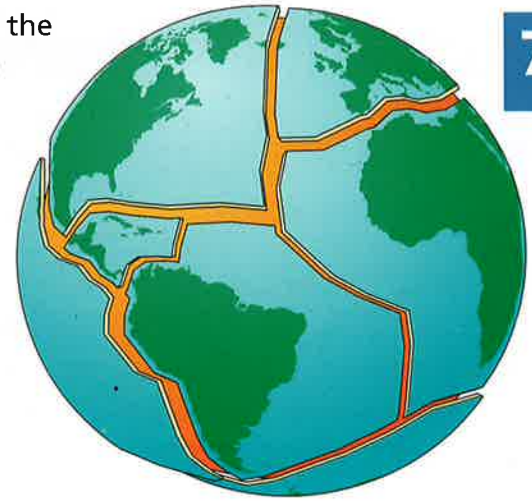


FIGURE 1.7.1b: The map of the Earth is changing very slowly because the plates are constantly moving.

Changing the Earth's surface

Where tectonic plates meet, they can push against each other, or move under or over each other. Earthquakes and volcanic eruptions occur at these points, and the crust may crumple to form mountain ranges. **Magma**, which is molten rock from the mantle, is less dense than the crust. It can rise to the surface through volcanoes (weak areas of the crust). **Lava** is the molten rock that escapes onto the Earth's surface. As this cools down it solidifies.

Geologists study volcanoes to try to predict future eruptions and to study the Earth's structure. Volcanoes can be very destructive. Even so, farming communities may choose to live near them because volcanic soil is very fertile.

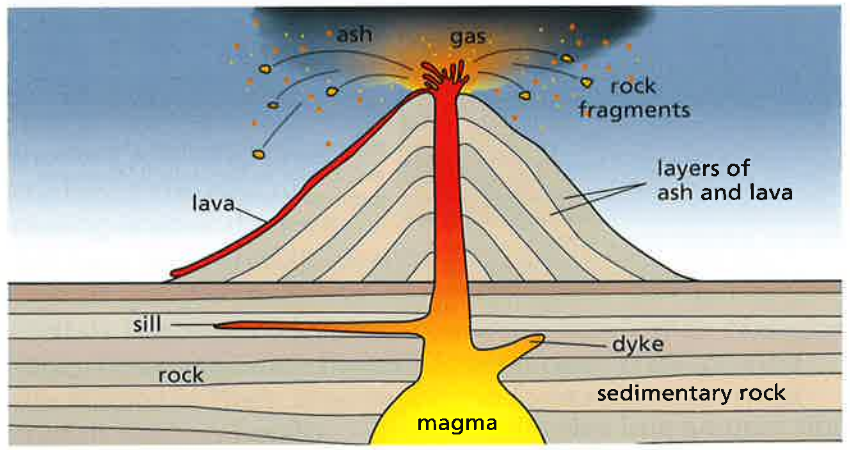


FIGURE 1.7.1c: The inside of a volcano, showing how the layers of ash and lava build up.

5. How do volcanoes form?
6. What is the difference between lava and magma?

Did you know...?

The cinder cone volcano Paricutin appeared in a Mexican cornfield on February 20, 1943. By the end of a year it was 336 m tall, and it reached its tallest height of 424 m in 1952. In geology, that is very quick.

Know this vocabulary

core
mantle
crust
lithosphere
tectonic plate
magma
lava

Exploring igneous rocks

We are learning how to:

- Describe how igneous rocks are formed.
- Explain how the pH of the magma affects the formation of rocks.
- Investigate the effect of cooling rate on the formation of crystals.

Some of the oldest rocks on Earth are igneous rocks. Other igneous rocks are being formed right now. The word 'igneous' comes from a Greek word for 'fire'. How do igneous rocks form? What are their features?

What are igneous rocks?

Igneous rocks form when hot molten rock from the Earth's mantle cools down and hardens. They have no layers, may be light- or dark-coloured, usually have crystals and rarely react with acids. They do not contain fossils because these would have melted when the magma formed.

There are two main types of igneous rock:

- **extrusive** – these form when magma flows onto the Earth's surface;
- **intrusive** – these form from magma below the Earth's surface in the crust.

Igneous rocks make up most of the rock on Earth, but they are often buried below the surface. One of the most common igneous rocks is granite, which is used for building and making statues. Other examples are pumice, basalt and obsidian.

FIGURE 1.7.2a: The Sierra Nevada mountains in the United States are made of granite.

1. Name four igneous rocks.
2. Describe some of the features of a typical igneous rock.

Looking at magma

Some volcanoes formed from acidic magma and volcanic ash. They are typically steep and conical, for example Mount Fuji in Japan. These volcanoes often exceed heights of 2500 m. They have periodic explosive eruptions. The acidic lava that flows from them is very viscous (thick and sticky). It cools and hardens before spreading very far. Rocks formed from acidic magma include granite, pegmatite and pumice.

FIGURE 1.7.2b: Mount Fuji was formed from acidic magma. Olympus Mons on Mars was formed from alkaline magma.

Other volcanoes formed from alkaline magma. They typically have shallow, sloping sides – for example, Olympus Mons on Mars and the Hawaiian volcanoes. They often eject large amounts of lava onto the ground. The alkaline lava that flows from them is thin and runny. It can travel long distances before it cools and hardens to form rocks. Rocks formed from alkaline magma include basalt and gabbro.

3. How does pH affect magma?
4. What is the relationship between magma viscosity and volcano shape?

Did you know...?

Obsidian forms from magma that cools so rapidly that no crystals develop – it forms a glass.

Crystal size

The rate at which lava or magma cools determines the size of the crystals in an igneous rock. If the rate of cooling is fast, the rock will have small crystals. If the rate of cooling is slow, the rock will have large crystals. Granite cools slowly and has large crystals; gabbro cools even more slowly and has even larger crystals. Intrusive rocks often cool more slowly than extrusive rocks. However, when **fissures** (cracks) open underground, the magma in them cools quickly to form rocks with small crystals (such as basalt).

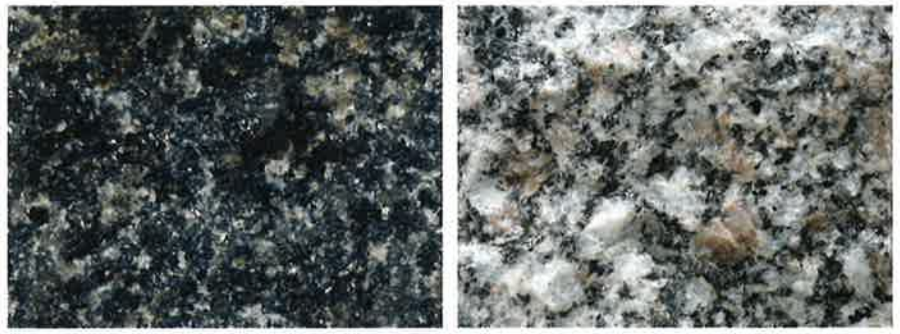


FIGURE 1.7.2c: Look carefully at the magnified images of these two rocks. What conclusions can you come to about how they cooled?

5. What is the relationship between rate of cooling and crystal size?
6. Compare the rate of cooling in intrusive and extrusive rocks.

Know this vocabulary

igneous rocks
extrusive
intrusive
fissure

Exploring sedimentary rocks

We are learning how to:

- Describe how sedimentary rocks are formed.
- Explain how fossils give clues about the past.
- Explain the properties of sedimentary rocks.

Sedimentary rocks are formed over thousands or even millions of years. What are their features? How are they formed?

Rocks in layers

Rocks suffer **weathering** and **erosion** – pieces break off and are then transported by wind or water. When river or sea currents slow down, rocks, pebbles and sediments drop to the riverbed or seabed – this is **deposition**. Over millions of years they are buried under more sediments. The weight of the upper layers compacts (presses together) and cements (sticks together) the lower sediments to form **sedimentary rocks**.

Sedimentary rocks are usually crumbly, found in layers called **strata** and can contain **fossils**. Examples are:

- sandstone – made of sand particles;
- limestone – made of tiny shells and skeletons of marine organisms;
- shale and mudstone – made of silt and clay particles that are too small to see;
- conglomerate – made of rounded pebbles.

1. How do rocks become sediments?
2. Name and describe three sedimentary rocks.

FIGURE 1.7.3a: Sedimentary rocks build up in layers and may contain fossils.

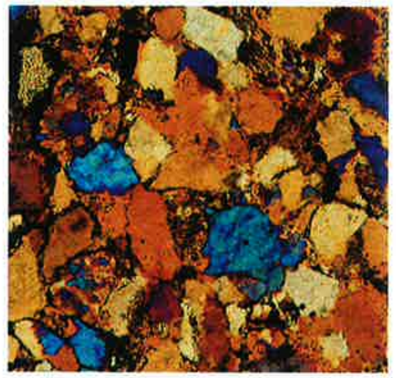


FIGURE 1.7.3b: Sedimentary rocks are made of rock particles and are usually porous, meaning water can pass through the gaps between the grains. This shows the grains in sandstone under a microscope.

Looking at fossils

A **fossil** is the preserved remains of a dead organism. Fossils give clues about the environment that the rock formed in. For example, they can tell us if it formed in fresh water or seawater.

Fossils form when dead organisms get covered in a layer of sediment before they can rot away. If the covering sediments change into sedimentary rocks, the remains of the animal or plant can also turn into rock but keep their original shape.

Did you know...?

Weathering is the *wearing down* of rock by physical, chemical or biological processes. Erosion is the *movement* of rock by water, ice or wind.

There are three main ways that fossils can form:

- hard body parts (shells or bones) can be covered by sediments and then replaced by **minerals**;
- softer parts of plants and animals can form casts or impressions;
- dead plants and animals can be preserved in amber (a sticky tree resin), tar pits or glaciers.

3. Is limestone made in the sea or on land? Explain your answer.
4. How do fossils form?

Breaking rocks

Rocks are gradually weathered – they wear away. Acid rain causes chemical weathering – it dissolves rocks such as marble and limestone. Waves pound on rocks and eventually cause cliffs to crumble. Fast water in rivers or strong waves on beaches pick up rocks, knocking off sharp edges and turning them into smooth weathered rock material. When the weathered rock material is deposited on the river or seabed, water seeps through the sediments. Minerals in the water can crystallise between the rock particles and cement them together.

Freeze–thaw weathering of rocks happens when water seeps into cracks in the rock and then freezes. As it freezes it expands, eventually breaking the rock apart.

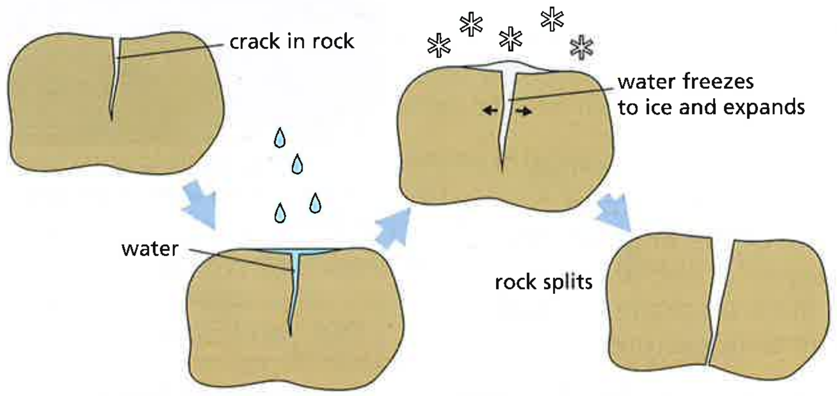


FIGURE 1.7.3d: How does water cause rocks to break apart?

Tree roots can also gradually break rocks apart as they grow. Some living organisms, such as bacteria and algae, produce chemicals that react with the rock and break it up.

5. What causes weathered rock material to become smooth?
6. Explain the processes of deposition, compaction and cementation.

FIGURE 1.7.3c: Fossils give us information. Dinosaur footprints can tell us about the dinosaur's size, weight and how it moved.

Did you know...?

Rocks and minerals are not the same thing. Minerals are the chemicals that rocks are made from.

Did you know...?

Sedimentary rocks cover most of the Earth's surface, but only make up a small percentage of the crust compared to metamorphic and igneous rocks.

Know this vocabulary

weathering
erosion
deposition
sedimentary rocks
strata
fossil
minerals
freeze–thaw

Exploring metamorphic rocks

We are learning how to:

- Describe how metamorphic rocks are formed.
- Explain the properties of metamorphic rocks.

The word 'metamorphic' comes from the Greek for 'change of form'. What are metamorphic rocks changed from? What are their features?

Making metamorphic rocks

Existing rocks that are subjected to large amounts of heat and/or pressure can change into another type of rock called **metamorphic** rock. The original rocks are usually found deep in the Earth's crust. The new metamorphic rock is generally very hard-wearing and resistant to weathering and erosion.

Examples of metamorphic rocks are:

- marble formed from limestone;
- slate formed from clay;
- schists formed from sandstone or shale.

1. Describe how metamorphic rocks are formed.
2. What type of rocks are limestone, clay, sandstone and shale?

Metamorphic changes

When existing rocks **metamorphose**, they change their crystal structure without melting. New crystals form ('recrystallisation') and the structure of the original rock changes permanently. This can happen in and around volcanoes, for example. The new minerals are more stable in the new conditions of pressure and temperature.

Different minerals form at different temperatures. The new minerals can be used to estimate the temperature, depth and pressure that the original rock metamorphosed at.

Limestone, chalk and marble are chemically identical but only marble is a metamorphic rock. Metamorphic rocks are usually very hard and shiny. Marble is a typical example – it is extremely hard and can be polished. Marble is used by sculptors because it can be carved into complex shapes.

FIGURE 1.7.4a: What are the names of the metamorphic rocks used in these pictures?

Did you know...?

Metamorphic rocks can be formed from igneous, sedimentary or other metamorphic rocks, but the changes from sedimentary to metamorphic are the most extreme.

TABLE 1.7.4: Examples of metamorphic rocks and their uses.

Original rock	Metamorphic rock after metamorphism	Uses of the metamorphic rock
sandstone (sand grains in layers)	quartzite – much harder; original layers destroyed	building stone
limestone (layers, often with fossils)	marble – much harder; shiny; no fossils left	building stone; statues; work surfaces
mudstone (layers; soft and crumbles easily)	slate – very hard, shiny; splits in a single direction to give flat sheets	roofing; facings for buildings

3. Explain how metamorphic rocks differ from sedimentary rocks.
4. Suggest why there are no fossils (or only very distorted ones) in metamorphic rocks formed from sedimentary rocks.

Metamorphic rocks in detail

Formation of metamorphic rocks varies a great deal depending on the temperature and pressure applied. Each set of conditions produces different rocks. The most intense metamorphism is called high-grade metamorphism. It produces gneiss (pronounced 'nice'), which has alternating bands of light and dark minerals. This type of metamorphism is often associated with the collision of tectonic plates and the formation of new mountains.

Heat and high pressure can destroy information contained in rocks. Limestone that is full of marine fossils may metamorphose into marble that is fossil-free. The heat (and pressure) destroys the fossils and hence the clues to the origin of the rock.

5. Why can many different metamorphic rocks be formed from the same sedimentary rock?
6. Metamorphic rocks do not usually provide geologists with much evidence about the past. Explain why not.
7. Ceramics are materials that are used to make products such as wash-hand basins and crockery.
   a) Suggest similarities and differences between ceramics and metamorphic rocks.
   b) Suggest whether ceramics are more similar to metamorphic or to other types of rock.

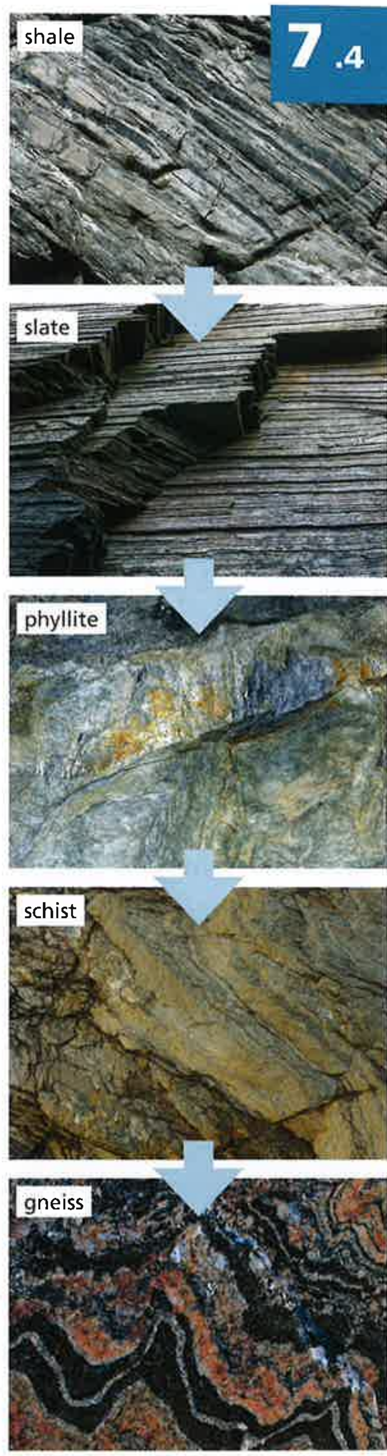


FIGURE 1.7.4b: The effect on shale (a sedimentary rock) of exposure to more and more heat and pressure. The shale metamorphoses, via slate, phyllite and schist into gneiss.

Know this vocabulary

metamorphic
metamorphose

Understanding the rock cycle

We are learning how to:

- Describe the rock cycle.
- Explain how rocks can change from one type to another.

The three main types of rock on Earth are all related and the amount of each type changes constantly. Which processes link the different rocks?

The rock cycle

The Earth's rocks are continually changing because of processes such as weathering, erosion and large Earth movements. The rocks are slowly recycled into other types over millions of years – this is known as the **rock cycle**.

The movement of tectonic plates and the Earth's inner heat drive the rock cycle. Look at Figure 1.7.5a, which illustrates the processes in the rock cycle. Mountains and hills form when buried rocks are moved to the surface. This is called **uplift**. Rocks at the surface are weathered and pieces break off. Erosion occurs when rock particles are worn away and moved elsewhere.

1. How are rocks changed from one type to another?
2. What is the difference between weathering and erosion?

Did you know…?

A Scottish scientist called James Hutton found evidence that the Earth had experienced extremely high pressures – enough to uplift and tilt rocks – and temperatures high enough to melt rocks and drive the rock cycle we understand today. He is recognised as the founder of modern geology.

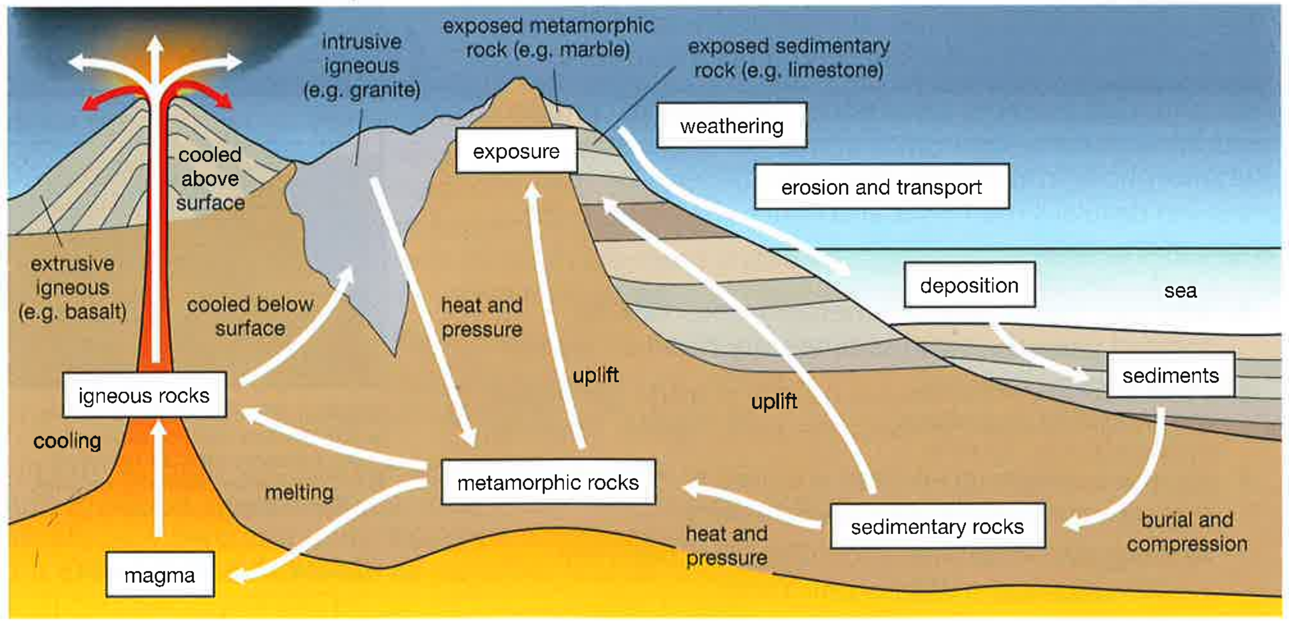


FIGURE 1.7.5a: Uplift causes the continual movement and cycling of rocks.

Folding rocks

Earth movements can squeeze layers of rock into massive folds, forming mountains – for example the Alps, the Rockies and the Zagros mountains. The Alps are so old that the top halves of the folds have been worn away by the weather.

Folding can be seen on a small scale in coastal cliffs (Figure 1.7.5b). When strata (layers of rock) are pushed up into a dome shape it is called an **upfold** or **anticline**. When strata are forced down into a bowl shape it is called a **syncline**.

Sediments and lava flows are usually deposited in horizontal layers due to the effect of gravity. Earth movements cause these layers to bend, tilt or fracture into pieces.

FIGURE 1.7.5b: Folded strata, clearly visible at Stair Hole cliffs in Dorset.

3. Explain the part these processes play in the rock cycle:
   - **a)** erosion;
   - **b)** deposition;
   - **c)** heat and pressure.
4. Explain how anticlines and synclines form.

Rocks on the move

The movement of the Earth's crust causes rocks deep underground to be brought up to the Earth's surface, in the process of uplift. Uplift is occurring continually in some areas of the world today, such as Taiwan.

Faulting occurs when rocks break because of the forces acting on them. Stress builds up over years until the rocks move. Rocks can move from a few centimetres up to a few metres. When this happens, huge amounts of energy are released in earthquakes.

FIGURE 1.7.5c: Taiwan is rising by over 1 cm every year. During a big earthquake in 1999, uplift of up to 9.5 metres in some places caused significant damage to many large buildings and structures.

5. Explain how rocks from deep underground can quickly reach the surface of the Earth.
6. Which of the processes in the rock cycle happen quickly and which happen slowly?

Know this vocabulary

rock cycle
uplift
upfold
anticline
syncline

Describing stars and galaxies

We are learning how to:

- Describe the characteristics of a star.
- Relate our Sun to other stars.
- Explain the concept of galaxies.

Our Sun is the star that maintains the conditions that allow life to exist on Earth. It sits in a galaxy called the Milky Way. The Milky Way is one of over 170 billion galaxies in the Universe. Each galaxy contains billions of stars.

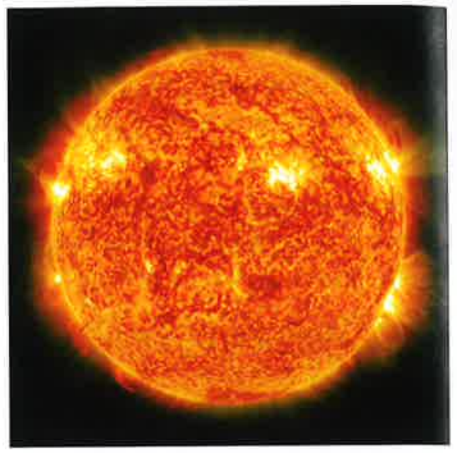


FIGURE 1.7.6a: The Sun – huge amounts of energy are released by nuclear fusion, including light. It takes light around eight minutes to travel from the Sun to the Earth.

Characteristics of a star

A **star** forms when a huge cloud of matter (usually hydrogen) is pulled together by its own gravity. Eventually the temperature and pressure become so high that the hydrogen atoms join to make helium. This process, known as **nuclear fusion**, releases the huge amount of energy that makes a star shine so brightly.

Our Sun is quite a small star. However, it has a diameter 109 times that of the Earth and it contains 99.9 per cent of the matter in the solar system.

1. What are the main chemical elements in the Sun?
2. Describe where the Sun gets its energy from.
3. Thinking about energy, suggest the main difference between a star and a planet.

Different types of stars

The size and age of a star determine its characteristics. Figure 1.7.6b shows two of the brightest stars in the night sky – Rigel and Betelgeuse. At about 57 times the diameter of the Sun, Rigel is a blue-white supergiant that shines with an intensity more than 50 000 times larger than the Sun. The extremely high rate at which it is fusing hydrogen accounts for its brilliance. Betelgeuse is a bigger, older star known as a **red giant**. It has run out of hydrogen so is now fusing helium atoms as its source of energy. Its average diameter is about 950 times that of the Sun.

When a star much larger than our Sun approaches the end of its life, its inner core can collapse to form a **neutron star**. A neutron star has a mass similar to that of the Sun, concentrated into a diameter of about 10 km.

FIGURE 1.7.6b: Rigel and Betelgeuse are stars in the constellation of Orion.

4. Suggest what the surface gravity of a neutron star would be like.
5. Explain why stars do not have an infinite life span.

Stars and galaxies

With the naked eye it is only possible to see a tiny fraction of the stars. Even our closest stars, such as Proxima Centauri and Sirius A, are approximately 100 000 000 000 000 km away from the Earth. In scientific notation this is written as 10^{14} km..

Our solar system and our closest stars are part of a **galaxy** called the Milky Way, which is similar in shape to the Andromeda galaxy shown in Figure 1.7.6c. Galaxies are so large it takes many years for light to travel across them, and billions of years for it to travel between galaxies.

Evidence about space is collected through telescopes and through analysis of the light that reaches the Earth. Scientists have shown that since the Universe was created in the Big Bang, it has been continually expanding. By analysing the light that arrives on Earth from distant galaxies, scientists are able to measure the rate of expansion.

FIGURE 1.7.6c: Andromeda galaxy – the bright haze consists of many distant stars.

6. Explain why scientific notation is sometimes used for writing numbers.
7. Explain the differences between these terms, and list their order of size: star, Universe, planet, galaxy.
8. Our ideas about the universe have sometimes changed – why aren't new explanations always immediately accepted?

Did you know...?

We are now discovering planets that orbit stars other than our Sun. These are called **exoplanets**.

Know this vocabulary

star
nuclear fusion
red giant
neutron star
galaxy
exoplanet

Explaining the effects of the Earth's motion

We are learning how to:

- Describe variation in length of day, apparent position of the Sun and seasonal variations.
- Compare these with changes in the opposite hemisphere.
- Explain these changes with reference to the motion of the Earth.

The Earth's rotation defines day length. The time taken for the Earth to orbit the Sun defines the length of a year. Because the orbit takes 365.25 days, we have an 'extra' day every leap year. Without this the seasons would drift – after 730 years, midsummer would be in December.

FIGURE 1.7.7a: Day and night are caused by the Earth spinning on its axis.

Day and night

Look at Figure 1.7.7a. On the side of the Earth that is facing the Sun it is day; and on the opposite side it is night.

Figure 1.7.7b shows how the length of daytime varies throughout the year at two locations.

1. Look at Figure 1.7.7b. Compare the length of daytime in the Arctic Circle and in northern France on:
   a) 21 December;
   b) 21 June.
2. What is special about 21 March and 21 September?

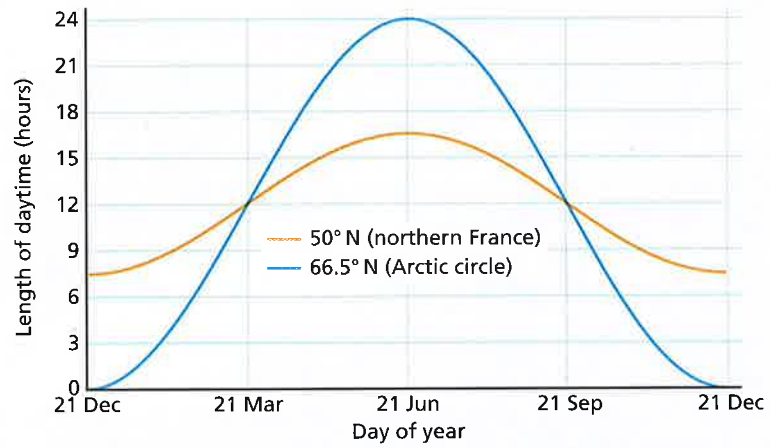


FIGURE 1.7.7b: Variation in length of daytime.

Tilt of the Earth's axis

The Earth's **axis of rotation** is tilted at 23°. Figure 1.7.7c shows this tilt and how the Earth orbits the Sun once a year. When the northern hemisphere is tilted away from the Sun, the daytimes are shorter. The Sun is low in the sky, even at midday and the amount of heat from the Sun is reduced – it is the **season** of winter. Six months later the Earth is on the other side of the Sun, which means that the northern hemisphere is now angled towards the Sun – it is summer.

3. How would the graph look different for locations in the southern hemisphere?

4. Explain why the daytimes are longer than the night-times during summer.
5. At what times of the year are daytimes and night-times of equal length? Explain why this happens.
6. Explain the changes in seasons and day length a country on the equator experiences.

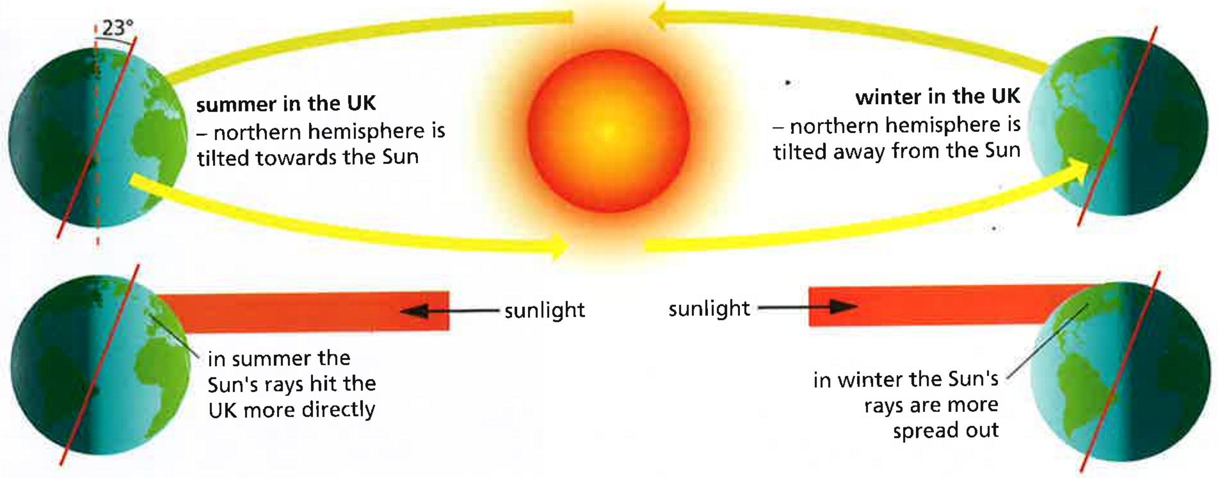


FIGURE 1.7.7c: The seasons are caused by the Earth's tilt.

Implications of the Earth's tilt

If the tilt angle of the Earth's axis were zero, we would not experience seasons as we currently do. There would be only small annual variations because of the Earth's slightly elliptical orbit, meaning that the Earth is closer to the Sun at some times than at others.

If the Earth's axis were tilted more than its current 23°, it would make the seasonal variations more extreme. At places where the Sun is directly overhead, the amount of energy reaching that place is at a maximum. Where the Sun's rays meet a place at an angle, the available energy is spread out over a larger area.

7. At midsummer on Earth, the Sun never sets at the poles – explain why. Draw diagrams to help.
8. Explain why plants grow less well in the winter than they do in the summer.
9. Mars is tilted more on its axis and has a much more elliptical orbit than the Earth. It spins at about the same rate as the Earth, but takes twice as long to complete one orbit. From this information, suggest how Mars' days, seasons and years might differ from those on Earth.

Did you know...?

The planet Uranus has a unique feature in the solar system – its axis is tilted at 82°, meaning it rotates 'on its side' as it orbits the Sun. Its orbit takes 84 Earth years.

Know this vocabulary

axis of rotation
season

Exploring our neighbours in the Universe

We are learning how to:

- Recall that the light year is used to measure astronomical distances.
- Explain the limitation of units such as km in describing astronomical distances.
- Explain what causes the appearance of the Moon to change.

The distance from the Earth to the Sun is about 150 million km. This distance is tiny compared to distances to other stars. Dealing with such vast distances is difficult, so special units are needed.

FIGURE 1.7.8a: The light from some stars has taken many millions of years to reach us.

Light years

When measuring distances across the Universe we often use the **light year** (or ly for short). It gives more manageable numbers than using kilometres. The unit is defined by how far light will travel in a year. When travelling through a vacuum, light has a speed of just under 300 000 km/s. This means that in 1 year, light will travel 9 460 000 000 000 km through space – this is how many km there are in 1 ly.

1. What does the abbreviation 'km/s' mean?
2. What unit is often used to measure distances across the Universe?
3. Explain why distances across the Universe are not normally measured in kilometres.

Distances in the Universe

Even when measuring in light years it still does not stop the distances involved being almost mind-numbing, for instance, look at Table 1.7.8. Even when Pluto is at its closest to the Earth, it is about 300 times further away from us than the Sun. However, the distance to Pluto from the Earth is minuscule compared to distances to other stars. Light from the far reaches of the Universe has taken 15 billion years to reach the Earth. This means that we are seeing those places as they were 15 billion years ago. It also means that manned missions would have to cope with journeys lasting long periods of time, such as years or even decades.

Did you know...?

As well as using light years to measure distance, astronomers use other units – the astronomical unit (AU), where 1 AU = the mean distance between the Earth and the Sun, and the parsec (pc), where 1 pc = 3.26 ly.

Examples in the Universe	Distance (ly)
Distance across the Milky Way galaxy	100 000
Earth to Sirius (one of our nearest stars)	8.6
Earth to the most distant point of the Universe	15 000 000 000
Earth to Pluto (at their closest)	0.000 44
Earth to the Sun	0.000 016
Earth to the Andromeda galaxy	2 500 000

TABLE 1.7.8: Some approximate distances in the Universe.

4. If you were to look at Sirius today, in which year would the light you see from it have set off?
5. When you look at two stars that are different distances away, you are not seeing them at the same point in time – explain why.
6. Why do these distances have implications for exploration of the other parts of the Universe?

How planets and moons look

Stars make their own light but planets and moons reflect the light. This means that only one side of them is lit at any one time and this changes their appearance when viewed from elsewhere. The Moon orbits the Earth but reflects light from the Sun so one half of the Moon is lit. We often don't see it as a complete sphere. If we can see all the lit side, we call that a full Moon. As the Moon orbits the Earth, we see less of the lit side until it becomes a crescent. The next stage is for the dark side to be facing us (new Moon) and it then gradually shows us more of the lit side again. These shapes are called phases of the Moon.

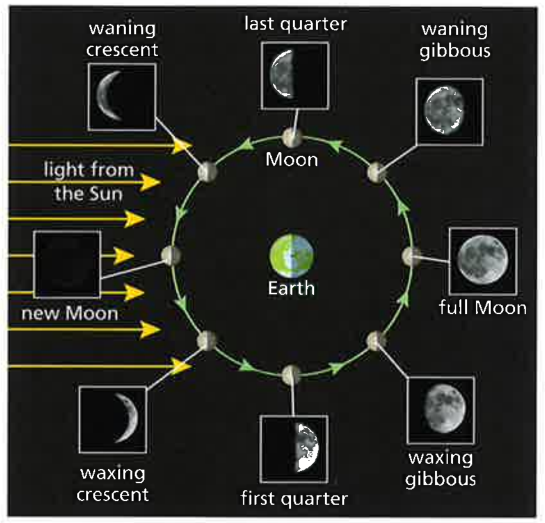


FIGURE 1.7.8b: The phases of the Moon.

7. If we can see half of the lit side, what shape will the Moon appear to be?
8. Why is one of the crescent Moons labelled 'waning' and the other 'waxing'?
9. Explain whether, if you lived on the Moon, you would see phases of the Earth.

   The same thing applies to planets as well. They are lit on one side by the Sun. Figure 1.7.8c shows how Venus appears from the Earth.
10. Draw and label diagrams to suggest why:
    a) we also see phases of Mercury;
    b) we don't see a full set of phases for planets in the solar system further out than Earth.

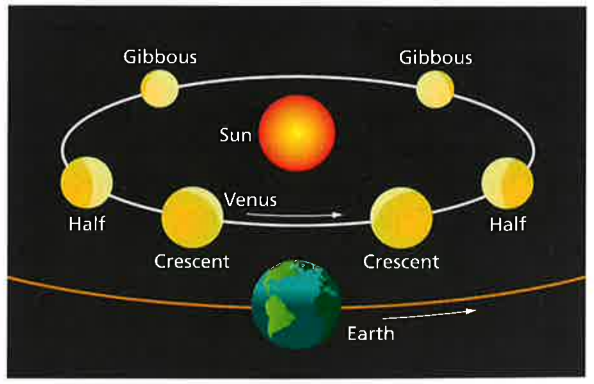


FIGURE 1.7.8c: The phases of Venus.

Know this vocabulary

light year (ly)

Using models in science

We are learning how to:

- Explore how we can use models to explain ideas in science.
- Construct an explanation using ideas and evidence.
- Decide if a model is good enough to be useful.

People make models for a variety of different reasons. If a town planner has some ideas about a new shopping centre they are proposing, they may build a model to show people what it would look like. It's a good way of getting people to see what might be good about it and also what problems it might cause. Scientists sometimes use models to explain ideas but more often to help them develop their ideas. Instead of drawing a conclusion and then making a model to illustrate it, they might do it the other way around – using a model helps them to draw a better conclusion.

FIGURE 1.7.9a: Students examining a model of the Earth and the Sun.

Modelling day length

A team of students is trying to come up with a **model**. Their teacher has asked them to devise a way of explaining why in the UK we get longer days in the summer and shorter days in the winter, but in the southern hemisphere it's the other way around. They've got a torch to represent the Sun and a model Earth on a knitting needle to represent the Earth. They're trying to work out how to position them.

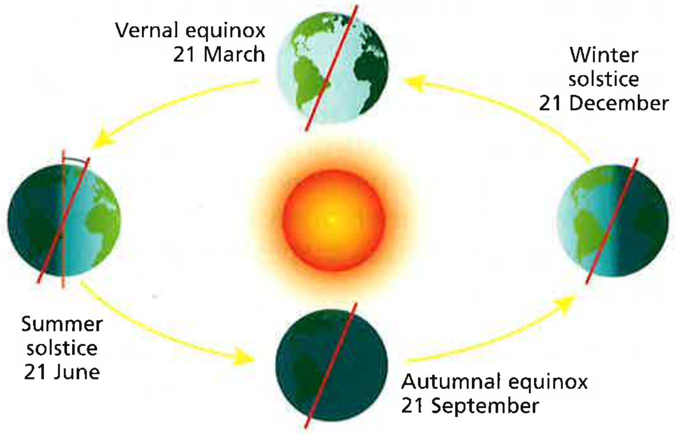


FIGURE 1.7.9b: Why does day length change over the year?

They've worked out that they have to tilt the needle. They angle the top of the Earth (the northern hemisphere) away from the torch and, as the Earth spins, it doesn't get light for as long. This is winter. They're not quite sure how to model summer though. Then they find a diagram in a book.

1. What does 'northern hemisphere' mean?
2. How does the students' model show that when it's winter in the northern hemisphere it's summer in the southern hemisphere?
3. How should the team show what will be happening six months later?

Modelling types of rock

A science teacher has found a great way of showing the difference between sedimentary, metamorphic and igneous rocks – she is going to get the class to use chocolate! First they're going to model sedimentary rocks. They grate some chocolate, wrap it in aluminium foil and squash it, really hard. Imagine what that will look like when they open it out and examine it.

FIGURE 1.7.9c: Grated chocolate can be used to model different types of rock.

Next they model metamorphic rock. They use some of the chocolate shavings left over along with some lumps and put them in a paper bun case. They float this on hot water and when it starts to melt take it out. They have to be careful examining this one because it's hot.

The last one they do is igneous rock. The teacher gathers up the various pieces of chocolate from the previous experiments and puts them in a foil dish, which she floats on hot water. This time it's kept there for several minutes until it's totally melted.

4. In what way will the sedimentary model look like a sedimentary rock?
5. How does the metamorphic model represent what happens to rocks that go through that process?
6. Explain how good the model for making igneous rocks is.

Scientists as modellers

Both of these models, the one showing seasonal change and the one showing rock processes, can be used to help us to understand the processes better. Sometimes we use a model because it's a convenient size, such as the one about seasons, and sometimes because it's safer and more convenient. Jake's teacher had to be careful with the molten chocolate but it was safer than lava.

However, a model represents only certain features, and we have to decide how well it represents them.

7. With the Sun–Earth model:
   a) Which features of the real Sun–Earth system did it represent well?
   b) Which features did it not represent well?
8. Evaluate the models of each type of rock-forming process using chocolate, clearly identifying the good features and the aspects less well represented.

Did you know...?

Using models is important in many areas of work. Climate scientists use models of the atmosphere. The structure of DNA was explained by building a model to show the double helix. Town planners use models to predict traffic flow, but such a model is difficult to get right because it depends on human behaviour.

Know this vocabulary

model

Checking your progress

To make good progress in understanding science you need to focus on these ideas and skills.

Name the layers that make up the Earth and recall that the Earth's surface is made of plates that move about.	Describe the characteristics of each layer of the Earth and recall that tectonic plates move very slowly.	Explain that earthquakes, volcanic eruptions and the formation of mountains can happen where tectonic plates meet; explain how volcanic activity changes the surface of the Earth.
Describe how igneous, sedimentary and metamorphic rocks are formed; give examples and describe how they can change from one type to another.	Describe the features and properties of different types of rocks, including crystals in igneous rocks, recrystallisation in metamorphic rocks and layers (burying fossils) in sedimentary rocks.	Explain the processes involved in the rock cycle and link these to how the rocks are formed.
Describe what is meant by weathering and erosion.	Identify causes of weathering and erosion.	Explain how weathering and erosion affect rocks.
Describe the relative motion of the Earth, Moon and Sun.	Explain how the motion of the Earth relative to the Sun causes day length and year length.	Explain how the relative motion of the Earth, Moon and Sun affects how we see objects from the Earth.
Explain how the Earth is tilted upon its axis.	Explain how the tilt of the Earth on its axis causes seasonal changes.	Explain the effects of the tilt on a planet's axis being greater or less.
Recall the time taken for light to reach Earth from the Sun and from the next nearest star.	Explain the choice of units used for measuring distances in space.	Explain how observations of stars are affected by the scale of the Universe.
Describe what a galaxy is.	Explain what has been learned from the observation of galaxies.	Explain the importance of the discovery of exoplanets.

Questions

KNOW. Questions 1–5

See how well you have understood the ideas in this chapter.

1. Which is the correct order of the layers of the Earth, starting from the centre? [1]

a) Mantle, inner core, outer core, crust.
b) Outer core, inner core, crust, mantle.
c) Inner core, outer core, crust, mantle.
d) Inner core, outer core, mantle, crust.

2. Which statement describes the mantle correctly? [1]

a) A relatively thin, rocky layer.
b) A very thick layer, some of which can flow.
c) Made of liquid nickel and iron.
d) Made of solid nickel and iron.

3. In the summer, in the UK, the days are longer and the average temperatures higher. Which of these statements explains why? [1]

a) In summer the Earth is closer to the Sun.
b) In summer the northern hemisphere is tilted towards the Sun.
c) The Earth's orbit is not exactly circular.
d) A long hot summer is needed to help plants grow.

4. It takes around eight minutes for light to reach the Earth from the Sun. Which of these statements is *not* true? [1]

a) The Sun appears in the sky to us where it was eight minutes previously.
b) Light from the stars takes much longer to reach us, often taking many years.
c) It takes eight minutes for light from all the stars to reach the Earth.
d) Light from the Sun takes different amounts of time to reach the different planets in the solar system.

5. The Moon is sometimes visible in the sky and sometimes not. Which of these statements is true? [1]

a) The Moon orbits the Sun and is sometimes therefore much further away from us.
b) During the day the Moon is on the other side of the Earth; its orbit brings it in view at night time.
c) Sometimes the Moon doesn't generate enough light to be seen.
d) Seeing the Moon depends on where it is in its orbit around the Earth and on the rotation of the Earth.

APPLY. Questions 6–8

See how well you can apply the ideas in this chapter to new situations.

6. Why does magma come out of volcanoes? [1]

a) It is less dense than the crust.
b) Uplift forces it out.
c) An explosion forces it out.
d) It is more dense than the crust.

7. Scientists find a new type of rock that has small crystals. What does this tell them? [2]

8. In its orbit around the Sun, the Earth is tilted on its axis by about 23°. Explain what we would notice happen about seasons and climate if it were tilted at a greater angle. [2]

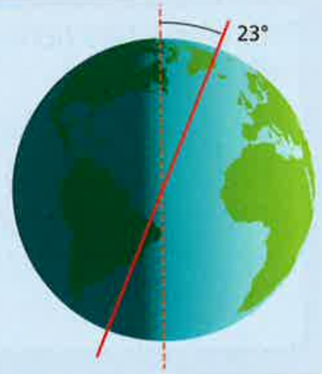


FIGURE 1.7.11a

EXTEND. Questions 9–10

See how well you can understand and explain new ideas and evidence.

9. Why does the water content of new sedimentary rock change as the rock forms? [2]

10. Table 1.7.11 shows the planets in the solar system, their masses and the number of moons they have. Suggest a pattern between the mass and the number of moons. [2]

Planet	Mass (units are 10^{24} kg, which is a shorthand way of writing 1,000,000,000,000,000,000,000,000 kg)	Number of moons
Mercury	0.33	0
Venus	4.87	0
Earth	5.97	1
Mars	0.64	2
Jupiter	1898	67
Saturn	569	62
Uranus	86.8	27
Neptune	102	14

TABLE 1.7.11