VOLCANOES

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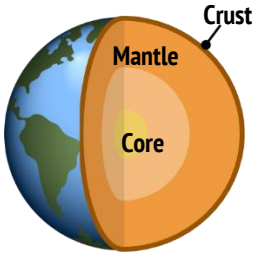
From left to right: Erta Ale lava lake, Ethiopia; Grand Prismatic Spring, Yellowstone, USA; Sarychev Peak Volcano, Russia; Lava flows from Kilauea, Hawaii

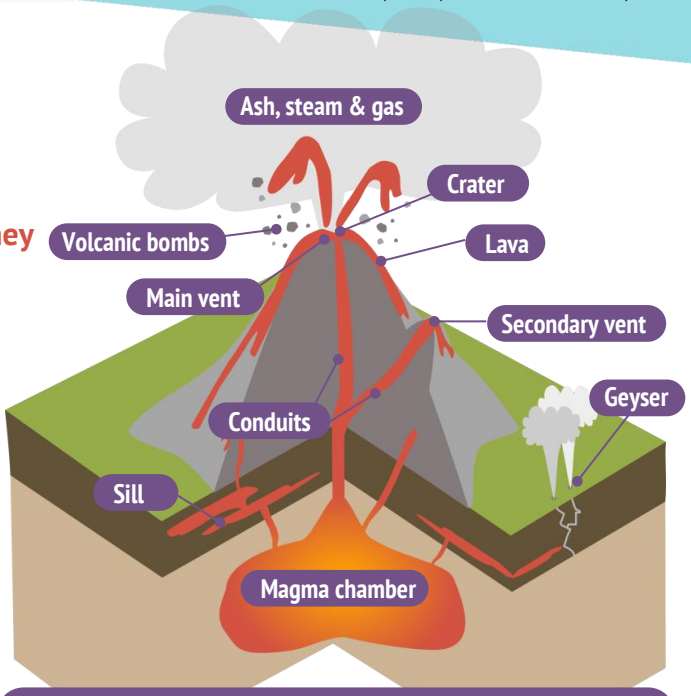
Throughout Earth's history volcanoes have erupted enormous amounts of molten rock onto the Earth's surface. Today there are about 500 currently active volcanoes on Earth, but what are volcanoes, how do they form and where does all this molten rock come from?



WHAT IS A VOLCANO?

Volcanoes are openings in the Earth's rocky **crust** which allow hot **molten** (melted) **rock**, **ash** and **gas** to escape from below the surface.

Volcanoes form when parts of the Earth's solid **mantle melts** to form pockets of hot liquid rock called **magma**. This magma collects in large pools deep underground known as **magma chambers**. As more and more magma is added to the magma chamber, the **pressure** increases and causes the rock around the magma chamber to crack. The hot liquid magma, which is lighter than the surrounding rock, is forced upwards through cracks in the crust and **erupts** on land through a **volcanic vent.** Magma that reaches the Earth's surface can erupt as **lava** (hot liquid rock)**, obsidian** (volcanic glass), **pumice** (a type of frothy volcanic glass) **volcanic ash** and **gas** depending on the type of eruption.



Magma chamber: pool of magma below the volcano
Vent: main opening in the ground surface
Conduit: channel which magma travels through
Lava: erupted magma
Crater: created when an eruption blows the top off a volcano
Volcanic bombs: large lumps of rock and molten blobs of magma thrown out from the volcano
Ash, steam & gas: material erupted from the volcano
Geyser: vent that shoots steam and boiling water into the air
Sill: flat sheet of igneous rock formed underground

Volcanoes are grouped into three types depending on how often they erupt:

- **Active volcanoes** are volcanoes that have erupted within the last 10,000 years e.g. **Mount Etna**, Italy
- **Dormant volcanoes** are volcanoes that have not erupted in the past 10,000 years, but could erupt again e.g. **Yellowstone Caldera**, USA
- **Extinct volcanoes** are volcanoes that have not erupted in the past 10,000 years and will not erupt again e.g. **Arthurs Seat**, Edinburgh

DID YOU KNOW?

The Earth is not the only place in the solar system to have volcanoes. The biggest volcano in the solar system is actually **Olympus Mons** on **Mars**. At 25km high, it's 3 times the height of Mount Everest and covers an area of 600,000km^2 - that's almost the same size as France!

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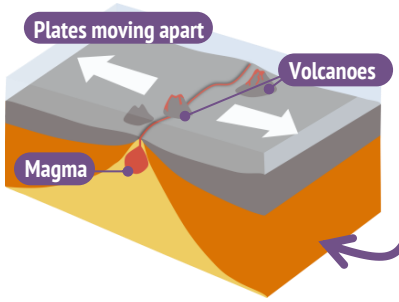
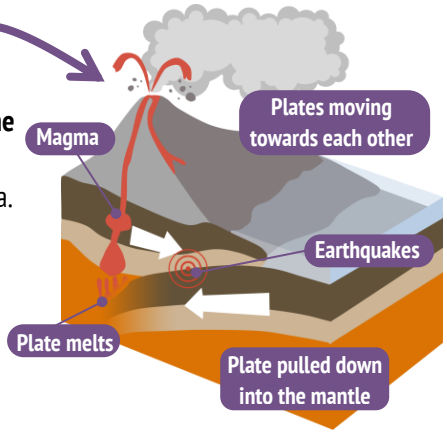
WHERE DO VOLCANOES FORM?

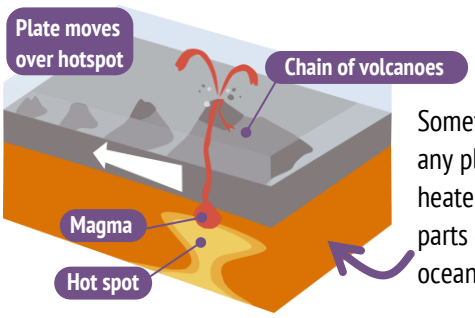
The Earth's surface is made from **tectonic plates** - huge slabs of the Earth's **crust** and uppermost **mantle** that fit together like a jigsaw puzzle and move around over millions of years. Volcanoes are usually located where these tectonic plates meet. This is especially true for the **Pacific Ring of Fire**, an area around the Pacific Ocean where over 75% of the volcanoes on Earth are found.



A **constructive plate boundary** is formed when two tectonic plates are moving away from each other. As they move apart, hot magma rises up between the two plates from the mantle below and erupts on the surface as lava. Over time, continued eruptions of lava forms volcanoes on the surface of the crust like at the **Mid Atlantic Ridge**.

Volcanoes can form when two tectonic plates are moving towards each other at a **destructive plate boundary**. Here a **subduction zone** forms which is where one plate is pulled down into the Earth's mantle. The high **heat** and **pressure** melts the plate to form magma. This magma then rises and erupts explosively on land as lava and forms volcanoes. The **Andes** mountain chain in South America is a chain of volcanoes above a subduction zone.





Sometimes volcanoes can form in the middle of plates far away from any plate boundaries. These volcanoes form above areas of super-heated rocks in the Earth's mantle called '**hotspots**'. Hotspots melt parts of the mantle and cause magma to rise and erupt as lava on the ocean floor, creating volcanoes like those on the **Hawaiian Islands**.

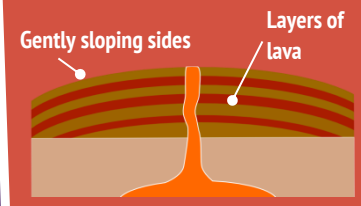
EFFECTS OF VOLCANIC ERUPTIONS

POSITIVE	NEGATIVE
Volcanic ash and lava are rich in **minerals** so break down to provide valuable **nutrients** for the soil. This creates very **fertile** soil which is good for growing fruit and vegetables.	Many lives can be lost as the result of volcanic eruptions.
Volcanoes are important **tourist attractions** which generate jobs and bring in money.	If the ash and from a volcanic eruption mixes with rainwater or snow this can trigger fast flowing mudflows called **lahars** which can destroy farmland, woodland and man-made structures including roads and bridges.
Volcanic areas are sources of **geothermal energy** (heat from the Earth), a type of **renewable energy** which can be used to heat buildings or be converted into electricity.	**Pyroclastic flows** (avalanches of hot rock and gas) cannot be outrun and can kill people instantly. This is what happened in the Italian towns of Pompeii and Herculaneum when **Mount Vesuvius** erupted in AD79.
Volcanic rocks such as **basalt** can be used for building materials.	Volcanic ash can cause disruption to weather and air travel e.g. the Icelandic **Eyjafjallajökull** eruption in 2010.
	Some **volcanic gases** can poison rivers and lakes and cause animals (including humans) to suffocate.

VOLCANO TYPES

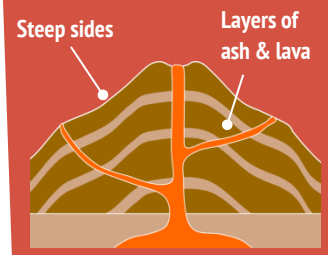
There are 2 main types of volcano – shield volcanoes and composite volcanoes.

Shield volcanoes form from gentle (**effusive**) eruptions of runny lava called **basalt**. Because it's so runny, this lava can travel a long way before it **solidifies** into rock and creates wide, sloping volcanoes in the shape of a shield.



Composite volcanoes are formed from layers of alternating lava and ash, usually at destructive plate boundaries. The lava that erupts to form composite volcanoes is much **thicker** and flows more slowly than basalt lava. This means that it cannot spread out very far before it solidifies so forms **cone-shaped** volcanoes with steep sides.

Because of the thicker lava, composite volcanoes tend to erupt explosively and can cause **pyroclastic flows**, clouds of super-heated rock ash and gas that blast down the side of a volcano during large eruptions.



LAVA FLOWS
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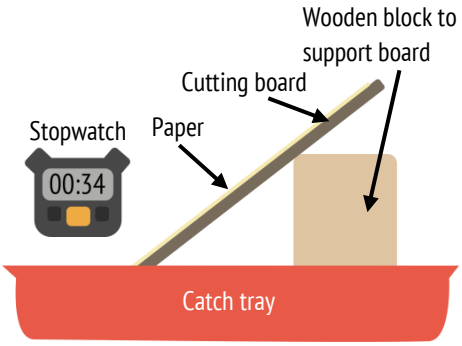
Lava is molten rock that is erupted from a volcano. Some volcanoes erupt lava that is very runny and can flow over large distances but others produce lava that is very sticky and can't flow very far at all.

The 'stickiness' of a liquid is known as its viscosity. The more viscous a liquid is, the stickier it is and the slower it will flow down a slope.

YOU WILL NEED:

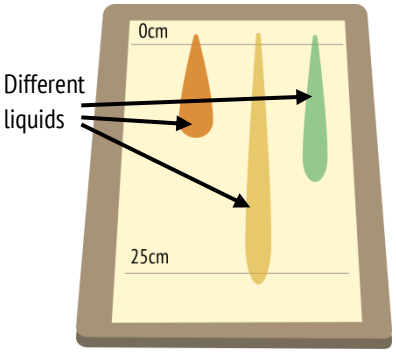
- Cutting board/ baking sheet
- Liquids of different viscosities (e.g. water, oil, washing up liquid, chocolate sauce, honey)
- Support for cutting board (e.g. wooden block)
- Paper
- Catch tray to catch liquids
- Graph paper
- Stopwatch

TASK: LAVA VISCOSITY (work in groups of 2 or more)



Using a ruler, draw a horizontal line at the top of your paper and label it 0cm - this will be your start line. Measure 25cm downward from this line and draw another horizontal line labelling it 25cm - this will be your finish line.

Stick your paper to your cutting board using masking tape and set up the board in a catch tray as in the diagram opposite.



Choose your first liquid and spoon a tablespoon of it at the top of your paper on the start line. At the same time start your stopwatch and measure how long it takes for the liquid to reach the finish line. Do this for all of your liquids and repeat each test 2 times so that you have 3 measurements for each liquid. Record your results in the table.

Liquid	Time taken 1	Time taken 2	Time taken 3	Mean time taken

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Plot your results below as a **bar graph** using the mean time taken on the y axis and the type of liquid on the x axis.

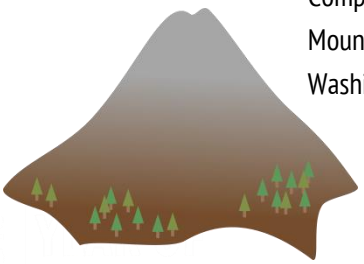
Which of your liquids was the **most viscous**?

Which of your liquids was the **least viscous**?

Look at the two volcanoes below. Based on the experiment you have just done, do you think the lava flows that created these volcanoes were **viscous** or **not very viscous**? Write your answers in the boxes.

Shield volcano e.g. Mauna Loa, Hawaii

Composite volcano e.g. Mount St. Helens, Washington



When volcanoes erupt they tend to either explode violently with huge clouds of ash and gas or the erupt gently with flowing rivers of red hot lava.

Will a **more** or **less viscous** lava cause an explosive eruption?

Will a **more** or **less viscous** lava cause a gentle eruption?

FOSSILS

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Left: Fossils found at Charmouth on the Jurassic Coast
Middle: Fossil lizard ©Trustees of the Natural History Museum
Right: *Allosaurus* and *Stegosaurus* dinosaur fossils Luke Jones/Wikimedia Commons

What are fossils? How do they form? Why do scientists study fossils and what can they tell us about the ancient creatures and plants that once lived on Earth?

Fossils are the **preserved evidence** of plants and animals that once lived on Earth. Fossils can be as tiny as a grain of pollen or as huge as a dinosaur skeleton! Scientists called **palaeontologists** study fossils to discover what animals and plants used to live on Earth and how life has changed (or **evolved**) over time. Without fossils we wouldn't know that woolly mammoths or dinosaurs ever existed!

When a plant or animal dies it is very unlikely that it will end up as a fossil. It will usually be eaten by **scavenging animals,** broken up by wind, ice and waves, or simply rot away. Even when fossils do form, typically only the **hard parts** such as teeth, shells and bones are preserved, so the **fossil record** has lots missing from it.

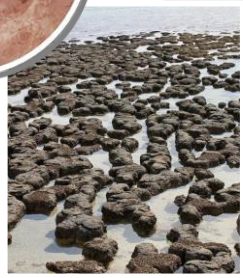
BODY & TRACE FOSSILS

There are two types of fossils, **body fossils** and **trace fossils**. Body fossils are plant and animal remains like leaves, teeth, shells and bones. Trace fossils are evidence left behind by animals, things like footprints, burrows and even poo!

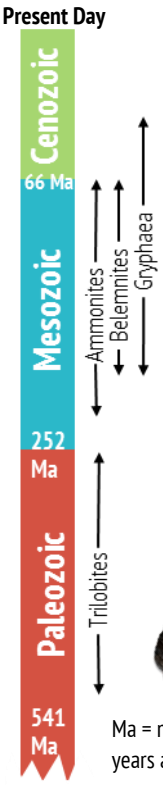
Trace fossils usually form as **moulds** or **casts.** A mould forms when something leaves a hollow imprint in soft sediment, like footprints on wet sand. A cast forms when a solid mould is filled in with sediment, creating a 3D impression of the original object.

- **Dinosaur footprint tracks** can reveal where a dinosaur lived, how fast it could run and even what the pattern of scales looked like on its skin!
- Fossil poo, or **coprolites**, can tell us about the diets of ancient animals as they often contain tiny bones, scales or plants that an animal had eaten but not fully **digested**. Fragments of crushed bone have been found in ***Tyrannosaurus rex*** coprolites telling us that this dinosaur must have had extremely powerful jaws!

Dinosaur footprint trace fossil. Can you spot three toes? Image: Pete Loader



SOME FOSSILS COMMONLY FOUND IN THE UK



Gryphaea

Ancient oysters that lived on shallow sea beds, sometimes called 'Devil's Toenails'.

Belemnites

Squid-like animals with lots of arms for catching prey. They had bullet shaped internal skeletons - usually the only parts found as fossils.

Ammonites

Squid-like marine predators with coiled shells. Propelled themselves through the sea by squirting jets of water from inside their shells.

Trilobites

Ancient marine animals related to scorpions and crustaceans (**arthropods**). Most species lived on the sea bed but some lived in reefs or swam in the open ocean.

Ma = millions of years ago

Gryphea: Malcolm Lidbury/Wikimedia Commons

DID YOU KNOW?

Stromatolites are some of the oldest fossils ever found on Earth. They might just look like rocks, but are actually made from layers of bacteria that grow over thousands of years. Most palaeontologists agree that the oldest stromatolites, found in Western Australia, are 3.43 billion (that's **3,430,000,000**) years old, but there could be stromatolites in Greenland that are 3.7 billion years old!

Modern stromatolites in Western Australia.

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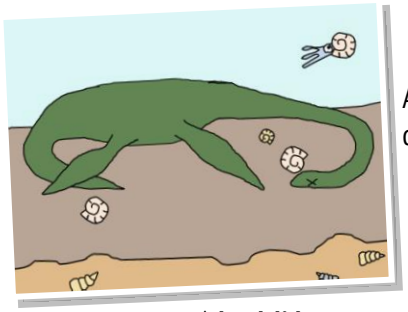
HOW DO FOSSILS FORM?

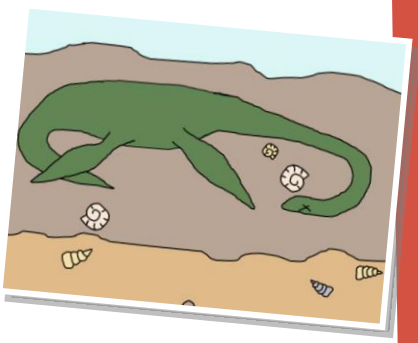
Fossils can form in a few different ways but usually an organism has to be **buried** very quickly in **soft sediment** such as mud or sand, in a calm, watery environment like the muddy sea floor, bottom of a lake or a river estuary. Here are the stages in which a fossil might form:



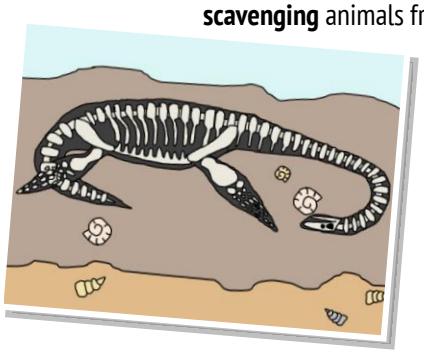
STAGE 1: DEATH

A marine reptile from the **Jurassic** period called a **plesiosaur** dies and its body falls to the sea floor.

STAGE 2: RAPID BURIAL



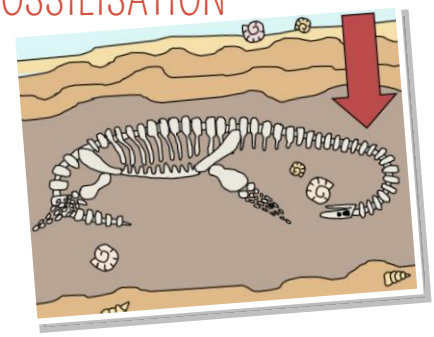
A **landslide** occurs nearby and the plesiosaur is buried quickly in mud, preventing **scavenging** animals from gobbling it up.



STAGE 3: DECAY OF SOFT PARTS

The muscles, skin and other soft parts of the plesiosaur are digested by bacteria in the sediments. Only the hardest parts such as the bones and teeth are left.

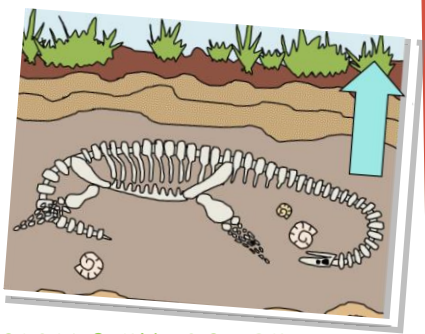
STAGE 4: BUILD-UP OF SEDIMENTS & FOSSILISATION



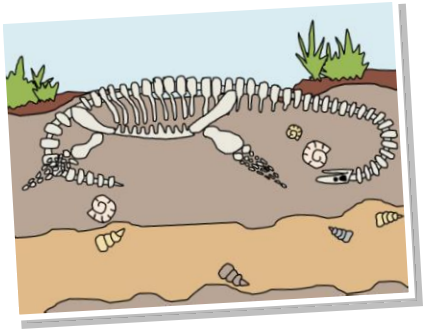
As time passes, more and more sediment builds up .The weight of the overlying layers squashes the soft mud and it begins to turns into rock. This is called **lithification**.

Water is squeezed out of the mud and seeps into the plesiosaur bones. Minerals and chemicals in this water gradually change the bones and teeth into stone. The plesiosaur is now a fossil but it is buried under layers and layers of rock under the ocean.

STAGE 5: UPLIFT ONTO LAND



Over millions of years, sections of the Earth's crust called **tectonic plates** move around. **Continents** crash into each other and shove the rocks upwards. Rocks that were previously at the bottom of the ocean can be raised above sea level!



STAGE 6: EROSION & EXPOSURE

Over time the rock layers are gradually stripped away by **erosion** (wind, rain, waves and ice). Part of the fossil is revealed at the surface to be discovered by a lucky fossil hunter!

EXCEPTIONAL PRESERVATION

Very rarely the soft parts of animals such as muscles, feathers, skin are preserved as fossils. Sometimes even entire animals made of **soft tissue**, like jellyfish and worms, are preserved. Palaeontologists call this **exceptional preservation**.

Exceptionally preserved fossil dragonfly from the Solnhofen limestones of Germany

FOSSIL COLOUR

Exceptional preservation can sometimes even show us prehistoric animal **colours**! Feathers, scales and hair contain **microscopic** structures called **melanosomes**. Melanosomes have different shapes depending on their colour and in extremely rare cases they can be preserved in fossils. Using **powerful microscopes**, palaeontologists can work out some of the colours of fossil feathers and scales.

Melanosomes have recently revealed that a dinosaur called ***Sinosauropteryx*** would have been covered in orange feathers with a white and orange striped tail! Another dinosaur called ***Microraptor*** is now known to have been covered in glossy black feathers like a starling!

Sinosauropteryx fossil from China with fossilised feathers and melanosomes!
Credit: James St. John/ Wikimedia Commons

FOSSILS
ACTIVITY SHEET

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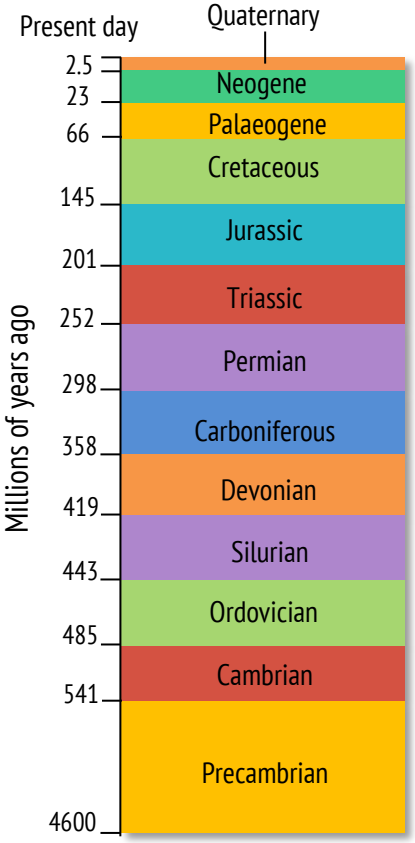
YOU WILL NEED:

- Geological Society 'Fossils' factsheet

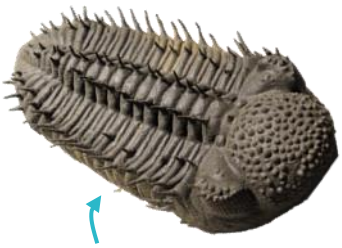
1. FOSSILS & THE GEOLOGICAL TIMESCALE

a) Look at the geological timescale and fossils below. Use the information to put the fossils in order of youngest to oldest and work out which geological time period each animal would have lived in.



Triceratops: 68 million years old

Ammonite: 170 million years old



Trilobite: 390 million years old

Woolly Mammoth: 100,000 years old

Brachiopod: 450 million years old

Youngest

Oldest

FOSSIL	AGE	GEOLOGICAL PERIOD

b) What geological time period do we live in?

_____

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2. SCIENTIFIC VOCABULARY

Draw lines to match these scientific words to the correct explanation.

COPROLITE	A scientist that studies fossils
PALAEONTOLOGIST	Squid like animals with a spiral shells – they propel themselves through the sea by squirting jets of water from inside their shell
AMMONITE	The remains of animals and plants - can include bones, leaves, teeth, scales and feathers
TRACE FOSSIL	Ancient marine animals related to scorpions – can look a bit like woodlice
TRILOBITE	Fossilized animal poo
BODY FOSSIL	A theory developed by Charles Darwin that says that some plants and animals are better at surviving than others in their species – these individuals will be more likely to pass on their genes to the next generation
EVOLUTION	Evidence left behind by animals such as footprints, burrows and even poo

3. FOSSILIZATION

How do fossils form? Draw four stages to show how a marine animal might become a fossil.

1.

2.

3.

4.

ROCKS IN SPACE

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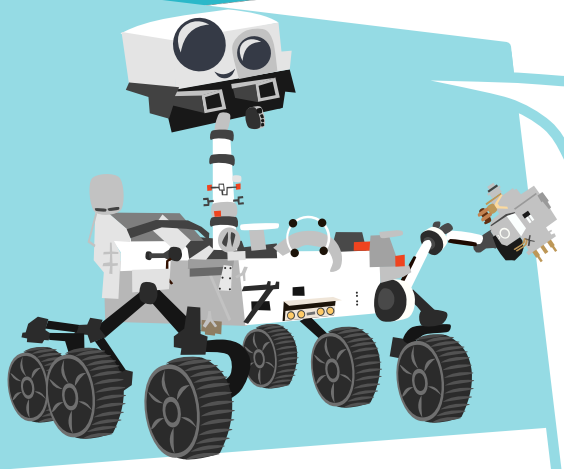


Hi I'm Percy, a rover designed by NASA to explore Mars. Come along with me as I tell you about the wonders I have seen!

My main mission is to understand the geology of Mars and to collect samples to be brought back to Earth. While exploring Mars I find rocks that might have formed in water. Finding water is important because it could have supported microbial life in Mars's past!

I was launched towards Mars on July 30 2020 and I arrived February 18th 2021, landing in Jezero Crater. NASA's plan is for me to spend at least 2 years looking around my landing site. I have already found clay that has given us some answers! Scientists can see from the clay that water carried clay minerals from the surrounding area into the crater. We also know that over 3.5 billion years ago, river channels spilled over the crater wall and created a lake!

Summarising the solar system in three parts

1. Inner planets

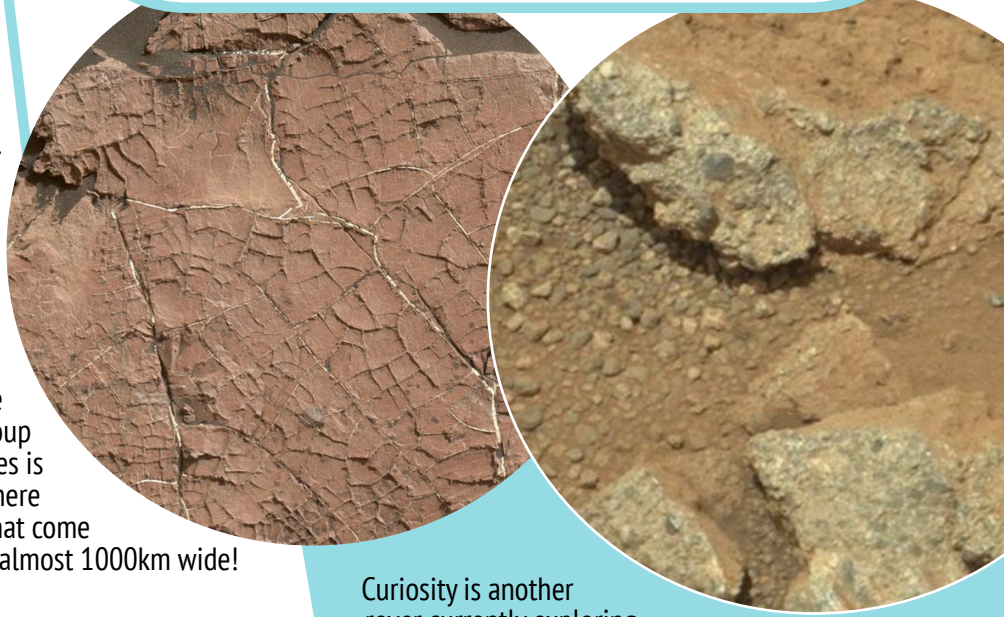
The inner planets are the four planets closest to the sun: Mercury, Venus, Earth and Mars. The inner planets all have solid rocky surfaces and are similar in size when compared to the outer plants. Inner planets also take quite short period of time to orbit the Sun and possess a small number of moons. For example Earth, as you know, only has one – The Moon!

2. Asteroid belt

In the large space between Mars and Jupiter, there are small bodies, mostly rocky or metallic, that group together and orbit the sun. This collection of bodies is called the asteroid belt. Scientists estimate that there are over 2 million asteroids in the asteroid belt, that come in sizes ranging from a small as a dust particle to almost 1000km wide!

3. Outer planets

The outer planets are Jupiter, Saturn, Uranus and Neptune. The four outer planets are often called gas giants, as they are made mostly of hydrogen and helium in gas and fluid form. These are the same elements that make up most of the sun. The outer planets have lots of similarities to each other; for example, they all have numerous moons and planetary rings, composed of dust and other small particles that encircle the planet in a thin plane.



Curiosity is another rover currently exploring Mars. It landed in Gale crater in 2012.

Curiosity found these features in the rock, which could show that water was once present on Mars's surface. These cracks often form in mud when water dries up, and pebbles are formed when small jagged stones are rolled and tumbled in flowing water.

ROCKS IN SPACE

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An ancient lava river on Venus


Olympus mons, a huge volcano on Mars

Glossary:

Satellite: a moon, planet or machine that orbits a star

Celestial bodies: Objects in space

Gravity: the force that attracts an object to the centre of a celestial body.

Igneous: rock formed from cooled molten lava or magma

Sedimentary: rock formed from broken up pieces of other rock, like sand or gravel

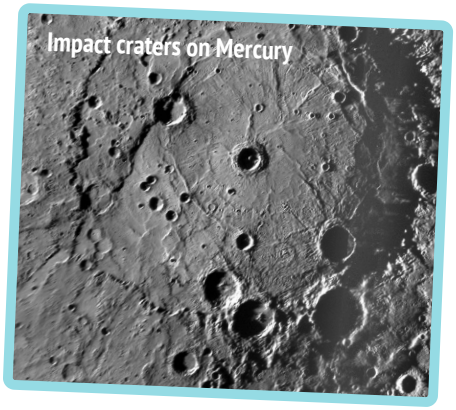
Weathered: when an object has been worn down by wind and rain

Eroded: when an object has been worn down by knocking, hitting or bumping against other objects

Space volcanoes!

The inner planets all have surfaces made predominantly of the **igneous** rock **basalt**, which forms when molten **lava** cools down to form hard rock. On Venus and Mercury, there is evidence of **flood basalts**, where lava flows out of several volcanoes at once or large cracks in the planets surface, covering a huge area with flat plains of basalt.

Venus and Mars also have enormous **volcanoes**, where ancient lava flows can be seen running from their summits like rivers. On some areas of Mars, the volcanic rocks have been **weathered** and **eroded** by ancient rivers to form sedimentary rocks made of sand and pebbles.


Impact craters on Mercury

All rocky bodies in the solar system, especially our Moon and Mercury, are covered in impact craters where meteorites have smashed into their surfaces!

Density

The inner planets are **denser** than the outer planets because they are solid and compact, whereas the outer planets are in a **gaseous state**. Density tells us how heavy an object is compared to the amount of space it takes up. For example, if you had a rock in one hand and a carrier bag full of feathers in the other, the rock would probably feel heavier even though it is much smaller. That's because rocks are usually very dense, but feathers are not!

Have a look at the table below that shows the different densities of the planets, in order of the highest density to the lowest. You can see Saturn's density is very low like the feathers, but Earth's is quite high like a rock!

Planet	Average density (g/cm^3)
Earth	5.5
Mercury	5.4
Venus	5.2
Mars	3.9
Neptune	1.6
Jupiter	1.3
Uranus	1.3
Saturn	0.7


Pluto is an example of a dwarf planet

What exactly is a planet?

Objects in our solar system are divided up into different categories depending on their **properties**.

Planet: Something that orbits a star but is not itself a satellite. It needs to have enough mass so it is almost spherical in shape, and has **cleared its orbit of other objects**. This process is also known as 'clearing the neighbourhood' and happens at the end of planet formation. The planet becomes gravitationally dominant, meaning there are no other bodies of similar size nearby, other than its natural satellites.

Moons: the natural satellites of planets. They orbit around an object in space, mainly the planets, dwarf planets or large enough asteroids.

Dwarf Planet: A spherical object that orbits a star but has not yet cleared its orbit of other smaller objects. Dwarf planets are known for having weaker gravities making them unable to clear their orbits.

Did you know?

Some people call Jupiter the solar system's vacuum cleaner as its powerful gravity pulls nearby comets and meteorites into its orbit.

ROCKS IN SPACE

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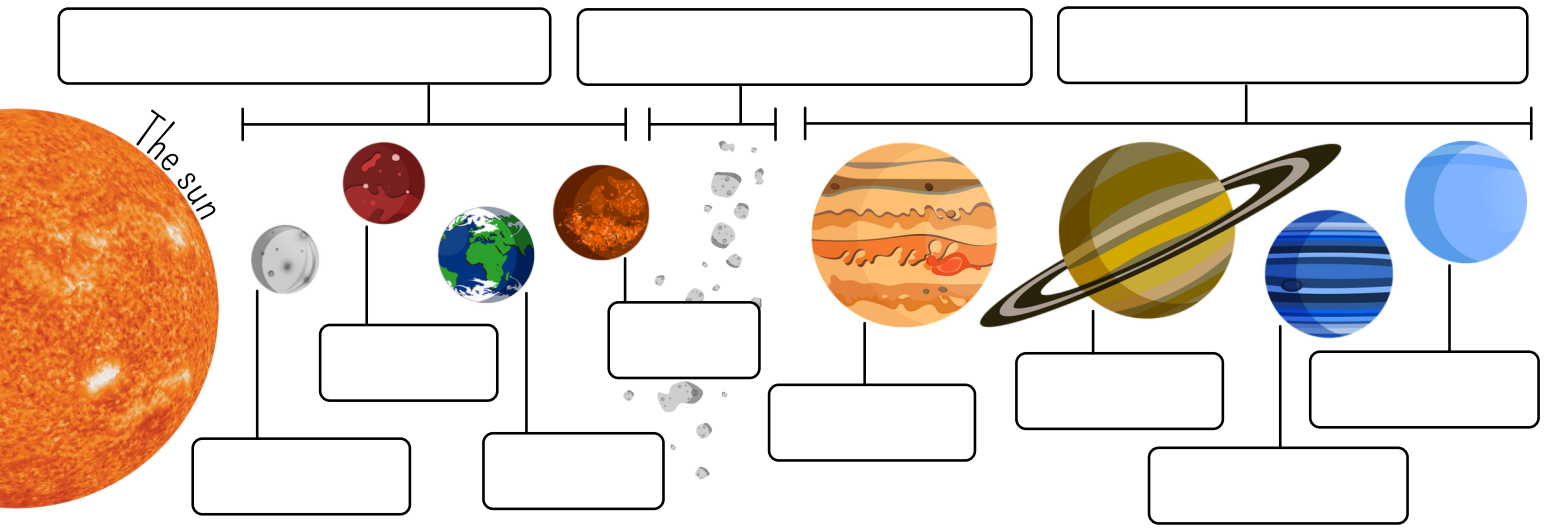
ACTIVITY SHEET

INNER AND OUTER PLANETS: Can you label these planets in our solar system and put them in their correct groups?



What is the name of the rock that forms from cooled lava flowing out of volcanoes?

_____

Is this an example of a sedimentary, igneous or metamorphic rock?

_____

Most rocky planets have impact craters on their surfaces. How are these formed?

_____

_____

FILL IN THE BLANKS!

Complete the sentences below using words from the word bank

WORDBANK: two moons core vary Earth three Sun less gas asteroid rock

The Solar System can be looked at in _____ sections. The inner planets are mostly formed from _____and the outer planets are mostly made of _____. Between the outer and inner parts lies the _____ belt. There are over _____ million asteroids that _____ in size.

The outer planets are_____ dense than the inner planets. The planet with the highest density is _____. This is because it has a compact _____.

Earth and the other planets in our solar system orbit the _____. Some planets are also orbited by smaller _____.

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ACTIVITY SHEET

DENSITY EXPERIMENT

Density tells us how heavy an object is compared to the amount of space it takes up. To calculate density you need the formula

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

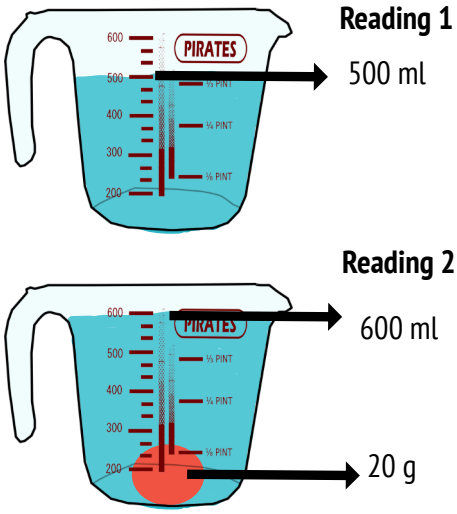
Can you work out how dense items in your house are? Have a go below! When doing this activity make sure you get an adult to help you with this. Also when choosing your items to submerge, make sure they are not electric and will not be damaged by the water.

What you will need:

- A measuring cylinder (or if you do not have one a measuring jug with 100ml increments)
- Water
- Ruler
- 5 items of your choice - make sure they fit in the jug and are a similar size but different weights - eg a marble, rubber or small rock
- Scales
- Calculator

1. First you need to find the mass each item. To do this, weigh each item on a scale. Make sure your scale is set to zero before you start and that the measurement is in grams. If using a jug you will need to use bigger items like a tennis ball, but if using a measuring cylinder the items can be small.
2. Fill the measuring cylinder or jug with water. Fill it about 2/3 full of water.
3. Before you put your item in, check the volume of water in the cylinder or jug already and write down the value below. Look at the diagram on the right to see how to do this.
4. Drop your first item into the jug, if the item sinks, then calculating its volume is easy! Just read the new water volume on the measuring jug Then take this number (reading 2) and subtract your first value from it. There is an example in the table below.
5. If the item floats, push it down with the tip of your finger until its just under the water. While holding it here take reading 2 as described in step 4
6. Repeat this with all of your items!
7. Now we are going to calculate the densities!.To do this divide the mass of each item by the volume.

Example



Item	Mass (G)	Volume (Ml)	Density (CM^3)
Red Ball	20	100	0.4

Which item had the highest density?

_____

Which item had the highest volume?

_____

Which item surprised you and why?

_____