SCIENCE DEPARTMENT
BGS

Year 7

Physics Friend

Space

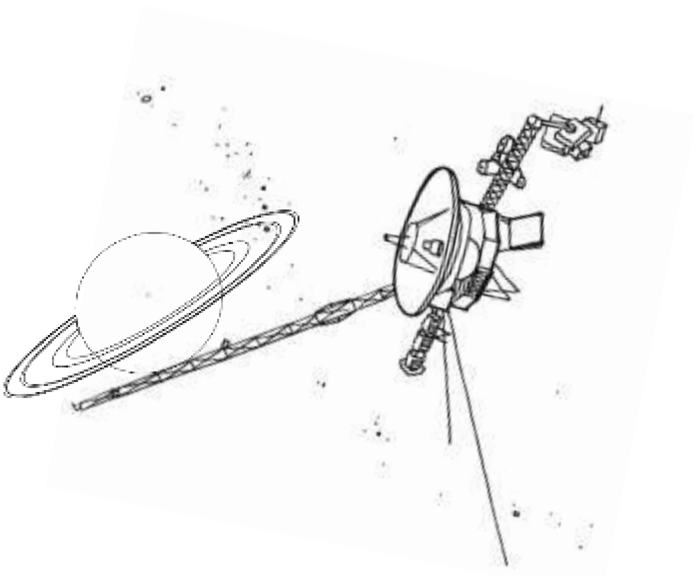
This booklet contains information to support your work in science lessons. You **must** bring it with you to all science lessons on the Space topic.

Replacement booklets must be paid for at a cost of £1.

Name:

Form:

Science Teacher:



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Key Words:

Gravity	Orbit	Galaxy	Supercluster	Milky way
Satellite	Solar	Non-luminous	Waxing	Waning
Crescent	Gibbous	Nebula	Protostar	Main sequence
Red giant	White dwarf	Supernova	Neutron star	Black hole
Orbiter	Nuclear fusion	Rover	Observatory	Flyby

The word search below contains the key words above

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Our Cosmic Address

We live on planet **Earth** which is part of a planetary system. A planetary system is the name given to a group of objects that orbit around stars. Our planetary system is called the **Solar System**. The star our planets orbit is called the Sun (Sol).

A **planetary system** is the name give to a group of objects which orbit around stars. An **orbit** is the path one object follows around another.

The Sun is one star of 100-400 billion stars (a large proportion of which have their own planetary systems) which are bound together gravitationally. A large group of stars like this is called a **galaxy**. The solar system is on the **Orion Arm** of the **Milky Way** galaxy.

The milky way is part of a small group (50-100) of galaxies called the Local Group. This group is part of a much, much larger group called the **Laniakea Supercluster** (Laniakea means 'immense heaven' in Hawaiian – it contains over 100,000 galaxies). All the galaxies we can see form the **Observable Universe**.

If we were to write our address properly on a letter it would read as follows:

Questions:

Q1: What is the name of the galaxy our solar system is part of? [1 mark(s)]

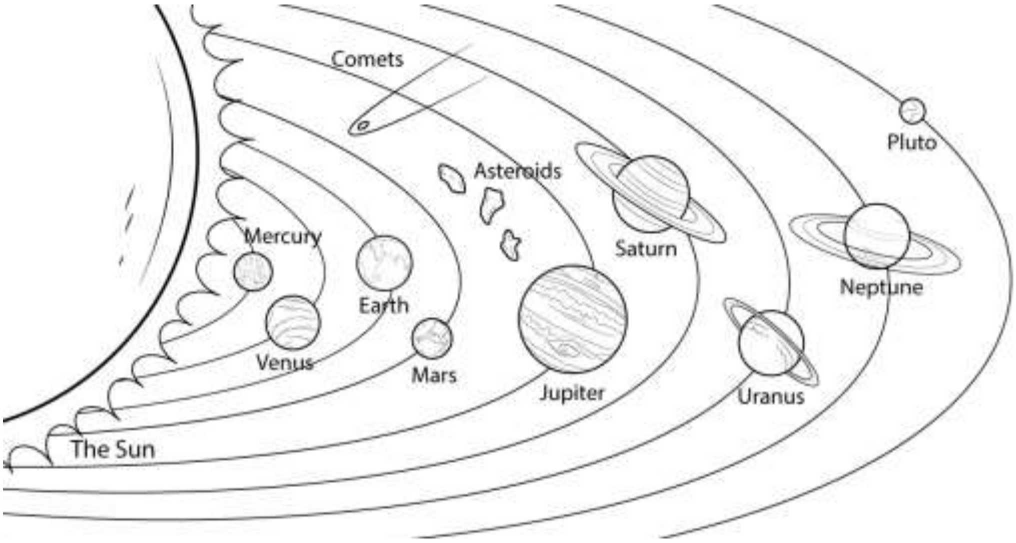
Q2: List two cosmic structures larger than a galaxy. [2 mark(s)]

Q3: What is the name of our star? [1 mark(s)]

Q4: What is a planetary system? [2 mark(s)]

Q5: Why is it called the 'observable universe'? [2 mark(s)]

The Solar System



There are many objects which orbit the Sun. Eight of them are classed as planets. To be named a planet an object must;

- Orbit a star
- Be approximately spherical
- Dominate its orbit (clears its neighbourhood of other objects).

(This is why Pluto is now classified as a dwarf planet – other smaller objects share its orbital path).

Planets with **rocky surfaces** (Mercury, Venus, Earth and Mars) are **Terrestrial** (Earth-like), and planets with **gaseous surfaces** (Jupiter, Saturn, Neptune & Uranus) are **Jovian** (Jupiter-like).

Objects which orbit a planet and not a star are called satellites. There are two types;

- Natural satellites – such as moons
- Artificial satellites – objects made by humans

It is very difficult to show an image of the solar system to scale, as the distances between the planets are immense. Most pictures also don't show the correct size of the planets relative to each other. The table below shows the distances between the planets in reality;

Object	**Mean distance from sun (km)**
Mercury	57,909,175
Venus	108,208,930
Earth	149,597,890
Mars	227,936,640
Jupiter	778,412,020
Saturn	1,426,752,400
Uranus	2,870,972,900
Neptune	4,498,252,900
Pluto	*5,906,380,000*
Kuiper belt (edge of the solar system)	*14,900,000,000*

Questions:

Q1: Name the four terrestrial planets. [2 mark(s)]

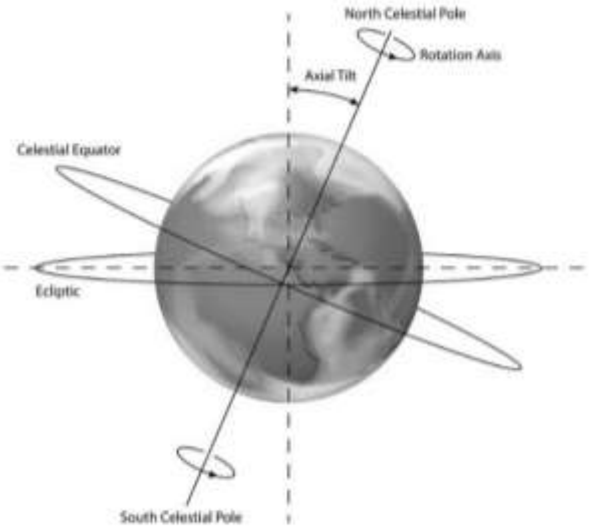
Q2: What are artificial satellites? [1 mark(s)]

Q3: State two criteria an object must meet to be called a planet. [2 mark(s)]

Q4: Why is Pluto no longer considered a planet? [1 mark(s)]

Q5: Name the gas giant planets in the correct order from the Sun. [2 mark(s)]

The Earth and the Sun

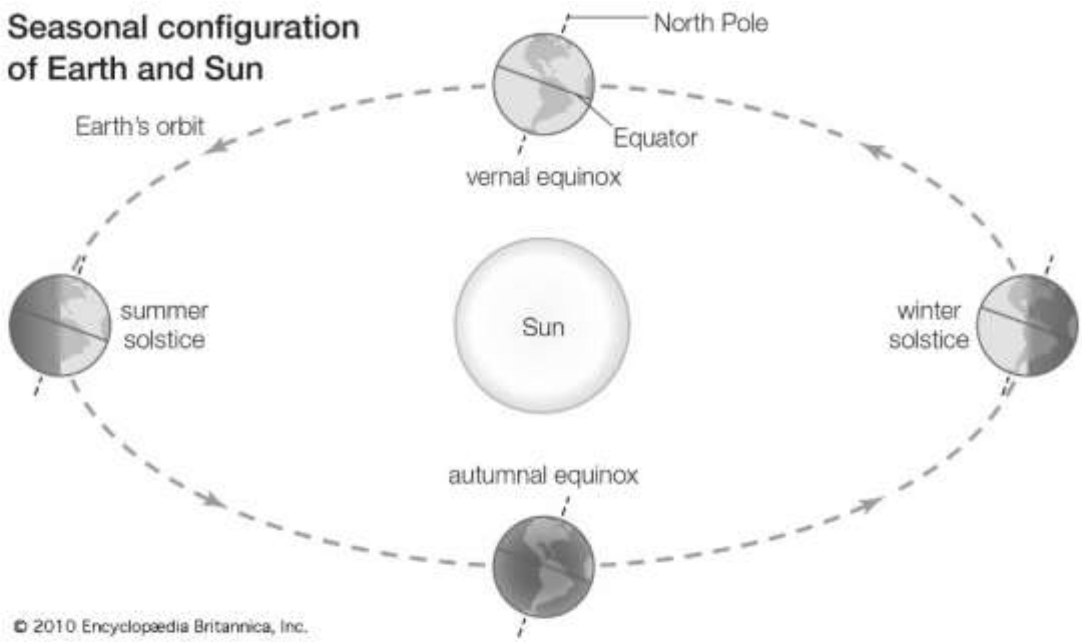


It takes the Earth one year to complete one revolution around the sun. We divide this into 365 ¼ days -though normally we could 365 days per year and have an extra day every fourth year (a leap year).

One day is the time it takes for the Earth to rotate once about its axis. We divide this in 24 hours, so one hour is one twenty-fourth of a day.

You can see from this diagram that Earth's axis is tilted (by 23.5°). This leads to the experience of the seasons (winter, spring, summer, autumn) as we know them.

The diagram below shows the Earth at different positions during its annual trip around the Sun. Notice how the orientation of the axis never changes. This means sometimes the northern hemisphere is pointed towards the Sun and is sometimes pointing away.



Some important points:

- During winter the northern hemisphere is tilted away from the Sun. This makes days shorter, nights longer, and temperatures lower.
- During spring and autumn, the northern hemisphere is neither tilted towards or away from the Sun, so days and nights are roughly equal in length.
- During summer, the northern hemisphere is tilted towards the Sun. This makes days longer, nights shorter and temperatures higher.
- When it is winter in the northern hemisphere, it is summer in the southern hemisphere and vice-versa.

Questions:

Q1: How long does the Earth take to orbit the Sun once? [1 mark(s)]

Q2: What causes day and night on Earth? [2 mark(s)]

Q3: How many hours are there in a day? [1 mark(s)]

Q4: Why is it warmer in summer than in winter? [2 mark(s)]

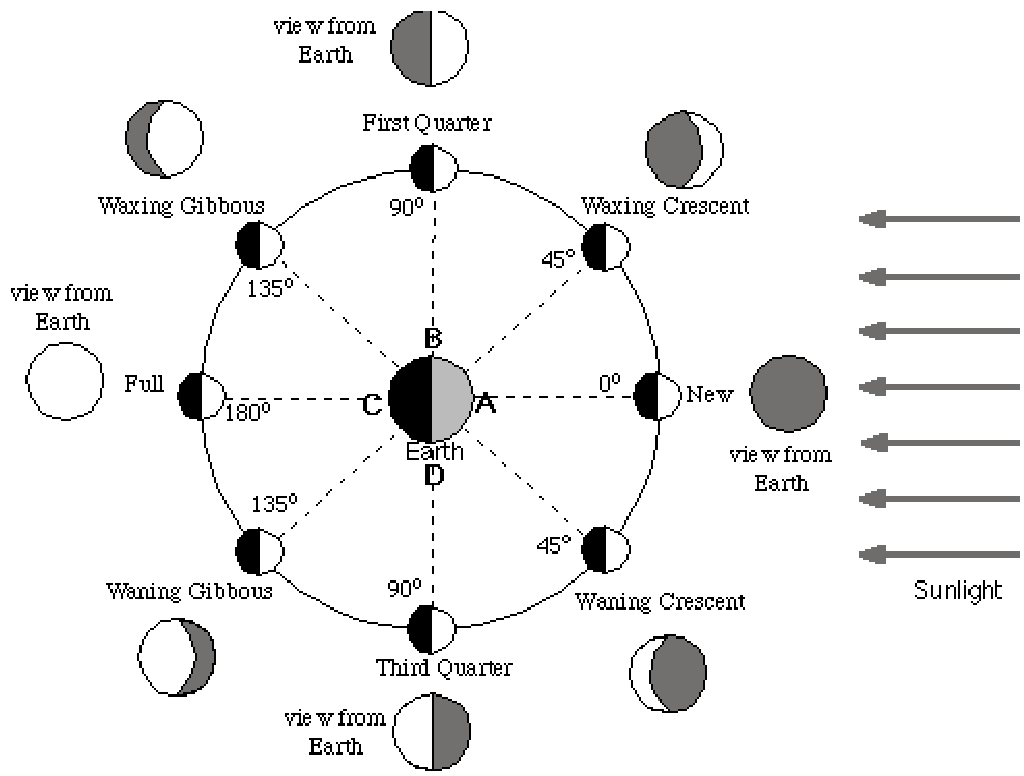
Q5: What is the tilt of the Earth's axis? [1 mark(s)]

The Earth and the Moon

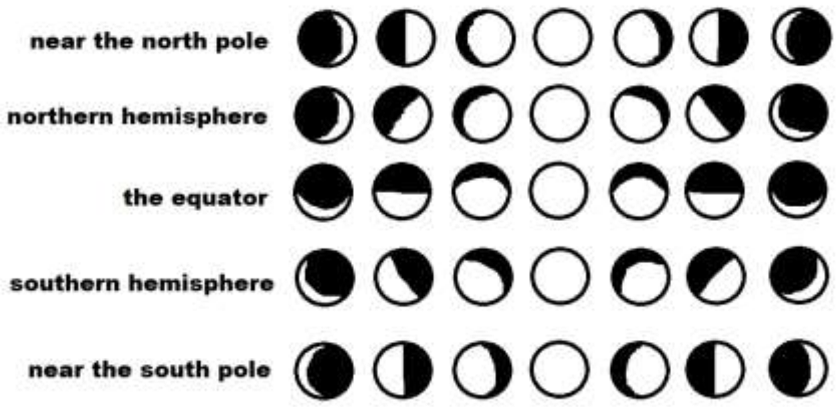
One half of the Moon's surface is illuminated by the Sun, and reflects the Sun's light. The moon is non-luminous (that means it does not generate its own light).

As the Moon revolves around the Earth, the portion of the illuminated side of the Moon that is visible to us changes. This gives the impression that the Moon changes shape – where in reality, it does not.

The diagram below shows the Moon in various positions in its Earth orbit, and then shows the view of the Moon as seen from Earth at each position. You will have to imagine that this is 'top down' view, looking down at the North pole.



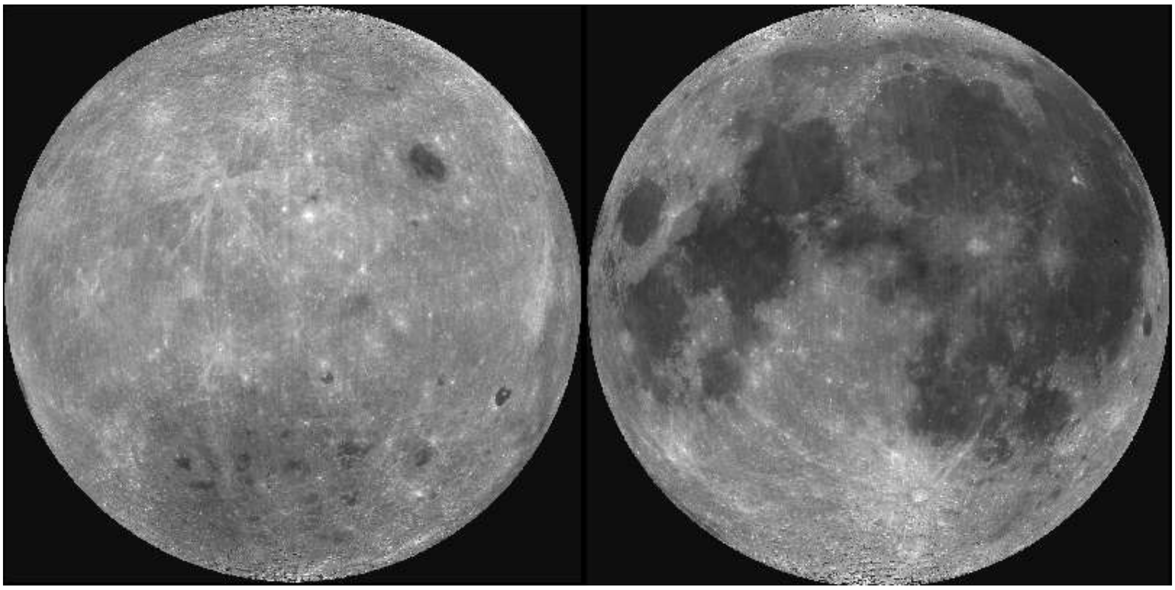
'**Waxing'** before a name of a phase means the size of the illuminated portion visible is increasing, and '**Waning'** means the opposite.



Any worksheets and questions you see will likely assume you are stood near the north pole!

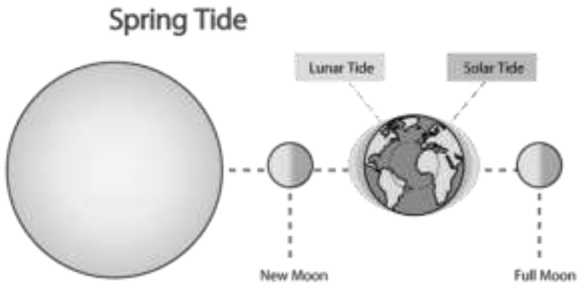
The actual 'shape' of the phase depends where you are on Earth!

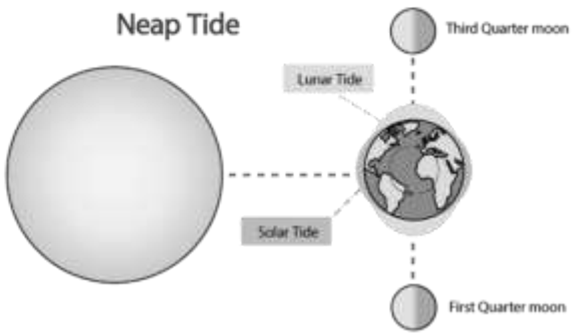
The 'Dark side of the Moon'



Another feature of the Moon is that it takes the same length of time (27 days) to rotate on its axis as it does to orbit the Earth – the result being that we only ever see the same face of the Moon!

The right-hand image is the Moon as we see it. The one on the left is the 'back' side of the moon which we never see!





The Tides

The gravitational pull of the Moon and the Sun causes the water in the oceans to 'bulge' outwards slightly.

As the Earth rotates, it appears to us as though the sea level is rising and falling – we call this movement of water level the tides.

Remember: The WIND causes waves, but it is gravity that causes the TIDES.

Questions:

Q1: Why does the Moon appear to shine? [1 mark(s)]

Q2: What is a natural satellite? [2 mark(s)]

Q3: Explain why we see different phases of the Moon. [2 mark(s)]

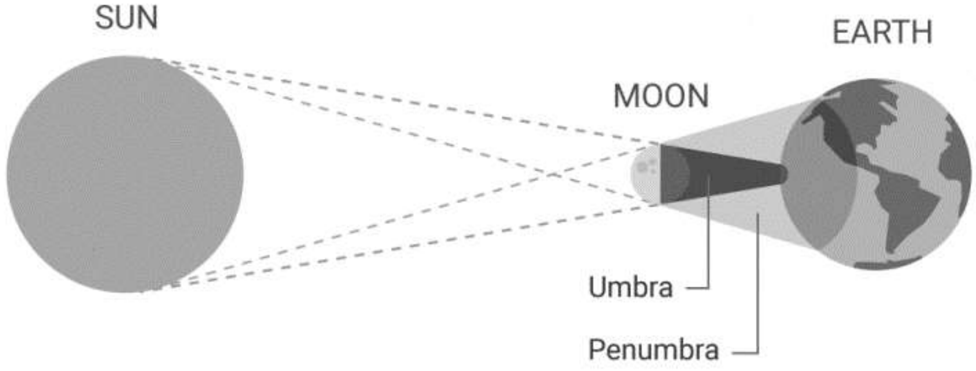
Q4: What causes tides on Earth? [2 mark(s)]

Q5: Name one phase of the Moon. [1 mark(s)]

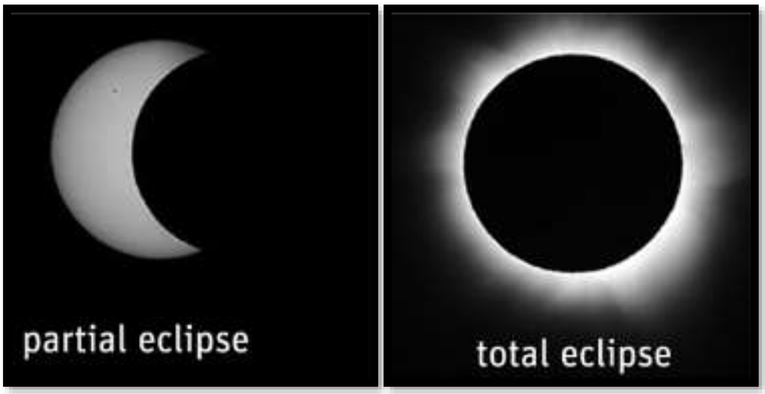
Eclipses *(extra detail that is not examined)*

Solar Eclipses

We have seen that the Moon, during its orbit of the Earth, can sometimes pass between the Sun and the Earth. Sometimes the Moon may block the light from the Sun hitting the Earth and cast a shadow on the Earth surface. This can cause a phenomenon called a **solar eclipse.** There are two different types of solar eclipse we need to know about.

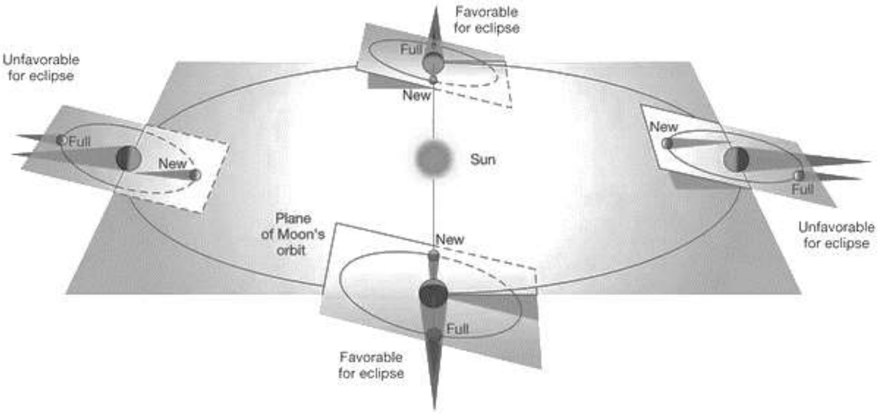


Any person stood on the Earth in the shadow cast by the moon called the **umbra**, would see a **total solar eclipse**, as the moon completely blocks the Sun's light. A person stood inside the **penumbra** (a shadow cast when the moon blocks **some** of the Sun's light), would see a **partial solar eclipse**.



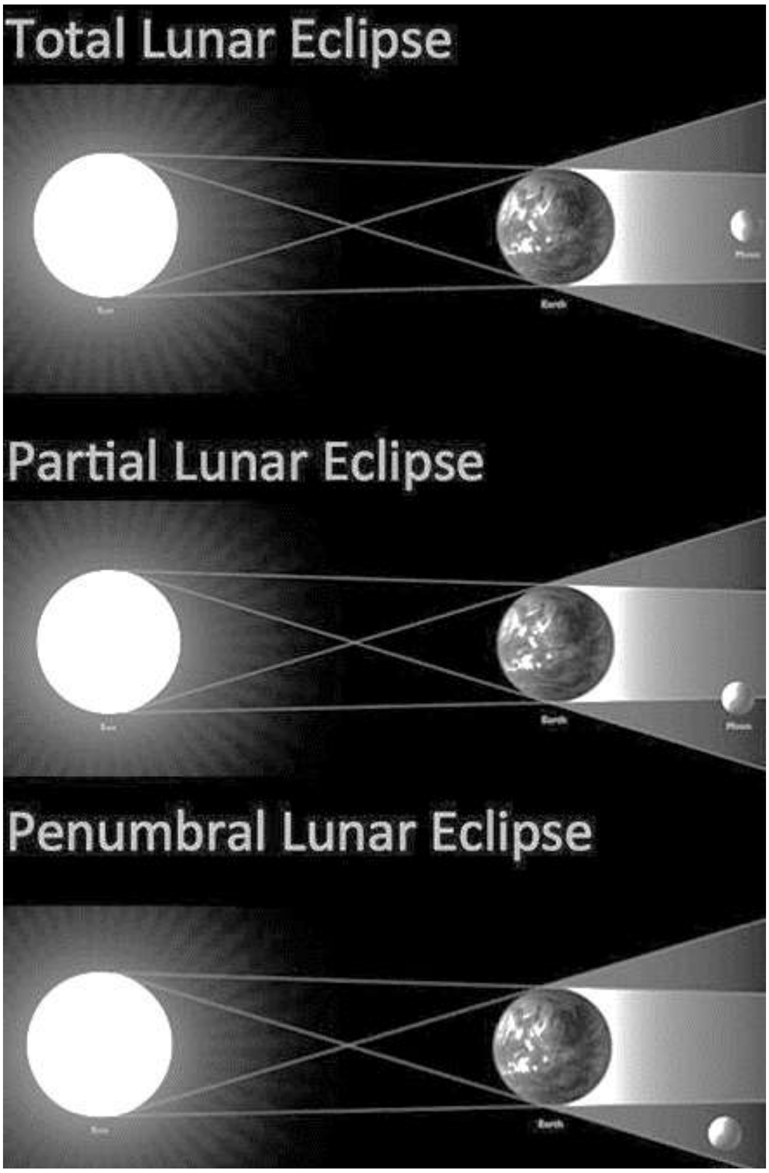
Scientists can use eclipses to study parts of the Sun we can't normally see – the solar corona is the glowing outline you can see on the picture of the total eclipse. The Sun is usually so bright we can't observe this directly!

Why are eclipses so rare?



Whenever we study topics such as phases of the moon, the diagrams we see are often oversimplified and appear to show the moon directly between the Earth and the Sun every month! However, in reality, the Moon's orbit around the Earth is tilted slightly, which means it isn't very often that everything lines up well enough to cause a total eclipse of any sort!

Lunar Eclipses



There is a second type of eclipse which occurs when the Moon passes trough the shadow the Earth casts due to the Sun's light. These eclipses are called **lunar eclipses** and fall into three categories.

A **penumbral lunar eclipse** occurs when part of the Sun's light is blocked from hitting the Moon by the Earth. This occurs when the Moon is in the Earth's **penumbra.**

A **partial lunar eclipse** occurs when the Moon is partially in the Earth's **penumbra** and partially in its **umbra**.

A **total lunar eclipse** occurs when the Moon is completely in the Earth's **umbra**.

You may hear a lunar eclipse being referred to as a **blood moon**. That is because red light from the Sun can be bent around the Earth and strike the Moon's surface. This can cause the moon to become a striking red colour!

When can I see one?

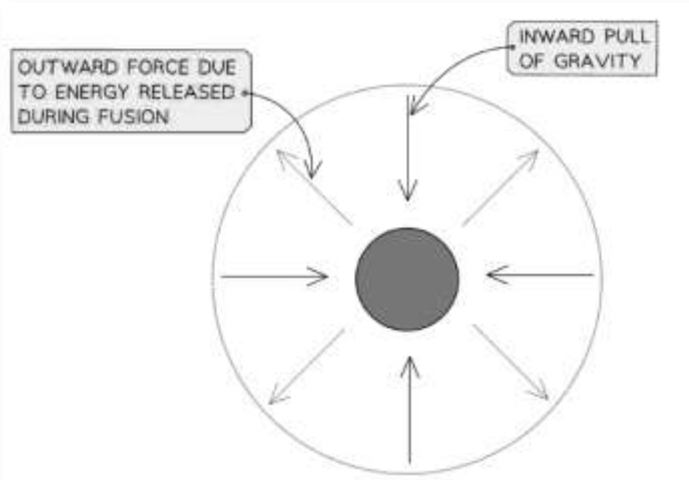
Sadly the next **total solar eclipse** that will pass over the UK won't happen until September 2090! However, below is a map of where you could witness solar eclipses across the world over the next 10 years!

Origin of the Solar System

A **nebula** (plural: nebulae) is a large cloud of particles – mainly consisting of Hydrogen as this is the most abundant element in the universe. To put the size of these clouds into context – the Eagle nebula (pictured right) is 100 light years across.

That means it takes light (the fastest thing there is at 300,000,000 m/s) 100 years to travel from one side of the nebula to the other!

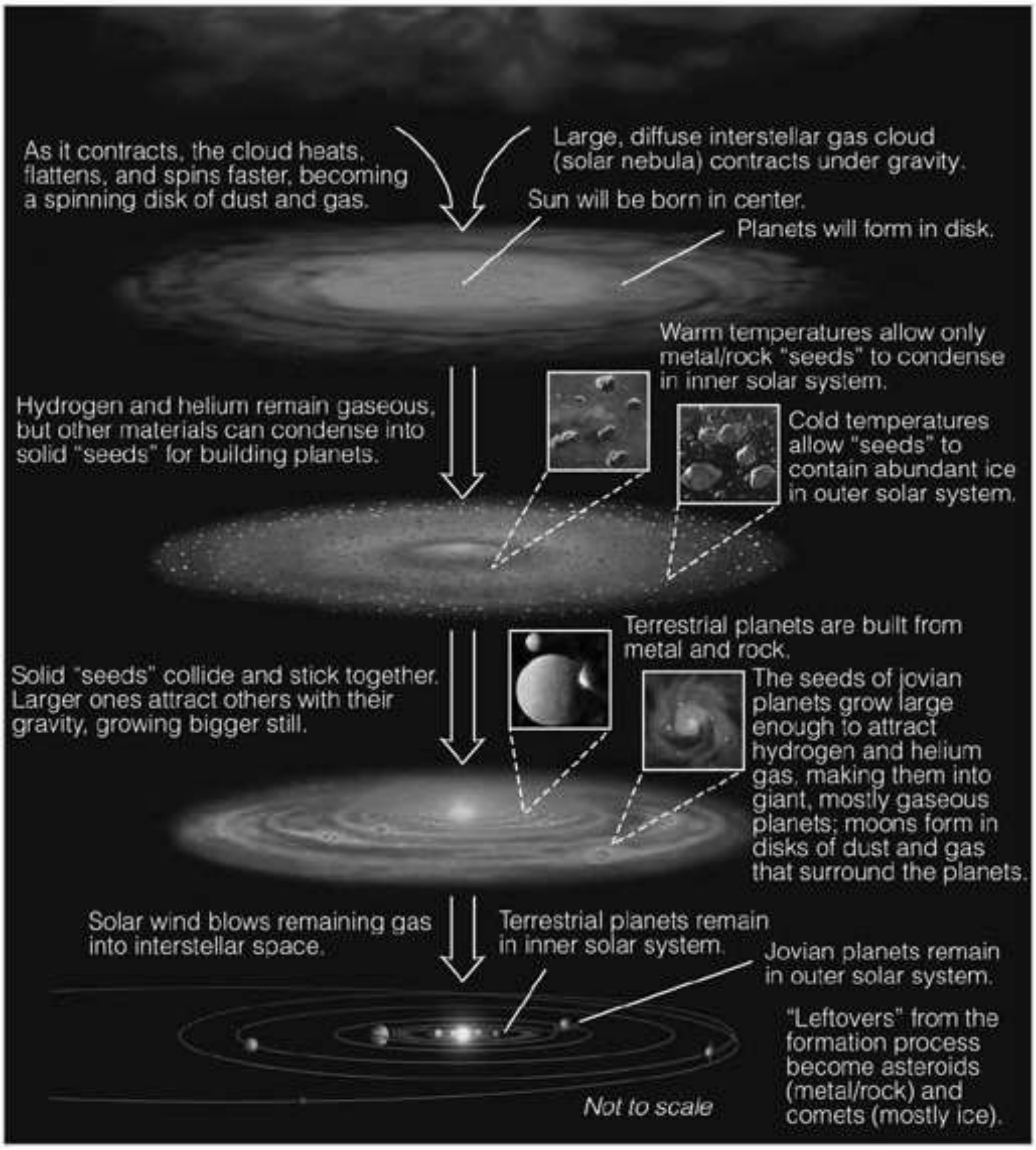
Gravity can cause parts of the nebula to begin to collapse together – the particles in these regions start to move quickly (picture water as if it were draining down a plughole, but never quite reaching it). This increases the temperature of these areas. A hot area of these fast-moving particles which are gravitationally bound together is called a **protostar**.



If the temperature and kinetic energy of these particles gets high enough, the smaller particles can collide and fuse together to make larger ones – this is called **nuclear fusion**.
Stars will spend most of their lives fusing hydrogen to helium. This phase is called their **main sequence**. During the main sequence the outwards pressure from fusion balances the inward collapse due to gravity and the star is stable.

Formation of the Planets

After the Sun was formed there was still a spinning disk of gas and dust. **Gravity** and **magnetism formed metals**, **rocks** and **ice**. The metal and rocks formed the **Terrestrial** planets. The ice and remaining gases formed the **Jovian** planets.



Questions:

Q1: What is a nebula? [1 mark(s)]

Q2: What is the force that pulls gas together to form stars? [1 mark(s)]

Q3: What is a protostar? [2 mark(s)]

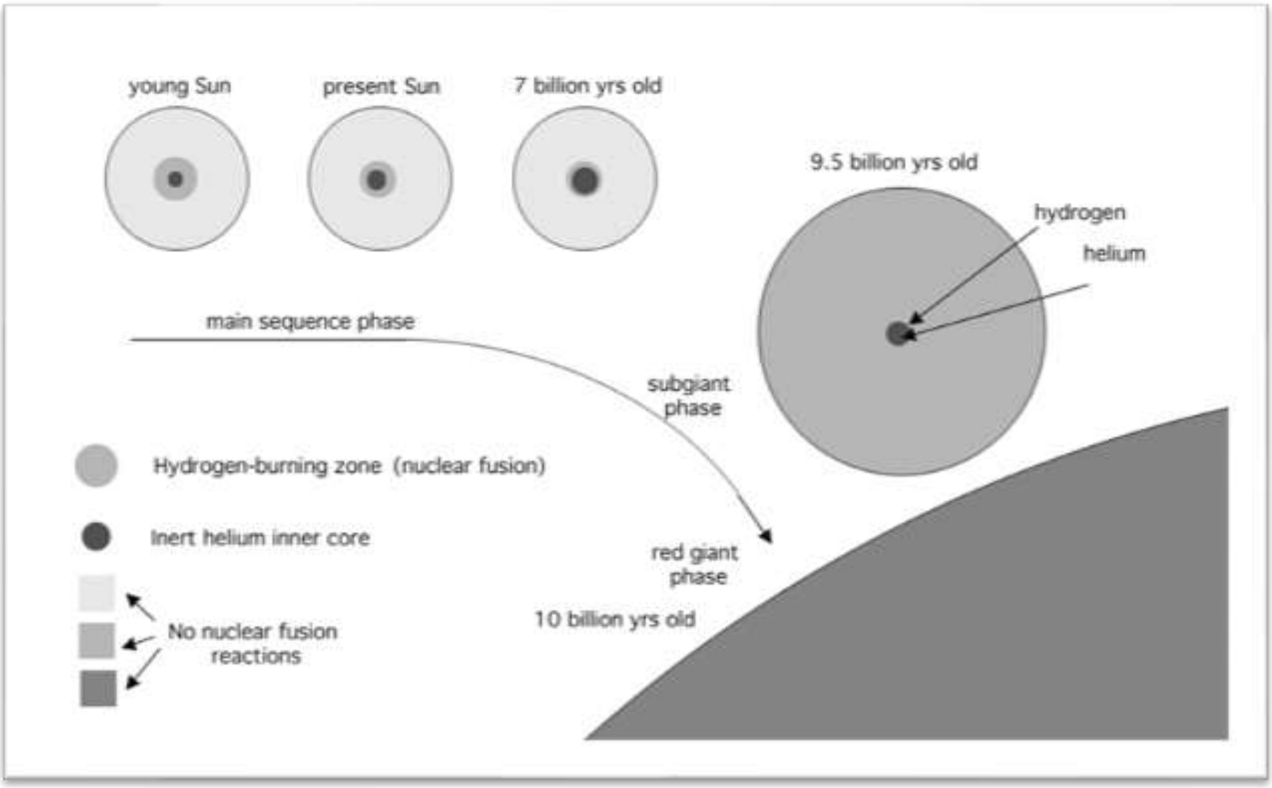
Q4: What happens when nuclear fusion begins? [2 mark(s)]

Q5: What are the two main types of planets and what are they made from? [2 mark(s)]

The Life Cycle of Stars

When a sun-like star **runs out of Hydrogen in its core**, the outwards pressure from fusion stops. The star collapses, raising the pressure inside the star. This triggers the fusion of Hydrogen in a layer around the core – called shell burning - which releases massive amounts of energy. The star will then rapidly expand and become a **Red giant.**

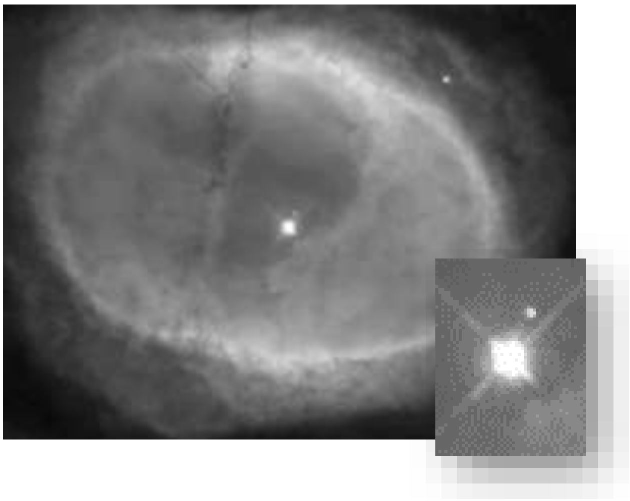
When the sun reaches this phase, it will become large enough to almost swallow the Earth! Fortunately, we have quite a while yet before this happens!



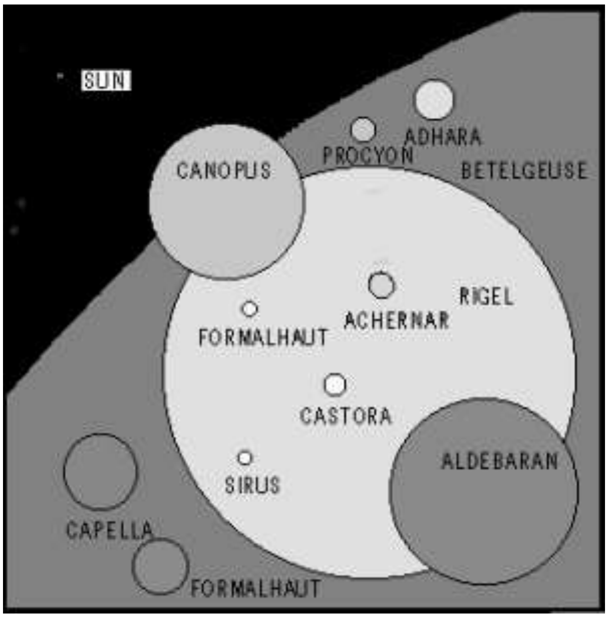
The diagram above shows the stages of fusion in the Sun as it ages. You do not need to learn the details of this diagram.

Eventually, stars like the sun run out of fuel entirely. Their outer layers drift away into space forming a **planetary nebula**, leaving behind a planet sized white hot core called a **white dwarf.** Over billions of years, the white dwarf cools, forming a **black dwarf**. However, the universe isn't old enough for any of these to be around yet!

This is a picture of NGC 3132, also know as the Eight-Burst Nebula. There are actually two stars in the centre of this nebula (see the close up image in the bottom right) – the smaller of the two is the white dwarf whose outer layers form the nebula, and the larger is a hot star giving off lots of ultraviolet light, which is making the nebula 'glow'.



Massive Stars



When stars form in nebulae, they can have a variety of masses. Our Sun is middle of the road, as far as stars go.

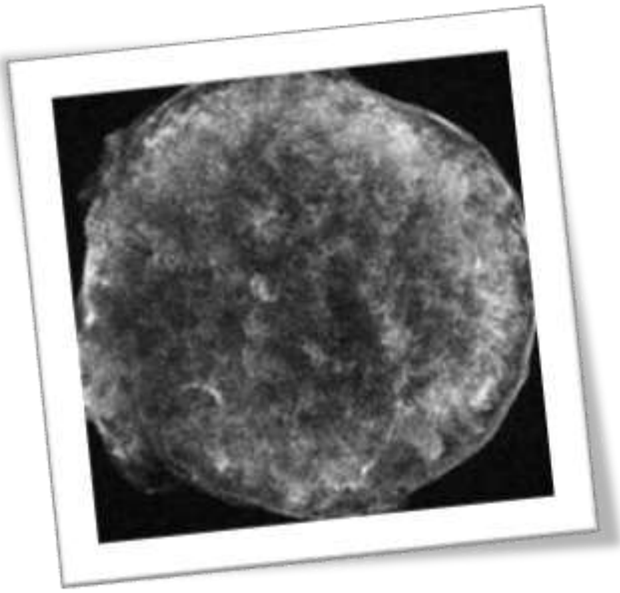
More massive stars have similar beginnings to the Sun. They form in **nebulae** due to gravitational attraction between particles and heat up to form a **protostar.** They fuse Hydrogen into Helium in their **main sequence** phase too.

It is after Hydrogen runs out in their core that their path differs from the Sun.

These stars have the mass to create enough pressure to fuse larger atoms together, well beyond Hydrogen. When one fuel source depletes a similar process takes place to the 'shell burning' stage which causes our Sun to expand into a Red Giant. In massive stars, however, this process can repeat multiple times, each time fusing heavier elements. During this time the star expands to become a **Red Supergiant**.

It is the fusion of Iron which brings the stars life to an end. The fusion of Iron does not release energy, as with the fusion of elements lighter than Iron. This means that when all fusion fuel besides Iron has been used, outwards pressure from fusion ceases, leaving only the inwards pressure due to gravity.

The outer layers of the star collapse under this pressure, then rebound outwards from the solid Iron core in one of the biggest known explosions in the universe- a **Supernova**.

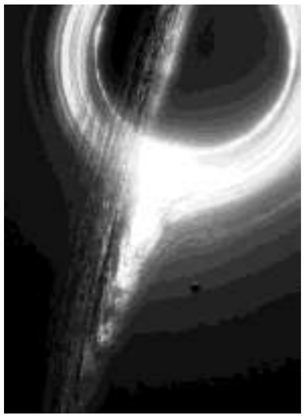


The picture on the right is of 'Tycho's Supernova' – this was visible to the naked eye in 1542, and we have since been able to image it with modern telescopes.

It is these explosions which create elements heavier than Iron, such as Copper, Gold and Lead. The supernovae then scatter these elements throughout the universe, to form more nebula, stars and planetary systems.

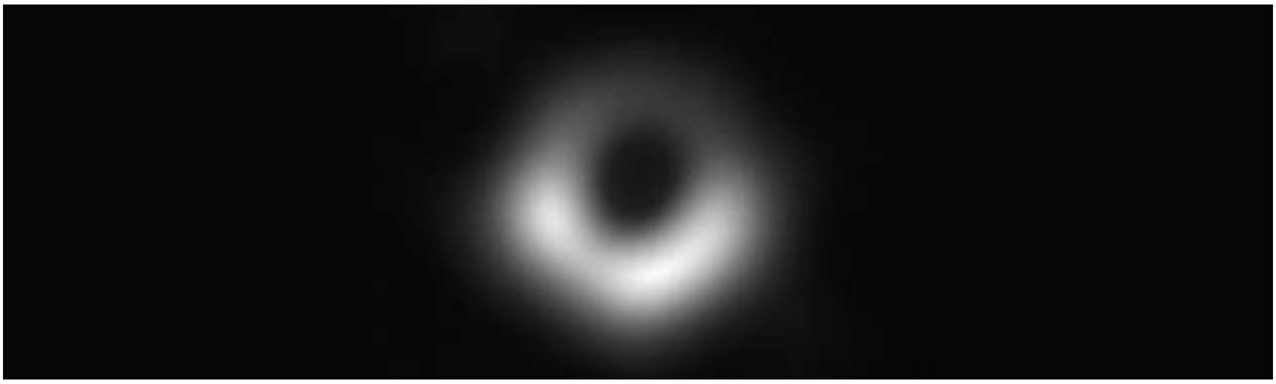
The core of the star either becomes compacted down into an incredibly dense **neutron star**, or, if the star is massive enough, the core collapses entirely to leave behind it a **black hole**. These are objects of such high density, with such a strong gravitational pull, that even light cannot escape them.

Black Holes – Extra information that is not examined



The picture to the right shows how a black hole was imagined in the movie Interstellar and was based on accepted scientific theory. If light passes too close to the impossibly dense singularity formed by the collapsing core of the star, it cannot escape. We cannot see the collapsed star itself, but a 'black' sphere showing the boundary that once passed, cannot be escaped from. This boundary is called the 'event horizon'. The glowing material in the image is the remnants of a neighbouring star, which has been pulled in to the black hole due to its immense gravitational pull. Scientists have long predicted the existence of such objects.

April 2019 saw the first ever successful imaging of such an object. The image below was captured by several hundred scientists using an array of telescopes and shows the glowing ring of matter being pulled into a supermassive black hole. This supermassive black hole is a whopping 55 MILLION LIGHT YEARS away, and has a mass approximately 6.5 BILLION times that of our Sun. Yes, the photo is a little blurry, but this black hole is not even in our galaxy!



Questions:

Q1: What will the Sun become after a Red Giant? [1 mark(s)]

Q2: What causes a star to explode as a supernova? [2 mark(s)]

Q3: What are two possible ends for massive stars? [2 mark(s)]

Q4: What balances gravity in a main sequence star? [1 mark(s)]

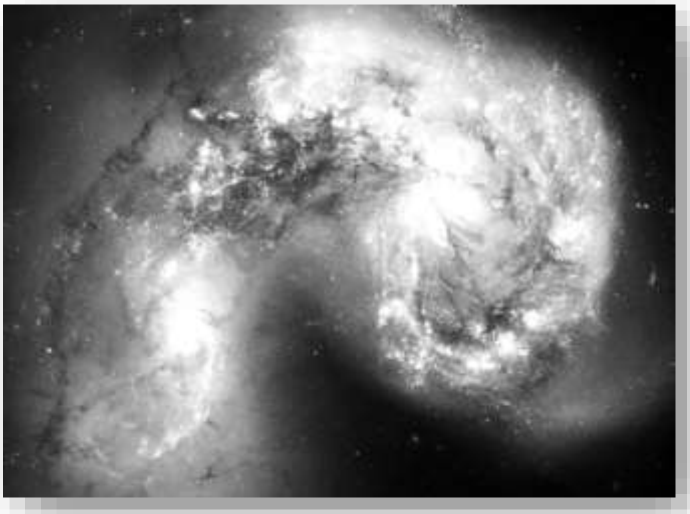
Q5: Name the first and last stage of the Sun’s life cycle. [2 mark(s)]

Exploring Space

Lots of things we know about objects and events in space, we know due to observations that have been made from the Earth using telescopes. However, we have also learned a lot from physically exploring space with technology. There are four main types of spacecraft used by humanity.

Observatory

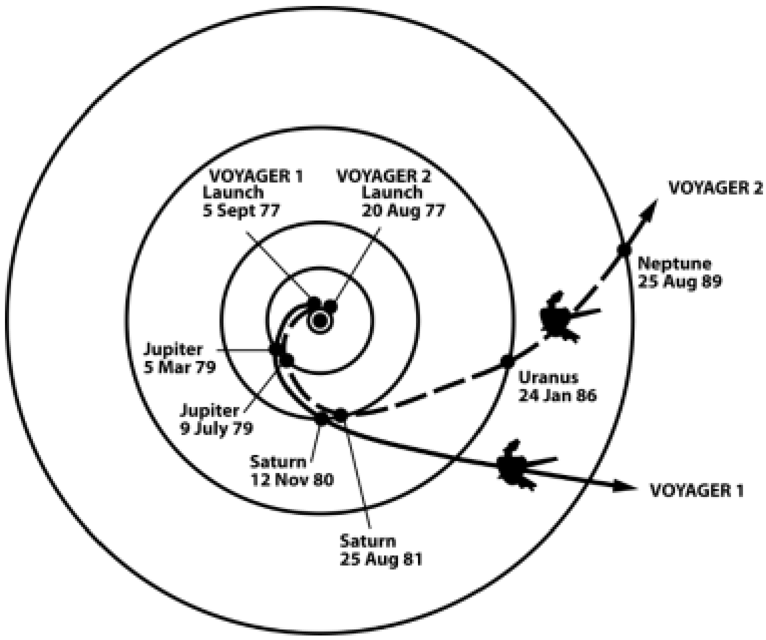
Observatory spacecraft are often placed in an Earth orbit and contain powerful telescopes, which can detect many different forms of light and so **collect data from very distant objects**.



Light itself comes in many forms, all of which are on the 'electromagnetic spectrum'. Some types of light are absorbed by our atmosphere, and some pass through. If we wish to collect light that is normally absorbed by the atmosphere, we must collect this from space.

The Hubble telescope is the most notable example of an observatory spacecraft. The photograph here was taken by Hubble and is the blazing wreckage of a collision between two spiral galaxies. Scientists take great interest in this collision, as our own galaxy will collide with a neighbour (Andromeda) in roughly a billion years!

Flyby



These spacecraft are launched from Earth, then use the gravitational pull of other objects to 'slingshot' to the furthest edges of the solar system. The image to the left shows the flight paths of two flyby spacecraft, Voyager 1 and Voyager 2. These are the only two human made objects to ever reach the edge of the solar system and travel to interstellar space!

Flyby spacecraft are excellent for **reconnaissance missions** and collecting data from **multiple locations**.

Orbiter

Once observatory or flyby spacecraft have conducted surveys of nearby objects, such as planets or moons, we can send an orbiter spacecraft. These spacecraft visit a particular object and remain in orbit around it. This allows **more detailed measurements over extended missions** – mapping planetary surfaces, observing weather formations, measuring magnetic fields, and things of this nature.

The picture on the right shows the shadow of Saturn's rings on the planets surface, together with Saturn's largest moon Titan. This image was captured by Cassini, a spacecraft which, launched in 1997, took its final images of Saturn in a controlled crash into Saturn's atmosphere in 2017.

Lander/Rover

If we wish to collect **in depth data** about an object in the solar system, such as soil **samples**, checking for microbial life, measuring the composition of the atmosphere, planetary geology, then our only choice is to land on the object. These missions are the most difficult of all, and lander spacecraft often feature the most advanced technology. They are usually the largest and most massive spacecraft, and hence are the most expensive to construct and launch.

To this date we have landed spacecraft on Venus, Mars, our Moon, Titan and several asteroids. A rover is an object that can leave a lander and travel around on an objects surface, collecting samples and taking photographs. Here is a famous 'selfie' taken by the Curiosity rover on Mars!

Questions:

Q1: What type of spacecraft stays in orbit around a planet? [1 mark(s)]

Q2: Name one space observatory. [1 mark(s)]

Q3: What type of spacecraft collects samples from the surface of a planet? [2 mark(s)]

Q4: Which spacecraft type is best for visiting many objects quickly? [1 mark(s)]

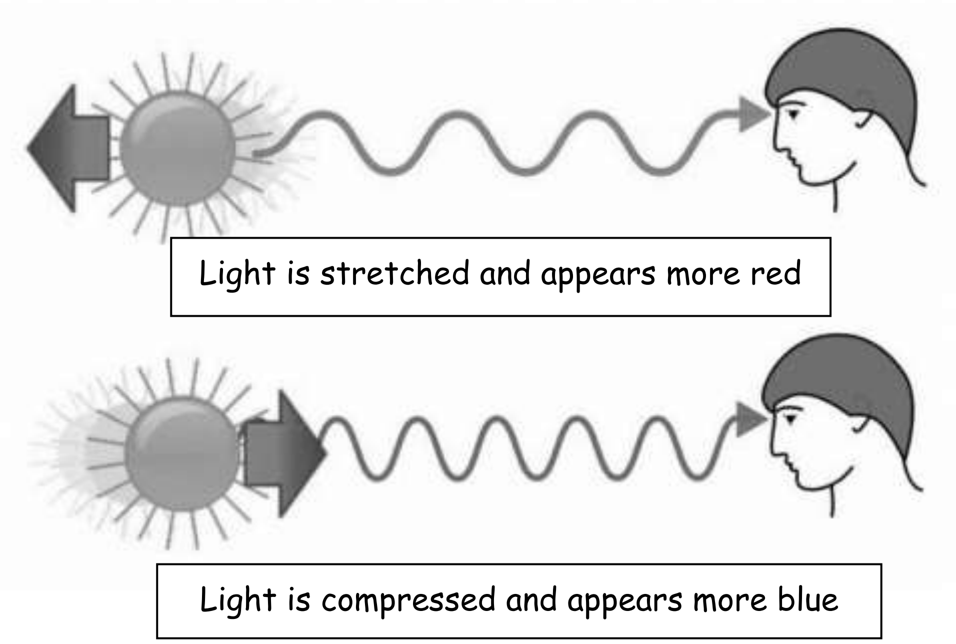
Q5: What is the main function of an observatory spacecraft? [2 mark(s)]

The Universe *(extra detail that is not examined)*

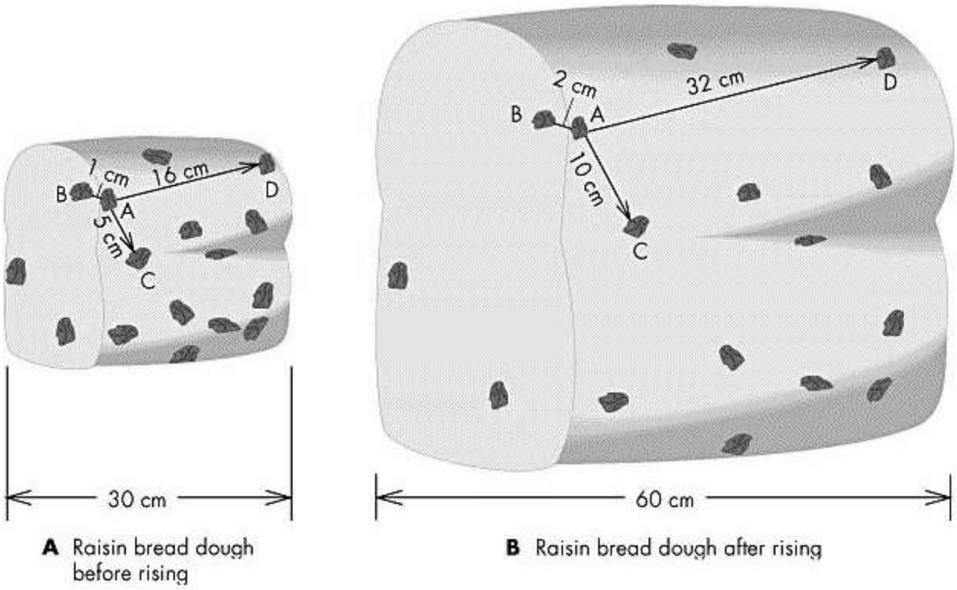
The current theory scientists use to explain the origins of the universe is called the **Big Bang theory**, and it states that the universe began as a very hot, very dense, very small region which rapidly expanded.

There are two key pieces of evidence which, currently, we can only explain with the big bang theory. The first piece of evidence is that the universe is expanding. That is, almost all objects, such as galaxies, are moving away from each other. We know this because the light emitted from distance objects has been **red-shifted**.

When a luminous object moves away from an observer, the light wave we detect appears to have been stretched. As red light is the most 'stretched' of the coloured light we can see, we say that light which has been stretched has been shifted 'towards red'. Light which has been compressed has been shifted 'towards blue', as blue is the most compressed coloured light we can see.



The 'raisin cake' model of the Universe



Imagine that the raisins in the cake above represent galaxies. As the cake expands, the raisins all move further apart from each other. Imagine our galaxy is one of the raisins, then no matter where we look, we see all the other raisins moving away from us. All the galaxies we observe show **red-shift**, which means their light has been stretched, which means they are **moving away** from us. So, the universe must be **expanding**!

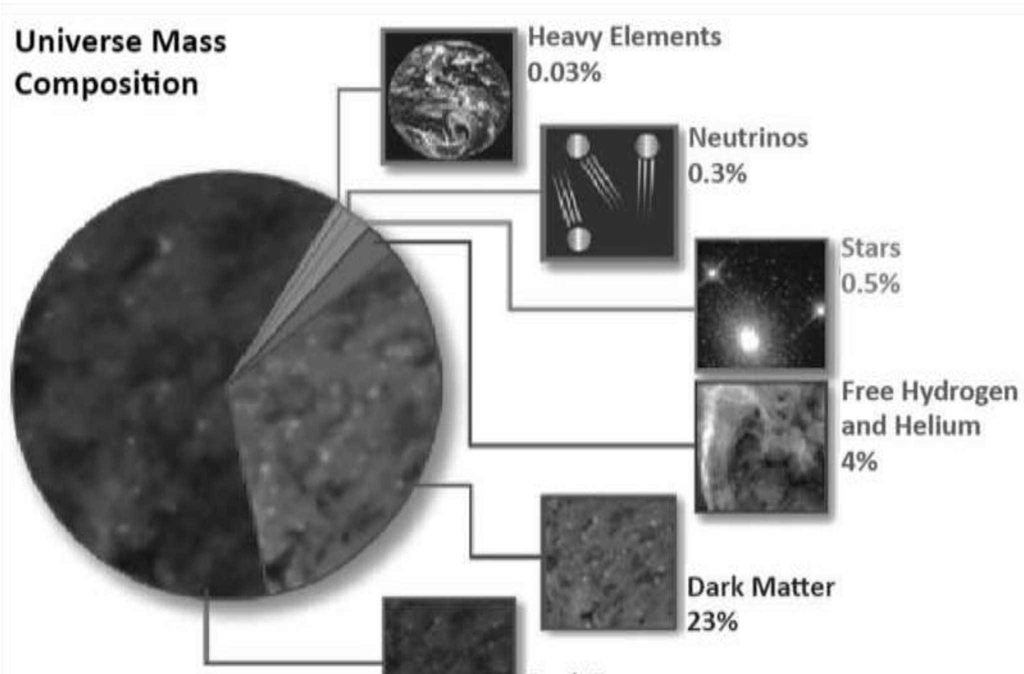
Cosmic microwave background radiation

Shortly after the big bang, a massive amount of energy was released, in the form of high energy gamma rays. As the universe has expanded, these gamma rays have been stretched and are now another time of wave called a microwave. We have detected these microwaves coming from all directions in space – further evidence for the big bang! These are often called **CMB** for short.

Unanswered questions

There are always more questions. Scientists have noticed that not only is the universe expanding, but the rate at which it is expanding is increasing! However, we do not know what the energy driving this acceleration is, or where it has come from! Scientists have dubbed this unknown source of energy '**Dark Energy'** as it is not something we can easily detect.

Also, from observations of the movement of stars within galaxies, and the motion of galaxies themselves, we have observed that most galaxies are behaving as though they had much, much more mass contained within them. However, we cannot detect anything that can account for this hidden mass! We have determined that there must be some form of substance, which we cannot detect, which contains all this extra mass. We have called this material **Dark Matter**.
In fact, from our measurements of the structure of the universe, we think that the matter we know of and can detect (atoms, elements, molecules etc), only accounts for about 5% of the actual universe!



Discovering the nature of dark matter and dark energy are some of the most pressing questions in the scientific community. Maybe you could be the one to help us come up with the answer? It will all start with your Science GCSE!

Revision Questions

1. What is the correct order of cosmic objects from smallest to largest?

2. What is the name of our planet, planetary system, galaxy, galaxy group, and supercluster?

3. What three criteria must an object meet to be called a planet?

4. What is the difference between terrestrial and Jovian planets?

5. What is a satellite? Name two types.

6. How long is: a day, a year, and an hour?

7. What causes the seasons on Earth?

8. Why do we have day and night?

9. Why does the Moon appear to 'shine' and change shape?

10. Name the main phases of the Moon in order starting with New Moon.

11. What causes tides on Earth?

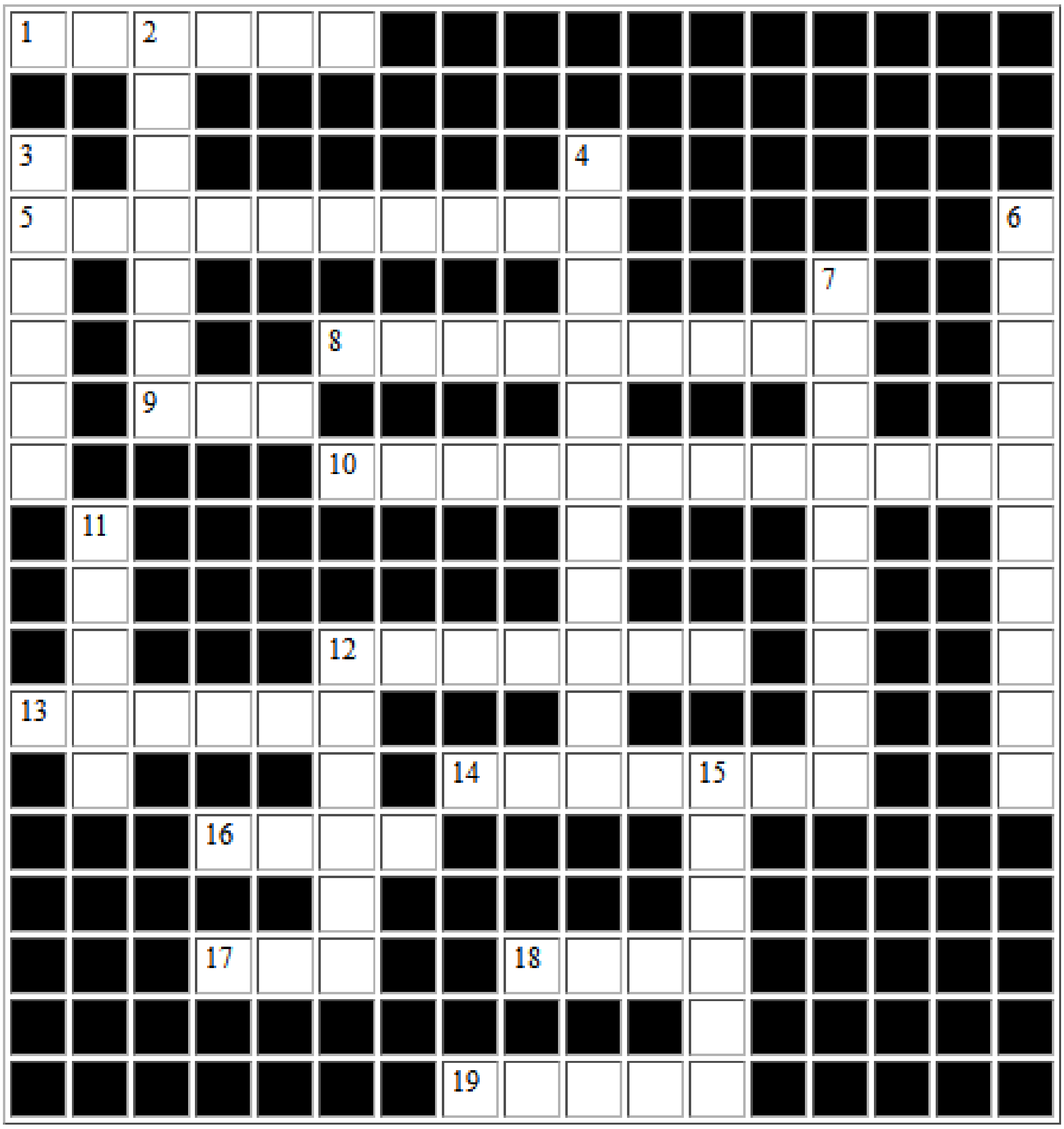
12. How did the Solar System form?

13. What keeps a main sequence star stable?

14. What are the stages in the life cycle of a star like our Sun?

15. Name and describe the four main types of space mission spacecraft.

Solar System Crossword



Across

1. The process where nuclei combine and release energy in stars
5. The part of the universe we can see due to light's travel time
8. A massive explosion marking the end of a large star's life
9. The star at the centre of our Solar System
10. A stable period in a star's life when fusion pressure balances gravity
12. The force that attracts objects with mass towards each other
13. A giant cloud of gas and dust in space where stars form
14. When one object blocks the light from another in space
16. The time it takes Earth to orbit the Sun once
17. The time it takes Earth to rotate once on its axis
18. A natural satellite of the Earth
19. The path one object takes around another due to gravity

Down

2. Caused by the tilt of the Earth's axis and its orbit
3. Gas giant planets like Jupiter and Saturn
4. Rocky planets like Earth and Mars
6. The hot, dense core left after a small star sheds its layers
7. An object that orbits a planet, natural or artificial
11. Caused by the gravitational pull of the Moon and Sun on Earth's oceans
12. A large group of stars, bound by gravity
15. A spherical object that orbits a star and dominates its orbit