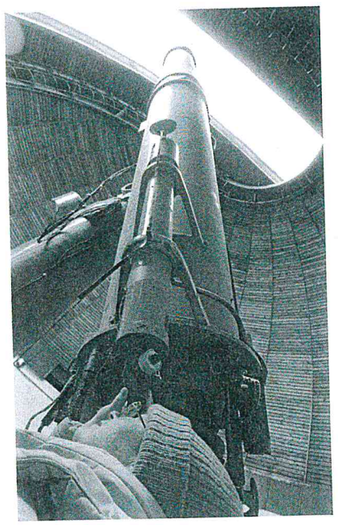
Extension

15.1

The origin of the Universe

Objectives

- Give the approximate age of the Universe
- Describe the Big Bang theory of the Universe, and evidence for it
- Compare the time that humans have lived on Earth with the age of the Earth



▲ *An astronomer using a telescope in an observatory.*

An **astronomer** looks at galaxies in the night sky. She works out that they are all moving away from the Earth. You might think that the Earth is special, or that it is the centre of the Universe, but that is *not* the case.

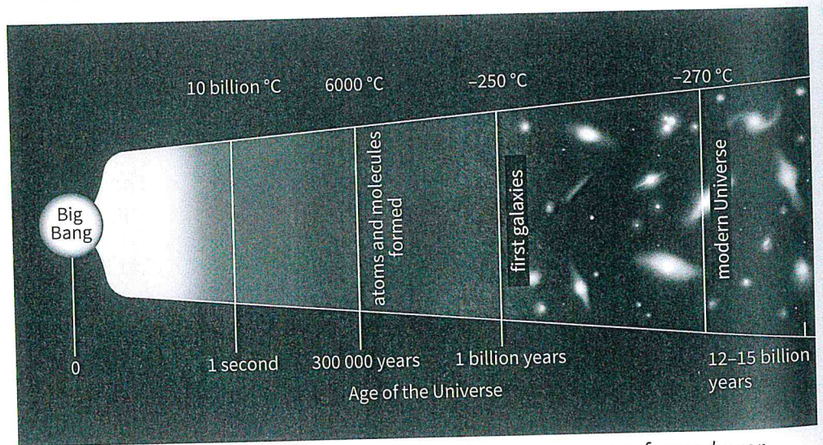
The Big Bang

Every galaxy is moving away from every other galaxy. Astronomers found evidence for this movement in the 1920s, when they used telescopes to measure how fast galaxies are moving. They also measured how far away they are. The further away they were, the faster they were moving.

Scientists used the evidence from their observations to develop an explanation called the **Big Bang**. It is an idea that explains observations and predicts what might happen in the future.

The Big Bang theory says:

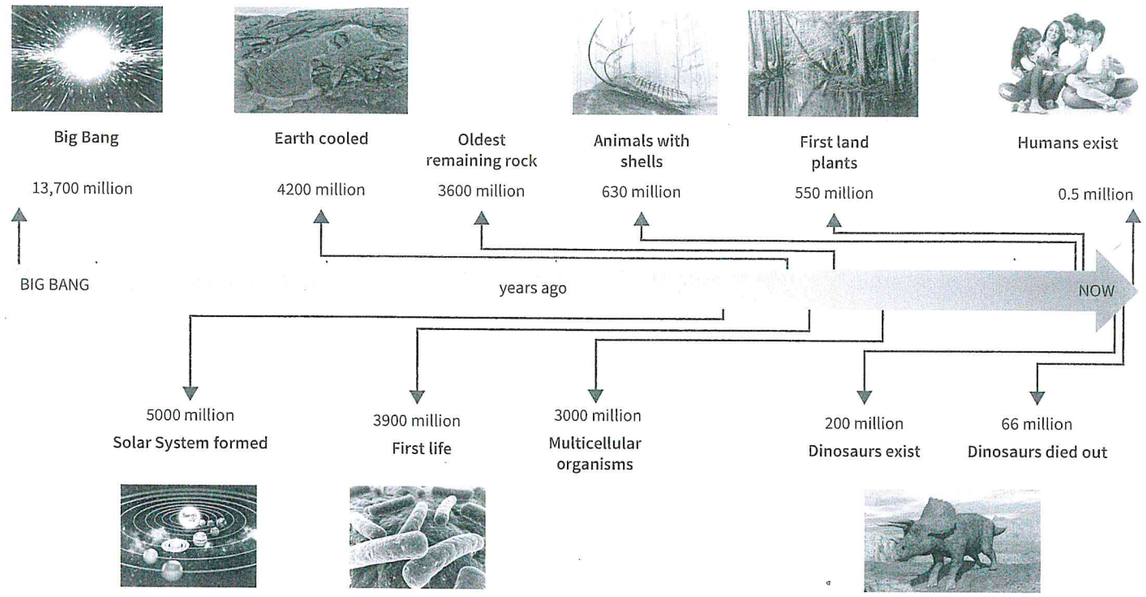
- The Universe began about 14 billion years ago.
- The whole Universe **expanded** from something smaller than an **atom** and hotter than anything we can imagine.
- In a fraction of a second the Universe grew to the size of a galaxy, and it has continued to expand ever since.
- As it expanded, it cooled, and energy changed into particles, making atoms and molecules of hydrogen and helium.
- Eventually there were stars, planets, moons, and galaxies, and the Universe we see today.



▲ *The Big Bang theory explains how the modern universe was formed over billions of years.*

The galaxies are moving away from us because the space in between all galaxies is expanding. There is nothing special about our galaxy, the Milky Way. If we lived in the **Andromeda** galaxy it would still appear that all the other galaxies, including the Milky Way, were moving away from us.

A timeline for the Universe



Sometimes it is easier to picture the timescale with an **analogy**.

- If the Universe started 24 hours ago, then the Earth would have formed 9 hours ago.
- The first animals would have appeared about an hour ago.
- Human beings would have existed for less than the time that it takes to blink your eyes.

The end of the Universe

No one knows what will happen to the Universe.

- It may expand forever.
- It may expand, and the expansion could get faster.
- Gravity may pull it back in again.
- It may expand to a certain size and stay that way.

To know what is going to happen we would need to be able to measure the mass of all the objects in the Universe.

This is *not* possible with the technology that we have at the moment.

Questions

1. **a.** Write down the age of the Universe.
   b. Write down the age of the Solar System.
2. Why is it difficult to predict what will happen to the Universe?
3. Could humans have seen a dinosaur? Explain your answer.

Key points

- Scientists think that the Universe began with a Big Bang about 14 billion years ago.
- Some evidence for the Big Bang is that all the galaxies are moving away from each other.
- Earth has existed for a fraction of the time that the Universe has existed.
- Humans have existed for a tiny fraction of the time that the Earth has existed.

15.2

Collisions, asteroids, and mass extinctions

Objectives

- Describe evidence for asteroid collisions
- Describe some consequences of asteroid collisions

About 66 million years ago a huge asteroid hit the Earth. Scientists think that this impact contributed to the extinction of the dinosaurs. Has this happened before?

▲ *An asteroid impact happened at the time the dinosaurs died out.*

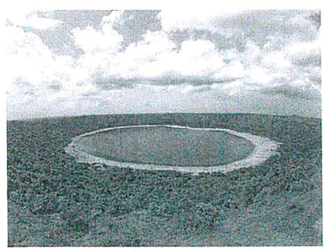
How do we know there have been asteroid impacts?

Asteroids can be pulled out of their orbit in the asteroid belt by Jupiter's gravity. Their new direction may take them on a collision course with the Earth. You learned about asteroids and **meteorites** on page 183.

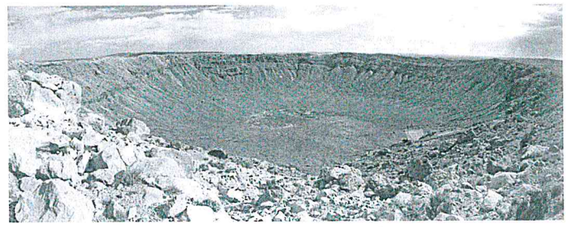
▲ *There are millions of craters on the Moon.*

There is evidence that very many asteroids have collided with objects in the Solar System in the past. If you look at the Moon you see it covered in **craters**. The Moon has been hit by lots of pieces of rock in the past. The conditions on the Moon mean that the craters are still visible.

What is the evidence for asteroid impacts on Earth?



▲ *The Lonar crater in India is now a lake.*



▶ *Meteor Crater in Arizona, USA, was formed when a piece of iron 40 m in diameter hit the Earth.*

There are some visible craters on the Earth. The crater produced by the asteroid that may have caused the extinction of the dinosaurs is deep off the coast of Mexico, and was not discovered until 1978.

What happens when an asteroid hits the Earth?

▲ *Some craters, like this one in Canada, are only visible from space.*

An asteroid with a diameter of 50 m can make a crater over a kilometre wide.

On impact, the ground and the asteroid can be **vaporised**. This sends material into the air in the form of dust, ash, and gas. If the asteroid hits the ocean it can cause a tsunami.

The effect of the impact depends what the asteroid is made of, and what it hits.

A large, metallic asteroid hitting soft rock will make a large crater.

What effect does an asteroid impact have?

If the asteroid is very large there will be enough dust to block out light from the Sun. The material that ends up in the Earth's atmosphere can change climate, and cause mass extinctions.

The climate depends on the balance between the energy that reaches the Earth from the Sun, and the energy that the Earth radiates into space.

If radiation from the Sun is blocked, then the temperature of the Earth would fall very quickly. This is called an **impact winter**. If the Sun was blocked out for a long time, then plants that rely on photosynthesis and animals that eat the plants would die. An impact winter that continued for over a year would make it difficult for humans to survive.

An event that causes a large percentage (75%–90%) of all species to disappear in a relatively short time is called a **mass extinction event.** Scientists think that these events happen on average approximately every 25 million years.

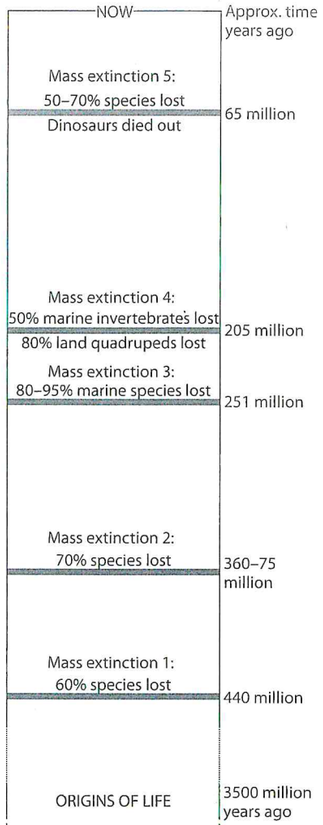
The most famous was the event that probably killed off most of the dinosaurs when an asteroid about 9 km in diameter hit the Earth.

However, most mass extinction events are thought to result from climate change due to volcanic emissions or changes to the Earth's oceans.

How often do significant asteroid impacts happen?

More than 100 tons of dust hits the Earth every day, but it gets burned up in the atmosphere.

An object the size of...	... hits the Earth every...	... and produces...
a car (5 m)	year	a fireball
a football field (100 m)	5000 years	a large crater, significant damage, tsunami
half (400 m) the tallest building in the world	100 000 years	climate change, impact winter, possible mass extinction



▲ *There have been five mass extinction events in Earth's history.*

Questions

1. Describe the two main effects of large asteroid impacts.
2. Explain why craters are easily seen on the Moon but *not* on Earth.
3. Suggest whether there are any objects in the Solar System that do *not* have craters.
4. Suggest why it is difficult to know the exact cause of a mass extinction event.

Key points

- Craters and meteorites show that asteroids have hit Earth in the past.
- Small asteroid impacts can cause small craters and fireballs.
- Large asteroid impacts can make craters, throw material into the atmosphere, and cause climate change and mass extinction.

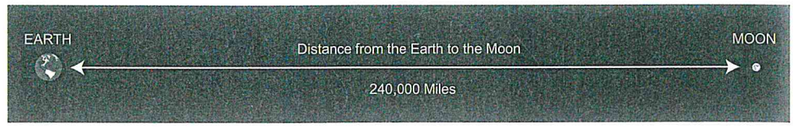
15.3

Collisions and the Moon

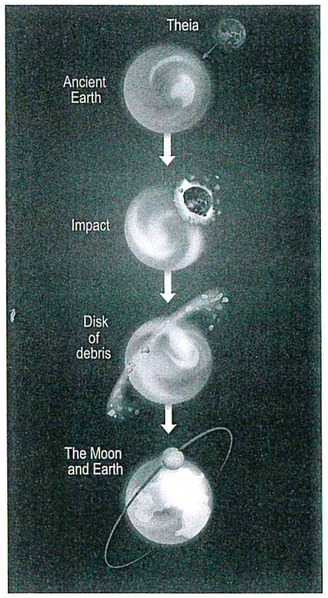
When you look up in the night sky you can usually see the Moon. It was *not* there when the Earth formed. How did it get there?

Objectives

- Describe the giant-impact hypothesis for the formation of the Moon
- Describe some of the evidence for and against the hypothesis
- Describe the evidence for other theories



▲ *The Earth and Moon to scale.*



▲ *Theia collides with the Earth.*

What is the 'giant-impact' hypothesis?

Most astronomers think that the Moon was formed when a giant object smashed into the Earth.

The Earth had formed by about 4.54 billion years ago from the gas and dust left from the formation of the Sun. In addition, various objects had hit the Earth later and been absorbed into it. Other objects, including planets, were made from the leftover gas and dust too.

- Gravity pulled together dust and gas.
- The dust contained iron that had been made in other stars.
- The iron formed the central core of the objects that formed.
- Debris rained down on the surface of the young Earth and probably kept the surface molten for a long time.

The **giant-impact hypothesis** says that the Moon formed at some time before 4 billion years ago.

- An object the size of Mars called Theia collided with the Earth.
- The energy of the collision heated the Earth and Theia.
- The molten iron cores of the two objects merged to form the core that the Earth has today.
- The lighter rock was thrown out into orbit and formed the Moon.
- After the Moon formed, the surfaces of both the Earth and the Moon cooled to produce a crust.

Astronomers can make predictions based on this hypothesis. Here are some of the predictions and some of the evidence for and against them.

Prediction	Evidence
The Earth should have an iron core.	Evidence suggests it does.
Some of the material of the Moon should be the same as the Earth, and some should be different because it came from Theia.	The material brought back from the Moon by the Apollo astronauts suggests that there is very little difference between the composition of the Earth and the Moon.
The Moon should orbit the Earth at a distance we can predict from models.	It does orbit at that distance.
The Moon's orbit should align with the Earth.	The orbits of the Earth and Moon do align.

Scientists have no direct evidence that the core of the Earth is made of iron. They think that it is made of iron because:

- it would account for the density of the Earth (if the core is made of rock then the density would be too low)
- the Earth has a magnetic field around, so it is likely that some metal element is moving in the core.

Other theories for the formation of the Moon

Co-formation theory

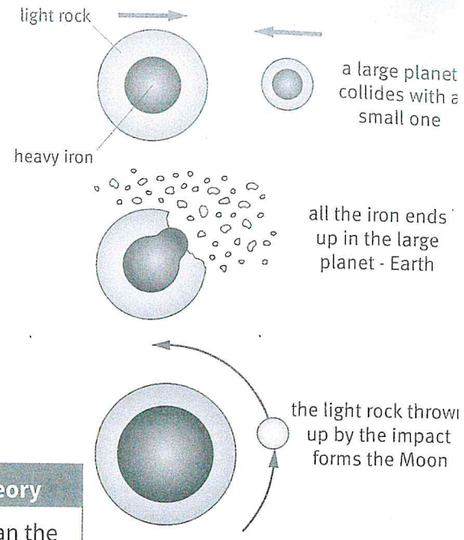
In one version of the **co-formation theory**, the Moon was formed alongside the Earth by gravity pulling together dust and gas. In another version, two objects the size of Mars collided, and the Earth and Moon formed from them.

Evidence for this theory	Evidence against this theory
• The Moon has a similar composition to the Earth. • The Moon would be in orbit at its present location.	• The Moon is less dense than the Earth. • The Moon does *not* seem to have a heavy core.

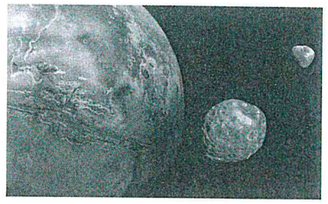
Capture theory

In the **capture theory** the Moon formed elsewhere in the Solar System. Earth's gravity captured the Moon as it was passing by.

Evidence for this theory	Evidence against this theory
• The Moon is less dense than the Earth.	• Objects that are captured are *not* usually spherical. • The orbits of objects captured this way do *not* align.



▲ *Did the molten iron cores merge?*



▲ *Some astronomers think that the two Martian moons (Phobos and Deimos) are captured asteroids.*

Science in context

There have been other theories about how the Moon formed. We are still not completely sure that the giant impact hypothesis is correct. Theories change over time. The co-formation and capture theories have been around for a long time.

Questions

1. Describe one piece of evidence that supports the giant-impact hypothesis, and one that does *not* support it.
2. Suggest why most scientists don't believe the other theories that have been proposed.
3. Suggest why astronomers might think that Mars's two moons are captured asteroids.

Key points

- The giant-impact hypothesis says that an object called Theia collided with a young Earth.
- The iron cores of the objects merged and the lighter rock formed the Moon.
- A lot of evidence supports the hypothesis, but not all.
- There are other theories, with less evidence.

15.4

Objectives

- Describe what a nebula is
- Describe how stars form and die

The life cycle of stars

When we look into the night sky we are looking back in time. The light from some of the objects has taken millions or billions of years to reach us. Some of the stars we are seeing are very young, and others have reached the end of their life cycle.

▲ *The Eagle Nebula is a stellar nursery.*

What is a nebula?

A **nebula** is a cloud of dust and gas. In some nebulae gravity pulls the gas together to make a star. These are called **stellar nurseries.**

When does a star shine?

Our Sun has a life cycle, as an animal does. Like all stars, it is born and it will die.

- The Sun was born from a cloud of gas and dust.
- Gravity pulled the gas together to form a **main-sequence star**, like our star is now.

▲ *The life cycle of our Sun.*

▲ *The Ring Nebula is a planetary nebula, not a stellar nursery.*

Nuclear fusion reactions produce the energy that makes the Sun shine. In nuclear fusion, hydrogen atoms fuse to make helium, and energy is released. Helium then fuses to make other elements. Elements up to iron in the Periodic Table are made in stars like our Sun. The temperatures and pressures needed for nuclear fusion are found in the centre of stars.

The Sun has enough fuel to shine like this for another 5 billion years. Eventually all of the hydrogen will be used up and it will go through the final stages of its life.

- It will grow to become a **red giant** and will swallow up Mercury, Venus, and possibly Earth as well.
- The outer layers will be thrown out into space to form clouds of gas called a **planetary nebula.** (A planetary nebula has nothing to do with planets. Astronomers thought they looked like planets.)
- The centre will shrink and become a hot **white dwarf**, and then cool down to become an invisible **black dwarf** star.

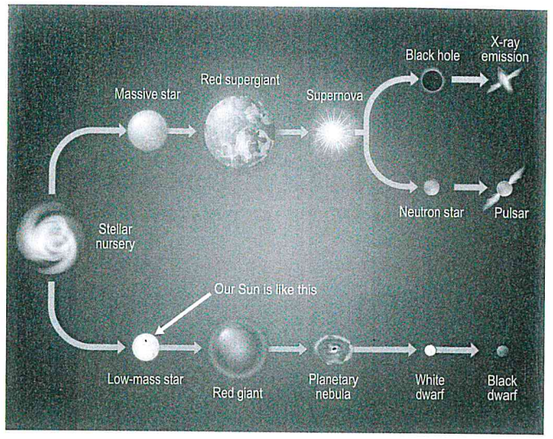
How is a stellar nursery formed?

Stars that are much bigger than our Sun are called **massive stars**. A massive star will turn into a **red supergiant**, explode to form a **supernova**, and then form a **neutron star** or a **black hole**.

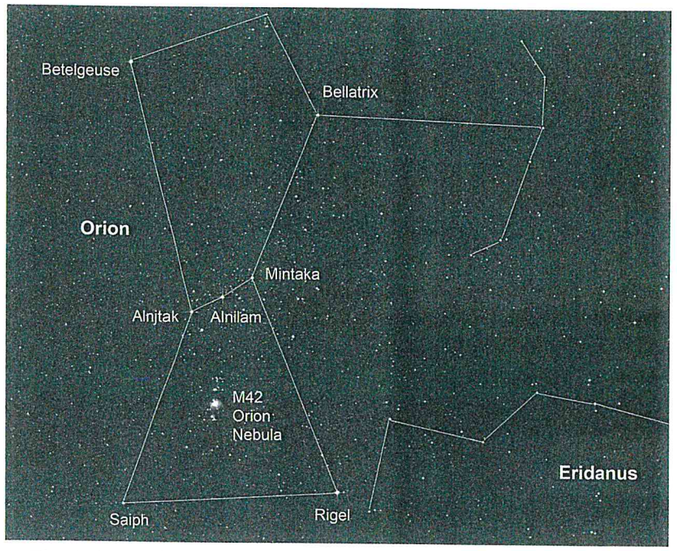
Massive stars eventually become supernovae. These are some of the most energetic explosions in the Universe. Elements that are heavier than iron in the Periodic Table are made in supernova explosions.

The remnants of the star are flung out into the universe to form nebulae. These nebulae can produce new stars and planets, like our Sun and our planet Earth.

You are made of stardust.



▲ *Life cycles of different types of stars.*



▲ *The Orion Nebula can be seen with the naked eye.*

▲ *The Orion Nebula looks beautiful through a large telescope.*

Questions

1. Match the words to their definitions:

A	Nebula	1	The type of star our Sun is now
B	Nuclear fusion	2	Cloud of dust and gas
C	Main sequence	3	The process that produces energy in stars
D	Red giant	4	What our Sun will become in about 5 billion years

2. Describe one similarity and one difference between the life cycle of a low-mass and a massive star.
3. Suggest why gold is more precious than diamond.

Key points

- Stars have two different possible life cycles depending on their mass.
- Low-mass stars like our Sun have a life cycle that ends up as a white dwarf, then a black dwarf.
- Massive stars end up as black holes or neutron stars.
- Both types of stars produce nebulae, which can go on to form new stars.
- Heavy elements are only made in supernova explosions.

Review 15.5

1. **a.** Describe one piece of evidence that there have been asteroid impacts on Earth. [1]

   b. Explain why scientists might disagree about the evidence. [1]

2. Give the letter of the correct statement. [1]

   A The size of an impact crater does not depend on the type of ground an asteroid hits.

   B The size of an impact crater does not depend on the type of material of the asteroid.

   C A bigger crater will be formed if the asteroid hits softer rock.

   D The Earth has only been hit by a few asteroids.

3. Which of the following is a piece of evidence for the giant-impact hypothesis? [1]

   A The Moon is orbiting the Earth at the expected distance.

   B People have landed on the Moon.

   C There is no atmosphere on the Moon.

   D The Moon has less gravity than the Earth.

4. Put these statements in order to describe the giant-impact hypothesis. [5]

   A The lighter rock was thrown out into orbit.

   B After the Moon formed the surfaces of Moon and Earth cooled to produce crusts.

   C The molten iron cores of the two objects merged to form the core that the Earth has today.

   D The energy of the collision heated the Earth and Theia.

   E The lighter rock came together to form the Moon.

   F An object the size of Mars called Theia collided with the Earth.

5. You can use primary and secondary data to develop explanations in science. TWS

   a. Describe the difference between primary and secondary data. [1]

   b. An astronomer uses some data from a science book to develop an explanation about the location of the Moon's orbit. Are the data primary or secondary data? [1]

   c. A student uses a table of numbers that they found in a magazine to find out about the number of moons around all the planets. Are the data primary or secondary data? [1]

   d. A teacher uses a telescope to make some observations of the craters on the Moon. Are the data primary or secondary data? [1]

   e. Which type of data are likely to be more reliable? Explain your answer. TWS [2]

6. Put these in order of age from youngest to oldest. [3]

   A the Sun **C** the Earth

   B the Universe **D** the Moon

7. An asteroid hit the remote Tunguska region of Russia in 1908, producing a fireball that flattened 80 million trees. No one was hurt.

   a. Explain why the complete asteroid was *not* found on the ground. [1]

   b. Define 'mass-extinction event'. [1]

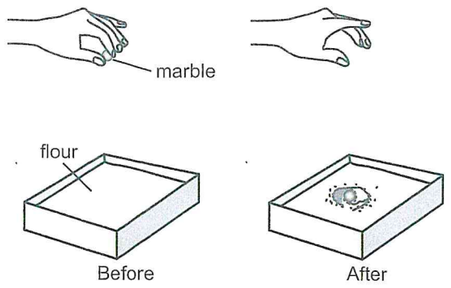
   c. Describe how an asteroid produces a mass extinction event. [3]

   d. Explain why mass extinctions are rare. [1]

8. A student wants to investigate impact craters.

They get a deep tray and fill it with flour.

When they drop a marble onto the tray it makes a crater.



a. Complete this sentence for a hypothesis about forming craters that they could test.

Craters are formed because the _____ of the falling marble is transferred to the flour, which makes the flour move. **[1]**

TWS **b.** Complete this sentence for a question that they could investigate.

I wonder how changing the _____ that I drop the marble from affects the _____ of the crater. **[2]**

c. Name the independent variable. **[1]**

d. Name the dependent variable. **[1]**

e. Name one control variable. **[1]**

TWS **f.** Describe and explain the type of graph that they could plot. **[2]**

7. Here are some statements that would provide evidence for different theories for how the Moon was formed.

A The Earth should have an iron core.

B Some of the material of the Moon should be the same as the Earth, and some should be different because it came from Theia.

C The Moon should orbit the Earth at a distance we can predict from models.

D The Moon's orbit should align with the Earth.

a. Give the letter or letters of the statements that are true. **[1]**

b. Give the letter of a statement that supports the giant-impact theory over other theories. **[1]**

c. Describe an alternative theory for the formation of the Moon. **[2]**

d. Explain why the theory you have described has *not* overtaken the giant-impact theory. **[1]**

10. A student is trying to explain the timeline for the formation of the Universe.
They use the idea of condensing the length of time that the Universe has been in existence to one year.

a. Copy the table and add the following events at the correct time. **[2]**

dinosaurs became extinct
Milky Way formed Earth formed

Date	Event
January 1	Big Bang
May	
Early September	Sun formed
Middle September	
December 7th	Dinosaurs lived
December 30th	
December 31st 9.25pm	Humans walk upright

b. Described what happened to the temperature of the Universe over time. **[1]**

c. The Universe has been expanding for about 14 billion years. Suggest the maximum distance, in light years, that the most powerful telescope possible could see into the Universe. Explain your answer. **[2]**