SAASTA AND SCOPEX TEACHER TRAINING

GRADE 9 TERM 4 TEACHER TRAINING MANUAL

National Research Foundation

South African Agency for Science and Technology Advancement

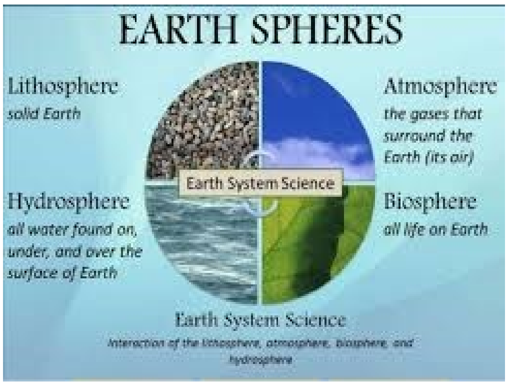
Table of Contents

Spheres of the Earth

The Earth can be understood as a complex system with many different parts and subsystems interact with each other.

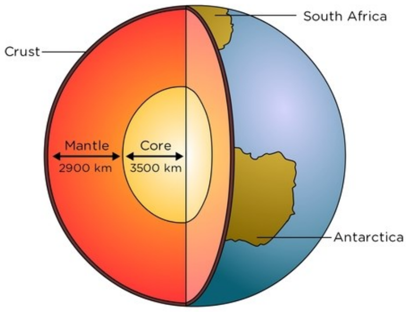
Four spheres interact on or near the surface of the Earth:

- The **Lithosphere** (*litho* – stone) consists of solid rock and soil
- The **Hydrosphere** (*hydro* – water) consists of water in all its forms
- The **Atmosphere** (*atmo* – air) is a layer of gases around the Earth
- The **Biosphere** (*bio* – life) consists of all living plants and animals and their interactions with rocks, soil, air and water
- As humans, we are also part of this interaction.
- There is a fine balance between these four systems - if the one becomes altered, it has an effect on all the others.



Lithosphere

- The Earth consists of four concentric layers called the
  - Inner core
  - Outer core
  - Mantle and
  - Crust
- The lithosphere includes
  - The Earth's crust
  - The upper part of the mantle.
  - All mountains, rocks, soil and minerals in the crust. Even the seafloor is part of the lithosphere, because it is also made up of sediments of sand and rock.



The core has two parts, the **inner core** which is solid and the **outer core** which is liquid. The mantle can also be divided into two parts, the **lower mantle** and the **upper mantle**. Some parts of the crust are found under the oceans. This is called the **oceanic crust**. Other parts of the crust form part of the continents and is called **continental crust**.

The brittle upper part of the mantle and the crust form the **lithosphere**. The lithosphere, the mantle and the core are sometimes called the **geosphere**. The geosphere is also one of the parts of the Earth, just like the **hydrosphere**, **atmosphere** and **biosphere.**

Activity: Investigating stones

Materials:

- magnifying glasses
- hammers
- paper towel
- samples collected, as described below

Instructions:

1. Collect the following items and bring them to school: sand, pebbles, a small stone/rock, a larger rock.
2. When you collect sand, stones or rock, look for the samples that look interesting and different and bring these to class.
3. Find at least four different items from different locations.
4. Study the different samples and complete the following table. If you have magnifying glasses available, use these to study the detail of the different samples.
5. Wrap some of the samples in paper towel and see if you can crush them with a hammer.

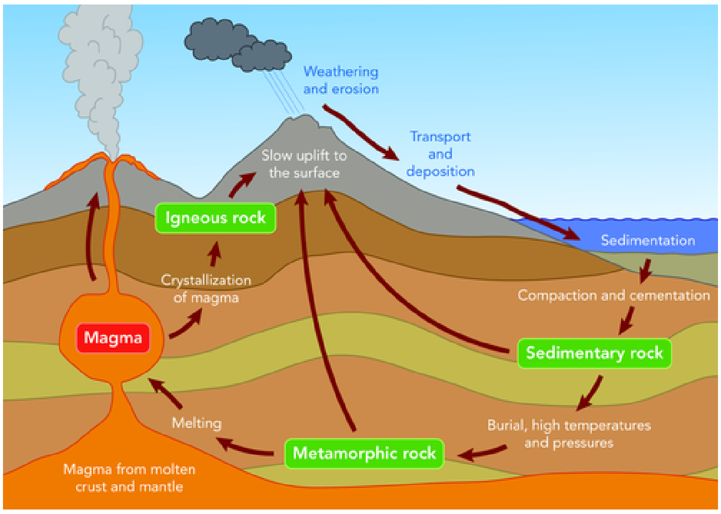
	Location Describe where you have found your sample.	**Shape and colour** Describe the size, shape and colour	**Texture** Describe the texture and hardness.	**Composition** Is it made of more than one material? Describe what it is made up of.
Sand				
Pebble				
Small stone/rock				
Larger rock				

The last investigation showed a lot of variety amongst the types of stone that are found in the area around your school. There is variation in shape, colour and texture amongst the different rocks on Earth.

The rock cycle

A cycle is a combination of processes that take place in a certain sequence and which repeat over and over again from the beginning. Processes in a cycle do not stop and are therefore said to be continuous.

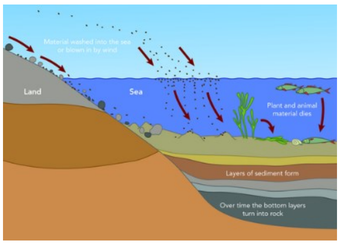
- The rock cycle is the natural continuous process in which rocks form, are broken down and re-form over long periods of time.
- There are three rock types: **Sedimentary, Metamorphic and Igneous**
- The rock cycle can be explained in the following steps:
  - Molten rock from the mantle (**magma**) pushes up through the crust
  - Pools of magma cool down slowly in the crust to form **igneous rocks**, **like granite**
  - Some magma escapes to the surface as a volcano
  - This magma cools down rapidly to form **igneous rocks, like pumice stone**
  - Rocks on the surface of the Earth are weathered by heat, cold, wind and water to form smaller particles
  - Wind and water transport these particles to flood plains and the sea by erosion
  - The particles are laid down as sediments
  - The sediments are covered by more layers
  - The pressure of many layers turns the lower layers into **sedimentary rock like sandstone**
  - Hot magma heats the surrounding rock and changes its chemical structure to form **metamorphic rock like slate from shale or marble from limestone**
  - Some rock is pushed below the crust, melts and becomes magma again



This Diagram summarizes the rock cycle.

Sedimentary rock

Sedimentary rocks are formed when layers of sediment solidify over time. Sediments are layers of particles from pre-existing rock or once-living organisms, for example, shells. Rocks on the surface of the Earth are weathered by expansion and contraction due to changes in temperature, wind and water, and also by erosion due to animals. Bigger rocks break up into smaller and smaller particles through the process of erosion.



Wind and water transport the loose, smaller particles, along with debris from living organisms, and some large stones, eventually depositing them on flood plains and in the sea. This is called **erosion**.

Although sedimentary rock is found in most places on Earth, these rocks make up only 8% of the Earth's crust. Different layers of sedimentary rock may be seen in the mountains and rocks around us on a daily basis.

You can see the layers in the sedimentary rock making up Table Mountain in Cape Town.

Sandstone rock in the Cederberg in the Western Cape.

There are different types of sedimentary rock, including **sandstone, limestone, dolomite, coal, shale and conglomerate.**

Limestone is a sedimentary rock made from the mineral calcium carbonate ($CaCO_3$), often formed from the remains of the skeletons of marine animals.

Coal is another example of sedimentary rock formed from the solidified remains of ancient plants at the bottom of swamps.

Activity: Modelling the formation of sedimentary rock

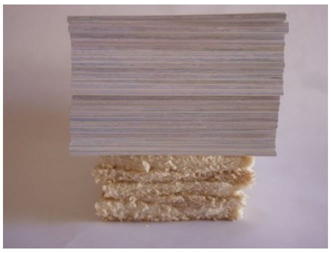
Materials:

- 3 slices of white bread
- 3 slices of brown bread
- heavy books or object

Instructions:

1. Cut off the crust from all the sides.
2. Layer the slices on top of each other, alternating the white and brown slices. Each slice represents a different layer of sediment.

1. Place a piece of plastic on top of the bread stack to protect the bottom book in your book stack, then place a pile of books on top of the bread stack. Observe what happens to the layers. Write your observations below.



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2. Add more books to the pile and observe. What happens to the layers?

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3. Remove the books from the bread pile. Can you distinguish the different layers now? Draw a labelled diagram of the bread layer.

4. Explain how this model demonstrates the formation of sedimentary rock.

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Metamorphic rock

Metamorphic rock makes up a large part of the Earth's crust. Metamorphic rocks are formed when sedimentary or igneous rocks are exposed to heat and pressure. Metamorphic rocks do not form on the surface of the Earth, but rather deeper underneath the surface where the temperatures and pressures are much higher. When other types of rock experience higher pressures and temperatures the rock crystals are squashed together. They undergo changes in crystal structure to form metamorphic rock.

- **'Metamorphic' refers to metamorphosis** - a process where one thing is transformed into a completely different thing, like a pupa becoming a butterfly.
- Metamorphic rock may move deeper into the Earth where they melt, forming magma. The magma may then cool and form igneous rock.
- Some examples of metamorphic rocks are **slate, marble, soapstone, and quartzite.**
- Slate is a metamorphic rock that was formed by shale (sedimentary rock) that was metamorphosed. Slate is often used for roofing or flooring. Since it can be cut into shapes and does not absorb moisture, it makes a good material for tiles

Roof tiles made from slate, which was formed from shale

Marble is a metamorphic rock that is produced from the metamorphosis of limestone

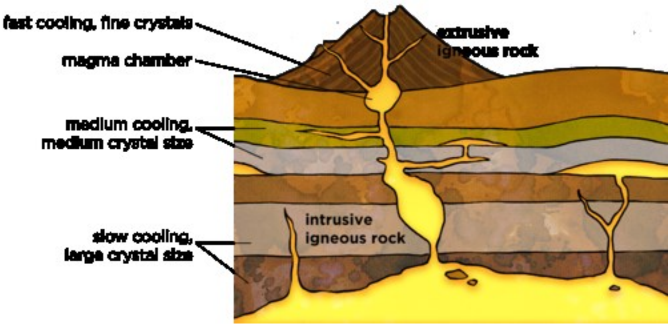
Soapstone carvings.

Soapstone is a relatively soft metamorphic rock. It is often used as an alternative natural stone countertop instead of granite or marble, for example in kitchens and laboratories. In laboratories it is unaffected by acids and alkalis. In kitchens it is not stained or altered by tomatoes, wine, vinegar, grape juice and other common food items. Soapstone is unaffected by heat. That means that hotpots can be placed directly on it without fear of melting, burning or other damage. Many statues and carvings are also made from soapstone.

Igneous rock

Igneous rock is formed when magma cools down. Three factors play a role when igneous rocks are formed:

1. **Where it is formed:** The rocks are formed on the surface they are called **intrusive rocks**. If they are formed under the surface they are called **extrusive rocks**.
2. **How quickly it cools:** When magma cools quickly, small crystals are formed and the resulting rock has a fine-grained texture. When it cools slowly, larger crystals form, resulting in a more coarse-grained rock. Sometimes the individual crystals can be seen with the naked eye.
3. **How much gas is trapped:** Magma contains molten rock and lots of gas. The gas is under pressure deep in the Earth. When the magma breaks through the surface, the gas is released. Depending on how quickly the magma cools down, the gas has more or less time to escape. When the magma cools down very quickly, lots of gas is trapped resulting in cavities and openings forming in the rock.



Examples of igneous rock are **basalt, granite and pumice**.

Basalt is the most common igneous rock and makes up a large part of the rocks just under the surface of the Earth. Most of the oceanic crust is basalt rock. It is a dark-coloured rock and is used as building material, particularly in building stone walls.

Basalt.

Granite is an igneous rock with large grains. It was formed from magma which slowly crystallised below the surface of the Earth. Granite is one of the most well-known types of rock. It is used to make numerous objects such as table tops, floor tiles and paving stone.

Various colours and patterns of granite rock

Pumice rock is an example of extrusive igneous rock. It is formed from the lava emitted during volcanic explosions. Because the lava cools down very quickly, a lot of gas is trapped in the rock. As a result, pumice is a very porous rock, with lots of holes in it, making it the only rock that can float on water. Pumice stones are used in lightweight concrete and as an abrasive in industries and in homes.

Pumice stone used as an exfoliator

Interesting Videos

https://youtu.be/04a_32NuYqs(Formation of sedimentary rock under the sea); https://youtu.be/99rGsXc9yWY (Rocks erode to form soil); https://youtu.be/pg_jKJFbA2A (Kitchen geology); https://youtu.be/pm6cCg_Do6k (The rock cycle); https://youtu.be/NAHY6965o08 (layers of the Earth); https://youtu.be/6Z4as_imJfM (How volcanos are formed); https://youtu.be/tQUe9C40NEE (Identifying rock types); https://youtu.be/8a7p1NFn64s (A brief introduction to minerals)

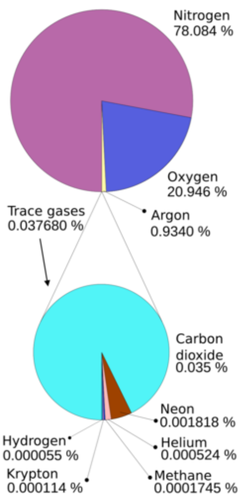
Mining of mineral resources

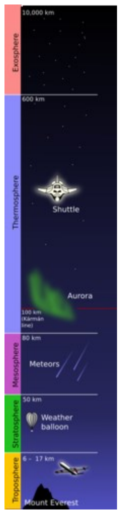
Give this as project, learners should research on:

- Extracting ore
  - Define what an ore is
  - Where they are found
  - Process used to extract ores from crust
  - Investigating how lead is extracted from its ore by heating lead oxide on a carbon block
- Refining minerals
  - Illustrating physical separation processes used in mining
  - Modern processes mix coke (a form of carbon made from coal) and other metals with iron to produce steel
- Mining in South Africa
  - Scale of mining activity in South Africa
  - Significant environmental impacts such as
    - creation of mine dumps
    - pollution of water resources
    - damage to places with high tourist or cultural heritage value
    - loss of farming and wild life environments
- Describe the:
  - Elements and compounds being mined
  - Chemical and physical separation methods used
  - Illegal mining

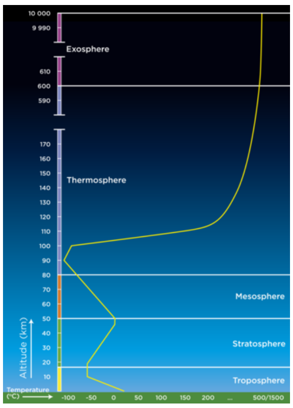
Atmosphere

- The atmosphere is the mixture of gases held around the Earth by gravity
- This mixture is known as air and consists of **nitrogen (78%), oxygen (21%), argon (0,93%) and carbon dioxide and other trace gases (0,04%)** including **water vapour (1%)**
- The **density** of the gas particles decreases as the distance from the Earth increases
- The atmosphere has four layers: **Troposphere, Stratosphere, Mesosphere, Thermosphere**
- Above the thermosphere, the atmosphere merges with outer space in the layer known as the **Exosphere** (not considered as part of the atmosphere due to low density of gases).
- Each layer has a different temperature gradient
    - temperature gradient is how much the temperature changes with height above sea level (altitude)
- The atmosphere is a very important part of the Earth. **It keeps the planet warm and protects us from the harmful radiation of the Sun**.
- It also ensures a **healthy balance between oxygen and carbon dioxide** so that life can be sustained on the planet.





Some endurance athletes spend several weeks training at high altitudes, preferably 2400 m above sea level, so that their bodies adapt by producing more red blood cells. This gives them a competitive advantage when returning to a lower altitude to compete. Similar reason why cars perfume better in coastal towns.



Troposphere

- Troposphere comes from the Greek word *tropein,* meaning to change, circulate or mix.
- This layer extends **from sea level to about 10 km** above the surface of the Earth
- It contains **more than 70% of the mass of the atmosphere** (particles closest together) and it has the greatest density
- Weather occurs in this layer
- All animals and plants live in this layer
- The air in the troposphere is in constant motion.
- As it is warmed by the Earth, the warm air moves away and gets replaced by cooler air which travels in convection currents.

The temperature in the troposphere decreases with altitude - the further you move away from the surface, the colder it becomes. The temperature decreases about 6,4°C for every kilometre increase in altitude.

Activity: Drawing a graph of the temperature gradient in the troposphere

1. Using the information in the previous text, set up your own table displaying the temperature change in the troposphere from 0 - 12 km.
2. Then draw a neat, accurate graph of this data.
3. Assume that the average temperature on the surface of the Earth is 16°C.
4. Choose an appropriate scale for the x- and y-axes of your graph.
5. Label the axes and give the graph a heading.

Use the following space to draw a table for your data.

Use the following space to draw your graph.

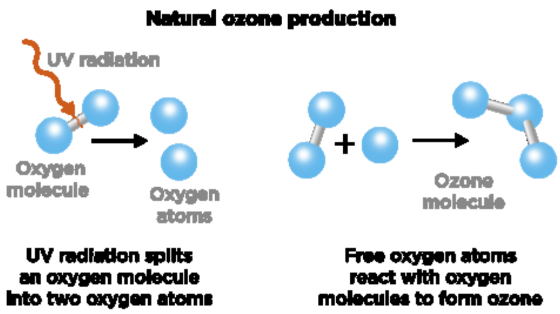
The temperature in the troposphere decreases steadily until it reaches about -60°C at about 10-12 km above sea level. The temperature here stabilises before it increases again. This is the transition zone between the troposphere and the stratosphere

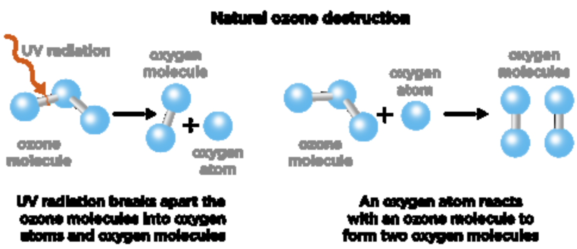
Stratosphere

- The stratosphere is the layer above the troposphere.
- It stretches from **12 km to 50 km** above the surface of the Earth.
- 90% of the mass of the atmosphere is found in the troposphere and the stratosphere.
- Aeroplanes fly in the lower part of the stratosphere because the air is much more stable than in the troposphere.
- Scientists use **weather balloons** to gather information on the temperature, atmospheric pressure, humidity and wind speed using a small device called a radiosonde.

A weather balloon being released

Ozone gas (O_3) is found in the stratosphere. Ozone gas is made up of ozone molecules. Each molecule consists of three oxygen atoms. Ozone plays an important role in absorbing harmful UV rays from the Sun by forming, breaking down and reforming ozone molecules over and over again. When UV light reaches the Earth, it can cause cancer, affect plant growth, and the life cycles of species





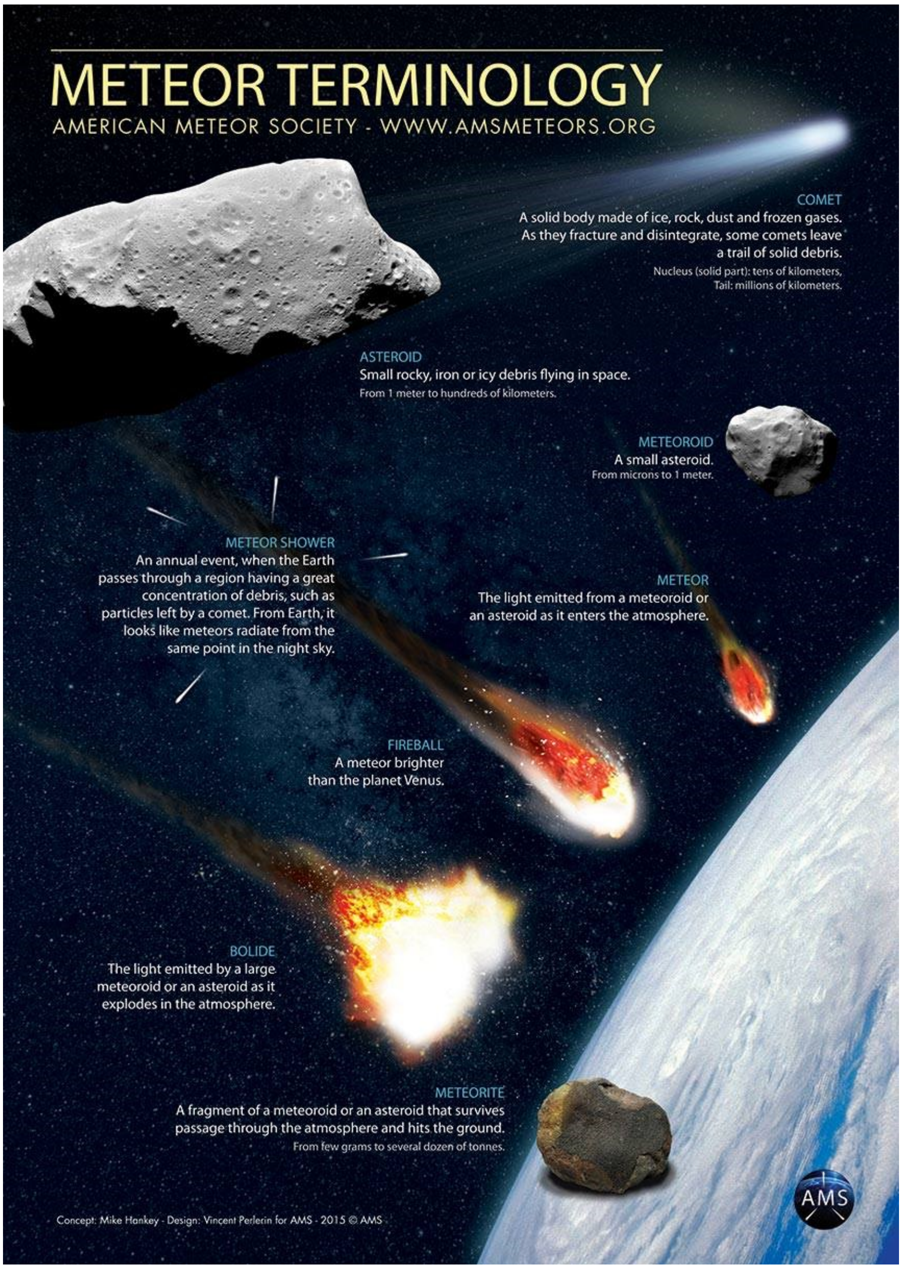
The ozone reactions lead to the heating of the stratosphere, increasing the temperature from -60°C to about 0°C. As a result, the air becomes warmer as you move further away from the Earth in the stratosphere.

The problem comes in when there are molecules present which interfere with these natural processes. **Chlorofluorocarbons, or CFCs**, are molecules which release chlorine atoms into the stratosphere. Chlorine atoms react with ozone, destroying it before it can absorb harmful UV rays forming the **ozone hole** which is an annual thinning of the ozone layer over Antarctica.

The Mesosphere

- The mesosphere **extends from around 50 km to 80 km** above the Earth's surface.
- The atmosphere reaches its **lowest temperature of -90 °C** in the mesosphere.
- The air density is extremely low, but there is still enough air to burn up rocks and dust entering from space.

A **meteor** is a rock that enters the atmosphere from space. They enter the atmosphere at speeds ranging from 11 km/sec (40 000 km/h) to 72 km/sec (260,000 km/h). As a meteor enters the atmosphere, the air in front of it is compressed. The air heats up and the meteor burns up as a result of heat and friction. When we look up at the night sky, we might see a streak of light flashing for a brief moment. This is commonly called a shooting star, but is in fact a meteor burning up in the mesosphere.



The Thermosphere

- The thermosphere is the layer of the atmosphere from 80 km upwards. The density of the air is extremely low.
- The temperature in the thermosphere **increases from - 90°C to as high as 1500°C** during increased solar activity.
- The thermosphere is very sensitive to an increase in energy and a small change in energy results in a high temperature increase.
- However, the thermosphere will feel cold as there are few particles present to collide with our skin and transfer enough energy for us to feel the heat.
- High energy light (for example, UV light) can cause atoms or molecules to lose electrons, forming ions.
- The region where this takes place is called the **ionosphere**. The ionosphere is found mainly in the thermosphere.
- The Sun also gives off charged particles (the **solar wind**), which can enter the Earth's atmosphere (mostly near the poles) and react with the ions and electrons in the ionosphere, causing a phenomenon called the **aurora**.
- The ionosphere **reflects longer wavelength radio waves**, we use for radio waves in radio and television (not satellite television), allowing the signal to be broadcast over a larger distance.
- The ions in the ionosphere absorb **ultraviolet radiation and X-rays**.
- Most satellites that we depend on every day are in **Low Earth Orbit (LEO),** orbiting the Earth at an altitude between 160 km and 2,000 km. The International Space Station (ISS) is situated at 370 km in the thermosphere.

The International Space Station orbits the Earth in the thermosphere

Sunset from the International Space Station. The troposphere is the deep orange and yellow layer. Several dark clouds are visible within this layer. The pink white layer above is the stratosphere. Above the stratosphere, blue layers show the mesosphere, thermosphere (dark blue) and exosphere (very dark blue), until it gradually fades to the blackness of outer space.

Activity: How thick are the layers of the atmosphere?

In this activity you will build a model to represent the different layers of the atmosphere. In addition to the model, you need to draw an accurate diagram to represent the thickness of each layer. Use a ruler to draw an accurate scale diagram.

Materials:

- large measuring cylinder or tall drinking glass
- corn kernels (popcorn)
- samp
- dried peas
- beans

Instructions:

1. Add a 0,5 cm layer of dried split peas to represent the troposphere (1 layer of peas thick).
2. Add a 1,5 cm layer of corn kernels on top of the peas to represent the stratosphere.
3. Add a 1,5 cm layer of samp on top of the corn kernels to represent the mesosphere.
4. Add a 24 cm layer of beans on top of the samp to represent the thermosphere.

Your column should look something like this

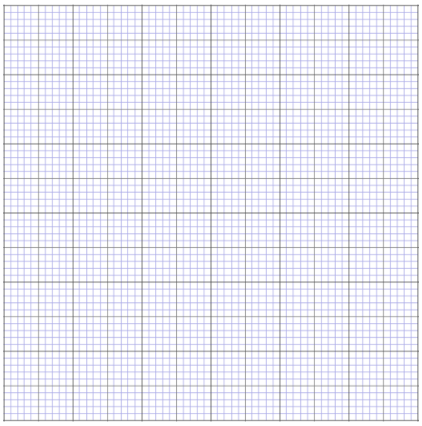
You will notice that the area where the two layers meet is not always clear cut. The kernels might have mixed a little bit. The atmosphere is the same. There is a not a clear line separating two layers, but they mingle in the area of contact.

Table showing the heights of the layers in Earth's atmosphere and in the model

Layer	Represented by	Height of layer (km)	Height of layer (cm)
Troposphere	Dried split peas	~10	0.5
Stratosphere	Corn kernels	~30	1.5
Mesosphere	Samp	~30	1.5
Thermosphere	Beans	~480	24

Questions:

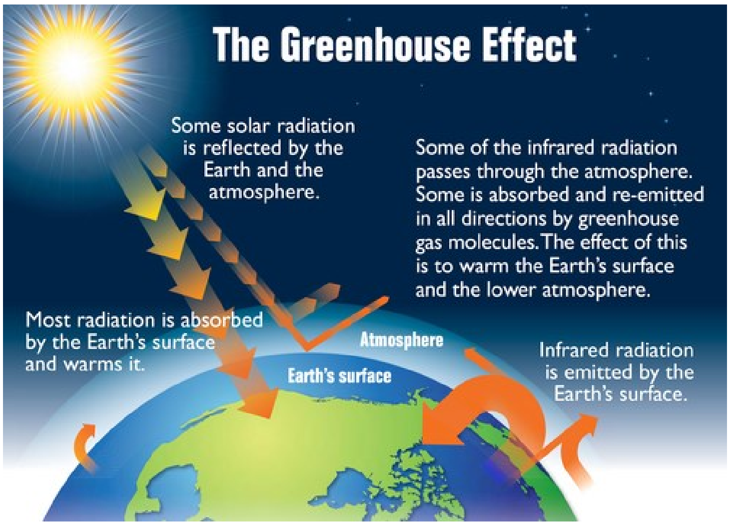
Draw a labelled diagram of the model using the graph paper. Include a scale. The density of the atmosphere decreases with altitude. Show this on your diagram as well.



1. What atmospheric layers are represented by the different grains in the model?
2. In the model in the activity, how many kilometres does 1 cm represent?
3. How much thicker is the stratosphere compared to the troposphere?
4. How much thicker is the thermosphere compared to all the other layers combined?
5. Where in this model would you expect to find clouds?
6. Where in this model would you expect to find the Drakensberg Mountains?
7. Where in this model would you expect to find a satellite?
8. Where in this model would you expect to find meteors burning up?
9. In which layer is there life? What is different about this layer?

The greenhouse effect

- The **greenhouse effect** is a natural phenomenon – it warms the atmosphere sufficiently to sustain life
- Greenhouse gases trap the ultraviolet radiation which then warms the air closest to the surface of the Earth
- The most common greenhouse gases are
    - **Carbon dioxide**
        - Carbon dioxide is a product of respiration in all organisms and also a gas given off by industrial processes and the burning of fossil fuels and vegetation.
    - **Water vapour**
        - Water vapour is formed when water evaporates on Earth
    - **Methane**
        - Methane is a gas, also called natural gas, which occurs in reservoirs beneath the surface of the Earth. It is also given off by decomposing plant and animal material and animals give off methane as part of their digestion
- Water vapour, methane and carbon dioxide are gases which let through incoming visible light from the Sun.
- The incoming radiation from the Sun is absorbed by the Earth's surface and warms it. The Earth's surface emits **infrared radiation**.
- Infrared radiation is absorbed by the greenhouse gases and re-emitted in all directions.
- This increases the temperature of the Earth's surface and lower atmosphere, above what it would be without the gases, called the **greenhouse effect**.
- These gases are very important to regulate the Earth's temperature.



Activity: A model of the greenhouse effect

In the greenhouse effect, carbon dioxide traps the heat of the Sun. In this investigation, you will use bottles with air and carbon dioxide, respectively, to model the greenhouse effect. You are going to investigate the following question: Does air or carbon dioxide absorb more heat?

Aim:

Write an aim for this investigation.

____

Hypothesis:

Write a hypothesis for this investigation.

____

Materials and Apparatus:

- two glass bottles or clear cold drink bottles with lids
- 2 thermometers
- Prestik
- heat source (two study lamps)
- vinegar
- bicarbonate of soda
- small cold drink bottle with lid

Method:

Set up the experiment as in the photograph.

1. Mark one bottle as 'Air' and the other bottle as 'CO_2'.
2. If the lids do not have the thermometers in them already, prepared by your teacher, make a hole in each of the lids. You can do this using a hammer and nail and hammering the nail through the lid into a wooden block. Secure the thermometer in each lid. You can use Prestik to do this.
3. Fill the first bottle with air and secure the thermometer and close the lid tightly.
4. Fill the second bottle with carbon dioxide:
    1. To collect a bottle of carbon dioxide, add one tablespoon of bicarbonate of soda to the small bottle.
    2. Add 10-20 ml of vinegar and place the lid back on.

3. Hold the mouth of the small bottle over the large CO_2 container and pour the CO_2 collecting in the small container into the large container. Hold the small bottle horizontal so that the vinegar does not spill into the bigger bottle, only the heavier carbon dioxide gas pours into the large container.
4. Add more vinegar when the effervescence stops. Repeat 2-3 times until the bottle is full. If a burning match at the mouth of the bottle goes out immediately, the bottle is full.
5. Secure the thermometer and close the lid tightly.

Pouring carbon dioxide from the small bottle into the large bottle.

6. Measure and record the starting temperature of both bottles.
7. Switch on the heat source and measure the temperature increase in both bottles. You need to decide for yourself what time increments are appropriate and record these in the table.

The CO_2 container with the light positioned to shine on it.

Results:

Complete the following table.

Time (min)	**Temperature of air bottle (°C)**	**Temperature of CO_2 bottle (°C)**

Represent your results by drawing a graph for each of the experiments to show how the temperature for each bottle changed over time. You need to decide what values to use for each axis. Label the axes clearly and provide a heading for each graph.

Questions:

What have you observed?

____

Conclusion:

What do you conclude for your experiment?

____

Global warming

- If there are more greenhouse gases in the atmosphere, more ultraviolet radiation will be trapped and the Earth will heat up.
- This will result in more of the polar ice melting than usual. Even a one degree difference in the average temperature has an effect on the melting of polar ice.
- If more ice than usual melts, the water levels in the oceans will rise and low-lying areas could flood.
- A change in the temperature will also result in a change in weather patterns. More rain will fall in some areas, and less in others.
- If this change is permanent, it is called **climate change**.
- Global warming affects weather patterns which in turn has a knock-on effect on agriculture and food production. This has an impact on food production and can lead to food shortage for humans and animals.
- Long term climate change can lead to the extinction of plants and animals, which are unable to adapt to changed conditions.

Investigating and report on the impact of global warming.

Interesting Videos

https://youtu.be/0F3QPY83NZQ (Global warming 101); https://youtu.be/Kr02VF3ralc (Climate science: Antarctica's ice cores); https://youtu.be/M2Jxs7lR8ZI (Climate change); https://youtu.be/Ge0jhYDcazY (Greenhouse effect); https://youtu.be/WaikvaAw2nk (Structure of the atmosphere); https://youtu.be/UqrA007yZWQ (Russian Meteor Explosion); https://youtu.be/XLY8m-dXOxo (Ozone layer damage); https://youtu.be/3CerJbZ-dm0 (A journey through the atmosphere)

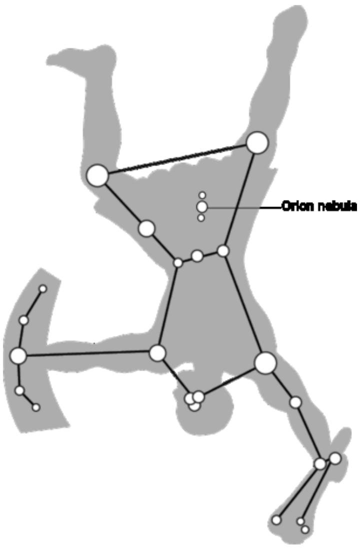
Stellar Evolution

- Stars do not live forever. Stars are born, live their lives, changing or *evolving* as they age, and eventually they die. Often stars do this in a much more spectacular way than humans do!
- Scientists speak of **stellar evolution** when talking about the birth, life and death of stars.
- The lifetime of individual stars is way too long for humans to observe.
- Because there are so many stars in the universe, we can see lots of them at different stages of their lives.
- In this way, astronomers can build up an overall picture of the process of stellar evolution.

The birth of a star

- Stars are born in vast, slowly rotating, clouds of cold gas and dust called nebulae (singular **nebula**).
- These large clouds are enormous, they have masses somewhere between 100 thousand and two million times the mass of the Sun and their diameters range from 50 to 300 light years across.
- These *nebulae* are **pulled together by gravity** and slowly collapse
- As they contract they heat up
- Once the temperature is high enough a **nuclear fusion** reaction begins, that changes hydrogen to helium

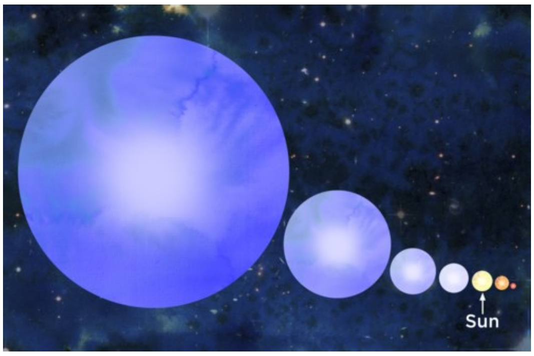
The "Pillars of creation"



Location of Orion nebula

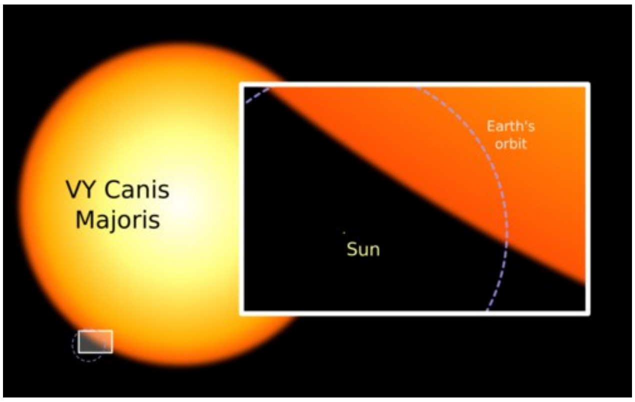
Life of a star

- A star is considered to be **'born' once nuclear fusion reactions begin** at its centre.
- Initially hydrogen is converted to helium deep inside the star.
- A star that is converting hydrogen to helium is called a **main sequence star**.
- Stars spend most of their lives as main sequence stars, converting hydrogen to helium at their centres or cores.
- A star may remain as a main sequence star for millions or billions of years.



Main sequence stars come in different sizes and colours

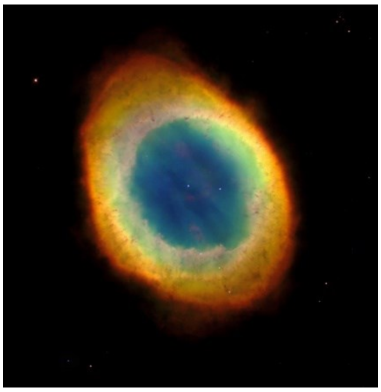
- Stars change in their appearance over billions of years
- Stars that look **blue are hotter (+30 000 °C)** and usually younger than stars that appear **red (-3 000 °C)**
- Our Sun is about half way through its life cycle – it is a medium-sized **yellow star (~6 000 °C)** with a lifespan of about 9 billion years
- A higher-mass star might have more material, but it also uses up the material more quickly due to its higher temperature.
- For example, the Sun will spend about 10 billion years as a main sequence star, but a star 10 times as massive will last for only 20 million years. A red dwarf, which is half the mass of the Sun, can last 80 to 100 billion years.



- When the hydrogen in the centre of the star is depleted, the star's core shrinks and heats up. This causes the outer part of the star, the star's atmosphere, which is still mostly hydrogen, to start to expand.
- The star becomes larger and brighter and its surface temperature cools so it glows red. The star is now a **red giant star**.
- Stars like the Sun will become red giants.
- Betelgeuse, in the constellation Orion, is a red giant star.

Death of a star

- As a star enters the final stages of its life, after it has become a red giant, the star becomes unstable and expands and contracts over and over.
- This causes the star's outer layers to become detached from the central part of the star and they gently puff off into space.
- The star then forms an expanding shell around the core of the star called a **planetary nebula** (planetary nebula have nothing to do with planets).
- Planetary nebulae glow beautifully as they absorb the energy emitted from the hot central star, they are found in many different shapes.

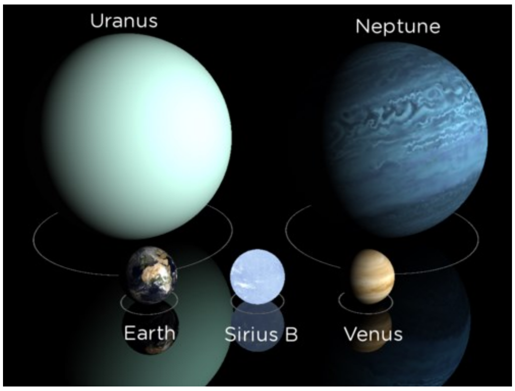


Ring Nebula

The Butterfly Nebula

- Sometime after puffing off its outer layers, the central star will run out of fuel. When this happens the central star begins to die.
- Gravity causes the star to collapse inwards and the star becomes incredibly dense and compact, about the size of the Earth.
- The star has then become a **white dwarf** star.
- White dwarfs have this name because of their small size and because they are so hot that they shine with a white hot light.
- The central parts of stars are much hotter than their surfaces, and a white dwarf is made from the remaining central parts of a star which explains why they are so hot.
- White dwarfs no longer produce energy via nuclear reactions and so as they radiate their energy into space in the form of light and heat. They slowly cool down over time.
- Eventually, once all of their energy is gone, they no longer emit any light.
- The star is now a dead **black dwarf** star and will remain like this forever.

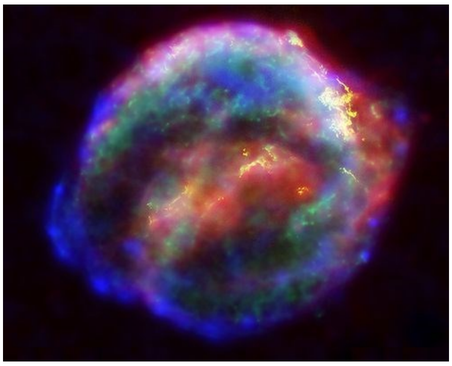
An ultraviolet image of the Helix Nebula. As the star in the centre approaches the end of its life and runs out of fuel, it shrinks into a much smaller, hotter and denser white dwarf star.



Relative size of Sirius B, a nearby white dwarf star, compared to some of the planets in our solar system. Stars and stellar remains can be smaller than planets.

Supernova

- So far we have looked at stars that are about the same mass as our Sun. But, what about stars that are more **massive**? How do they die?
- Stars more than eight times the mass of the Sun end their lives spectacularly.
- When the hydrogen at their cores becomes depleted, they swell into red **super giants** which are even larger than red giants.
- The collapsing outer layers of the star hit the small central core with such a force that they rebound and send a ripple outwards through the star blowing the outer layers of the star into space in a huge explosion called a **supernova**.
- For a week or so, a supernova can outshine all of the other stars in its galaxy. However, they quickly fade over time.
- The central star left behind is either made of neutrons and it is called a **neutron star**.
- If the initial star was really massive, a **black hole** forms.



The remnants of Kepler's supernova. The explosion was observed in 1604.

Activity: A model of the greenhouse effect

MATERIALS:

- yellow round balloon - one per pair or group
- black marker
- red marker
- scissors
- 2 cm small white styrofoam ball - one per pair

INSTRUCTIONS:

1. In this activity you will work in pairs. One of you will instruct your partner using the instructions below. Your partner will follow your instructions. Decide which of you will be the instructor and which of you will be the experimenter.
2. Experimenter: Insert the white styrofoam ball into the deflated balloon.
3. Instructor: Read out the step-by-step instructions from the table below (listed in order). First state the time from the star's birth which is given in the left hand column, then tell your partner what to do with the balloon.
4. Experimenter: Follow the instructions from your partner very carefully. You will be demonstrating how a Sun-like star evolves over time.

Step Number	Instructions
1) A Star is born	Blow up the balloon to about 6 cm in diameter
2) 5 million years	Wait
3) 10 million years	Wait
4) 500 million years	Wait - planets are being formed around the star
5) 1 billion years	Blow the balloon up a little bit
6) 9 billion years	Blow up the balloon some more and colour it red - it is now a red giant star
7) 10 billion years	Blow the balloon up a little bit. The outer layers are now being blown off. To simulate this, slowly allow the balloon to deflate. Cut the balloon into pieces and scatter them around the white ball. The star has now become a white dwarf (the ball) surrounded by a planetary nebula (the pieces of balloon)
50 billion years	Move the planetary nebula farther away from the white dwarf
500 billion years	Remove the planetary nebula and colour the ball black - the star is now a black dwarf

Interesting Videos

https://youtu.be/WTKA2biEVgg (Crab Nebula); https://youtu.be/xp-8HysWkxw (Largest black holes in the Universe); https://youtu.be/GYKyt3C0oT4 (What's inside a black hole); https://youtu.be/iauIP8swfBY (How the Sun will die); https://youtu.be/7kw1qRl3lKI (Colours of stars); https://youtu.be/Bcz4vGvoxQA (The biggest stars in the Universe); https://youtu.be/4s7vyDLgk3M (Life cycle of stars); https://youtu.be/wnb20chqbxM (Birth of a star)