Planetary Homeostasis & The Climate Crisis

1. How do Greenhouses work?

Strawberries, Supermarkets, and Growing Seasons

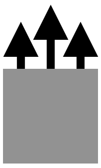
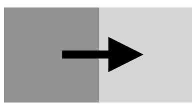
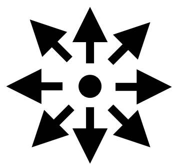
In the U.K., anyone can walk into a supermarket and find strawberries for sale. Finding strawberries for sale in U.K. supermarkets seems normal. Strawberries are found for sale in supermarkets during the summer months, and during the winter months. Every month of the year, there are strawberries for sale in U.K. supermarkets. Strawberries can be eaten fresh, or prepared in jams, juice, pies, ice cream, milkshakes and chocolate.

Many people in the U.K. grow their own strawberries. Growing strawberries is a popular plant for people to have in their gardens, or in plant pots in their homes. Strawberries grow best in warm temperatures between $16^{o}C$ and $24^{o}C$. These are the temperatures that the U.K. normally has during the summer months. It is no surprise then, that the summer months are the most popular time for people in the U.K. to grow strawberries.

It is harder to grow strawberries outside of the summer months, because the air temperature is not between $16^{o}C$ and $24^{o}C$. To grow strawberries outside of the summer months requires the people growing them to maintain a higher air temperature than the season is creating. People growing strawberries in plant pots inside can raise the temperature inside their houses. People growing strawberries outside in their gardens may need to use a greenhouse.

Greenhouses allow people to grow fruit like strawberries outside of the summer months when the air temperature isn't between $16^{o}C$ and $24^{o}C$. We are going to examine how greenhouses work, so that we can better understand what the Earth's 'Greenhouse Effect' is. This will help us understand the 'Enhanced Greenhouse Effect' and Climate Change better.

Understanding how Greenhouses work → **helps us to** → Understand how 'The Greenhouse Effect' works → **helps us to** → Understand Climate Change really well.

Convection	Conduction	Radiation
		

Example	Convection	Conduction	Radiation
I stand in front of a radiator			
I stand in front of a radiator with my hands above it			
I stand in front of a radiator with one hand above it and one hand on it			
I stand outside with sunlight on me			
I stand in the shade			
I sit in the shade on a hot surface			
I sit in the shade on a cold surface			
I stand behind a window with sunlight on me			
I stand behind a window with the sunlight on me and a radiator behind me			
I stand behind a window with the sunlight on me and a radiator behind me with my hands above it			
I stand I stand behind a window with a radiator behind me with one hand above it and one hand on it			

Now that we're clear on the differences between convection, conduction, and radiation, we can begin to examine how a greenhouse works. Work your way through the following questions, many of them can be answered with a short answer of very few words, some are answered with 'yes' or 'no'. Where more lines are given, you will need to write more to explain your thinking. What is most important is that you think really hard about greenhouses and how convection, conduction, and radiation allow heat energy to be transferred.

1. Can solar radiation enter the greenhouse through the glass?	
2. Can solar radiation reflect off the floor surface and leave through the glass?	
3. Can the floor of the greenhouse be heated by solar radiation?	
4. Can the floor of the greenhouse heat the air above it?	
5. What process does the heated air rise by?	

6. Can the rising heated air leave the greenhouse?	
7. Can the rising heated air increase the temperature of the glass in the greenhouses ceiling?	
8. What process is the greenhouses' ceiling heated by?	
9. How is the air temperature different inside and outside the greenhouse?	
10. Is it more accurate to say that greenhouses **reduce** or **prevent** the loss of heat?	

11. Why is it more accurate to say that greenhouses reduce the loss of heat, rather than prevent the loss of heat?

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12. Why is it crucial that a greenhouse is made of glass?

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We are going to read a piece of academic writing. Academic writing is different to everyday writing. In academic writing we use much more precise language, we choose words that are much more specific in their meaning. We are going to read an academic description of a greenhouse, then we are going to look carefully at the word choice, then you are going to redraft its meaning below. We are doing this so that we learn more about academic writing and can learn to write more like academics.

Greenhouse’s maintain higher internal air temperature than their surroundings by significantly reducing convectional heat loss whilst enabling penetration by solar radiation.

Redraft:

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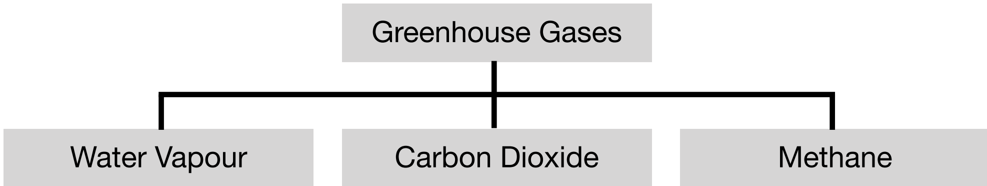
2. The Greenhouse Effect

Greenhouse Gases

The sun is the nearest star to the Earth. The Sun radiates heat and light in every direction. The Sun radiates heat and light in every direction as waves of energy. We call these waves of energy solar radiation because it is radiated from the sun in every direction. Radiation refers to the fact that it travels outward in all directions as a wave, and solar means the sun.

The surface of the Earth is warmed up by solar radiation. There are gases in the atmosphere called greenhouse gases. Carbon dioxide is an example of a greenhouse gas. Two other examples of greenhouse gases are water vapour, and methane.

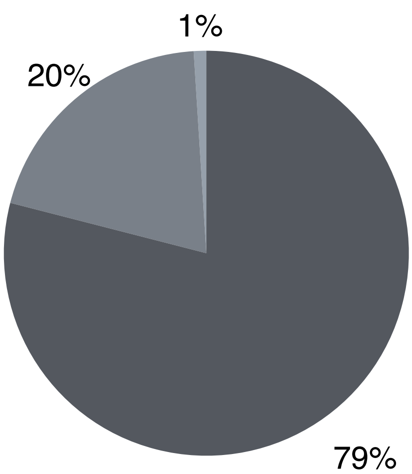


Solar radiation is able to reach the surface of Earth, but most of the heat doesn't leave the Earth's atmosphere because of greenhouse gases. The greenhouses gases get their name because they allow solar radiation to reach the Earth's surface, but trap most of the heat. Greenhouse gases work in a similar way to greenhouses, but not exactly the same.

The effect of greenhouse gases in the atmosphere is essential. When something is essential it means that we could not survive without it. We could not survive without the effect of greenhouse gases in the atmosphere. If there was no greenhouse effect created by greenhouse gases in the atmosphere then there would be no life on Earth.

The effect of greenhouse gases keeps the average temperature on the Earth at 14^{o}C. Without the greenhouse gases the temperature would be -18^{o}C.

The Earth's Atmosphere



Nitrogen (79%), a colourless, odourless gas. Number 7 on the Periodic Table of Elements

Oxygen (20%), a colourless, odourless gas. Number 8 on the Periodic Table of Elements. Essential for the respiration of all living things.

All other gases (1%), including all of the greenhouse gases including water vapour, carbon dioxide, and methane.

Greenhouse Gases

A greenhouse gas is any gas in the atmosphere that acts like the glass in a greenhouse. The greenhouse effect is very important for all life on Earth. With no greenhouse gases in the atmosphere, the average temperature on the Earth's surface would be -18oC. This is because of the important job that greenhouse gases do. As part of the atmosphere, greenhouse gases allow solar radiation, light and heat from the sun, to reach the surface of the Earth.

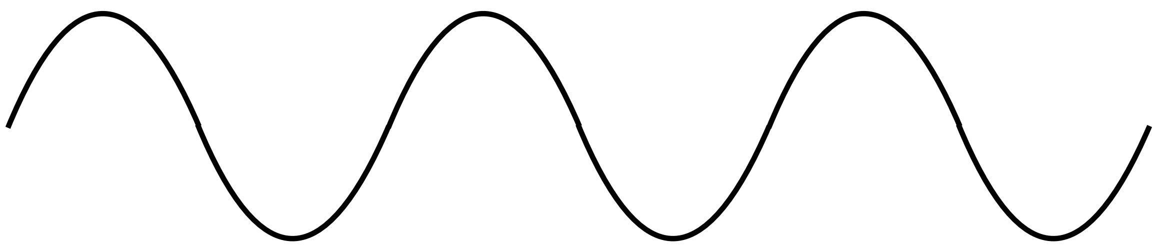
The sun is the nearest star to the Earth. The Sun radiates heat and light in every direction. The Sun radiates heat and light in every direction as waves of energy. We call these waves of energy solar radiation because it is radiated from the sun in every direction. Radiation refers to the fact that it travels outward in all directions as a wave, and solar means the sun.

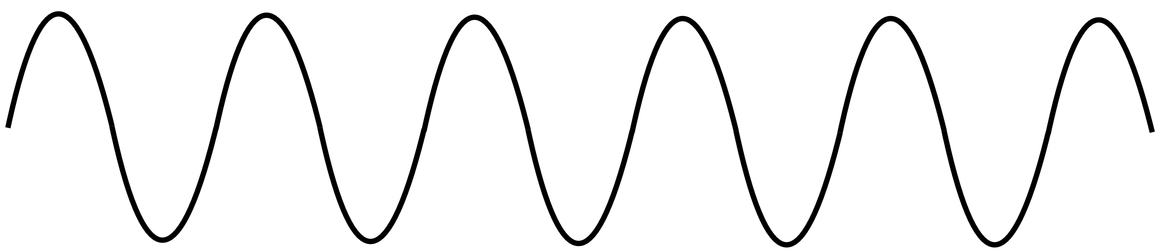
When the light and heat from the sun, traveling as solar radiation reaches the surface of the Earth, the temperature of the Earth's surface increases. Some of the energy from the solar radiation is absorbed by the Earth's surface. This is an energy transfer. The heat energy has transferred from the solar radiation, to the Earth's surface. The solar radiation is reflected off of the Earth's surface and back into space. Whilst the solar radiation travels back through the Earth's atmosphere some of it is reflected back to Earth again by greenhouse gases.

There is some important science we need to understand to explain this process better.

The solar radiation that travels from the Sun to the Earth is a wave. All waves have peaks and troughs. The peaks are the highest parts of the wave. The troughs are the lowest parts of the wave. The distance between the peaks is called the wave length. The further apart the peaks are, the longer the wave is. The closer together the peaks are, the shorter the wave is. The peaks on a long wave are far apart, the peaks on a short wave are close together.

Annotate the waves below to show every peak and every trough. Then, annotate the waves to show how wavelength is measured, and which has a longer wavelength.





The paragraph below describes how the wavelength of solar radiation changes when it has reached the surface of the Earth and energy has been transferred. However, it is incorrect. You need to reverse every time it talks about wavelength. Two have been completed as examples to help you.

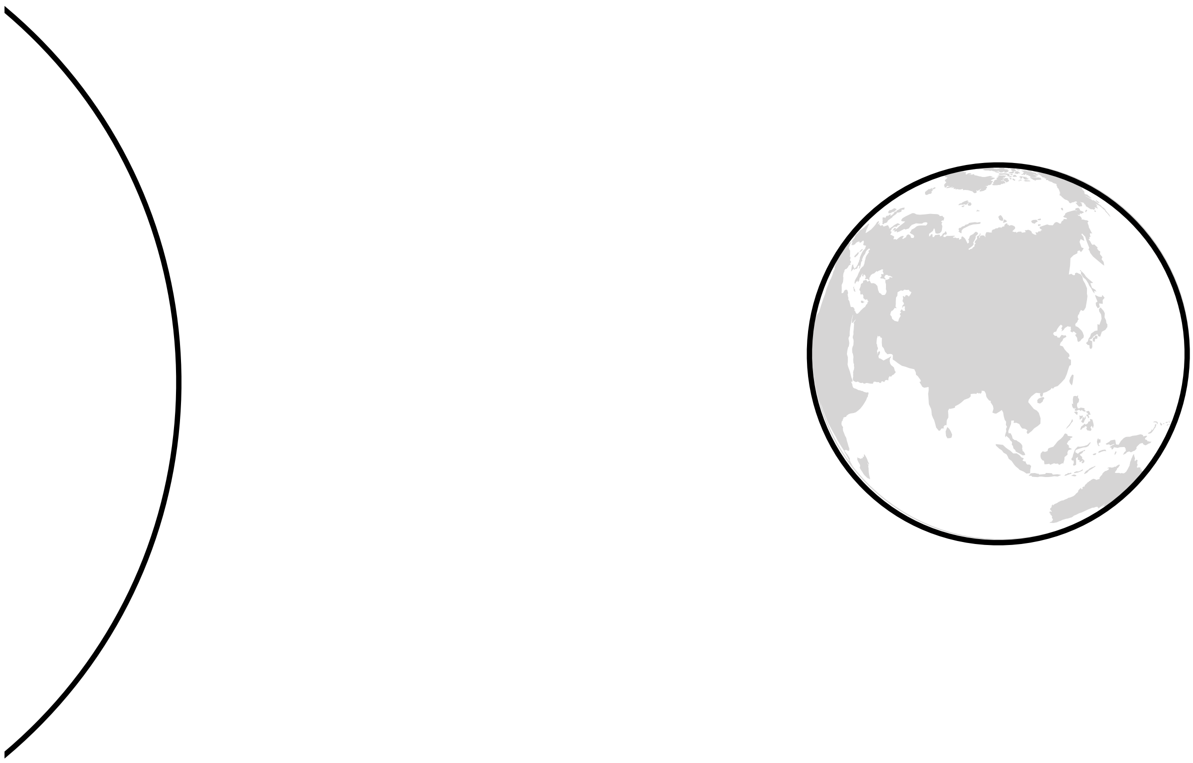
Most of the solar radiation that travels from the sun to the Earth is ~~long wave~~ short-wave radiation. The peaks in long wave radiation are ~~far apart~~ close together. Once the solar radiation has been reflected off the Earth's surface, it becomes short-wave radiation. Reflecting off the Earth's surface, and heating up the surface of the Earth, shorten the length of the radiation wave. The peaks of the wave are closer together once it has been reflected off the surface of the Earth.

1. Which is the nearest star to the Earth?	
2. Which direction does this star radiate heat and light?	
3. What name do we give to the radiated heat and light?	
4. What is the unit of measurement for temperature?	
5. What is the average temperature on the Earth's surface because of the Greenhouse Effect?	
6. What would the average temperature be on the Earth's surface without the Greenhouse Effect?	
7. Name three greenhouse gases in the Earth's atmosphere.	

8. What word do we use to describe something we cannot survive without?	
9. What provides the heat for the surface of the Earth?	
10. What word do we use to describe something that light can travel through?	
11. What word do we use to describe something that light cannot travel through?	
12. What is the name given to gases that cause the Greenhouse Effect?	
13. Name the three ways that heat is transferred.	
14. Where are Greenhouse gases located?	

Greenhouse gases in the atmosphere absorb and radiate heat energy from short-wave radiation. Greenhouse gases in the atmosphere do not absorb and radiate heat energy from long-wave radiation. This means that solar radiation from the sun can travel through the Earth's atmosphere without being affected by greenhouse gases because it is a long-wave. However, solar radiation that has been reflected off the Earth's surface is a short-wave, as it travels through the Earth's atmosphere towards space it is affected by greenhouse gases.

We are going to do some dual coding, and draw a diagram to explain this process together:



3. The Enhanced Greenhouse Effect

Retrieval Practice

1. What is the highest part of a wave called?	
2. How is wavelength measured?	
3. How is the wavelength of solar radiation different after being reflected off the Earth's surface?	
4. How is the temperature of the Earth's surface different after solar radiation has reflected off it?	

5. What is the lowest part of a wave called?	
6. What direction does radiated heat travel in?	
7. Do greenhouse gases affect solar radiation directly from the sun?	
8. Do greenhouse gases affect solar radiation that has been reflected off the Earth's surface?	

9. Consider your answers to the last two questions, explain why one is affected, and the other one isn't?

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10. Why isn't the quantity of solar radiation reaching the Earth's surface affected by greenhouse gases?

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The concentration of Greenhouse Gases

The word concentration means how much of a thing there is, in a place. Let’s think about the city of London. If only three people in London drove a Ferrari, we would say that the concentration of Ferrari’s in London was very low. This is because there would be more Ferrari’s in other cities that aren’t London. If there were 100 Ferrari’s in London, we would still say the concentration was low, because of how many cars there would be in London which aren’t Ferrari’s. If half of all the people in London owned a Ferrari, we would say that the concentration of Ferrari’s in London was very high, because there would be more Ferrari's in London than anywhere else on Earth.

We also use the word concentrate to describe orange squash. Orange squash is sold ‘concentrated’ and people dilute it at home. Diluting something means to reduce the level of concentration. Orange squash is diluted in water, the level of concentration is lowered, and we can drink it. If the concentration is too low, we add more orange squash, if the concentration is too high, we add more water, until the concentration level is right for us to drink it.

We use the word concentration to describe and measure the level of greenhouse gases in the atmosphere. We can think of greenhouse gases like the orange squash in the glass of water. The glass of water is the atmosphere, and the orange squash are the greenhouse gases. Like the orange squash in the water, the greenhouse gases are mixed in with the rest of the atmosphere. Unlike the orange squash, the greenhouse gases aren’t orange, or blue, they are transparent and don’t have a colour.

Carbon Dioxide is one of the greenhouse gases. The unit of measurement for the concentration of carbon dioxide in the atmosphere is ‘parts per million’. Instead of writing ‘Parts per million’ we abbreviate it to ppm. This is like centimetres being abbreviated to cm, or kilograms being abbreviated to kg, or Member of Parliament being abbreviated to MP. ‘Parts per million’ is abbreviated to ppm, so if the concentration of carbon dioxide in the atmosphere was 280 parts per million, we would write it as 280ppm.

11. Why would **decreasing** the concentration of greenhouse gases in the atmosphere decrease the average temperature on the Earth’s surface?

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12. Why would **increasing** the concentration of greenhouse gases in the atmosphere increase the average temperature on the Earth’s surface?

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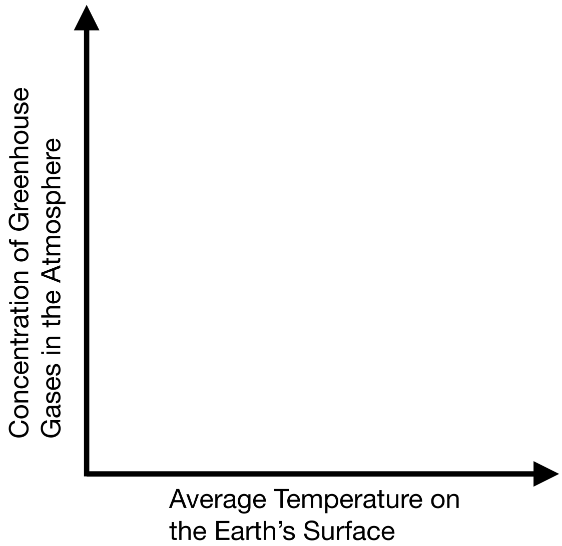
The greenhouse effect is essential for all life on Earth, however, by increasing the concentration of greenhouse gases in the atmosphere the greenhouse effect has been enhanced. We use the word enhanced to describe something that has been increased, intensified, or improved. The enhanced greenhouse effect is where more heat is absorbed and radiated by the higher concentration of greenhouse gases in the atmosphere. As more heat is absorbed and radiated by a higher concentration of greenhouse gases in the atmosphere, the temperature of the Earth's surface increases.

Draw a simple graph of relationship between greenhouse gases and temperature



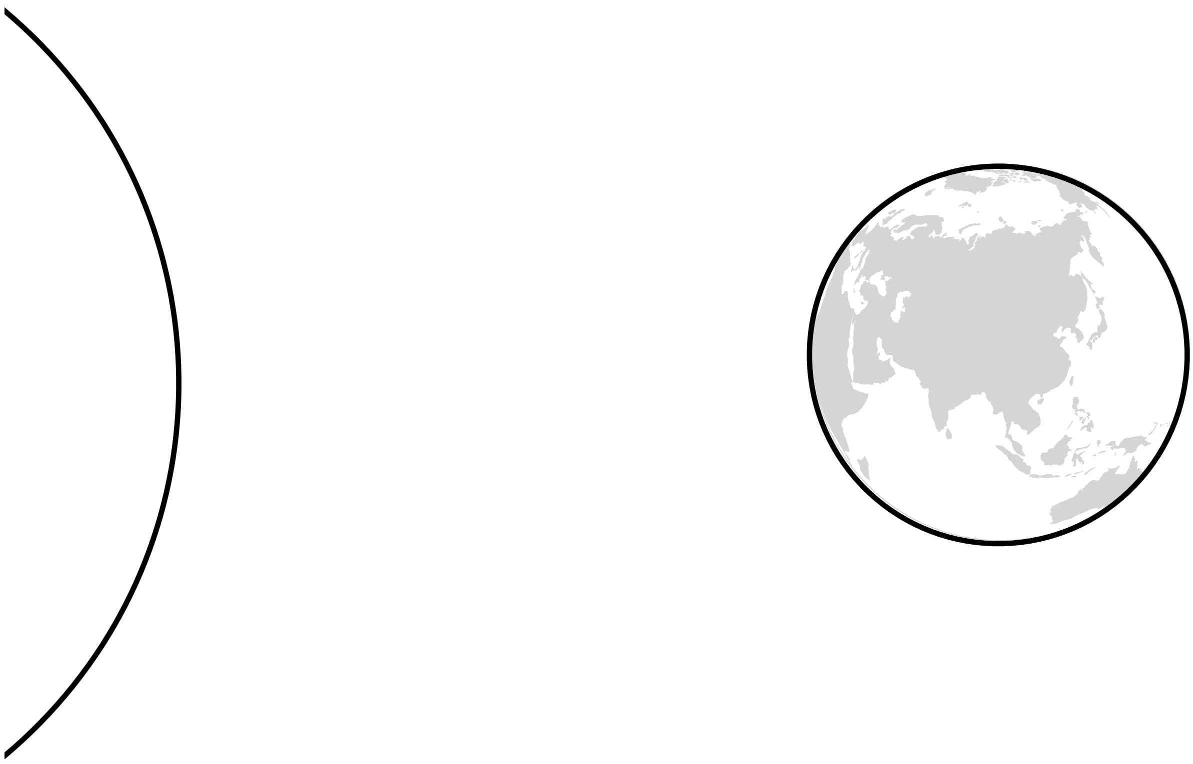
Writing Practice

Below are some sentences. The sentences describe things we have been learning about the Greenhouse effect. The sentences are written in everyday language. Your challenge is to redraft the everyday language using academic language.

Everyday Language	Academic Redraft
9. The ground gets hotter when the sun shines on it.	
10. There are gases that you can't see in the air, they are making it hotter and hotter.	
11. The light is long when it shines down, when it bounces back it's not as long.	
12. It would be freezing, or even colder, if there weren't any gases in the air to keep it warm.	
13. The more gases in the air, the bigger the effect becomes.	

The enhanced greenhouse effect is where more heat is absorbed and radiated by the higher concentration of greenhouse gases in the atmosphere. As more heat is absorbed and radiated by a higher concentration of greenhouse gases in the atmosphere, the temperature of the Earth's surface increases.

Draw a simple diagram below to show the enhanced greenhouse effect.



First Draft.
Explain the **difference** between the 'greenhouse effect' and the 'enhanced greenhouse effect'.

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Development Space

Redraft.
Explain the **difference** between the 'greenhouse effect' and the 'enhanced greenhouse effect'.

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4. What is Homeostasis?

Retrieval Practice

1. What is the name of the Earth's nearest star?	
2. Is solar radiation a long-wave or short-wave?	
3. Name three greenhouse gases found in the Earth's atmosphere.	
4. What wavelengths are affected by greenhouse gases?	

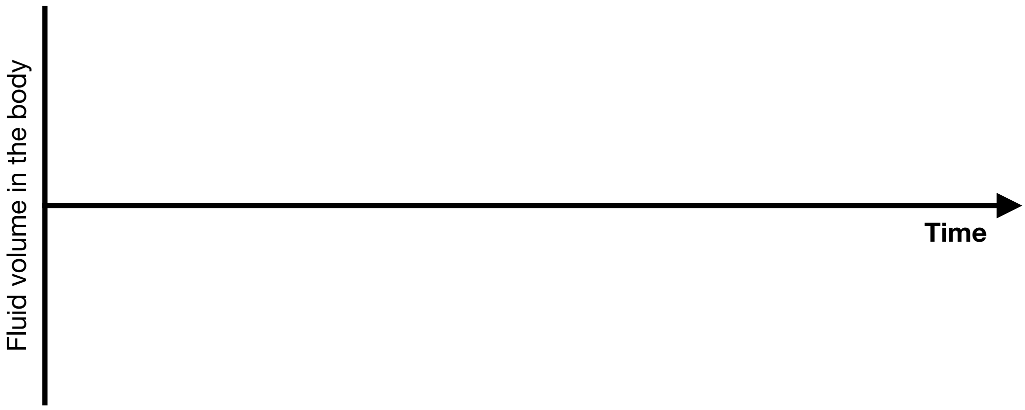
5. What do greenhouse gases do to radiation that's been reflected off the Earth's Surface?	
6. What is the unit of measurement for carbon dioxide in the atmosphere?	
7. What would happen to the temperature if greenhouse gas concentrations were lowered?	
8. How is wavelength measured?	

Writing Practice
Below are some sentences. The sentences describe things we have been learning about the Greenhouse effect. The sentences are written in everyday language. Your challenge is to redraft the everyday language using academic language.

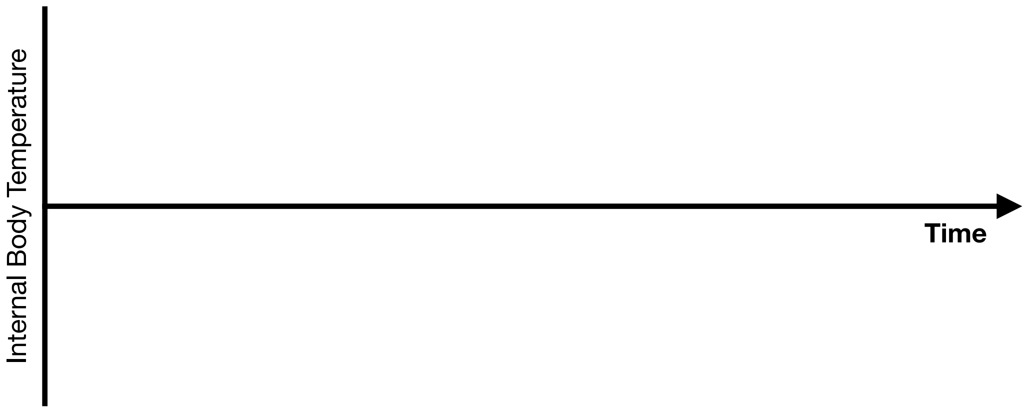
Everyday Language	**Academic Redraft**
9. The ground gets hotter when the sun shines on it.	
10. There are gases that you can't see in the air, they are making it hotter and hotter.	
11. The light is long when it shines down, when it bounces back it's not as long.	
12. It would be freezing, or even colder, if there weren't any gases in the air to keep it warm.	
13. The more gases in the air, the bigger the effect becomes.	

Homeostasis

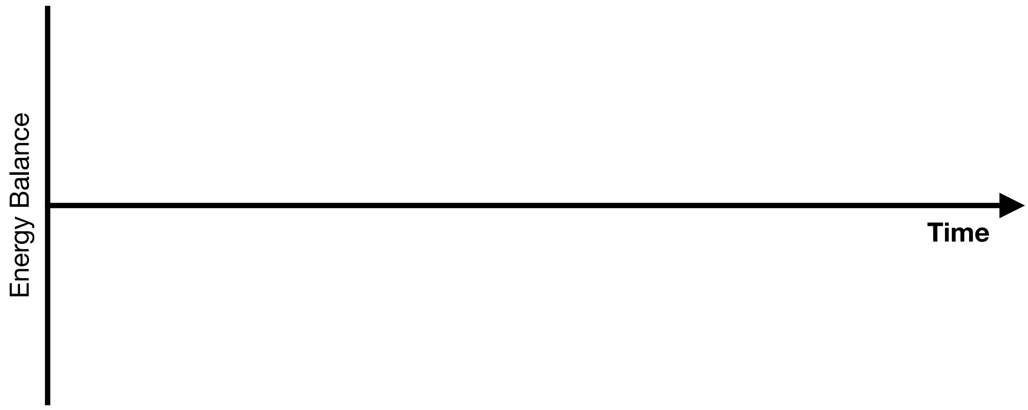
To understand the word homeostasis we're going to think about what happens when we drink a glass of water. When we drink a glass of water the fluid volume in our bodies increase. We use the word volume to describe the amount and size of the water in our bodies, and we use the word fluid because the water is a liquid. The more glasses of water we drink, the more the fluid volume in our bodies increases. We are going to draw this process together:



Now that we've looked at one example of homeostasis, let's look at another. We're going to think about what happens when our bodies get hot from exercise. We move a lot when we're exercising, and our internal body temperature increases. Our internal body temperature is normally 37^{0}C. When we move a lot during exercise our internal body temperature can increase to 38^{0}C and possibly even 39^{0}C. This is hotter than our bodies are normally and they react to lower our body temperature. Let's draw this process together:



We're going to look at one final example of homeostasis in the human body. Think about hunger, and when you feel hungry and when you feel full. Think about the relationship between the energy we get from eating, and the amount of food we eat. Do we need more food when we're moving a lot, or do we need more food when we're sitting still? Think about the last two examples that we have drawn together and do your best to draw a graph of energy balance in the human body.



We should now have a good picture of what homeostasis means in the human body. There is some language that is used when learning about homeostasis that we need to be able to use. The word homeostasis is made of two words. The word homeo is from Greek, and it means similar. The word stasis is also Greek, and it means ‘standing still’. Put together, the word homeostasis means that something can stay still, or the remain the same.

We know from the three examples of homeostasis in the human body that remaining the same doesn’t mean that it is always exactly the same all of the time. When we looked at fluid volume in the human body we learned that it increases, and then something makes it decrease. Homeostasis then, doesn’t mean that something never changes, it means that it always returns to the same state that it was before it began to change.

The highest and lowest levels of fluid volume, body temperature, or energy balance, are called thresholds. The thresholds are how far up or down something can go and still return to the midpoint, average, or typical level for homeostasis. Once we have drunk enough glasses of water, we will need to go to the bathroom. Out body has reached the threshold of fluid volume in our bodies, and we need to take action to return it to the typical level.

Something stays in homeostasis as long as it stays within the maximum and minimum threshold. The maximum and minimum thresholds act as boundaries for homeostasis. As it gets nearer to the maximum or minimum threshold, actions will be taken to return it to the midpoint, average, or typical level. The closer it gets to the threshold, the stronger the action becomes.

14. What does the word **homeostasis** mean?

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15. When learning about homeostasis, what does the word **threshold** mean?

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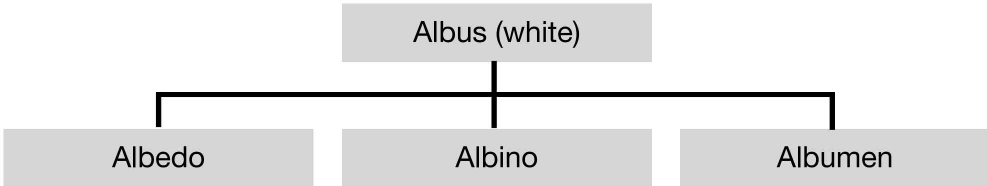
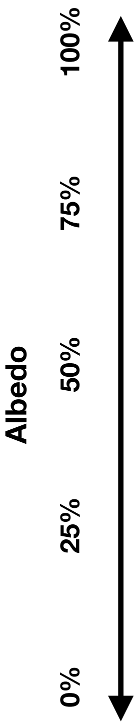
5. What is albedo?

Albedo

The word albedo is Latin. In Latin the world albus means white. From the latin word albus we get the word albino, which means an animal or person a that has very white skin and hair. We also get the word albumen, which is the name for the white part of an egg. The word albedo is a measure of how white an object or surface is. Albedo measures how much light is reflected by an object without being absorbed.



A way to understand albedo is to think about t-shirts. On a hot day, would it be more comfortable to wear and white t-shirt or a black t-shirt? The answer is because of albedo. A white t-shirt reflects more light without being absorbed. The more light that is absorbed, the hotter we will get. As we have learned from looking at homeostasis, wearing a black t-shirt on a hot day will exceed our internal body temperature threshold and we will begin to sweat.



To help us think about albedo you are going to place the following types of surface onto a graph. The graph goes from 0% to 100%. At 0%, all of the light is absorbed, making it the hottest surface. At 100%, all of the light is reflected and none of it is absorbed, making it the coldest surface.

Surfaces

Deciduous Trees

Desert Sand

Fresh Snow

Green Grass

New Concrete

Road Asphalt

1. What does is mean if a surface has a **high** albedo?

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2. What does it means if a surface has a **low** albedo?

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3. Define the word **albedo**

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This is a photo taken on the Pic d'Arsine in the Ecrin National Park. Pic d'Arsine is the name of the mountain, pic is the French word for peak. The Ecrin National Park is an area of beautiful mountains, protected by law in what South East of France.

The mountains in the Ecrin National Park, including pic d'Arsine, are covered in the snow during the winter. The temperatures are below 0^0C and all of the precipitation falls as snow. The ground on the mountains is below 0^0C, and the snow stays frozen on the ground during the winter.

During the summer months, the air temperature rises to be above 0^0C. The photo was taken during August, when the air temperature was 12^0C. We should expect that if the air temperature is above 0^0C, that the snow should melt, and there shouldn't be any large patches of snow on the side of the mountain.

First Draft.
Explain the **why** the snow patches on pic d'Arsine would survive into summertime.

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Development Space

Redraft.
Explain the **why** the snow patches on pic d'Arsine would survive into summertime.

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6. What is planetary homeostasis and how can Daisyworld help us understand it?

Retrieval Practice

1. How is the surface of the Earth heated by the sun?	
2. How does wavelength change when solar radiation is reflected off the surface?	
3. How is the enhanced greenhouse effect different from the greenhouse effect?	
4. Explain what homeostasis is using an example	
5. Explain what albedo is	

6. Draw, label and annotate a diagram of the greenhouse effect

Daisyworld

We have looked at homeostasis in the human body, now we are going to look at homeostasis in the atmosphere of the Earth. Atmospheric homeostasis is the idea that the temperature might increase or decrease, but it will get near to a threshold, and an action will take it back to normal. To understand atmospheric homeostasis we need to use everything we have studied so far.

Greenhouse Gas Concentration
Short-wave radiation reflecting off the Earth's surface is absorbed and radiated by greenhouse gases in the atmosphere. The higher the concentration of greenhouse gases, the higher the temperature, as more short-wave radiation is absorbed and radiated in the atmosphere.

Homeostasis
As temperature, or greenhouse gas concentrations, increase or decrease, they reach a threshold and actions return them to normal levels. The temperature and greenhouse gas concentrations are kept stable by always increasing and decreasing.

Albedo
Different surfaces absorb and reflect different amounts of light. The higher the albedo of a surface, the more light is reflected, and the lower the temperature of the surface.

Planetary Homeostasis
The temperature of the Earth's surface is kept within thresholds by changes in the surface albedo and greenhouse gas concentrations.

Daisyworld
A simple model of the Earth that shows how surface albedo creates planetary homeostasis.

Daisyworld is a model. A model is a simple version of the real world. There is a huge variety and quantity of life on Earth. The variety and quantity of life on Earth is so huge that it makes it very hard to study all of it, all at the same time. To make it easier to study, and for us to understand, we use models. Daisyworld is a model of the Earth.

Daisyworld was created by a British scientist called James Lovelock. James Lovelock is an independent scientist. An independent scientist is a scientist who doesn’t work for anyone. Normally, when a scientist works for someone, or for a company, they have to research what they are told to research. James Lovelock is able to choose what to research because he is an independent scientist, and doesn't work for anyone or for a company.

James Lovelock used to work for NASA. NASA is an acronym for the North American Space Agency. NASA is a large organisation in the USA that sends people and ships into space. When James Lovelock worked for NASA he was involved in looking for life on other planets. This is a very difficult thing to do. James Lovelock, and the people he was working with, had to think of a way of checking for life without actually visiting a planet, and without knowing what the life there might be like.

Whilst researching how to find life on other planets, James Lovelock and other scientists at NASA learnt a lot about life on Earth. James Lovelock left NASA to continue to research life on Earth as an independent scientist. James Lovelock doesn't work for anyone, but he does write books and talk about his research. Writing books and talking about his research allows him to make enough money to continue his research independently.

7. What does it mean when someone is an independent scientist?

………

8. Who did James Lovelock previously work for?

………

9. How is James Lovelock able to afford to be an independent scientist?

………

James Lovelock has written a number of books. The most famous book that James Lovelock has written in the ‘Gaia Hypothesis’. A hypothesis is a word you have likely heard in a Science lesson. A hypothesis is an explanation for something that can be tested and is based on evidence. The word Gaia is from Ancient Greece. In the religion of Ancient Greece, Gaia is the name for the ancient god who became the Earth. The name Gaia is made from two words, Geo, meaning the Earth, and Aia, which means Grandmother. The meaning of Gaia is often used today when people talk about ‘mother nature’. James Lovelock’s Gaia Hypothesis is a testable, evidence-based explanation for planetary homeostasis.

Gaia
Ancient Greek mother goddess of the Earth

+

Hypothesis
An explanation for something that can be tested and is based on evidence

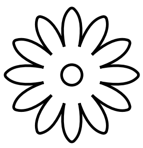
=

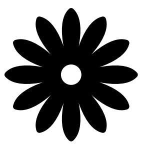
Gaia Hypothesis
Lovelock's testable, evidence-based, explanation for planetary homeostasis

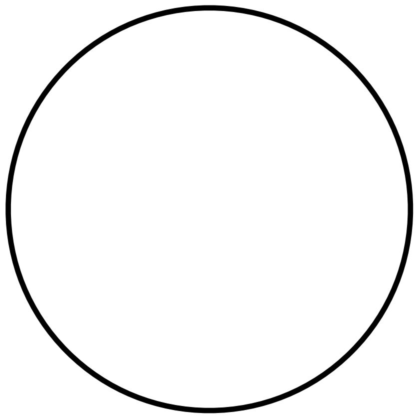
Daisyworld is model that explains the Gaia Hypothesis. Daisyworld was created by James Lovelock and another British scientist Andrew Watson to help people understand the Gaia Hypothesis.

We are going to draw Daisyworld together to make sure that we understand it. First of all, we are going to imagine a very simple world. There are only two types of plant on this simple world. These two types of plant are the only life on the whole of the planet. One is a black daisy, and the other is a white daisy.

At the start of the Daisyworld model, the temperature is low. Black daisies grow best in cooler temperatures. So we are going to draw back daisies on the surface of our Daisyworld model planet. We have studied albedo, so we know that there is a difference between the white and black daisies.







10. Which type of daisy will have a higher albedo?

....

11. Which type of daisy will have absorb more of the heat from solar radiation?

....

12. What do you predict will happen to the temperature of the surface of Daisyworld while it is covered in black daisies?

....

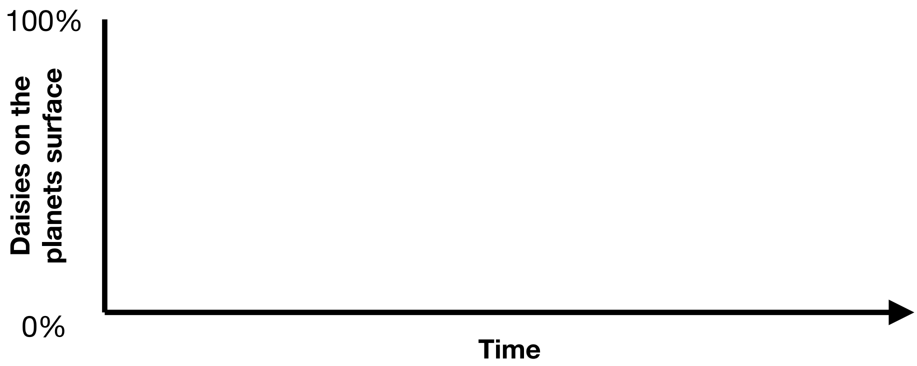
....

....

....

The albedo of the black daisies is low. More of the heat from solar radiation is absorbed than reflected. The temperature at the surface of the planet begins to increase because more of the heat is absorbed, and less is reflected.

White daises are better at growing in warmer temperatures. Black daisies are better at growing in cooler temperatures. As the temperature increases, the number of black daisies decreases, and the number of white daisies increases. We can draw this change as a graph.



13. What do you predict will happen to the temperature of the surface of Daisyworld while it is covered in white daisies?

………

………

………

………

The albedo of the white daisies is high. More of the heat from solar radiation is reflected then absorbed. The temperature at the surface begins to decrease because more of the heat is reflected, and less is absorbed.

Black daisies are better at growing in cooler temperatures. White daisies are better at growing in hotter temperatures. As the temperature decreases, more black daisies begin to grow. The number of black daisies increase as the temperature lowers

14. Which type of daisy grows best in hotter conditions?

………

15. Which type of daisy grows best in cooler conditions?

………

16. Which type of daisy will increase in number as the temperature increases?

………

17. Which type of daisy will increase in number as the temperature decreases?

………

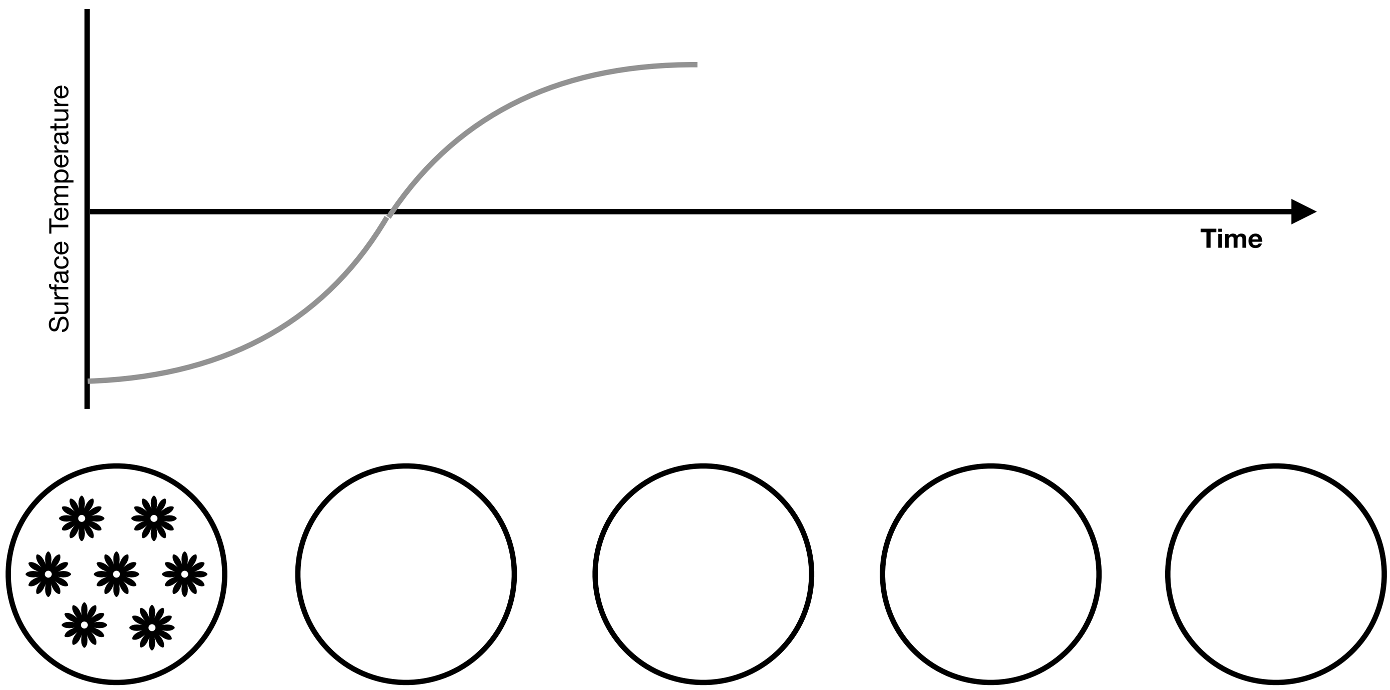
18. If the surface is mostly covered in white daisies, what will happen to the temperature?

………

19. If the surface is mostly covered in black daisies, what will happen to the temperature??

………

20. Think about the homeostasis diagrams you have drawn before for fluid volume in the body, internal body temperature, and energy balance. Draw the surface temperature of Daisyworld on the homeostasis graph below. Underneath the homeostasis graph, draw which type of daisies would be on the surface of the planet. The graph has been started for you.



As the surface temperature gets close to a threshold, an action is taken to reduce the temperature. The action in Daisyworld is a change in the type of daisy that grows, and this changes the surface albedo. The name for actions like this are feedback loops. The surface temperature begins to get too high and it creates a feedback loop to lower the temperature. Daisyworld is a simple model for understanding how plants are a part of feedback loops in planetary homeostasis

7. What is the Gaia Hypothesis?

Retrieval Practice
Match the head and tail of the sentence neatly using a ruler.

1. A hypothesis is an explanation…	…level something can get to before it returns to the midpoint, average, or typical level.
2. Thresholds are the minimum and maximum…	…carbon dioxide, water vapour, and methane.
3. In planetary homeostasis the…	…how much solar radiation is reflected instead of being absorbed
4. Feedback loops act to…	…because otherwise it would be -18oC .
5. Is a scientist is independent…	..based on evidence that can be tested.
6. An independent scientist is able…	…a long-wave.
7. Examples of greenhouse gases include…	…designed to help people understand planetary homeostasis.
8. Greenhouse gases in the atmosphere…	…temperature is kept within thresholds by feedback loops.
9. The greenhouse effect is considered essential…	…outwards in every direction.
10. The concentration of greenhouse gases…	…it means they don't work for another person or company.
11. Daisyworld is a model…	…short-wave radiation.
12. Albedo is a way of measuring…	…keep something within thresholds by returning it to the midpoint, average, or typical level.
13. Solar Radiation travels..	…absorb and radiate head in every direction
14. Before being reflected, solar radiation is…	…to choose what they research because they don't work for another person or a company.
15. Greenhouse gases only interact with…	…is measured in parts per million.

The Gaia Hypothesis

The Gaia Hypothesis, created by James Lovelock, is a way of explaining planetary homeostasis. Planetary homeostasis is like the homeostasis we have studied in the human body, but on the scale of a planet. James Lovelock, creator of the Gaia Hypothesis, argues that the Earth has been kept at a steady temperature by homeostasis.

We know from studying homeostasis in the human body that this does not mean that the temperature has always been exactly the same. We know from studying homeostasis in the human body that this means the temperature of the Earth has been kept between a maximum and minimum threshold by feedback loops.

When the temperature of the Earth increases, a feedback loop lowers the temperature. James Lovelock, creator of the Gaia Hypothesis, argues that this could be a change in the concentration of greenhouse gases, or it could be a change in the surface albedo of the planet.

16. Would an increase or decrease in the concentration of greenhouse gases lead to a decrease in the temperature?

……………………………………………………………………

17. Would an increase or decrease in the surface albedo lead to a decrease in the temperature?

……………………………………………………………………

18. What does the term 'feedback loop' mean, when studying homeostasis?

……

……

……

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19. Which British Scientist developed the Gaia Hypothesis?

……………………………………………………………………

20. What does the word hypothesis mean?

……

……

James Lovelock first published the Gaia Hypothesis in 1979. When James Lovelock first published The Gaia Hypothesis in 1979, opinion in the scientific community was divided. The scientific community is way of talking about all the scientists interested in researching something. When opinion is divided it means that not everyone feels the same way about something. When we say that the Gaia Hypothesis divided opinion in 1979, we mean that many scientists agreed with it, and many scientists strongly disagreed with it.

James Lovelock has admitted that when he first published the Gaia Hypothesis, it was based on an observation, and didn't have a lot of evidence. An observation is when we look at something, and try to understand it. James Lovelock was sharing what he could see, and what he thought was happening. In 1979, James Lovelock didn't have much evidence to support the Gaia Hypothesis. Forty years later, after dedicating his life to researching the Gaia Hypothesis as an independent scientist, there is a lot of evidence to support Gaia Hypothesis.

Although a much larger number of scientists support the Gaia Hypothesis now than in 1979, it is still divisive amongst the scientific community. We are going to look at some of the evidence for planetary homeostasis that supports the Gaia Hypothesis. Interestingly, the evidence we are going to look at has come from Antarctica.

Antarctica is a land covered in ice and snow. We call the ice that covers the land, ice sheets. You can think of the ice sheets as sheets of ice on top of land in Antarctica, like bedsheets on a mattress, or a table cloth on a table. The ice sheets cover the land.

Every year, a little more snow is added on top of the ice sheets. We call this accumulation. When something accumulates it grows. As something accumulates, there is more of it. A person accumulating wealth is getting richer, a person accumulating cars will need a bigger garage.

Every year, new snow accumulates on top of the ice sheets that are already in Antarctica. The snow builds up slowly. Only a little snow accumulates each year. We call this speed gradual; new snow gradually accumulates on top of the ice sheets in Antarctica.

As the snow gradually accumulates, each year's new accumulation of snow pushes down on the ice sheets. The weight of the newly accumulated snow pushing down on the ice sheets creates pressure. Pressure, as you will have learnt in your Science lessons, is the force acting on an area. In the example we are learning about, the force is the weight of the newly accumulated snow, and the area is the older ice sheets underneath it.

The pressure from the weight of the newly accumulated snow compresses the older ice sheet underneath it. When something is compressed, it gets smaller. When something gets smaller it takes up less volume. The older snow and ice takes up less volume when it is compressed. This is because it has been made smaller by the pressure of the gradually accumulating new snow on top of it.

Snow that has been compressed is called firn. To help us understand firn, we can think about snowballs. When we make snowballs we apply pressure to reduce the volume of the snowball and make it stick together better. The snowball has been compressed by the pressure of our hands. Firn holds together better than loose snow because it has been compressed.

Every year, loose snow gradually accumulates on top of the older snow, firn, and ice that make up the ice sheets in Antarctica. The gradually accumulating loose snow adds pressure which compresses the firn and ice in the ice sheet underneath it. Loose snow is compressed and becomes firn, firn is compressed further and becomes ice.

6. What does the word accumulation mean?

………

7. Why is the accumulation of snow in Antarctica described as gradual?

………

8. What changes snow into firn, and firn into ice?

………

9. Why will the oldest ice be at the bottom of the ice sheet?

………

………

………

………

10. Why will the pressure at the bottom of the ice sheet be the highest?

………

………

………

………

11. Imagine you have measured the pressure at the surface of the ice sheet, at the bottom, and many places between the surface and the bottom. Why will the pressure increase as you measure from the surface of the ice sheet to the bottom of the ice sheet?

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8. What does the Vostok Ice Core Data tell us?

Retrieval Practice

1. What is the name of the Earth's nearest star?	
2. Is solar radiation a long-wave or short-wave?	
3. Name three greenhouse gases found in the Earth's atmosphere.	
4. What wavelengths are affected by greenhouse gases?	

5. What do greenhouse gases do to radiation that's been reflected off the Earth's Surface?	
6. What is the unit of measurement for carbon dioxide in the atmosphere?	
7. What would happen to the temperature if greenhouse gas concentrations were lowered?	
8. How is wavelength measured?	

9. What does is mean if a surface has a **high** albedo?

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10. What does it means if a surface has a **low** albedo?

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11. Define the word **albedo**

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Loose snow gradually accumulates on top of the Antarctic ice sheets every year. The loose snow at the very surface will have frozen this year. Firn, lower volume compressed snow, 30m below the surface, will have frozen around 100 years ago. Ice, 95m below the surface will have frozen around 2500 years ago.

We can drill into ice, just like we can drill into wood. We can drill into ice in the Antarctic ice sheet and look at ice that froze hundreds and thousands of years ago. The Vostok Ice Station is a Russian base on the Antarctic Ice Sheet. The drilling at the Vostok Ice Station has produced the deepest ice holes that have been drilled. The deepest hole drilled at the Vostok Ice Station is 3623m deep.

When the loose snow freezes and accumulates on the surface of the Antarctic ice sheet it freezes with the exact amount of oxygen, hydrogen, carbon dioxide, and other gases currently in the atmosphere. The word preserve means to ‘keep the same’. The loose snow that freezes and accumulates in Antarctica preserves the exact atmosphere at the time it freezes. This means that Firn 30m deep is made of the atmosphere around 100 years ago, and ice 95m is made of the atmosphere around 2500 years ago.

By carefully taking the ice out of the holes drilled into the ice sheet at the Vostok Ice Station we can look at atmospheres from the past. By carefully extracting cores from the drills, we can examine historic atmospheres. Looking at historic atmospheres from ice cores is called reconstructing. Constructing means to build, and construction workers build houses, roads, and other things.

Reconstructing means to build something again. Because the atmosphere’s that are frozen in the ice cores have already happened; we say we are reconstructing them. Ice cores drilled from the Antarctic ice sheets allow us to reconstruct historic atmospheres and study them by melting the ice and measuring the amount of oxygen, hydrogen, carbon dioxide, and other atmospheric gases in them.

The deepest holes drilled at the Vostok Ice Station are 3623m deep. The ice cores are 420,000 years old. This means that we have been able to reconstruct historic atmospheres for the last 420,000 years; looking at the level of oxygen, hydrogen, carbon dioxide, and other gases. The reconstructed historic atmospheric data for the last 420,000 years is known as the ‘Vostok Ice Core Data’.

12. Where are the deepest ice cores drilled?

………

13. Where are the deepest ice cores the oldest?

………

14. How far back does the 'Vostok Ice Core Data' allow us to reconstruct?

………

15. Why do we use the word 'reconstructing' when looking at historic atmospheres from ice cores?

………

16. How do ice cores allow us to reconstruct historic atmospheres?

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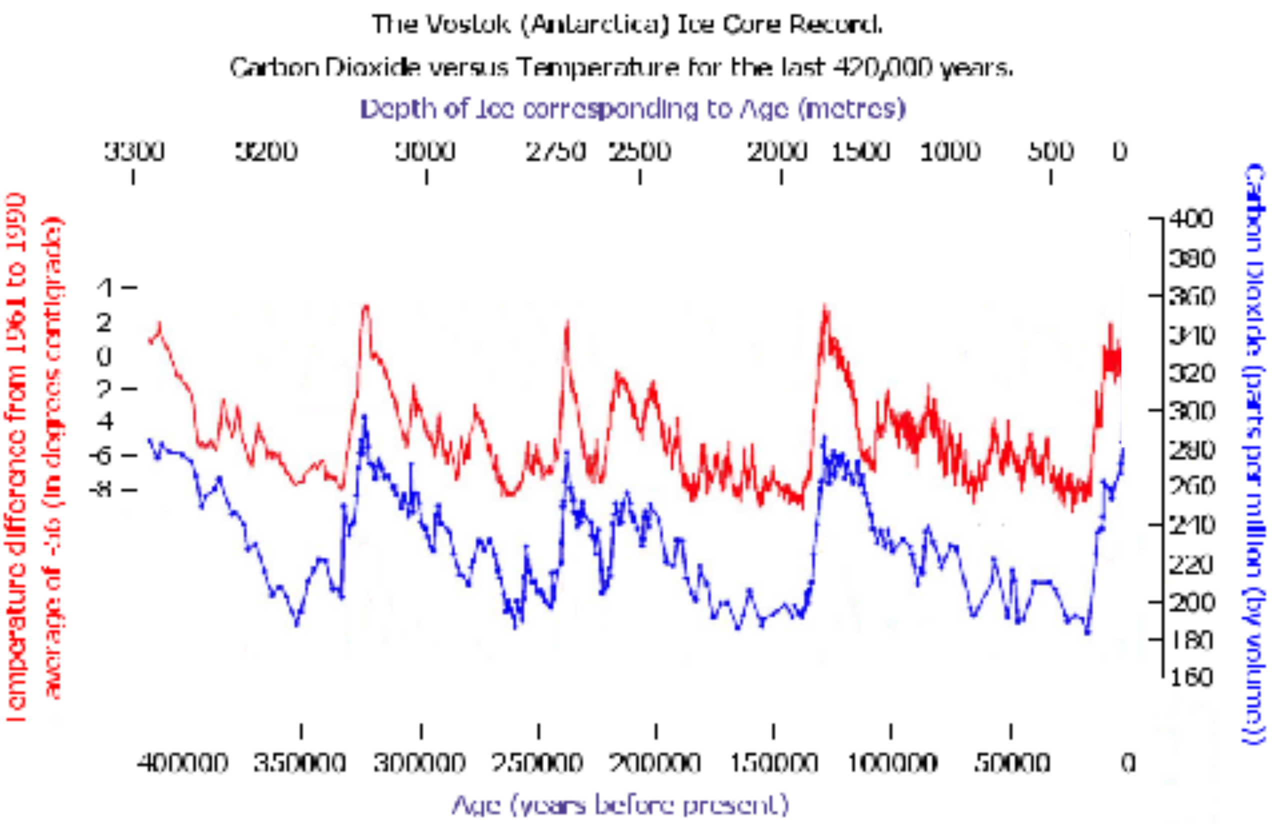
The graph on the next page is the data from the Vostok Ice Cores. It shows the concentration of carbon dioxide, a greenhouse gas, in parts per million, for the last 420,000 years. Using the concentration of gases found in the Vostok Ice Cores, scientists have been able to reconstruct historic temperatures. Scientists have been able to reconstruct historic temperatures and compare them to the average temperature we had between 1961 and 1990. This means we can see that there were times in the Earth's past when the temperature was higher and lower than the 1961-1990 average.

The sentences below the graph analyse the Vostok Ice Core Data. You have two tasks. The first task is to match the everyday sentence to the academic sentence by drawing a neat line, with a ruler. The second task is to write in whether the sentence is true or false.



Everyday Language
The gas in the air never gets more than 300.
The temperature has been eight degrees less than it is now.
It gets hotter when there's more greenhouse gases.
It's been 6 degrees hotter than now
Carbon dioxide has been less than 100 in the past
The highest levels of carbon dioxide are about 200,000 years apart.
You can see that the gas level goes up and down in a pattern.

Academic Langauge	True/False
The temperature correlates with carbon dioxide concentrations	
Previous carbon dioxide concentrations have been lower than 100ppm.	
Approximately two hundred thousand years separate spikes in carbon dioxide.	
Carbon Dioxide never exceeds 300ppm	
A cyclical pattern of carbon dioxide concentrations is visible.	
Historic temperature reconstructions have been six degrees above the 1961-1990 average.	
Historic temperature reconstructions have been eight degrees below the 1961-1990 average.	

9. What evidence is there that the Earth is no longer in planetary homeostasis?

Retrieval Practice
Read through the following paragraph describing what we have learnt about solar radiation, the greenhouse effect, planetary homeostasis and ice core data. Using the first letter to help you, fill in the gaps to complete the paragraph and practice retrieving the academic language we have used.

L_______ w_______ solar radiation is r_____________ out in all directions by the sun. Some of the solar radiation radiated by the sun reaches the s_________ of the Earth after travelling through the atmosphere. When the solar radiation is r_________ off the surface of the Earth, some of the heat energy is t________. This energy transfer i__________ the surface temperature of the Earth, and shortens the w_________ of the solar radiation.

The amount of heat that is a__________ by the surface of the Earth depends on the a_________. When the surface albedo is high, more light is r___________ and the less heat is absorbed. When the albedo is l_____, more heat is a___________ and less light is reflected.

When the solar radiation is reflected off the Earth's surface, the wavelength is shortened. As the solar radiation travels back through the a____________ towards space, g____________ gases in the atmosphere absorb and r__________ the heat. The heat that is absorbed and radiated increases the temperature.

The greenhouse effect is e____________ for all life on Earth. Without the greenhouse effect the Earth's t___________ would be -18oC. The V___________ Ice Core Data has allowed scientists to r____________ historic atmospheres and calculate historic temperatures. The evidence is clear that the Earth's atmosphere has been in planetary h________________ for the last 420,000 years.

We know from looking at the work of James Lovelock and the findings of the Vostok Ice Core Data that the Earth has been in planetary homeostasis for the past 420,000 years. The evidence is now clear that the Earth is no longer in homeostasis. To understand this, we need to learn about the research being done in Hawaii.

Out in the Pacific ocean is the island of Hawaii. The island of Hawaii is one of the fifty states in the United States of America. This makes Hawaii a part of the USA, and the Hawaiian people, Americans. The island of Hawaii is made of five volcanoes. One of the volcanoes that make up Hawaii is Mauna Loa. Mauna Loa is considered to be the largest volcano on Earth.

Mauna Loa is home to an observatory. An observatory is a place used for observing. Observing, is looking and trying to understand what you can measure. An observatory is a place where observations are made, and where those observations are recorded and researched. The Mauna Loa observatory specialises in climate observatory. Specialising means that the observatory only observes one thing, but it observes that one things really well. Observing the climate involves studying and recording the concentration of gases in the atmosphere.

1. What hypothesis did James Lovelock publish in 1979?

....

2. Where was the Vostok Ice Core Data obtained?

....

3. Which country is Hawaii in?

....

4. What does an observatory do?

....

....

5. What do we mean by the term 'specialised'?

....

....

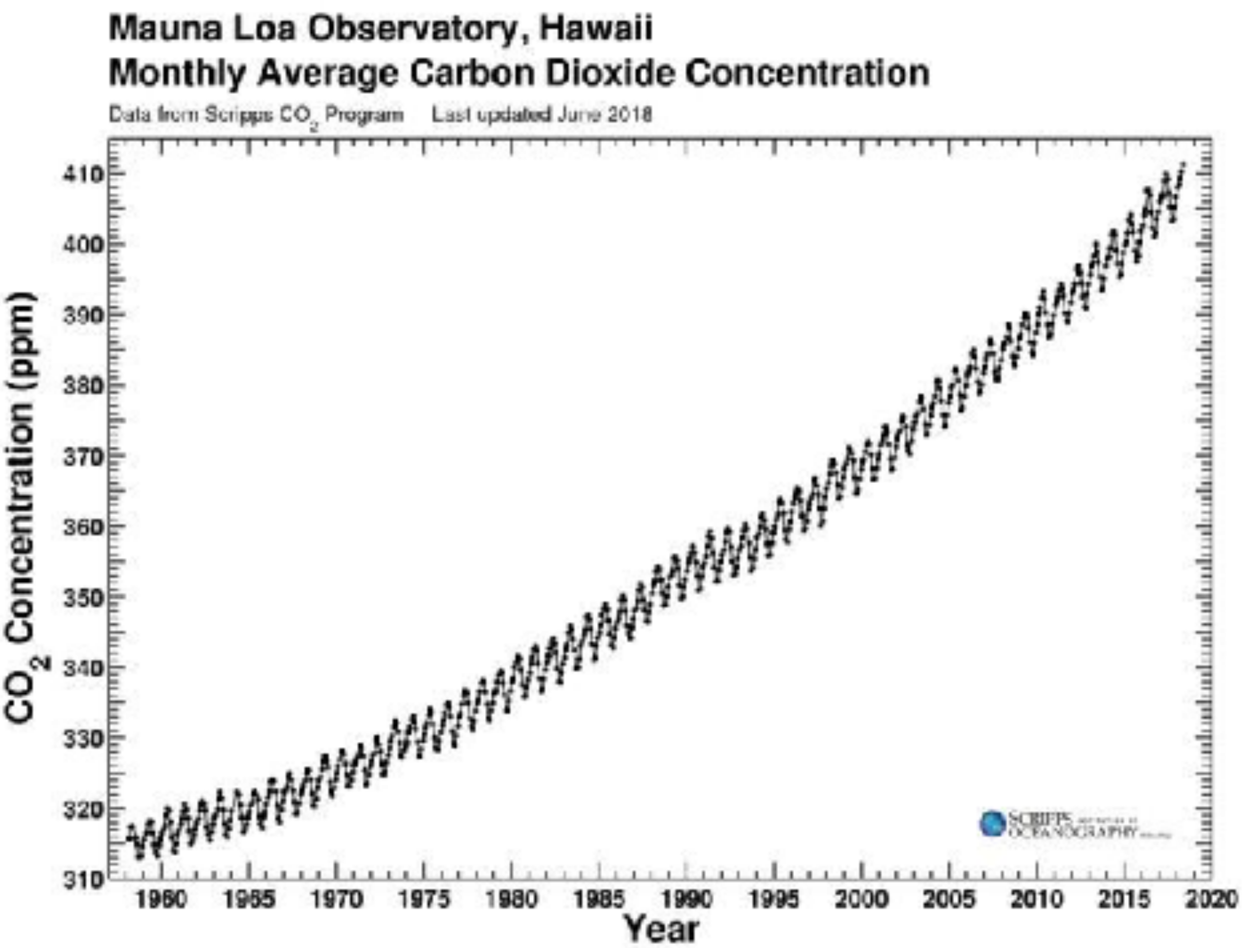
Mauna Loa, Hawaii, is considered a good place for a climate observatory. Hawaii is in the Pacific Ocean. Hawaii is a long way from large cities, or places that are creating a lot of pollution. The pollution from large cities, created by a high concentration of people, can affect the concentration of gases in the air around the city. We can understand this by thinking about the city of London. The city of London has more polluted air than anywhere else in the U.K. If we measured the concentration of gases in the air in London, and the concentration of gases in the air in North West Scotland, the numbers would be very different.

Mauna Loa is a long way from large cities, or places that are creating a lot of pollution. This means that the records at the Mauna Loa observatory are trusted. It is important that we can trust the evidence from the Mauna Loa observatory, because the evidence from the Mauna Loa observatory shows that the Earth is no longer in planetary homeostasis.

Since 1958 the Mauna Loa observatory has recorded greenhouse gas concentrations in the atmosphere. The Observatory was first directed by Charles Keeling, then his son Ralph Keeling, and currently Elmer Robinson. The Mauna Loa Observatory has continually measured greenhouse gas concentrations in the atmosphere since 1958 under Charles Keeling. This makes observations made by the Mauna Loa Observatory the longest continual record of greenhouse gas concentrations in the atmosphere.

The graph of accumulating carbon dioxide, a greenhouse gas, in the atmosphere is known as the Keeling Curve. It is named after Charles Keeling in recognition of his work in directing the Mauna Loa Observatory from 1958 until his death in 2005. Dr Naomi Oreskes, Professor of History of Science at Harvard University, has said that the Keeling Curve is one of the most important scientific works of the 20th century. The measurements collected at Mauna Loa Observatory show a continual accumulation of carbon dioxide concentrations in the atmosphere from 313ppm in March 1958, to 406ppm in November 2018.

The observations made at the Mauna Loa Observatory are dramatic when compared with the Vostok Ice Core Data, which shows that during the last 420,000 years, the concentration of carbon dioxide never once exceeded 300ppm.



6. What was the highest carbon dioxide concentration in the Vostok Ice Core Data? ………………………………………………………… 7. What was the carbon dioxide concentration in March 1958? ………………………………………………………… 8. What was the carbon dioxide concentration in November 2018? ………………………………………………………… 9. What was increase in carbon dioxide concentration between 1958 and 2018? …………………………………………………………	10. Draw a line of best fit on the Keeling Curve graph from 1958 to 1973. 11. Draw a line of best fit on the Keeling Curve graph from 1973 to 1996. 12. Draw a line of best fit on the Keeling Curve graph from 1996 to 2018 13. How much higher than the Vostok Ice Core Data maximum was the carbon dioxide concentration in March 1958? ………………………………………………………… 14. How much higher than the Vostok Ice Core Data maximum was the carbon dioxide concentration in November 2018? …………………………………………………………

15. Why is the graph of carbon dioxide accumulations in the atmosphere observed at the Mauna Loa Observatory called the Keeling Curve?

……

……

16. What does the word ‘continuous’ mean, when talking about the Keeling Curve?

……

……

……

……

17. Why is the word accumulation appropriate when describing the change in carbon dioxide observed in the Keeling Curve?

……

……

……

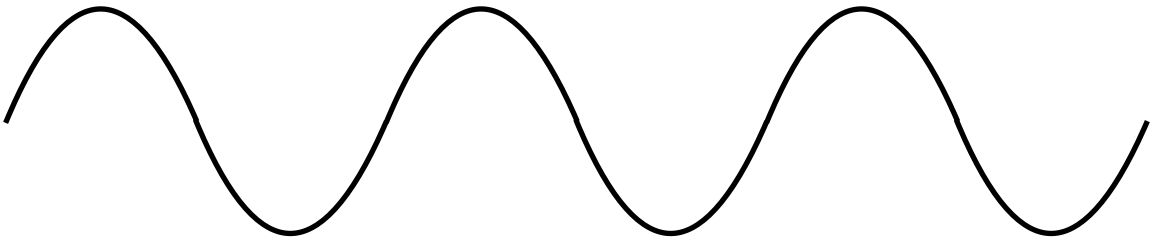
……

10. Why is the amount of carbon dioxide in the atmosphere increasing?

Retrieval Practice

1. Draw, label and annotate a diagram of the greenhouse effect

2. Label the diagram of solar radiation to show the locations of peaks, troughs, and how wavelength is measured.



Human Activity
Human activity, since the Industrial Revolution, has increased the amount of greenhouse gases in the atmosphere. We know that the concentration of greenhouse gases in the atmosphere is higher now than in the past because of the observations made by the Mauna Loa Observatory.

11. Where is the Mauna Loa Observatory located?

………………………………………………………

12. What makes Mauna Loa is good location for a climate observatory?

………

………

13. What does the Mauna Loa observatory observe?

………………………………………………………

14. What is the name of the graph published by the Mauna Loa observatory?

………………………………………………………

15. How are scientists able to reconstruct historic carbon dioxide concentration levels?

………

………

………

………

Before the Industrial Revolution, carbon dioxide concentrations in the atmosphere were below 300ppm. The Industrial Revolution is something you will learn more about in your History lessons at the end of the year. The word industry comes from Latin. The Latin word *industria* which means diligent, active, hardworking, and persistent. We use the word industrious to describe hardwork, and industry to describe different types of work, for example:

- The steel industry, means all of the people who work making steel. It can also include all of the machines used by people working to make steel.

- The tourism industry, means the employees who are involved in tourism businesses, but it can also include the activities that tourists do while on holiday, and the vehicles the travel around in.

In the Industrial Revolution, the word industrial means the way in which we work. The word revolution means to change. The word revolution is an old French word for turning round a circle. Revolvers, a type of pistol, get their name because the cylinder containing the round revolves, it turns round in a circle.

The word revolution means a change, moving round to something new. In the Industrial Revolution, the words mean that we way in which people work, changed. Before the Industrial Revolution people used to collect food from fields by hand, after the Industrial Revolution they were collected by machine.

Before the Industrial Revolution people used to sow clothes by hand, after the Industrial Revolution they were made by machine. During the Industrial Revolution many inventions and discoveries were made in the use of steam engines and electricity. Historians are in agreement that the Industrial Revolution is the most important event in the history of humanity since early humans learned to keep animals and grow crops for food. The Industrial Revolution affected every part of everyones lives; nothing was the same after it had happened.

We can draw the changes in greenhouse gas concentrations before and after the Industrial Revolution, using evidence from the Vostok Ice Core Data and the Keeling Curve.

Fossil fuels are very energy dense. Being energy dense means burning a small amount of fossil fuels can generate a lot more energy than burning the same amount of any other type of fuel. Fossil fuels are packed full of energy, the way to say this, is that fossil fuels are very energy dense.

Fossil fuels are safe and easy to transport. Fossil fuels don't explode and they don't accidentally catch on fire. Fossil fuels are easy to store. They don’t go off, and they don't lose energy when they are stored.

Fossil fuels don’t require high levels of technology to release their energy. Energy dense fossil fuels release their energy when they are combusted. Combusted means to burn, or be set on fire. When they are combusted, fossil fuels release their energy easily.

The use of fossil fuels for energy and the Industrial Revolution go hand-in-hand. The phrase hand-in-hand means two things that come together, and it is based on people in love who arrive somewhere holding hands; they have arrived hand-in-hand. The Industrial Revolution began 200 years ago. Before the Industrial Revolution we didn't use fossil fuels for energy like we do now. We relied on the effort of people to collect crops instead of machines, and used animals like horses to pull carts. Since the Industrial Revolution we have used fossil fuels for energy.

Modern low-carbon alternatives have been available for 20-30 years. We have been using fossil fuels to generate energy for 200 years. This means that since the Industrial Revolution the way in which we live our lives has been because we have generated energy by combusting fossil fuels. The way we design our cities, the national grid, private car ownership, and roads, are all because we have spent 200 years responding to generating energy by fossil fuel combustion.