Welcome to the National Scientific Thinking Challenge, 2024.

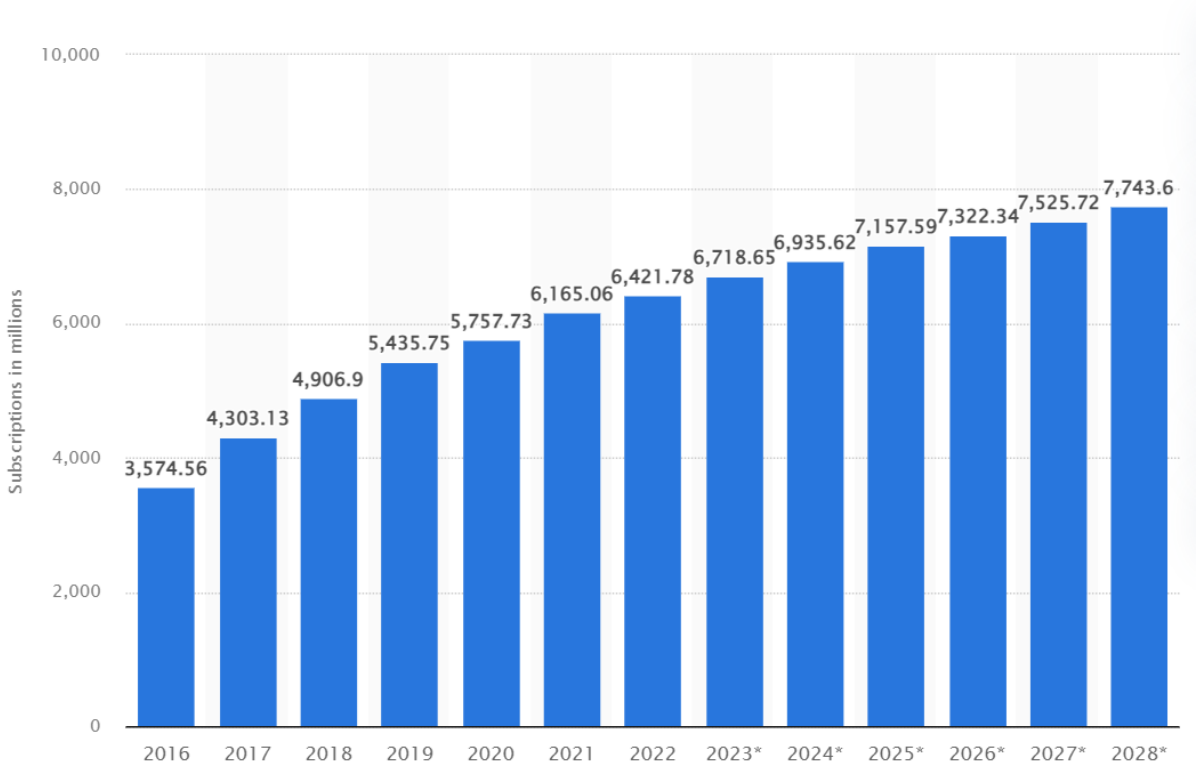
All of the questions should be answered using the information provided. They are meant to be quite challenging but also interesting and maybe even fun!

There is quite a lot to read. This is so we can give you the information you need. Take your time and we hope you enjoy the questions.

- Information is given in blue, like this.
- **The questions are written in black, like this.**
- You are allowed to use a calculator and to write on paper if you want to work things out or make notes.
- There are 38 questions for you to try.
- Don't press the SUBMIT button until you have had a go at all of the questions!

Section 1: Smartphones. This section has 5 questions.

Graph showing the number of smartphone mobile network subscriptions worldwide in millions from 2016 to 2022 with forecasts from 2023 to 2028. *Source: Statista.com*



Question 1: How many smartphone mobile network subscriptions were there, worldwide, in 2022?

A. The graph does not show this.
B. 6,421,780,000
C. 642,178
D. 6,422 (Rounded up to the nearest whole number)

Question 2: How many smartphone subscriptions were there, worldwide, in 2023? Read the information at the top of the graph carefully before you answer this one.

A. 6,718,650,000
B. 671,865
C. 6,719 (rounded up to the nearest whole number)
D. The graph does not show this.

Question 3: Does the number of worldwide mobile network subscriptions also tell us the number of mobile phone users in the world?

A. Yes, obviously! Without a subscription, you can't use a smartphone!
B. Yes, it does. Whilst some people might have 2 smartphones or use a pay-as-you-go system rather than having a subscription, for example, it is still a pretty good estimate when averaged over such a large set of data.
C. No. It lets us make estimates and shows the growth of smartphone use. People might have two mobile phones, some people might use pay-as-you-go phones and not all mobile phones are smartphones.
D. No. Notice how the data go up to 2028. We clearly cannot use this graph because it is making predictions not showing data.

Question 4: What, using the numbers on the above graph, is the percentage increase in the given number of worldwide smartphone mobile phone subscriptions between 2018 and 2023?

A. Step One: 6,718,650,000 - 4,906,900,000 = 1,811,750,000. Step Two: (1,811,750,000 ÷ 4,906,900,000) x 100% = 37%
B. (4906.9 ÷ 6718.65) x 100% = 73%
C. Step One: 6,718,650,000 - 4,906,900,000 = 1,811,750,000. Step Two: (1,811,750,000 ÷ 6,718,650,000) x 100% = 27%
D. (6718.65 ÷ 4906.9) x 100% = 137%

Read this statement before the next question:

"Currently, we can say that there are around 7 billion smartphone subscriptions in the world and around 8 billion people."

Question 5: Which of the following sentences represents the fairest and most accurate conclusion that can be drawn from the statement above?

A. Pretty much every person on Earth has a smartphone.
B. It is reasonable to assume that almost 90% of all the human beings on Earth have a smartphone.
C. There are 7 smartphone subscriptions for every 8 people on Earth.

D. 87.5% of the global population owns a smartphone.

Section 2. This section is about hot air balloons. It contains 5 questions.

This table of data shows, amongst other things, the density of air at different temperatures. (Density is mass per unit volume. Here, the unit is kg/m^3, or the mass (in kilograms) of 1 cubic metre of air.)

TABLE C.1 Physical Properties of Air at Standard Atmospheric Pressure (SI Units)[a]

Temperature (°C)	Density, ρ (kg/m³)	Dynamic viscosity, μ (N·s/m²)	Kinematic viscosity, ν (m²/s)	Specific heat ratio, γ
−40	1.514	1.57 E − 5	1.04 E − 5	1.401
−20	1.395	1.63 E − 5	1.17 E − 5	1.401
0	1.292	1.71 E − 5	1.32 E − 5	1.401
5	1.269	1.73 E − 5	1.36 E − 5	1.401
10	1.247	1.76 E − 5	1.41 E − 5	1.401
15	1.225	1.80 E − 5	1.47 E − 5	1.401
20	1.204	1.82 E − 5	1.51 E − 5	1.401
25	1.184	1.85 E − 5	1.56 E − 5	1.401
30	1.165	1.86 E − 5	1.60 E − 5	1.400
40	1.127	1.87 E − 5	1.66 E − 5	1.400
50	1.109	1.95 E − 5	1.76 E − 5	1.400
60	1.060	1.97 E − 5	1.86 E − 5	1.399
70	1.029	2.03 E − 5	1.97 E − 5	1.399
80	0.9996	2.07 E − 5	2.07 E − 5	1.399
90	0.9721	2.14 E − 5	2.20 E − 5	1.398
100	0.9461	2.17 E − 5	2.29 E − 5	1.397
200	0.7461	2.53 E − 5	3.39 E − 5	1.390
300	0.6159	2.98 E − 5	4.84 E − 5	1.379
400	0.5243	3.32 E − 5	6.34 E − 5	1.368
500	0.4565	3.64 E − 5	7.97 E − 5	1.357
1000	0.2772	5.04 E − 5	1.82 E − 4	1.321

[a] Based on data from R. D. Blevins, *Applied Fluid Dynamics Handbook*, Van Nostrand Reinhold Co., Inc., New York, 1984.

A hot air balloon floats because hot air is “lighter” (less dense) than cool air.

Density = mass ÷ volume

The table above shows the density of air at standard atmospheric pressure (Approximately, Earth's average air pressure at sea level) in kilograms per cubic metre (kg / m^3) at different temperatures.

Question 6: Using the data table above, what is the mass of 4000 m^3 of air at 15°C?

A. 1.225 kg / m^3
B. 4000 x 1.225 = 4900 kg
C. 4000 kg
D. 4000 ÷ 1.225 = 3265 kg

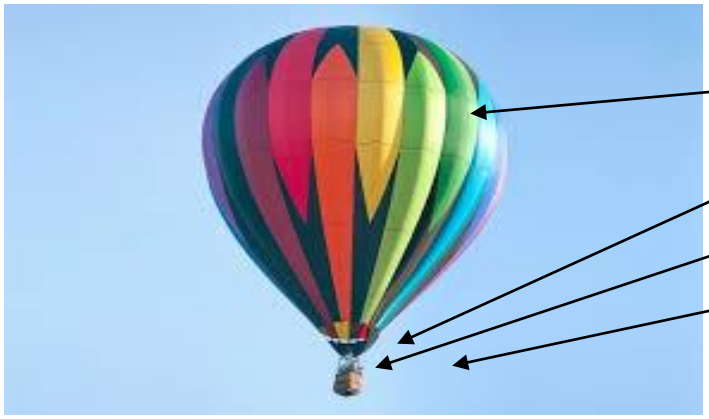
Question 7: Using the table what is the difference in mass between 4000 m^3 of air at 20°C and 4000 m^3 of air at 200 °C?

A. 4,000 x (1.204 – 0.7461) = 1831.6 kg
B. 1.204 – 0.7461 = 0.4579 kg
C. 4000 x (200 – 20) = 720,000 kg
D. (1.401 – 1.39) x 4000 = 44 kg

The air inside a hot air balloon may be heated to approximately 100°C higher than the surrounding air temperature.

We are going to see whether a large hot air balloon, containing a volume of 4000 m^3 of hot air, can take off when the surrounding air temperature is 10 °C.

This is a diagram of the hot air balloon including the masses of its component parts:



Vital information: As a balloon is inflated, it gets bigger and moves the surrounding air out of the way. A hot air balloon can take off if the mass of the colder air it pushes out of the way (displaces) is greater than the total mass of every part of the hot air balloon, including the passengers and the hot air inside it.

Question 8: When inflated, what is the volume of cold air that this balloon envelope displaces (pushes out of the way)?

A. There is no way to answer this question.
B. 4000 m^2
C. 4000 cm^3
D. 4,000 m^3

Question 9: What is the total mass of the hot air balloon, the passengers and 4000 m^3 of hot air at 100°C inside the balloon envelope? (All of the information is provided above.)

A. 500 kg. This is the combined mass of passengers which is what must be lifted by the balloon.
B. Total mass of balloon plus passengers: 150 + 250 + 100 + 500 = 1000 kg. Mass of hot air: 4000 x 0.9461 = 3784.4 kg. Total mass of hot air balloon, passengers and the the hot air: 1000 + 3784.4 = 4780 kg *(3 s.f.)*
C. Total mass of the hot air balloon: 150 + 250 + 100 + 500 = 1000 kg. Mass of the hot air inside it: 4000 x 1.247 = 4,988 kg. Total mass of everything: 1000 + 4988 = 5988 kg *(3 s.f.)*
D. Passengers and load (500kg) + mass of hot air at 100 °C (4000 x 0.9461 = 3784.4) = 4280 kg *(3 s.f.)*

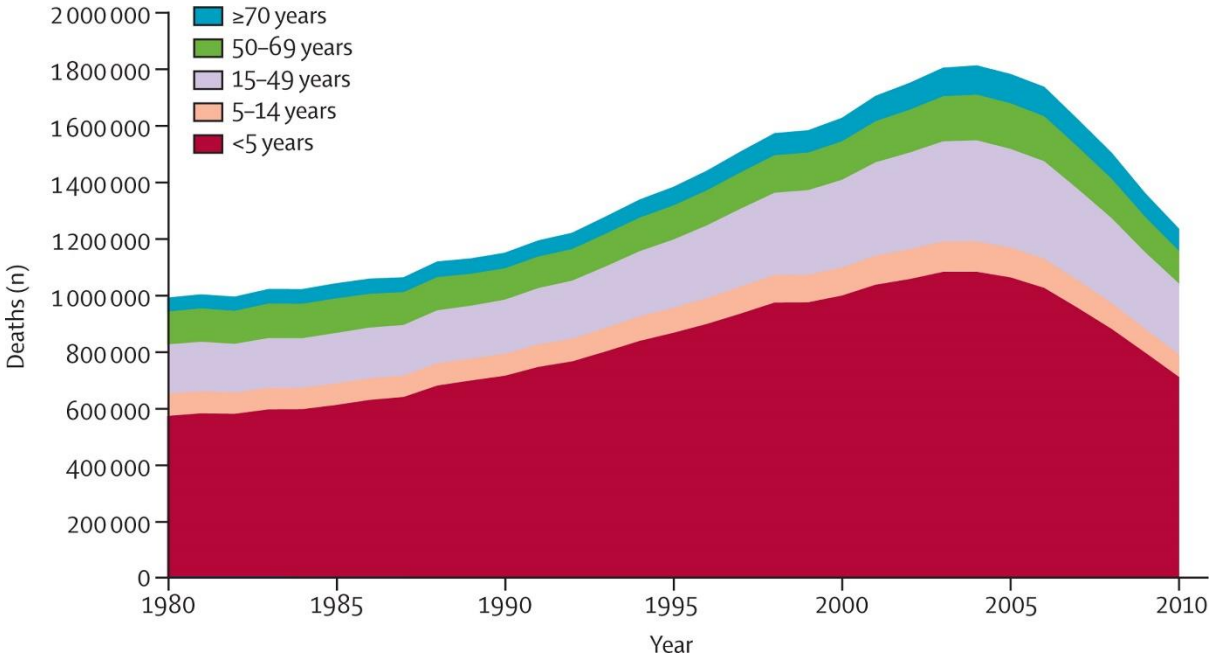
Question 10: Can the hot air balloon take off if the air inside it is 100°C and the surrounding air is 10°C? Which statement is the most scientifically correct?

A. If the mass of the 4000 m^3 of hot air inside the balloon is less that the mass of the same volume of cold air then it will take off.
B. Yes, it will, you can see this simply by looking at the table of data: the density of the hot air inside the balloon is less than the density of the cold air surrounding it. The hot air will rise, taking the balloon up with it.
C. Mass of 4000 m^3 of cold air displaced by the balloon = 1.247 x 4000 = 4988 kg. Mass of 4000 m^3 of the balloon, passengers and hot air at 100°C = 4780 kg. So, yes, the balloon will take off.
D. As long as it is not tied to the ground, it will float gently upwards into the sky.

Section 3: This section is about malaria. It contains 7 questions.

Malaria is a life-threatening disease spread to humans by some types of mosquitoes. It is mostly found in tropical countries. It is preventable and curable.

Graph showing total global malaria mortality between 1980 and 2010. *Source: The Lancet*



On the y-axis you will see Deaths (n), "n" just means the total number.

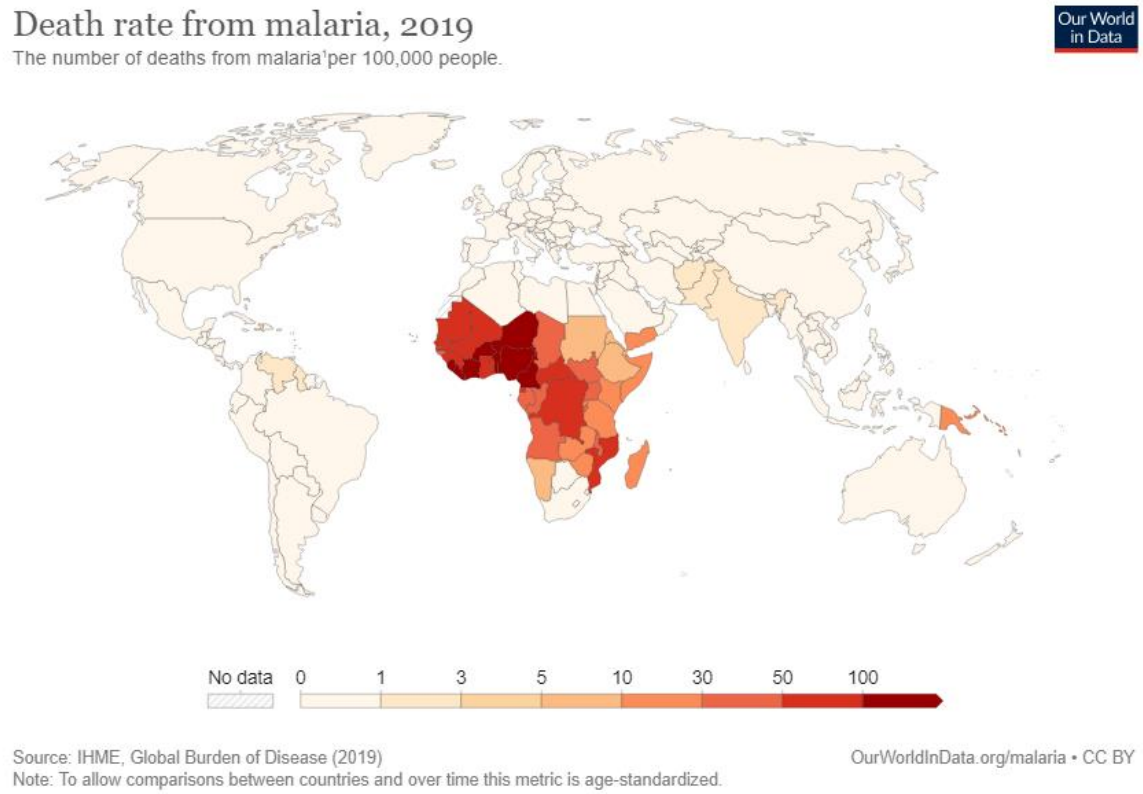
Question 11: By studying the graph above, select which statements correctly relate to the information shown:

A. The highest numbers of malaria deaths occur in those aged over 70.
B. The majority of malaria deaths occur in people aged under 5 years old.
C. There has been a reduction in global malaria mortality since 2005 to the present day.
D. The number of malaria deaths, shown on this graph, peaks around 2004.
E. Men are more likely to die from malaria than women.

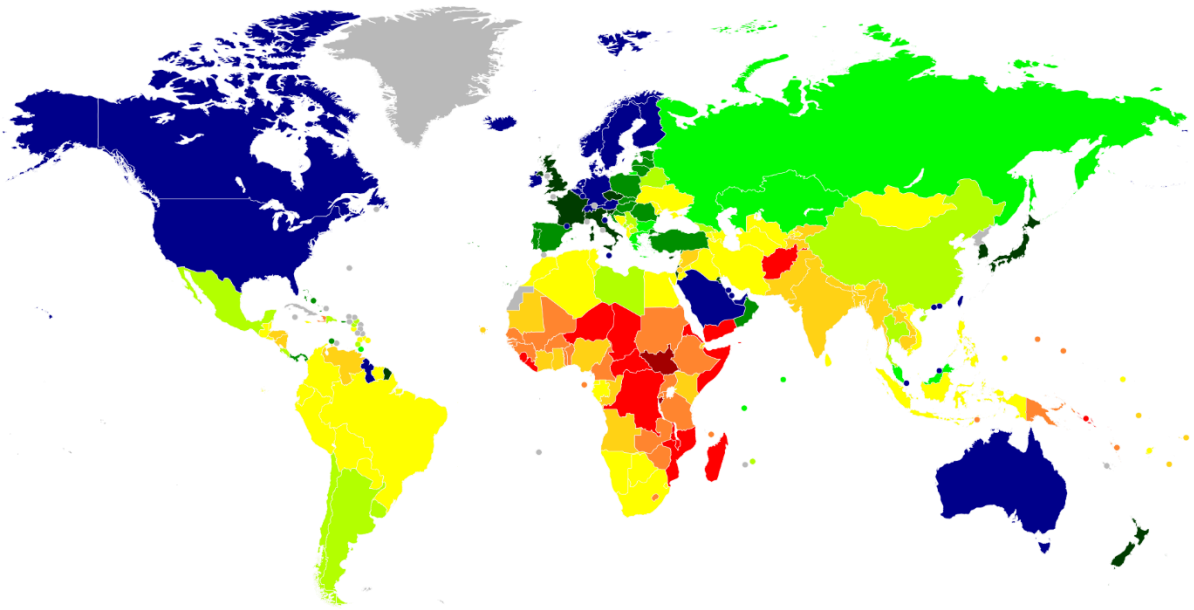
Which are correct?

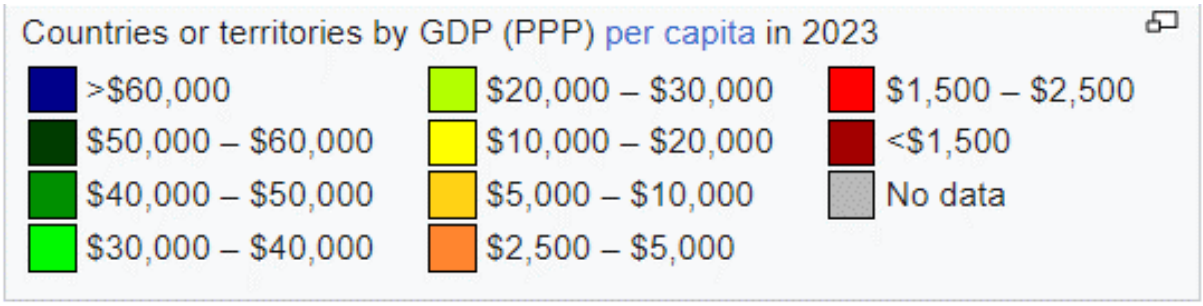
A. A and D
B. B and D
C. B and C
D. D and E

This map shows the number of deaths from malaria, per 100,000 people in each country of the world during 2019.



This map shows Gross Domestic Product, GDP per person by country. GDP Is a measure of wealth.





Map by Allice Hunter File:World map (Miller cylindrical projection, blank).svgData from IMF: World Economic Outlook Database, April 2023. IMF.org. International Monetary Fund

Question 12: Which of the following hypotheses (suggestions) is fairest, based upon the information shown in the two maps?

A. If mosquitoes which carry malaria live in a country which has a low gross domestic product, that country is likely to have a higher rate of malaria deaths.
B. Malaria is mostly found in Africa due to good conditions for the mosquitoes which transmit the disease being found there.
C. People don't die from malaria in richer countries. You can clearly see that the richer (blue) countries, have the lowest rates of malaria deaths.
D. The countries with high rates of malaria deaths have lower gross domestic products.

Information: The number of malaria deaths is lower than the number of malaria infections. Malaria is treatable with medication and can be prevented by the use of insect repellents and insecticide treated nets to protect people when they are sleeping. There is also a new malaria vaccine in use in Ghana and Nigeria.

The World Health Organisation (WHO) writes, "since 2015, 9 countries have been certified by the WHO Director-General as malaria-free, including Maldives (2015), Sri Lanka (2016), Kyrgyzstan (2016), Paraguay (2018), Uzbekistan (2018), Argentina (2019), Algeria (2019), China (2021) and El Salvador (2021).

(https://www.who.int/news-room/fact-sheets/detail/malaria)

Question 13: Having read that information, look again at the two maps. Which statement is most likely to be correct when considering why some countries are not malaria free?

A. Progress is being made against malaria, worldwide, in all places.

B. If, as in the very poorest countries affected by malaria, the things required to treat and prevent the disease cannot be afforded, it is going to be very hard to eradicate malaria in those places.
C. Countries with the lowest GDP seem to have the highest death rates from malaria. The two things might be connected but we cannot say how using the information provided.
D. People don't die from malaria in richer countries. You can clearly see that the richer (blue) countries, have the lowest rates of malaria deaths.

A malaria drug called Artesunate is recommended for severe cases. It is administered intravenously or as an injection into muscle. The dosage is stated at "2 – 4 mg / kg" (read as "two to four milligrams of medicine per kilogram body weight of the patient") over a 12-hour period.

Question 14: How much of this medicine should be given, per dose, to a patient weighing 80kg?

A. 2 – 4 mg
B. It is not possible to calculate this from the information provided.
C. 160 – 320 mg
D. Any amount between 2 mg and 4 kg

The symptoms of malaria, include repeating cycles of chills and shivering, then high body temperature (fever) before profuse sweating brings the body temperature down to normal (37^{o}C) again.

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Definition: a **parasite** is an organism that lives in or on an organism of another species (its host) and benefits by taking nutrients at the other's expense.

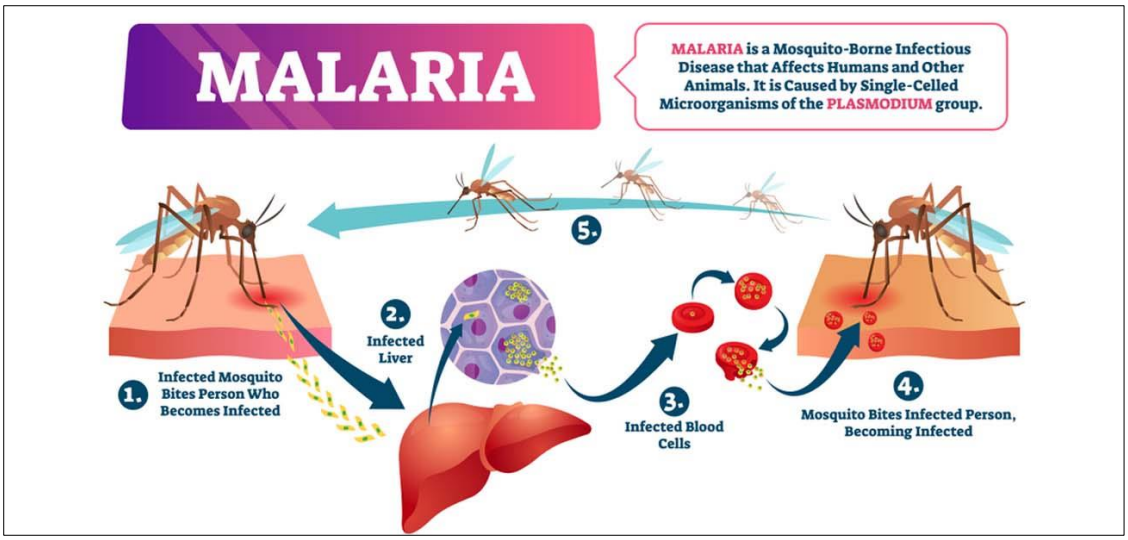
_____

Malaria is caused by plasmodium parasites. There are different types of plasmodium parasites, which will cause fever cycles lasting for different lengths of time. This is shown in this table.

Different patterns of fever (high body temperature and associated symptoms):

Type of Malaria	*Length of Fever Cycle*
Plasmodium knowlesi	24 hours
Plasmodium falciparum Plasmodium vivax Plasmodium ovale	48 hours
Plasmodium malariae	72 hours

Here is more information about malaria and how the disease works inside our bodies:



Source: drvidyullata.com

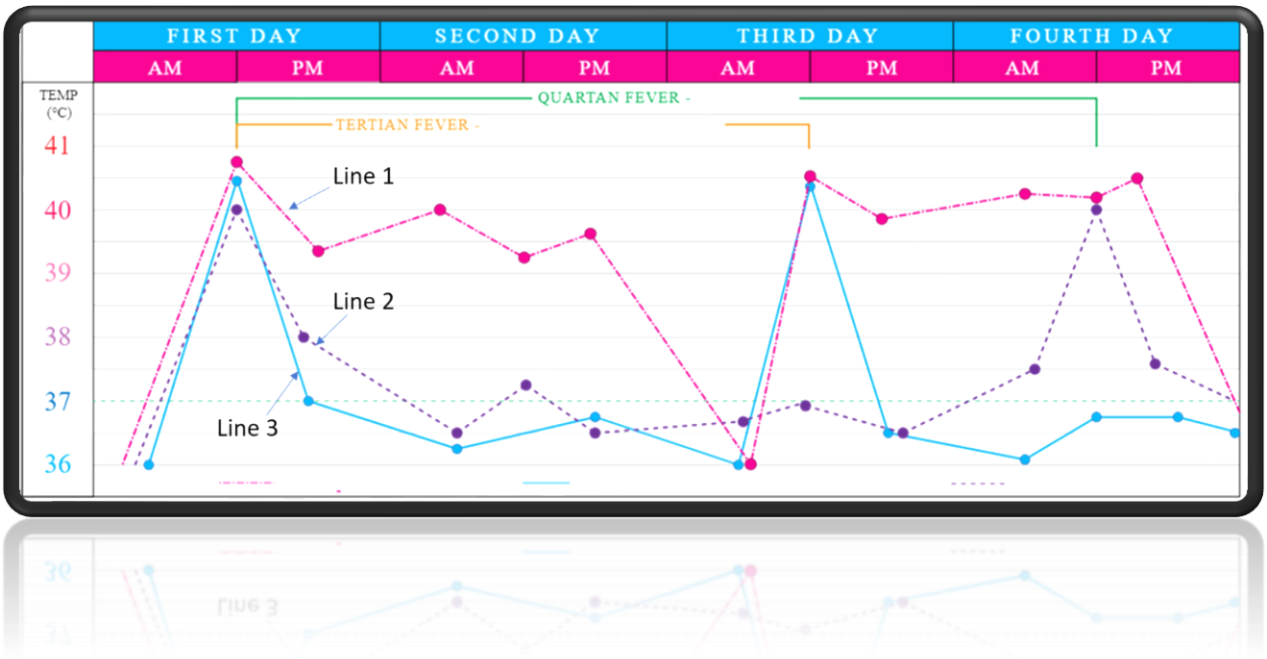
More information about how Malaria works:

- Mosquito bites human and parasites travel to the liver.
- Parasites multiply in the liver cells for 2 – 10 days. Infected liver cells burst releasing more invasive versions of themselves into the bloodstream. The person feels fine during this stage.
- Parasites enter red blood cells where they multiply rapidly for 24, 48 or 72 hours depending on the type of parasite.
- Eventually, the infected red blood cells burst. This triggers the body's immune system to fight the invaders. Many more parasites have been released. These will infect more red blood cells.

Question 15: Having looked at the information above, why do different types (or "strains") of malaria have different patterns of fever (meaning lengths of time between the patient feeling ill with a fever)?

A. The time delay between fevers corresponds to the breeding cycle of the infected mosquitoes.
B. The amount of time between fevers corresponds to the length of time it takes for malaria parasites to enter red blood cells, reproduce inside them, until the red blood cells burst open releasing more parasites into the blood.
C. Younger, fitter people will have faster patterns of fever and older people have slower patterns of fever.
D. The symptoms of a fever are not caused by the malaria parasites, they are caused by the body's immune system fighting the parasites.

This is a temperature chart showing body temperatures for patients infected with different strains of malaria. (*Source, Commons Wikimedia, edited*.)



Use any information provided in this section to answer these two questions

Question 16: Which line is most likely to show changes in a person's body temperature following infection by P. Malariae? (Hint: use the table above of information relating to different strains of plasmodium.)

A. Line 2
B. Line 3
C. Line 1
D. 37 °C

Question 17: Look carefully, there is a green dotted horizontal line (----------) across the graph. Why is this shown?

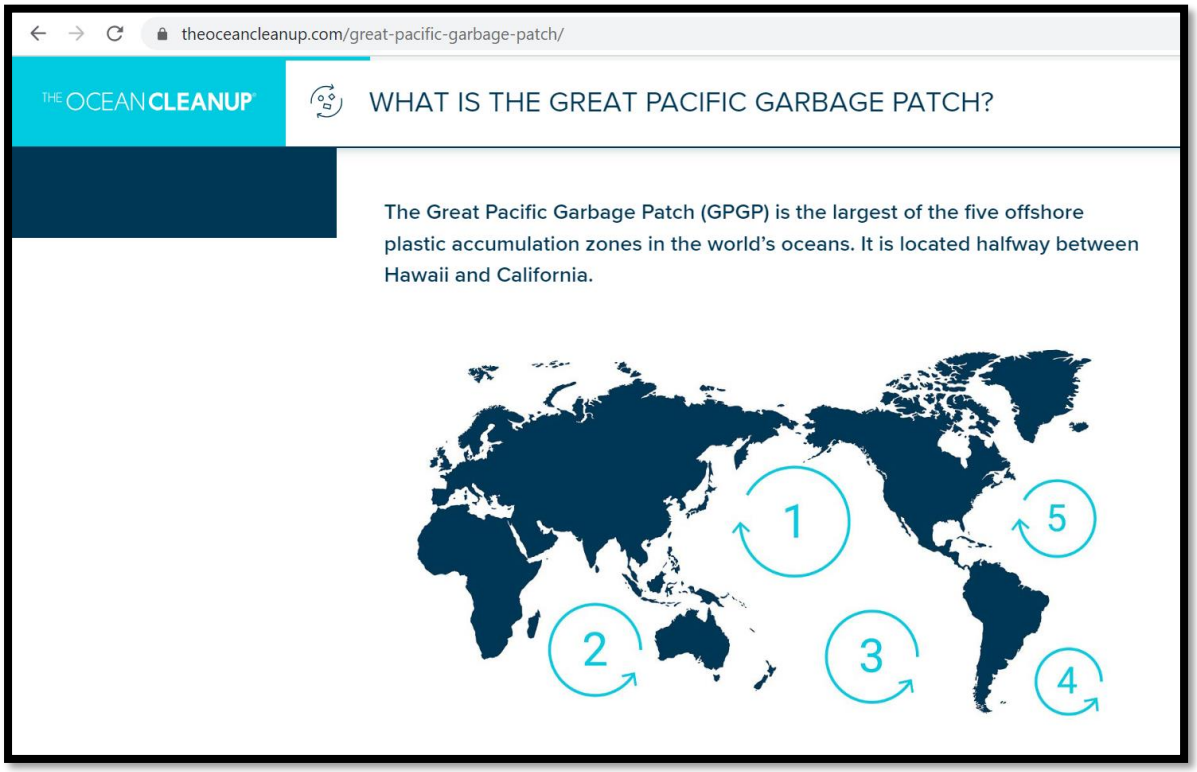
A. It is important to have a baseline, or a horizontal axis for a graph.
B. Green is a different colour, so it shows that this result is not part of the experiment.
C. People aged 37 are not at high risk of dying from malaria.
D. It allows us to compare the temperatures of the patient with normal body temperature.

If you found that question interesting, make sure you find out more about the amazing, work that is currently being done on malaria vaccines.

Section 4: This section is about some of the work of an organisation called The Ocean Cleanup. It contains 8 questions.

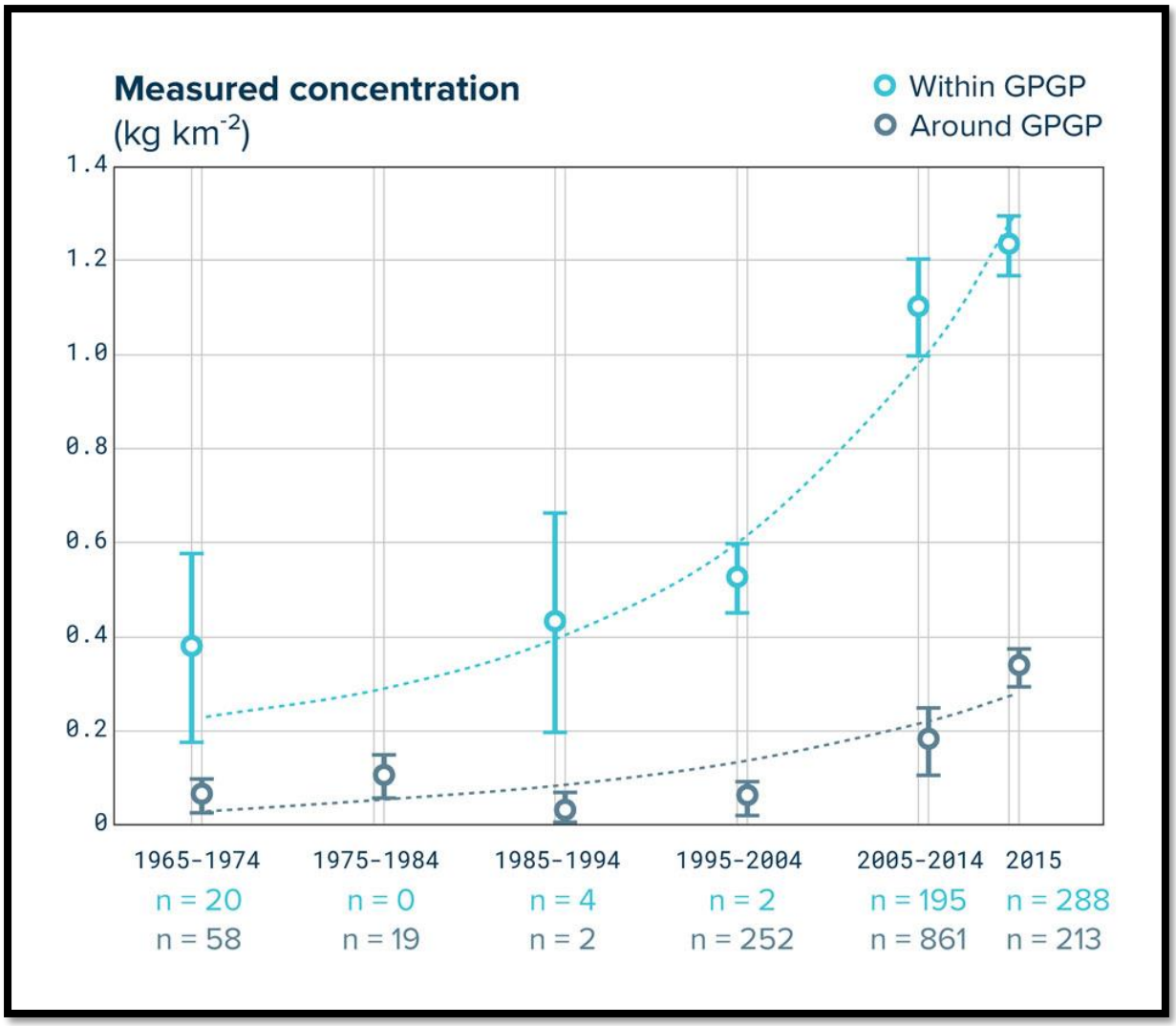
The Ocean Cleanup is a non-profit organisation, based in the Netherlands, working to rid the World's Oceans of Plastic. Their work is of global importance.

It is estimated that around 80,000 tonnes of plastic, from large objects to tiny microplastics are to be found floating in the oceans between California and Hawaii, this is the mass of 500 jumbo jets. It occupies an area of 1.6 million km^2, three times the area of France, and is known as the **Great Pacific Garbage Patch (GPGP). (Shown on the map below as area 1.)**



Remember: GPGP stands for "Great Pacific Garbage Patch".

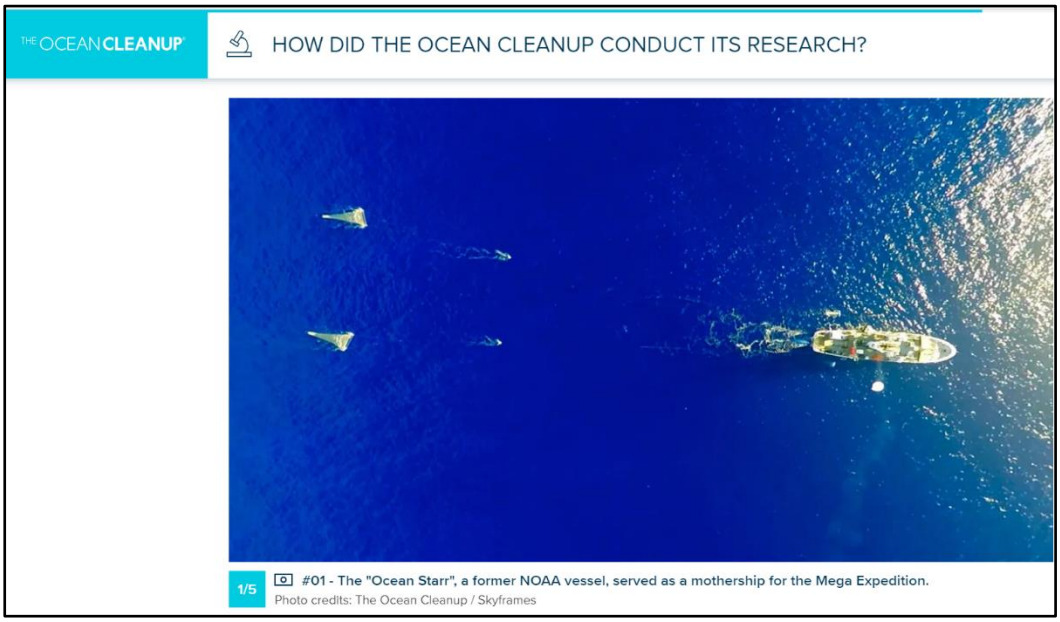
Huge surveys of the GPGP, by boats and aircraft, created the following graph showing how the concentration of plastic per square kilometre of the GPGP has changed with time:



Source: The Ocean Cleanup. ("n" means number of results and kg km^{-2} means kg of plastic measured per square kilometre of ocean.

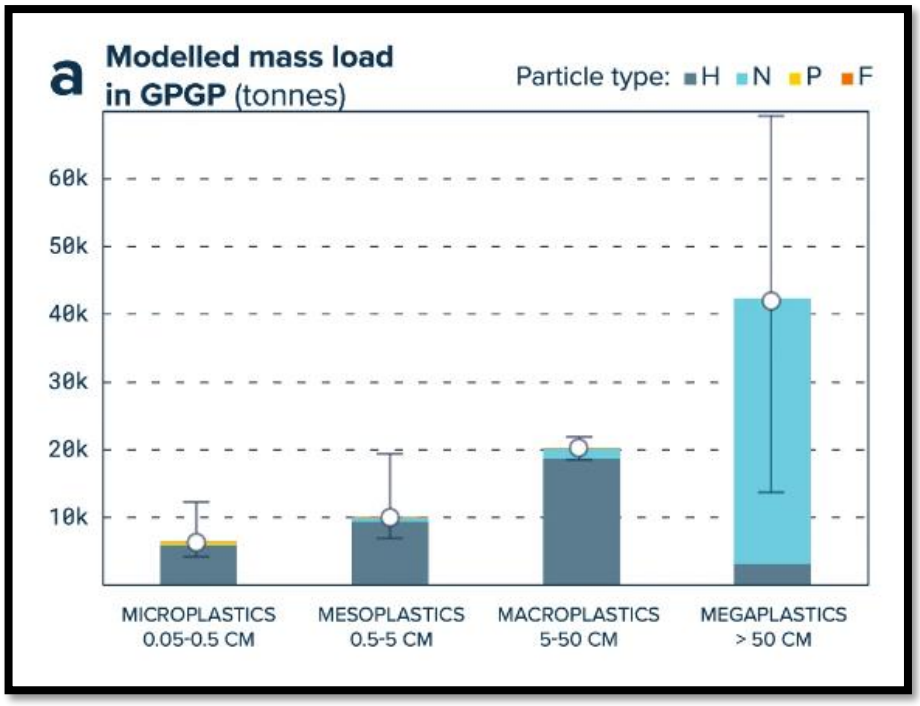
Question 18: Which of the following statements is the most useful interpretation of the graph above? (In terms of trying to understand how the amount of plastic in the GPGP is changing as time passes.)

A. The mass of plastic in each square kilometre of the GPGP is increasing exponentially. Therefore, plastic is entering the GPGP faster than it is leaving it.
B. There is more plastic in the GPGP than there is in the ocean around it.
C. More measurements have been taken in recent years.
D. There were 238 measurements recorded within the GPGP in 2015 which means that year's result is likely to be accurate.



The Ocean Cleanup Project has studied the GPGP in tremendous detail. They have used ships to drag nets through the water (as shown above) and a large aircraft to measure plastic levels from the air (as shown in the second picture).

Computer programmes were used to make accurate estimates as to the quantities of plastic to be found in the whole GPGP and what sizes those plastic objects were likely to have. These results were published in a prestigious scientific journal called *Nature*:



Source, The Ocean Cleanup, published in the Journal Nature, March 2018 (k means 1000, so 20k means 20,000, etc.)

Graph (a) Plastic mass distribution within the GPGP between size (bars) and type (colours). Plastic types: **H** = hard plastic, plastic sheet and film. **N** = Plastic lines, ropes and fishing nets. **P** = plastic pellets. **F** = formed, or moulded plastic objects.

Whiskers extend from lower to upper estimates per size class.

Question 19: Most of the mass (kg) of the plastic to be found in the GPGP belongs to which size category?

A. Mesoplastics, 0.5 – 5 cm
B. Macroplastics, 5 – 50 cm
C. Megaplastics, >50cm
D. Microplastics, 0.05 – 0.5 cm

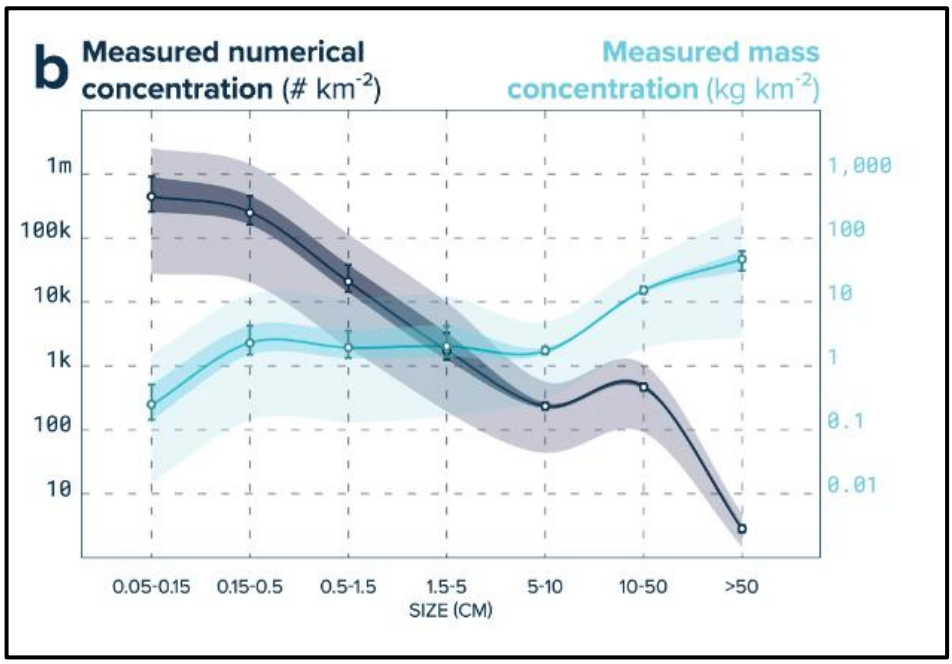
Question 20: Look carefully at the bar on the graph above relating to just "MACROPLASTICS (5 – 50 CM)". Use the information provided to work out what sort of plastic accounts for most of the mass of macroplastics that are found in the GPGP?

A. Pellet plastics
B. Hard plastics, sheet and film
C. Formed, or moulded, plastic objects
D. Hard plastic, plastic sheet and film

Question 21: Plastic type N accounts for the largest total mass of all the plastic types to be found in the GPGP. Knowing this, which industry could be targeted to play a very significant role in reducing the total mass of plastic in the GPGP?

A. Fishing
B. Tourism in the countries bordering the Pacific Ocean
C. Watersports, including SCUBA diving.
D. The manufacture of food packaging

This graph presents two sets of data at the same time. The measured numerical concentration of plastic (number of pieces per square kilometre) and the measured mass concentration of plastic (kilograms of plastic per square kilometre).



Source: Ocean Cleanup and *Nature*

(# means "number", "k" means 1000 and "m" means 1,000,000. Measure mass concentration means the number of kilograms of plastic per square kilometer of ocean)

The lighter shaded areas extend from the 5th to 95th percentile. (A measure of the range of the results.)

The letter "b" in the top left corner is not relevant here.

Question 22: Which statement best describes the information that is presented in this graph?

A. In dark grey, this graph shows how the number of pieces of plastic per km^2 varies with the size of those pieces. In light blue, it shows how the mass (kg) of plastic objects to be found per km^2 of ocean varies with the size of the pieces.
B. It shows, in dark grey, that the number of pieces of plastic per square kilometre is decreasing as time passes but it also shows, in light blue, that the mass of the pieces of plastic per square kilometre is increasing.
C. The most commonly found pieces of plastic are very small in size.
D. The graphs shows that the majority of the mass of the plastic to be found in the GPGP is made up of big objects in the water.

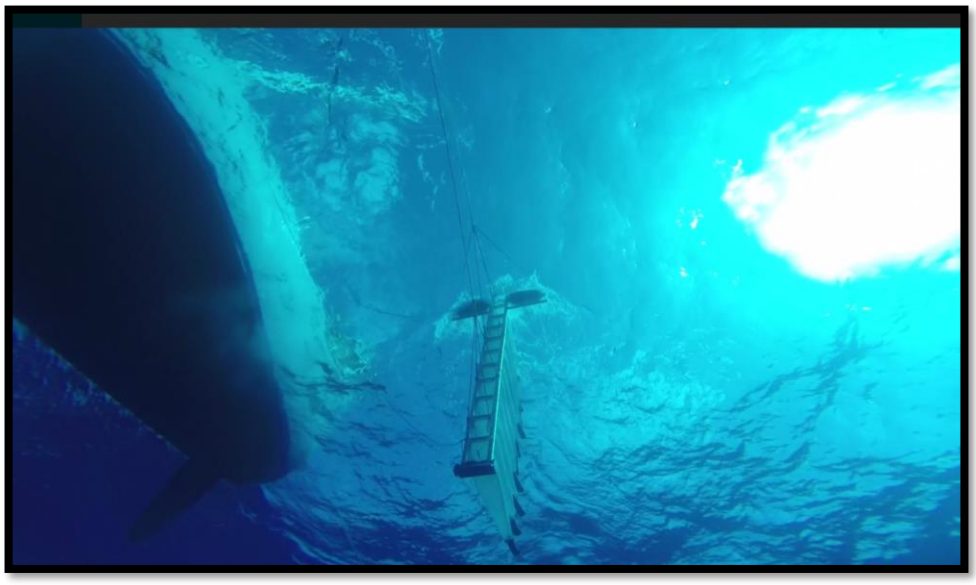
Question 23: Look at the line presented in dark grey on the graph above. (The line that runs from the top left corner down to the bottom right corner.) **Which statement accurately describes information shown by this line?**

A. The number of large plastic objects in the ocean is decreasing.
B. The bigger the size of the plastic object, the more of them there are to be found in the GPGP.
C. Large plastic objects weigh more than small plastic objects.
D. There are fewer large plastic objects than small plastic objects to be found in the GPGP.

Question 24: Look at the light blue information (upper right corner to lower left corner of graph). Which statement most accurately describes what this part of the graph is telling us?

A. A large plastic object has a greater mass than a small plastic object.
B. The largest plastic objects have been floating in the ocean for the longest time.
C. Most of the mass of the plastic in the GPGP comes from the largest plastic objects.
D. The smallest plastic objects move fastest through the ocean.

Scientists at The Ocean Cleanup dragged this special net behind a ship through the GPGP.



Question 25: What do you think the net in this picture is designed to do?

A. It is designed not to get caught in the ship's propeller.
B. It captures plastic floating in the ocean at different depths below the surface.
C. Measure the temperature of the water at different depths below the surface.
D. Measure the oxygen levels of the water at different depths below the surface.

We would very much like to thank The Ocean Cleanup for helping us to write this question.

Section 5: This section relates to how an engine might be best used for a specific purpose, with minimal environmental impact. It contains 3 questions.

Ottawa, a large city in Canada, can experience heavy snowfall in winter.

Source: CTV News

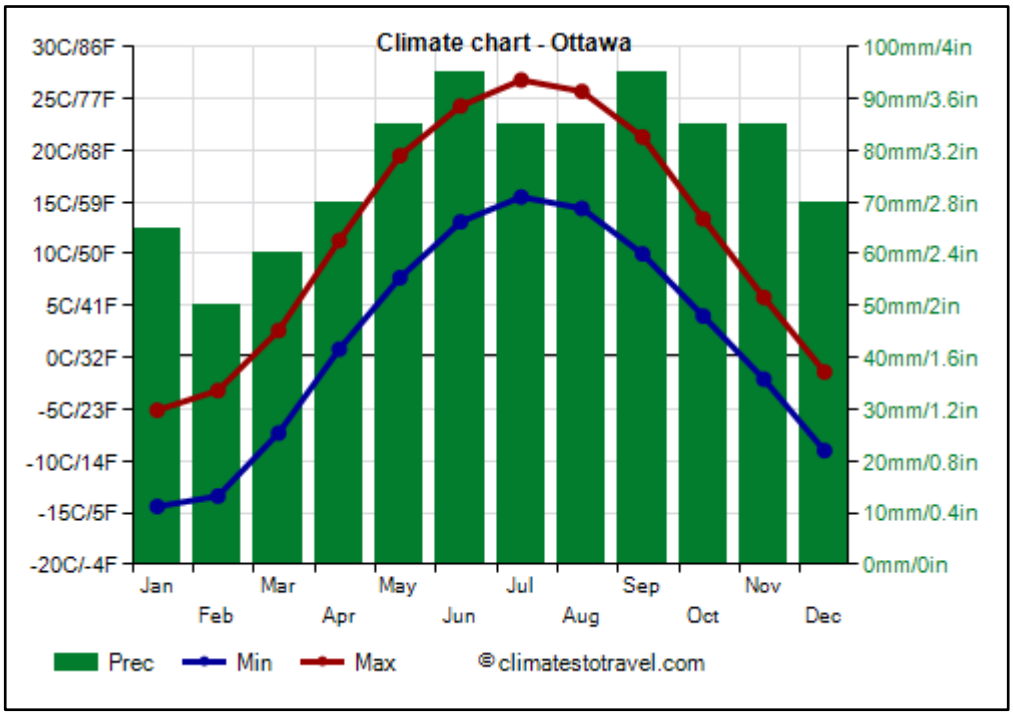
A snowblower can be used to clear paths of snow:

Source: Honda Canada

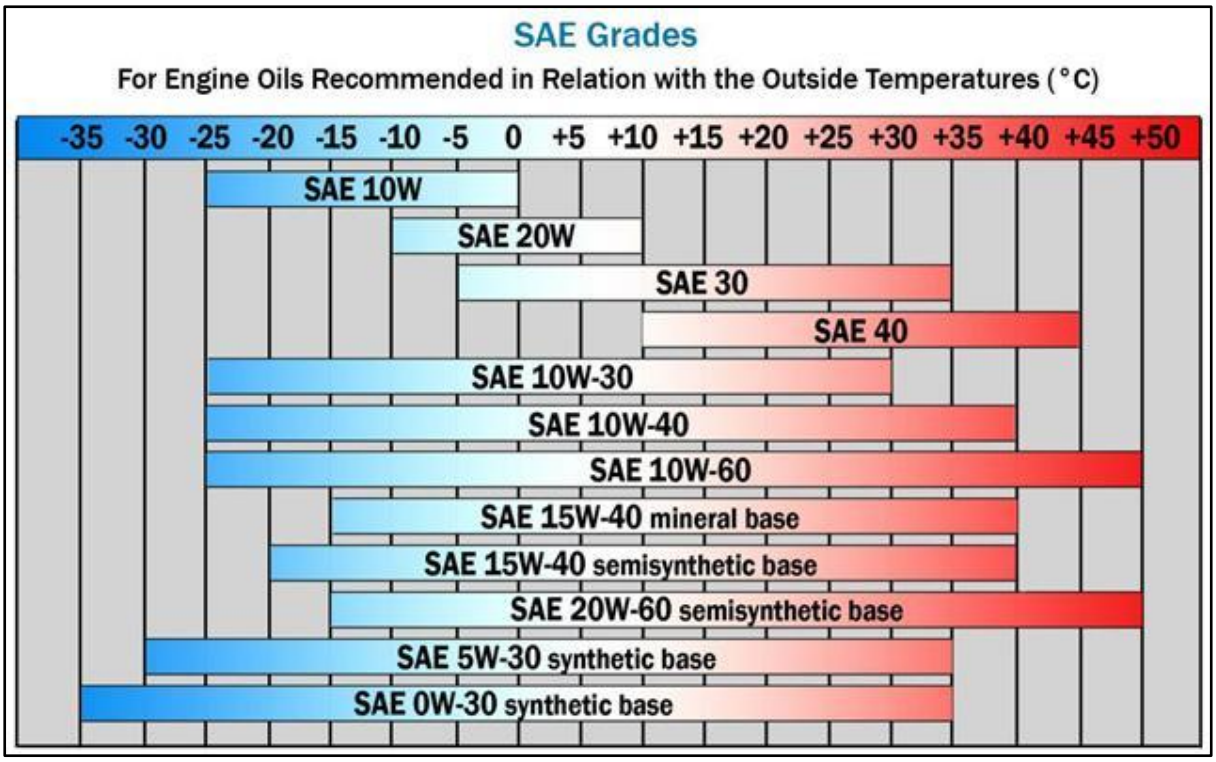
When the engine of a snowblower is serviced, fresh (clean) oil has to be put into the engine.

Oil can be bought with different thicknesses (“viscosity” is the correct term for thickness or gloopiness). These are given as SAE numbers. (SAE = Society of Automotive Engineers)

Use this graph which shows average temperatures in Ottawa and the chart of oil viscosities to select the best oil to put into the snowblower:



"Prec" means precipation, referring to rain or snow depending on the season.



Question 26: select the best engine oil for the snowblower from the selection in the table above:

A. SAE 40
B. SAE 10W-30
C. SAE 20W
D. SAE 30

The owner of the snow blower wants to convert the engine to run on a renewable fuel so that it would have a lower environmental impact. The only option she has is to convert the engine to run to bioethanol. Ethanol is an alcohol that can be made by the fermentation and distillation of starchy crops such as corn.

Question 27: If we assume that the engine can be converted to run on ethanol, what information does she need to know about ethanol to understand <u>whether the engine will work</u> using this fuel?

A. The tax on bioethanol
B. Whether the fuel can be stored legally at her home
C. The availability of this fuel where she lives.
D. The freezing point of ethanol

Question 28: The owner of the snowblower was told by her child, who is in Year 10, that she was wasting her time converting the snowblower to run on bioethanol. He gave four reasons which are listed below in the next question.

Which of the following objections is the <u>weakest?</u> (Or, to word it another way, which objection makes the least sense from a scientific point of view?

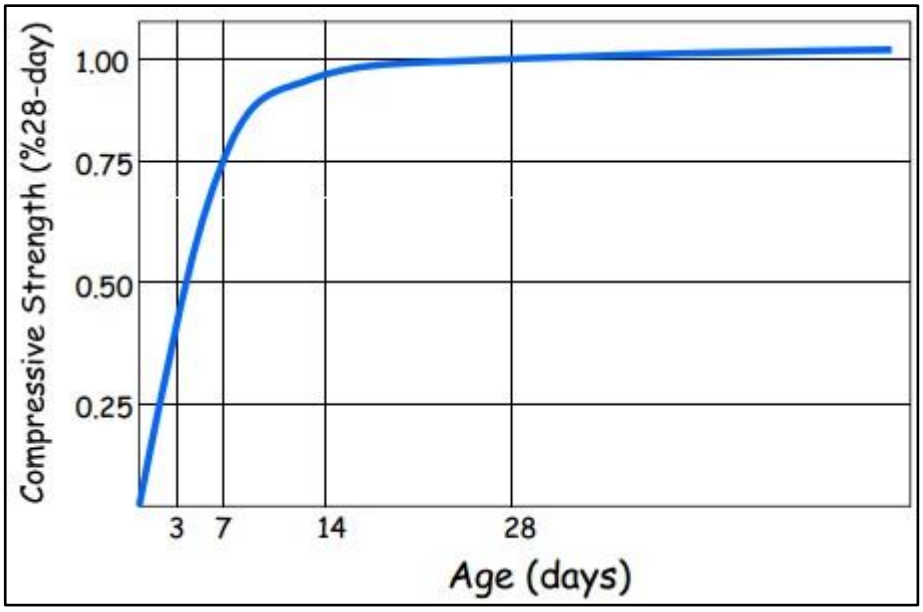
A. *Objection 1:* "Pure ethanol is flammable and poisonous. Storing it at home is dangerous."
B. *Objection 2:* "The snowblower is only used occasionally. The amount of fuel it burns in a year is tiny, compared to our car. If we walk to the shops instead of driving, that would have a greater environmental impact, overall!
C. *Objection 3:* "The amount of carbon dioxide released by the snowblower in use is tiny compared to the amount of carbon dioxide released by creating it from raw materials and delivering it to our home. It would be best to just look after it well so we don't need to buy another one for a really long time."
D. *Objection 4:* "Ethanol absorbs water. (Eg: wine contains ethanol and water.) Storing the snowblower for months without using it is likely to allow the fuel to absorb moisture from the atmosphere and this will mean the snowblower won't work when we need it."

Section 6: This section is about **cement** and how changing the way it is made could really help to combat climate change. (It contains 8 questions.)

Concrete is an engineering material that simulates the properties of rock. It is usually a mixture of sand, gravel and crushed rock, mixed with a binder, eg: cement. When water is mixed in, a chemical reaction occurs and the cement hardens, forming concrete: a hard, dense material that is able to withstand very strong crushing forces. (Engineers say that concrete is very strong under compression.)

Fun fact! Concrete is the second most widely used substance on Earth, after water!

The first questions in this section asks you to use this graph. "Compressive strength" means how strong the concrete is when being crushed. "Age" means how long after the concrete was made.



Source: CivilEngineeringBible.com

Use the graph showing "Compressive Strength against Age", above to answer these questions:

Question 29: Estimate how long it takes for freshly made concrete to acquire half of its maximum strength under compression (crushing forces).

A. 4 days
B. 3 days
C. 7 days

D. 14 days (half of 28)

Question 30: What does 0.75 mean on the vertical axis of the graph showing Compressive Strength against Age?

A. The concrete now has three quarters of the compressive strength as it will have after another 21 days.
B. Three quarters of the time for the concrete to set has now passed.
C. The concrete has a compressive strength of 0.75 units
D. The concrete is suitable for 0.75 (75%) of all possible applications.

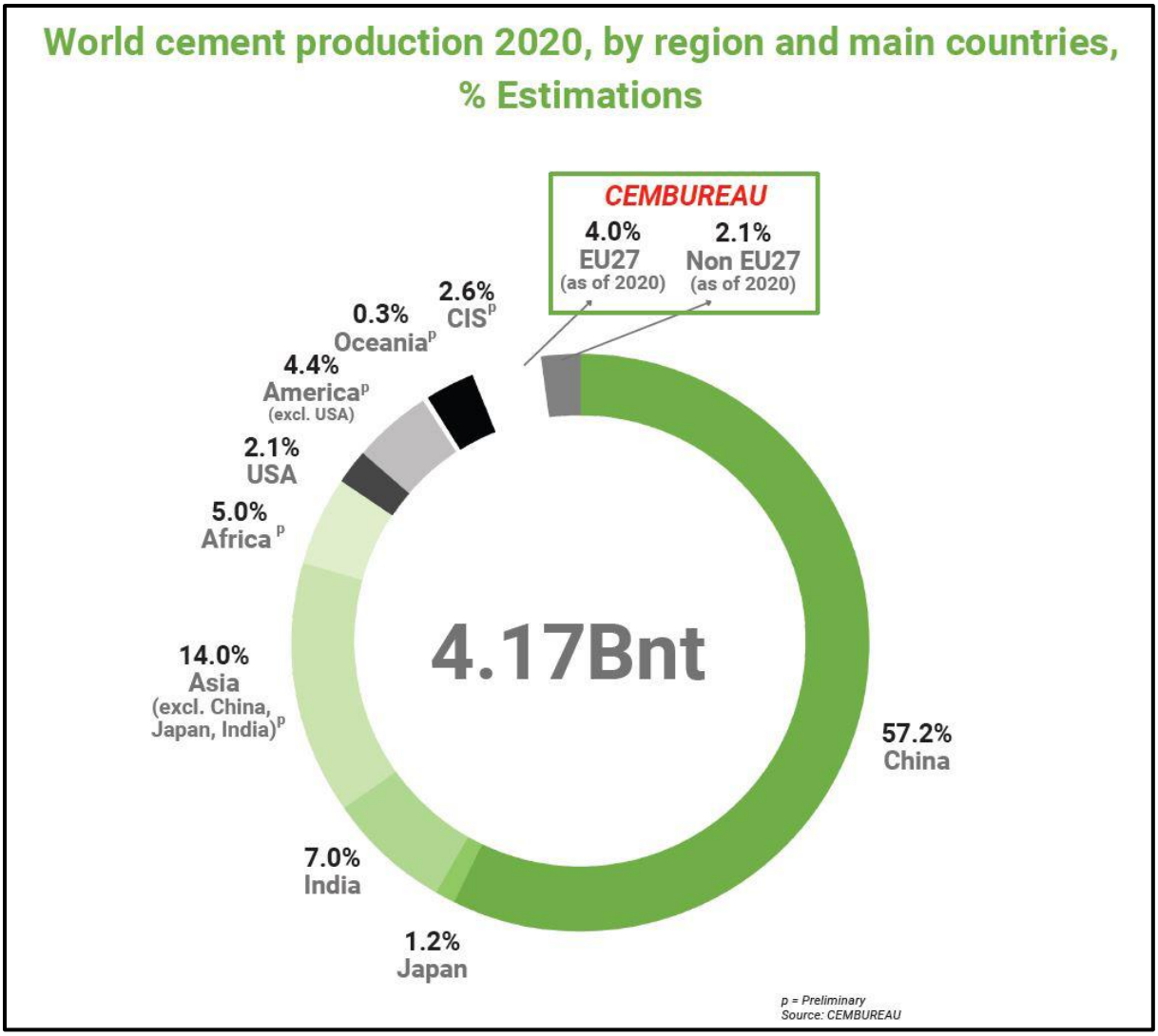
Question 31: By looking at the graph showing Compressive Strength against Age. Which answer is best for the question, "is the concrete at full strength after 28 days"?

A. No, but the concrete is almost at full strength and the gains in compressive strength are very small after 28 days.
B. The concrete is at full strength after 28 days, the whole point of the graph is to show that this is true.
C. No.
D. There are no scientific units on the y-axis and so it is not possible to answer this question.

Many scientists think that ways must be found to remove carbon dioxide from the atmosphere in response to climate change.

Cement production accounts for 8% of global carbon dioxide (CO_2) emissions. Finding ways to make cement that does not make so much CO_2 is vital to combat climate change.

The following two questions ask you to consider the information shown in this pie chart:



Source: Climatebonds.net

Notes for the diagram (not essential): *Cembureau* is the European Cement Makers' Association. *EU27* means the 27 member states of the European Union. *Non EU27* means countries within Europe which are not members of the EU. Eg: UK, Norway, Switzerland… *CIS*: means *Commonwealth of Independent States*, 9 countries, including Russia, Belarus, Khazakstan and others…

Note: Bnt – Billion tonnes

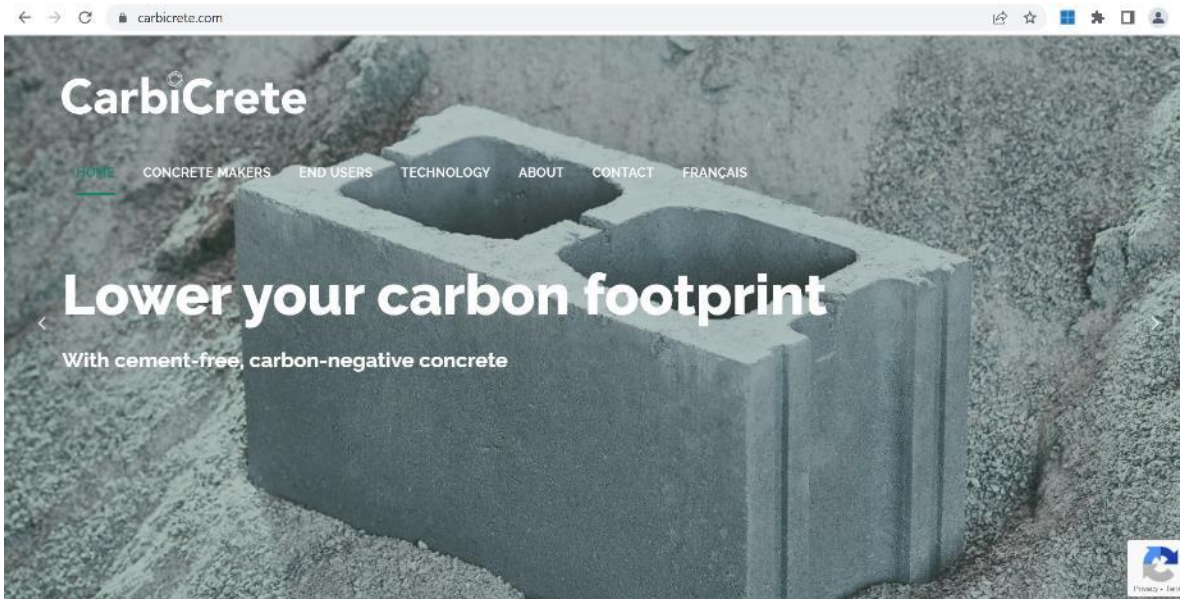
Question 32: how many tonnes of cement was produced by China in 2020?

A. 0.572 x 4.17 = 2.29 Bnt (billion tonnes)
B. 4.17 x 57.2 = 238.5 Bnt (billion tonnes)
C. 4.17 Bnt (billion tonnes)
D. 57.2% of all the cement made in the world that year.

Question 33: From the pie chart above, we see that China is producing more than half of the world's cement. Which of the following suggested explanations is most likely to be correct?

A. China has the world's fastest-growing economy and the largest economy. Cement is needed to build cities, roads and other infrastructure.
B. The processes used to make cement in China are less efficient and therefore release much more carbon dioxide.
C. Local geology and the possibility of earthquakes in some regions of China means buildings must be made stronger, requiring more cement.
D. China manufactures many things, including things made with cement, which are exported to other countries.

One company, based in the Canadian province of Quebec, called Carbicrete, has found a way to create concrete building blocks without using cement. In fact, the process absorbs carbon dioxide!



It is made by mixing concrete in the normal way but using the waste product from steel manufacture, called "slag", instead of cement. To finish the concrete, the blocks are put into a pressure chamber, carbon dioxide is pumped in a chemical reaction occurs, absorbing large amounts of carbon dioxide, and solid concrete blocks are formed.

(All results are taken from "Production of Cement Free Construction Blocks from Industry Wastes", The Journal of Cleaner Production 137 (2016), 1339-1346.)

A lot of scientific experiments and tests have been carried out on this new form of concrete. We are going to study some of the results and decide if this new type of concrete is any good.

The new type of concrete block is called "slag-bond concrete", because it is made with the waste, slag, from steel manufacture.

Look at the table below (called Table 5 from that Journal article) and then read the four statements below. You will have to decide which statements are correct.

Table 5
Density and water absorption of slag-bond concrete blocks.

Product	Slag-bond concrete block	Commercial cement block
Density (kg/m^3)	2545.0 ± 25.1	2254.9 ± 52.7
Water absorption (%)	6.7 ± 0.1	5.5 ± 0.2

Here are four statements relating to Table 5 above:

i. A slag bond concrete block has a mass of 2545.0 kg
ii. A commercial cement block can absorb more water than a slag bond concrete block.
iii. A slag bond concrete blocks is stronger than a commercial concrete block.
iv. A construction worker would notice that a slag bond concrete block feels heavier than a commercial cement block.

Question 34: which two statements above are correct, based upon the information provided in Table 5 above?

A. Options ii. and iv.
B. Options i. and iv.
C. Options iii. and iv.
D. Options i. and ii.

The next question uses results gathered from experiments to test the compressive strength of the concrete blocks. The results are shown in the bar chart below, labelled "Figure 6" from the research paper.

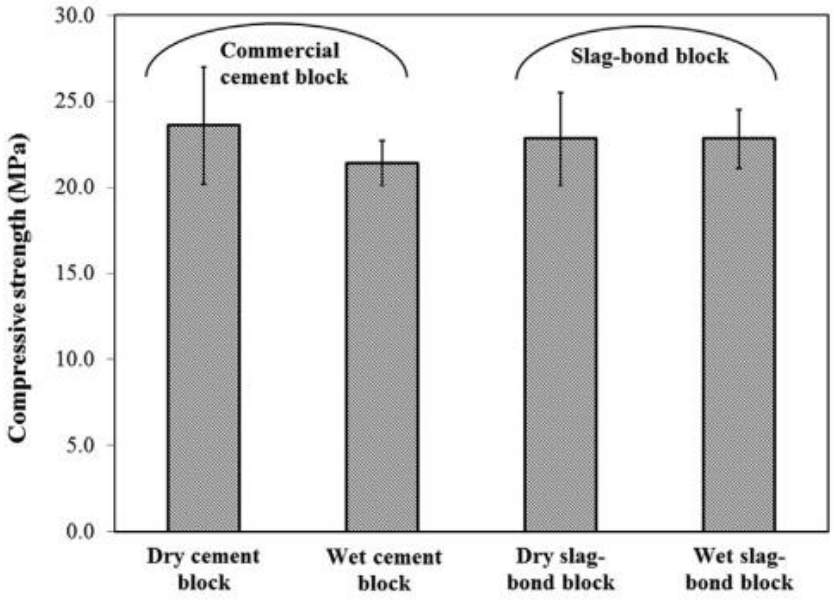


Fig. 6. Dry and wet compressive strength of commercial cement and slag-bond concrete blocks.

Note: Compressive Strength means ability to withstand being crushed. MPa means megapascals, a large unit of pressure. Pressure is force spread over an area. 1 MPa would mean a force of 1 million Newtons spread over 1 m^2. Air pressure is 10x less than 1MPa.

Question 35: From the bar chart labelled Fig. 6, pick the statement that best summarises the information:

A. Slag bond and commercial concrete blocks have very similar strengths. Commercial cement blocks are slightly weaker when wet, slag bond blocks are not.
B. Dry cement blocks are the most popular, wet cement blocks are the least popular. Wet and dry slag bond blocks are equally popular.
C. You can build the tallest structures using dry cement blocks.
D. It would be possible to apply a pressure of around 23 million Newtons per square metre on a dry cement block before it breaks.

Finally, for this section, use the table below (labelled Table 7) as well as the information above to answer this question.

Table 7
Cost comparison between slag-bond concrete block and commercial cement block (US cents).

Id	Item	Slag-bond concrete block (US cents/block)	Concrete masonry block (US cents/block)
(a)	Normal aggregate	0.0	20.9
(b)	Expanded aggregate	27.5	0.0
(c)	Steel slag	3.0	0.0
(d)	Cement	0.0	16.6
(e)	Transportation of cement	0.0	0.7
(f)	Transportation of aggregate	0.9	2.2
(g)	Transportation of slag	1.5	0.0
(h)	Grinding of steel slag	1.8	0.0
(i)	CO_2 capture and transportation	2.1	0.0
(j)	Steam curing	0.0	2.8
Total cost (US cents)		36.8	43.3

Question 36: Which things cannot be correctly stated about the slag bond concrete blocks?

A. They are slightly heavier than commercial cement blocks.
B. They absorb carbon dioxide from the air during manufacture (so are called “carbon negative”.
C. They are more expensive than commercial concrete blocks.
D. They are equally strong whether wet or dry.

(Note: you might be interested in developments in steel manufacture. “Green Steel Manufacture” uses hydrogen and creates water as a by-product not carbon dioxide. It still produces the waste, slag, however which, as you now know, can be used to make carbon negative cement.)

Finally, here is a question about astronomy and the search for planets outside of our solar system.

WASP – the **W**ide-Angle **S**earch for **P**lanets, uses a system of robotic telescopes situated at observatories at various locations on Earth, including the Canary islands and South Africa. This is a picture of a WASP telescope:

Source: https://wasp-planets.net/about/

An exoplanet is not part of our solar system. It is a planet orbiting a star other than our Sun. The WASP programme has now found over 150 exoplanets and has studied them all in further detail.

First, we are going to consider how an exoplanet can be detected and, then, we will consider how information about such a distant planet can be discovered.

Look at this diagram, showing a planet passing in front of the star it is orbiting. Below is a graph of brightness of the star against time.

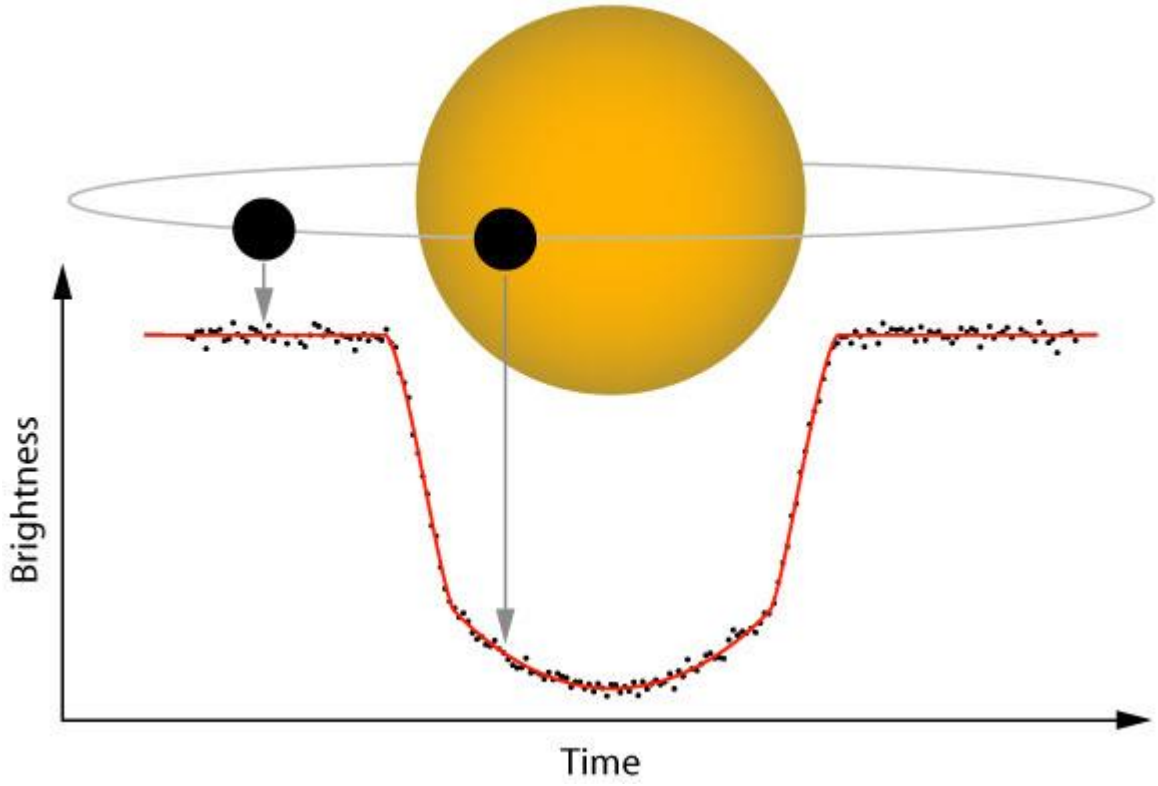


Diagram of exoplanet orbiting a star. Source: https://wasp-planets.net/about/

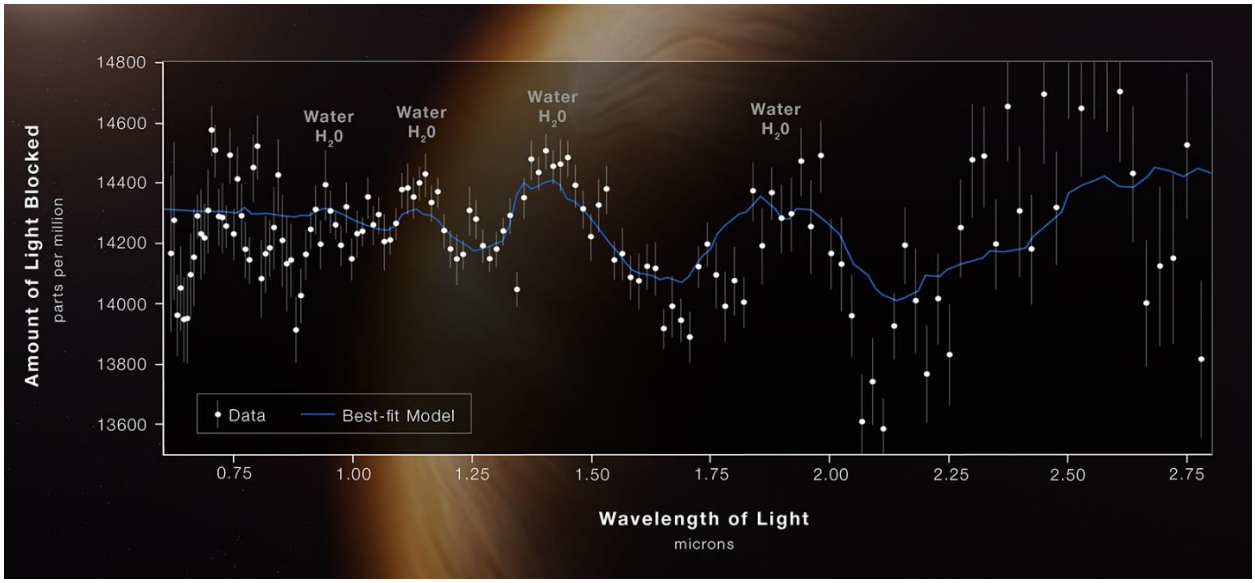
Question 37: By looking at the diagram oribiting a star, above, how do you think the exoplanet is detected here on Earth?

A. As the orbiting exoplanet passes in front of its parent star, it blocks the starlight slightly. On Earth, the astronomers see a reduction in the brightness of the star as this happens.
B. The exoplanet reflects less light as it moves in front of its parent star.
C. On Earth, the astronomers focus on the star and they can see the shadow of the planet passing in front of it.
D. The exoplanet moves down and back up again due to gravitational effects as it moves across, in front of the star.

WASP 96b is a giant, gas exoplanet about 1,120 light years away from Earth in the Constellation Pheonix. It has a mass of slightly under half that of Jupiter.

Astronomers have studied light being reflected by WASP-96b and have concluded that there must be water in its atmosphere. This is exciting because life, as we know it, requires water.

That was the last question. You can go back and check your answers. Press the submit button when you are ready.



Transmission spectrum of WASP-96b:
https://webbtelescope.org/contents/media/images/2022/032/01G72VSFW756JW5SXWV1HYMQK4

The horizontal axis shows, "Wavelength of Light" (microns). Wavelength is a measure of how stretched out or compact a wave is and micron is one thousand times smaller than one millimetre. Light waves with the wavelengths shown on the graph above are all of the family known as "infra-red light". "Parts per million" is a number expressed as a fraction of one million. (Just like a percentage is a number expressed as a fraction of 100.)

Question 38: Which one of these suggestions best explains how the astronomers know that there must be water in the atmosphere of WASP-96b, despite it being so far away?

A. Experiments done here on Earth show that water vapour absorbs infrared light at certain wavelengths. The graph shows that the atmosphere of planet WASP-96b is absorbing infra-red light at exactly the same wavelengths.
B. The graph shows that infrared light is being transmitted by water. This could be rain, clouds or fog. Experiments that have been done here on Earth give exactly the same results.
C. Experiments done here on Earth show that water vapour absorbs infrared light at certain wavelengths. The graph shows that water is reflecting infrared light from the surface of WASP-96b.
D. This is a trick question. It is simply not possible to deduce that there is water on WASP-96b from the data.