2024 JUNIOR SCIENCE OLYMPIAD EXAM

JUNIOR YEAR 7 & 8

TO BE COMPLETED BY THE STUDENT. USE CAPITAL LETTERS.

First Name: ……..…..…… Last Name…….

Date of Birth: ……/……/...….

□ Male □ Female □ Unspecified

Year 7 □ Year 8 □ Year 9 □ Year 10 □ Other: …….

Name of School: ……..……..**State:** ……...

Examiners Use Only:

2024 JUNIOR SCIENCE OLYMPIAD EXAM

7 & 8

Time Allowed

Reading Time: 10 minutes

Examination Time: 120 minutes

INSTRUCTIONS

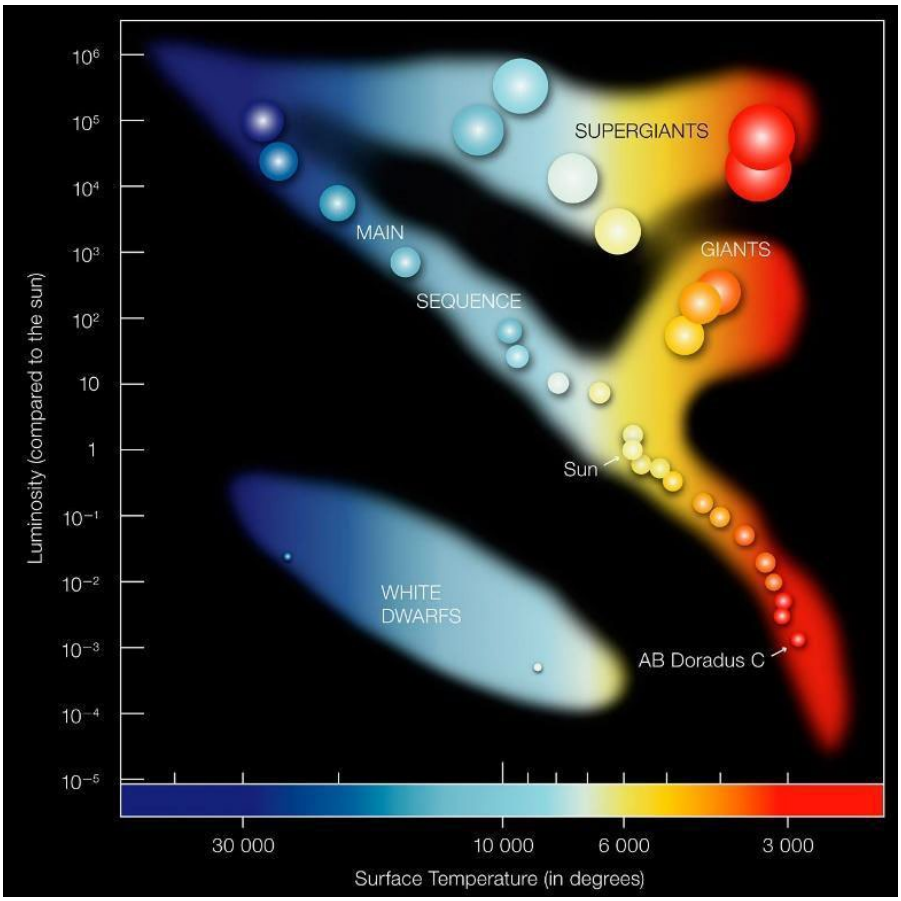
- Attempt all questions in ALL sections of this paper.
- Permitted materials: non-programmable, non-graphical calculator, pens, pencils, erasers and a ruler.
- Answer all questions on the MULTIPLE CHOICE ANSWER SHEET PROVIDED. Use a pencil.
- Marks will not be deducted for incorrect answers.

MARKS

- 1 mark for each question unless otherwise specified
- Total marks for the paper 54 marks

Integrity of Competition

If there is evidence of collusion or other academic dishonesty, students will be disqualified. Markers' decisions are final.

Q	Question
Info	The theme of the 2024 Australian Junior Science Olympiad exam is *extremes*. Exam advice: Question difficulty varies throughout the exam. If you find yourself stuck on a question, it is a good idea to pick an answer, flag the question for later review, and move on to other questions.
1	(1 mark) As extreme environments go, stars are a good place to start. Stars are massive balls of plasma held together at extreme pressures and temperatures by gravity. The diagram below is a **Hertzsprung-Russell diagram**, which classifies stars according to their luminosity (proportional to how much energy they emit every second) and their surface temperature. *Note 1: the colour of a star is determined by its temperature: the hotter an object is, the bluer the light it emits.* *Note 2: the relative sizes of the stars on the diagram are represented by the size of the circles.*  **Image credit:** European Southern Observatory.

Based on this diagram, which of the following statements is **correct**?

A. Stars classified as giants are cooler and less luminous than the sun

B. A small star will be less luminous than a large star of the same temperature

C. Stars on the 'main sequence' show a trend of decreasing luminosity with increasing temperature.

D. The Sun is about 100 times as luminous as AB Doradus C

2

(2 marks; 0.5 marks per statement)

How bright an object appears depends on how far away it is from the observer. A star's luminosity tells you how bright it would appear if you were right next to it.

Xan is standing in her backyard observing two stars. Star A appears brighter to her than Star B, and she is thinking about what this means about the two stars.

Based on Xan's observation, indicate whether each of the four statements below is **possible** or **not possible**.

Star A has a higher luminosity than Star B and is further away.	Possible / not possible.
Star A has a lower luminosity than Star B and is further away.	Possible / not possible.
Star A has a higher luminosity than Star B and is closer.	Possible / not possible.
Star A has a lower luminosity than Star B and is closer.	Possible / not possible.

3	(1 mark) A neutron star forms when a massive star runs out of fuel. The outer layers of the star are blown off and form a gaseous nebula, while the core of the star collapses inwards under its own gravity to form the neutron star. The compressive forces during the collapse are so great that protons and electrons are crushed together and the resulting object – the neutron star – is made entirely of neutrons. In an **ordinary atom**, which of the following particles are located in the nucleus? I. Electron II. Proton III. Neutron A. I and II B. II and III C. I and III D. All three particles
4	(1 mark) The gravitational field strength on the surface of an object can be represented by this equation: $$gravitational\ field\ strength = k\frac{m}{r^2}$$ k is a constant. m is the mass of the object. r is the radius of the object. A neutron star has a mass about 500 000 times greater than the Earth, and a radius about 0.001 times that of the Earth. How much stronger is the gravitational field strength on the surface of a neutron star than on the surface of the Earth? A. About 500 times stronger B. About 500 000 times stronger C. About 500 000 000 times stronger D. About 500 000 000 000 times stronger

5	(1 mark) A pulsar is a highly magnetized rotating neutron star that emits beams of electromagnetic radiation from its poles. The magnetic field of a pulsar acts as a brake to its rotation, slowing it down. As it slows down it emits energy as light to its surroundings, usually a nebula (a cloud of gas and dust). The period of a pulsar is the length of time it takes to complete a rotation. Some years later, Xan – now an astronomer – finds two neutron stars. They have the same mass, and when she initially observes them, they have the same period. Over time, she observers that the period of the first pulsar is increasing rapidly, while the period of the second pulsar is only increasing slowly. *Select the terms to make the following sentence **correct**.* Xan deduces that compared to the second pulsar, the first pulsar is likely to have a [stronger/weaker] magnetic field and the nebula that surrounds it will appear [dimmer/brighter].
	***This information relates to the following two questions**.* Light is a kind of electromagnetic wave. As well as visible light, stars and other objects in the universe emit electromagnetic waves of many other kinds, including x-rays, ultraviolet, infrared and radio waves. Electromagnetic waves consist of oscillating electric and magnetic fields. The **wavelength** determines what type of electromagnetic radiation the wave is. Radio waves have a much longer wavelength than visible light. The energy carried by the wave depends upon the **amplitude** of the electric field. Waves with low amplitude electric fields are harder to detect than those with higher amplitude electric fields.

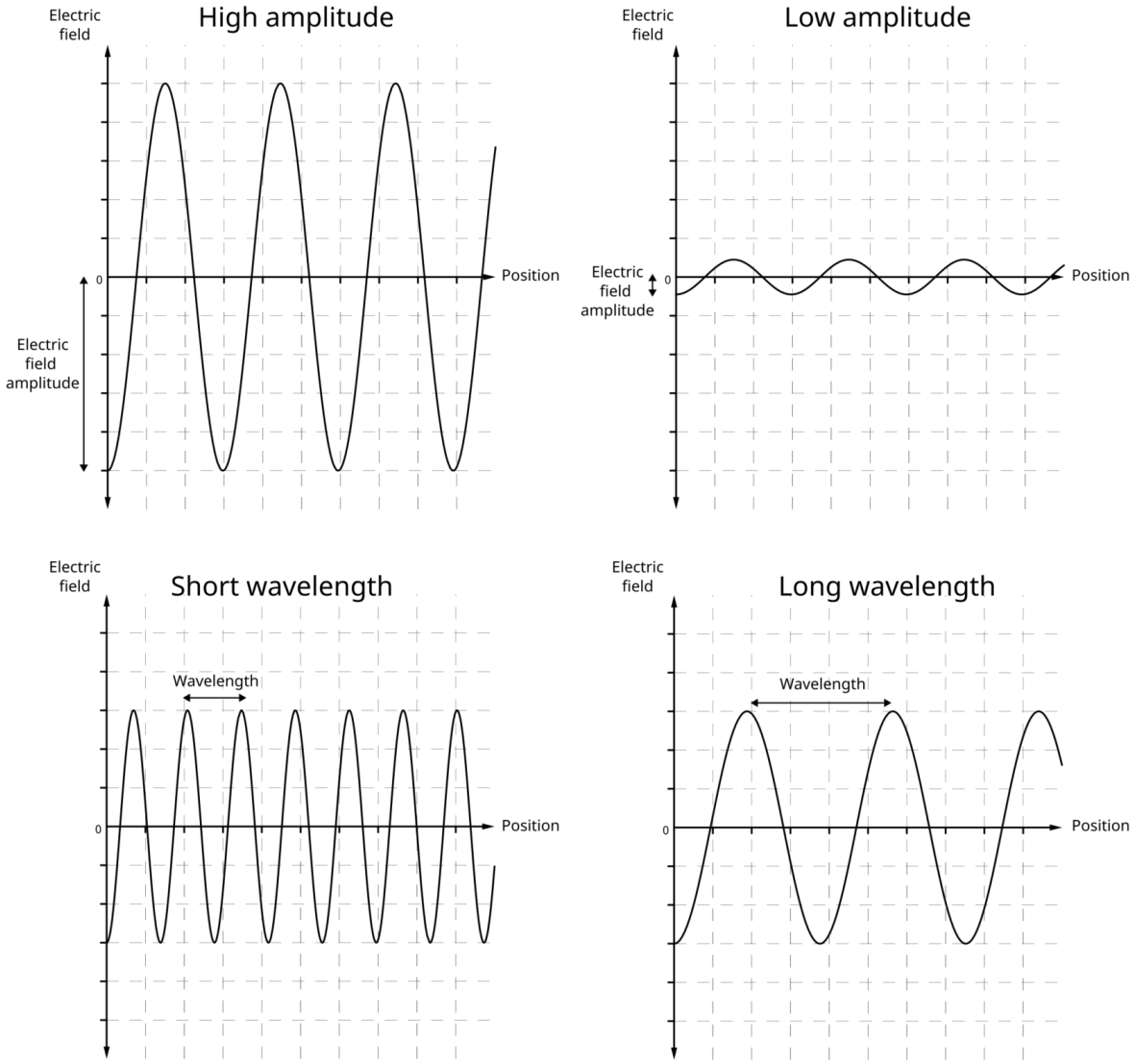
	The diagram below illustrates high and low amplitude waves, as well as short and long wavelength waves. 
6	(1 mark) To detect distant objects in the universe, we use a variety of extremely sensitive detection methods. The **Square Kilometre Array-Low** (SKA-Low) is a new radio telescope currently being constructed in the desert in Western Australia. It consists of arrays of “Christmas tree”- style antennae (see photo below) designed to detect faint radio waves from very distant sources.

Image credit: SKA Observatory

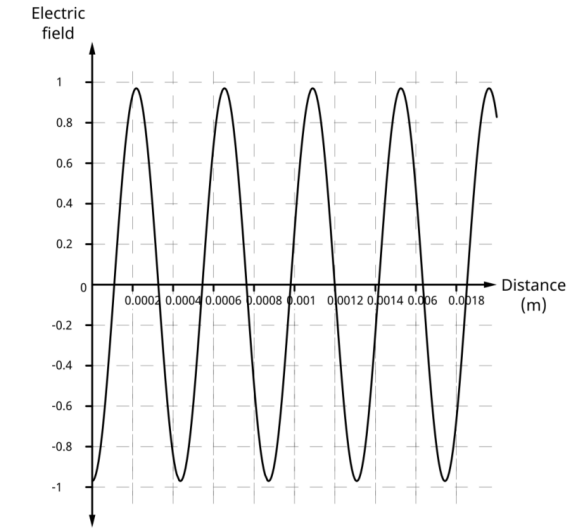
The radio waves the telescope is designed to detect have:

1) Electric fields with very low amplitude.
2) Wavelengths that are approximately two times the length of the metal arms on the antennae in the photo.

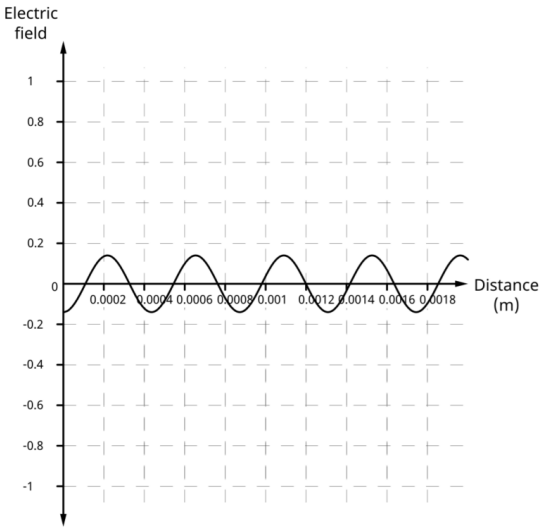
Which of the following could represent the faint radio waves that the SKA low telescope is designed to detect?

Answer: C

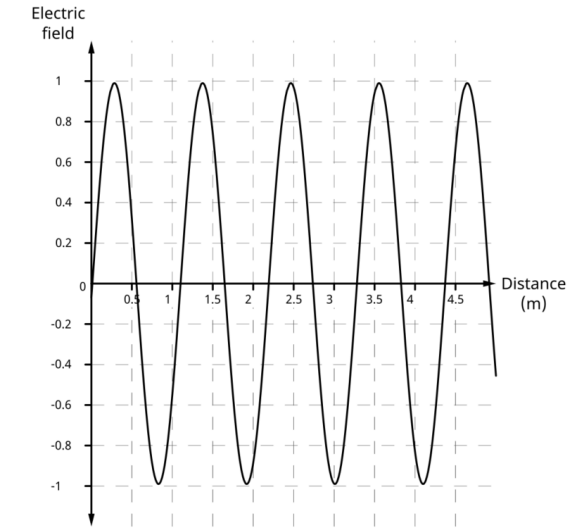
A.



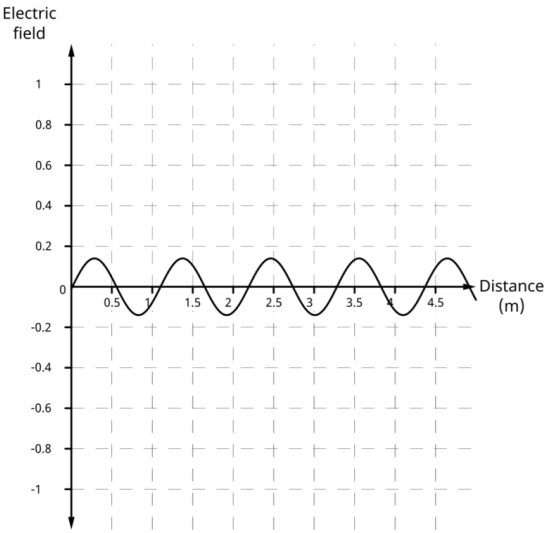
B.



C.



D.



7 (1 mark)

The relationship between the speed v, wavelength, λ, and the frequency f, of a wave is:

$$v = f\lambda$$

Frequency is the number of waves that pass by a fixed point each second. It is measured in Hertz (Hz). Wavelength is measured in metres.

The speed of radio waves is the same as the speed of visible light, $v = 300\ million\ m/s$.

Which of the following radio wave frequencies is the SKA-Low telescope designed to detect?

A. 27 Hz
B. 2700 Hz
C. 270 000 Hz
D. 270 million Hz

This information relates to the following 5 questions.

The process which generates the extreme energies of most stars is **nuclear fusion**, which is one kind of **nuclear reaction**. Nuclear reactions produce some of the most extreme conditions of temperature and pressure observed by humans.

While there are many types of nuclear reactions, they all involve the nucleus of an atom being changed in some way.

Atoms that have the same number of protons but different numbers of neutrons are known as **isotopes**. The table below shows two isotopes.

Number of protons:	6	6
Number of neutrons:	6	7
Identity of atom:	carbon-12	carbon-13

The number of protons and neutrons in a nucleus affects its stability. An isotope that is radioactive has an unstable nucleus which **decays** (undergoes a nuclear reaction) in order to lower its energy and become more stable.

When a nucleus decays, it releases energy in the form of either energetic particles, or electromagnetic waves (e.g. gamma rays).

8 (1 mark)

Alpha decay is a common type of nuclear reaction.

In alpha decay, the unstable nucleus ejects a small energetic particle made of two protons and two neutrons called an alpha particle.

Ejected alpha particles lose energy by colliding with other atoms in their surroundings. Eventually they pick up stray electrons and become stable neutral atoms.

What type of atom does an alpha particle end up as?

A. a helium atom
B. a beryllium atom
C. it depends on the type of nucleus the alpha particle was originally ejected from
D. a proton

9 (2 marks; 0.5, 0.5, 1)

Beta decay is another kind of nuclear reaction. In beta decay, one neutron in the unstable nucleus is converted into one proton and an electron. The new proton remains in the nucleus. The highly energetic electron is ejected from the nucleus.

A tellurium-128 atom contains 52 protons and 76 neutrons. It undergoes two successive beta decays.

What is the product of this nuclear reaction?

Select the correct answers in the table below.

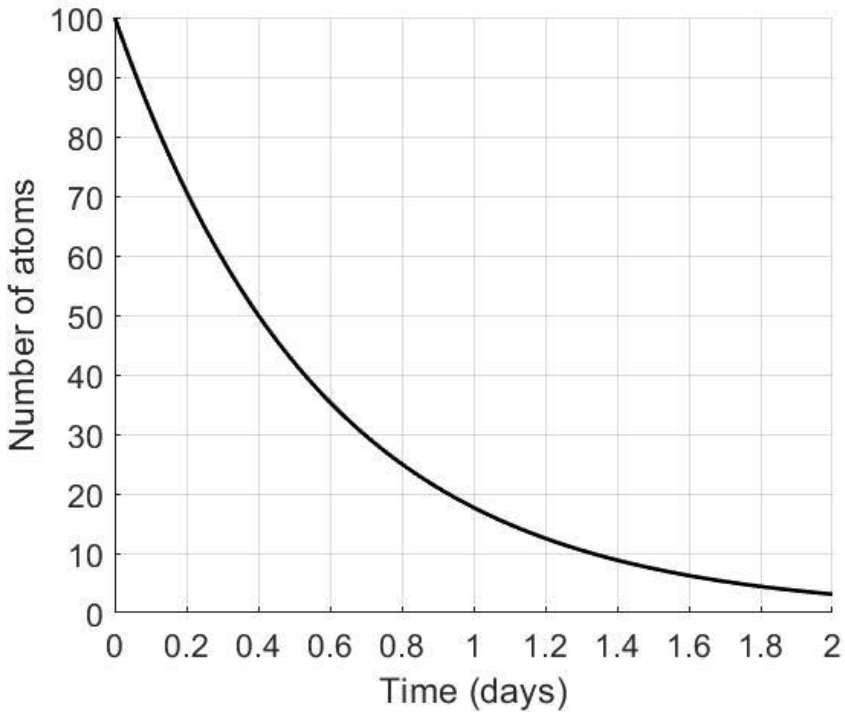
Number of protons:	48/49/50/51/52/53/54
Number of neutrons:	74/75/76/77/78/79
Identity of atom:	Tin-119 Tin-128 Tellurium-126 Xenon-128 Xenon-131

10 (1 mark)

The **half-life** of a radioactive isotope is the time it takes for exactly half of the atoms in a sample to decay.

It is impossible to know when an individual atom will decay. However, the half-life value for an isotope allows you to predict what fraction of atoms in a sample will have decayed after a particular time has elapsed.

The graph below represents the decay of a radioactive sample.



What is the half-life of this process?

A. 0.4 days
B. 0.5 days
C. 0.52 days
D. 0.28 days

11	(2 marks; 1,1) The standard unit of energy is the Joule (J). However, the energy changes involved in nuclear reactions are commonly reported using an energy unit called the **electron volt** (eV). 1 eV = 1.602 x 10^{-19} Joules 1MeV = 1 mega electron volt = 1 000 000 eV 1MJ = 1 megaJoule = 1 000 000 J 1.00g of uranium-235 contains 2.56 x 10^{21} atoms. The decay energy (the energy emitted by the alpha decay of a single atom) of uranium-235 is 7.496 x 10^{-13} J. a) Convert this value of energy to MeV. Give your answer to 3 decimal places. Numerical answer: 4.679 MeV b) Calculate the energy emitted when 1.00g of uranium-235 undergoes complete alpha decay. Give your answer to the nearest megaJoule. Numerical answer: 1919 MJ
12	(1 mark) Nuclear decay can also be used to determine the ages of ancient artefacts. The most common isotope of carbon is carbon-12, with six protons and six neutrons. However, a small proportion of carbon atoms are carbon-14, which is unstable and undergoes beta decay. This isotope is used in radiocarbon dating of ancient artefacts. On the scale of the history of life on Earth, carbon-14 has a relatively short half-life of 5730 years. Nevertheless, throughout Earth's history, there has been a roughly constant proportion of carbon-14 on the planet. Which of the following is a plausible reason for this? A. All carbon-14 atoms must have been generated when the Earth was formed. B. Carbon-14 is being circulated in the carbon cycle. C. Carbon-14 atoms are produced at a constant rate by living organisms D. Carbon-14 is constantly replenished from other carbon isotopes by cosmic ray interactions in the atmosphere

	E. Carbon-14 atoms are preserved in a stable form in rocks.
	This information relates to the following 4 questions. Chemical explosions (as opposed to nuclear explosions) are the result of chemical reactions that occur at extremely fast rates and release large amounts of energy. Nitroglycerin is a common explosive with the chemical formula $C_3H_5N_3O_9$. When used as an explosive, it undergoes the following reaction, producing four different gaseous products. $4\ C_3H_5N_3O_9\,(l) \rightarrow 12\ CO_2\,(g) + 10\ H_2O\,(g) + 6\ N_2\,(g) + O_2\,(g)$
13	(1 mark) A small amount of nitroglycerin is exploded in a closed container. Which is the most accurate description of the contents of the container after the explosion? A. A mixture of elements and compounds made up of molecules. B. A pure substance, made up of molecules. C. A mixture of compounds, made up of elements. D. A mixture of elements, made up of atoms. E. A mixture of compounds, made up of molecules.
14	(1 mark) How many molecules of gas are produced from the reaction of 4 molecules of nitroglycerin? A. 12 B. 28 C. 29 D. 33
15	(1 mark) If 75 molecules of nitrogen are produced during this reaction, how many molecules of nitroglycerin must have reacted? Numerical answer: 50

16 (2 marks)

The table shows the relative weight of each molecule involved in the reaction of nitroglycerin.

Molecule	**Relative weight**
$C_3H_5N_3O_9$	227
CO_2	44
H_2O	18
N_2	28
O_2	32

Calculate the amount of nitrogen (in grams) that is produced when 1.0 g of nitroglycerin explodes.

Give your answer to two decimal places.

Numerical answer: 0.19 g

17 (1 mark)

Humans have developed technology that allows us to survive in extreme environments such as Antarctica.

Image credit: NASA, public domain.

The photo shows Jo, a scientist in Antarctica about to pull on a sled carrying her equipment over the ice. The sled is initially stationary.

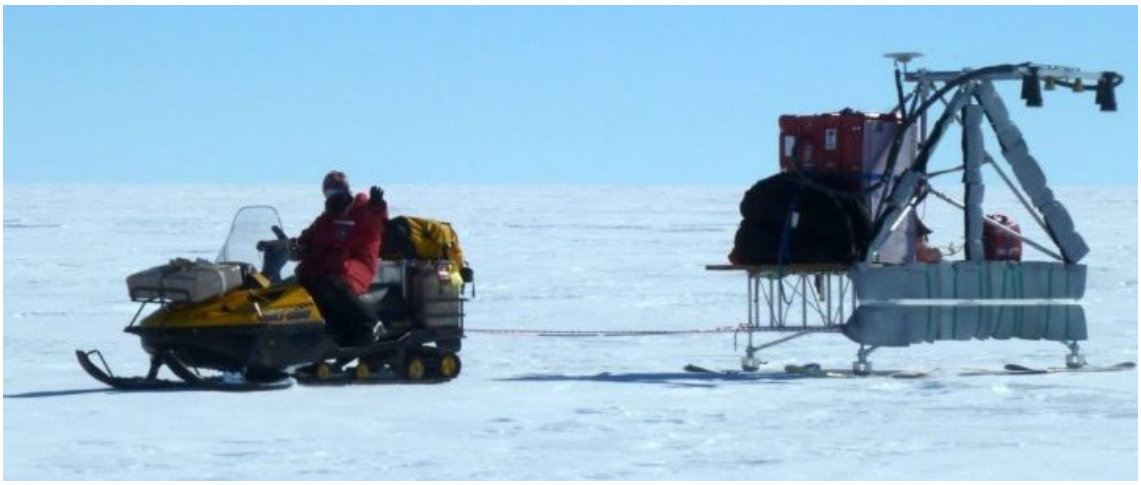
Which of the following are **true** statements about what Jo must do to get the sled to start moving?

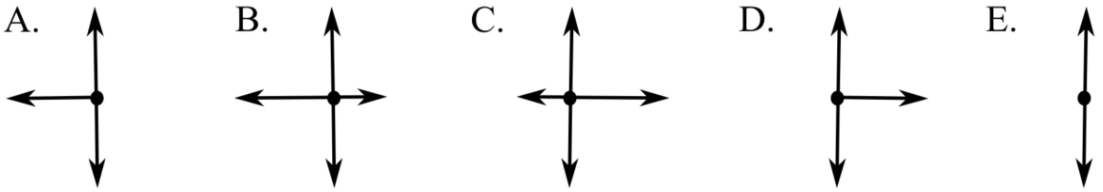
I) the force Jo applies to the sled must be momentarily larger than the force the sled exerts back on her.

II) she must apply a force greater than the weight of the sled

III) she must apply a force to the sled that is larger than the frictional force acting on the sled

A. I only
B. II only
C. I and II
D. III only
E. I, II and III

18	(1 mark) In the motion diagram below, the dots represent the **position of the sled at equal intervals of time**, as Jo pulls the sled from right to left. The location of the sled is marked at four moments in time: t_A, t_B, t_C and t_D. final position initial position t_D t_C t_B t_A At which time is the sled moving with the greatest speed? A. t_A B. t_B C. t_C D. t_D
19	(1 mark) In the photo, Bob, a scientist, is riding a snowmobile which is towing a radar sled with a cable.  **Image credit:** NASA, public domain. Initially, the snowmobile pulls the sled across the ice to the left at an increasing speed. At time t_0 the connector attaching the sled to the snowmobile suddenly snaps and the sled is no longer connected to the snowmobile. The sled continues to move to the left for some time after time t_0, gradually slowing down and eventually coming to rest. Which of the following diagrams could represent the forces acting on the sled **after** the connector snaps at t_0?



A. Diagram A
B. Diagram B
C. Diagram C
D. Diagram D
E. Diagram E

20 (1 mark)

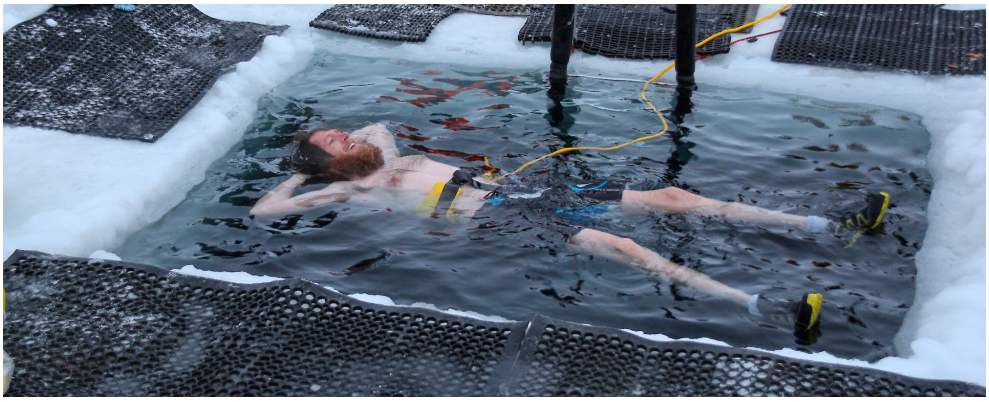


Image credit: Cliff Simpson-Davis

A midwinter swim is an Australian Antarctic Expedition tradition. Salt water freezes at a lower temperature than freshwater, and the temperature of the water in the bath is -2°C.

People rapidly lose thermal energy (heat) when immersed in water. One way in which this occurs is by convection: the movement of a fluid (a liquid or a gas) past the skin.

The rate of thermal energy loss due to convection is:

$$q_{conv} = hA(T_C - T_F)$$

Symbol	Definition	Value
h	Convective heat transfer coefficient	For water: $h_W = 12500\ Wm^{-2}K^{-1}$ For air: $h_{air} = 20\ Wm^{-2}K^{-1}$
A	Surface area of the person	
T_C	Core temperature of the person	$T_C = 37^oC$
T_F	Temperature of the fluid (liquid or gas)	

In the midwinter swim, Bob wears minimal clothes, walks through Antarctic air ($T_{air} = -22^oC$) and jumps in a pool with freezing salty water ($T_W = -2^oC$).

Calculate the ratio of the rate of heat loss when Bob is swimming compared to when he is walking through the air:

$$\frac{rate\ of\ heat\ loss\ in\ water}{rate\ of\ heat\ loss\ in\ air} = \frac{q_{conv}(water)}{q_{conv}(air)}$$

A. 1400
B. 410
C. 14
D. 50
E. 1.4

21 (1 mark)

When mammals are exposed to cold temperatures, the homeostatic mechanisms in their bodies respond to maintain their internal temperature.

Which of the following would occur when Bob takes his icy bath?

The blood vessels in his skin:

A. Dilate, allowing blood to keep the skin warm.
B. Constrict, forcing blood to flow through the vessels in the skin.
C. Dilate, causing blood to pass through the cold skin more quickly.
D. Dilate, preventing blood flow near the surface of the skin.
E. Constrict, reducing heat loss from blood near the surface of the skin.

22 (1 mark)

To avoid hypothermia, members of the Australian Antarctic expedition must limit the time they spend in freezing water.

The equation for conservation of energy during the time a person swims is:

$$Change\ in\ internal\ thermal\ energy\ =\ heat\ generated\ -\ heat\ lost$$

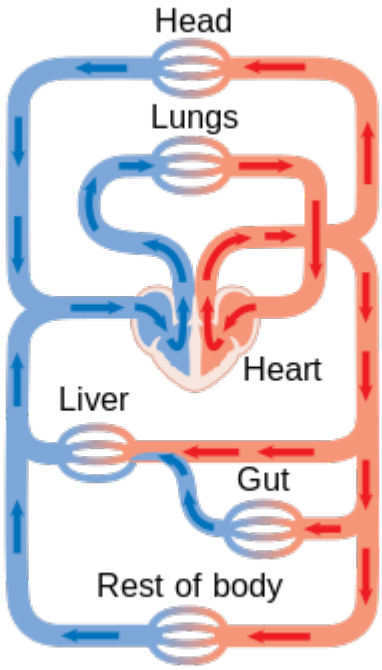
Heat is generated due to the person metabolising food. The average male metabolic rate is 7000 kJ/day.

Bob swims in freezing water for 1 minute. The rate of heat loss due to conduction and convection for Bob is $q\ =\ 878\ J/s$

What is the change in the internal thermal energy of Bob over the duration of his swim?

A. -6.1kJ
B. -48kJ
C. -53kJ
D. -58kJ
E. -6900kJ

23	(1 mark) Arteries carry blood away from the heart, while veins carry blood towards the heart. It is sometimes said that arteries always carry oxygenated blood and veins always carry deoxygenated blood. In which part of the circulatory system is this **not** true?



Red vessels: oxygenated blood
Blue vessels: deoxygenated blood

Image credit: Cancer Research UK, CC BY-SA 4.0, via Wikimedia Commons

A. The head
B. The gut/liver
C. The lungs
D. The rest of the body

This information relates to the following 2 questions.

Apart from voluntarily swimming in freezing water, another extreme activity undertaken by humans is bungee jumping.

In bungee jumping, participants' legs are attached to an elastic cord. They jump off a tall structure, bounce, then come to rest.

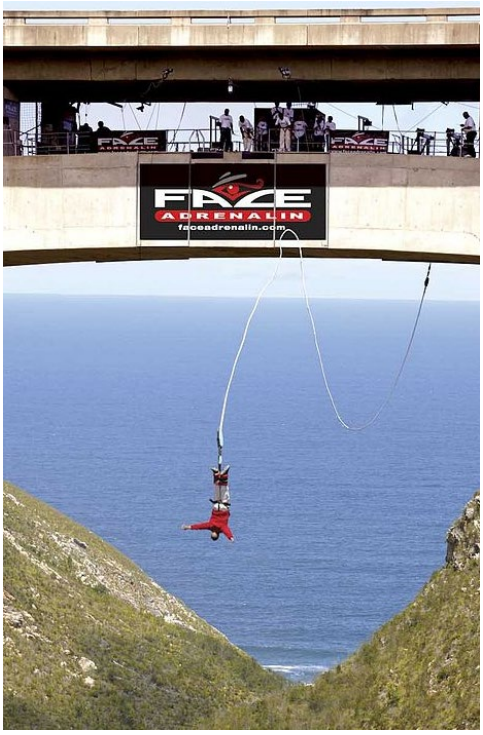
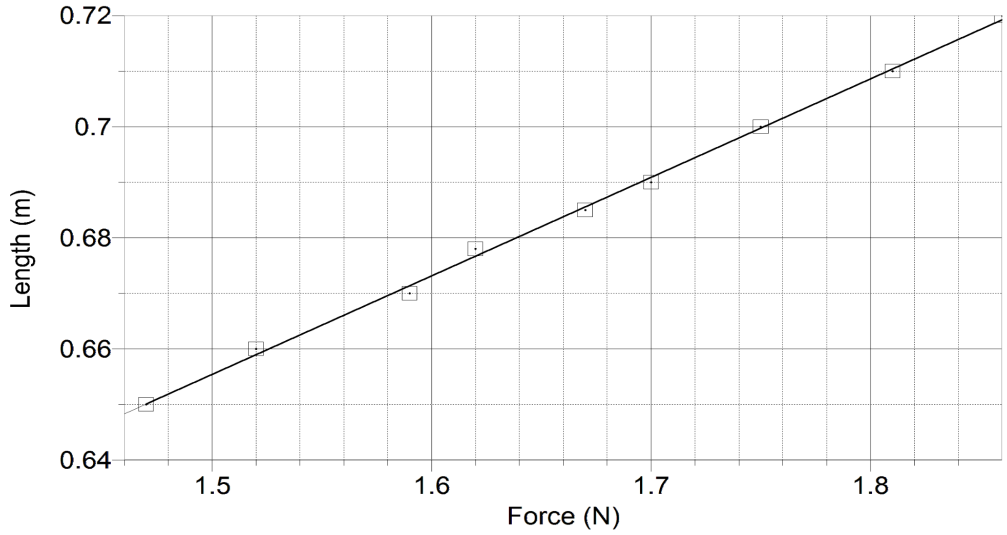


Image credit: Face Adrenalin, CC BY 3.0 via Wikimedia Commons

24 (2 marks)

The graph below shows how the length of a bungee cord changes with the force that is applied to stretch it.



a) What is the independent variable in this experiment?

A. The force applied to the bungee cord.
B. The change in length of the bungee cord.
C. The length of the bungee cord.

b) Determine the gradient of the line of best fit shown on the graph.

A. 0.18m/N
B. 0.18N/m
C. 0.41m/N
D. 0.41N/m
E. 0.43N/m
F. 0.43m/N

25 (1 mark)

Lynn would like to determine how the diameter of a bungee cord affects how much it stretches.

Which set of experimental measurements would allow her to determine this relationship?

	Experimental values				Stretch (cm)
	Length of bungee cord (m)	Diameter of bungee cord (cm)	Force applied to bungee cord (N)	Manufacturing company	
A.	1.0 2.0 3.0	1.0 1.0 1.0	200N 200N 200N	X Y Z	12 25 30
B.	1.0 2.0 3.0	1.0 1.5 2.0	200N 400N 600N	X Y Z	12 22 32
C.	3.0 3.0 3.0	1.0 1.5 2.0	200N 400N 600N	X X X	28 32 36
D.	3.0 3.0 3.0	1.0 1.5 2.0	200N 200N 200N	X X X	31 19 10

Answer: D.

This information relates to the following 6 questions.

Extremophiles are organisms that can live and reproduce in conditions that would be lethal to most lifeforms. Extremophiles are generally bacteria or archaea, but this group also includes some protists and multicellular organisms (such as tardigrades).

Many types of extremophiles exist, each adapted to survive in a particular environment. For instance, thermophiles can live at very high temperatures; acidophiles can tolerate very acidic environments, and halophiles live in extremely salty water.

Haloquadratum walsbyi is a single-celled organism from the Archea kingdom that is found in water bodies with high salt concentration. It has the unusual feature of being rectangular in shape, and its name, *Haloquadratum* or "salt square", reflects this.

H. walsbyi was first found in a brine pool in the Sinai peninsula in Egypt, and has since been found in hypersaline (extremely salty) lakes and water bodies all over the world, including Lake Tyrell in Victoria.

H. walsbyi is often found growing in association with *Dunaliella salina*, a single-celled halophile alga. The image below shows cells of these two species in water from Lake Tyrell in Victoria.

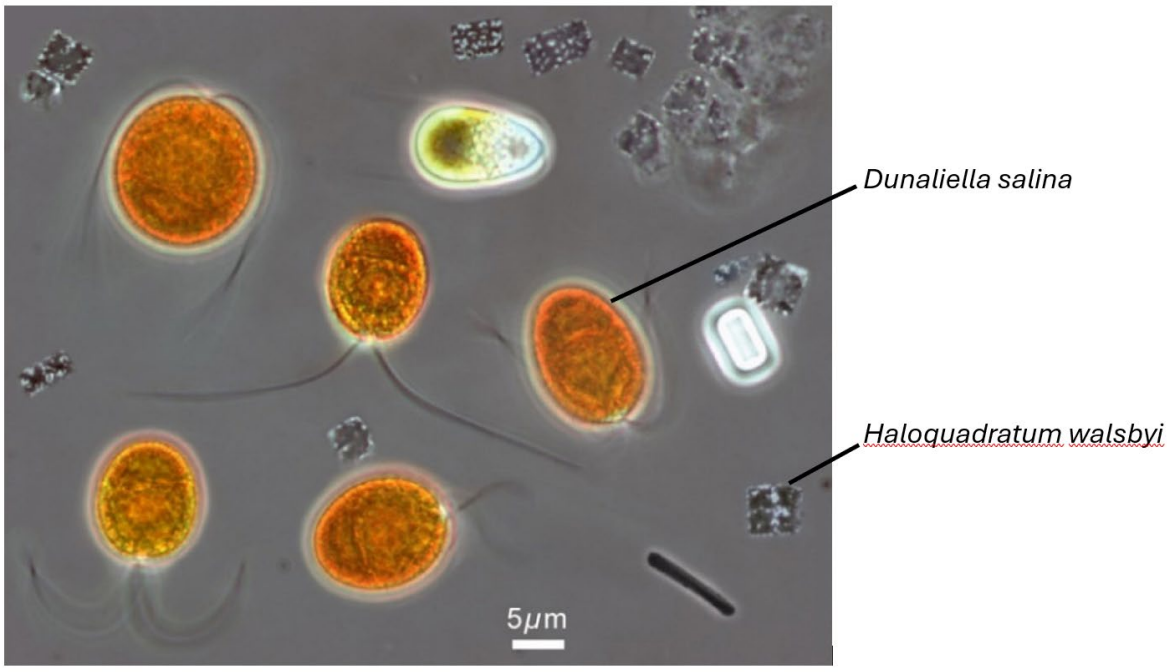


Image credit: Mike Dyall-Smith et al. CC BY-SA 4.0, via Wikimedia Commons

26 (1 mark)

Cells of the alga *Dunaliella salina* produce large amounts of a chemical called **glycerol** to help maintain their internal osmotic pressure. Some of this glycerol is excreted into the surrounding water.

Haloquadratum walsbyi harvests glycerol as food for its own use.

Based on this information, which of the following terms can be used to describe the ecological relationship between *Haloquadratum walsbyi* and *Dunaliella salina*?

I. Symbiotic
II. Commensal
III. Parasitic

A. I only
B. II only
C. III only
D. I and II
E. I and III
F. II and III
G. I, II and III

27 (1 mark)

On the surface of cells of *H. walsbyi* there is a high density of a particular protein called bacteriorhodopsin. *H. walsbyi* uses this protein to collect light energy, which it then uses to drive its own cell processes.

Organisms can be classified according to the way they obtain carbon and energy from their environment:

	Obtains energy from:	
Obtains carbon from:	**Chemical reactions**	**Light**
CO_2 in the environment	Chemoautotroph	Photoautotroph
Carbon-based molecules from other organisms	Chemoheterotroph	Photoheterotroph

Based on this information, which of the following statements is true?

I. *H. walsbyi* is a photoheterotroph
II. A photoautotroph would not undergo respiration
III. Humans are chemoheterotrophs

A. I only
B. II only
C. III only
D. I and II
E. I and III
F. II and III
G. I, II and III

28 (1 mark)

An object will float in a liquid if it has a lower average density than the liquid. Salty water is denser than fresh water.

The density of an object is calculated as:

$$density = \frac{mass}{volume}$$

H. walsbyi cells contain numerous small gas bubbles called **vacuoles** (seen as bright spots in the Lake Tyrell photograph above). The vacuoles are usually located around the edges of the cells and help them stay oriented horizontally to the surface of the water.

If floating *H. walsbyi* cells are subjected to high pressures, they sink.

Based on this information, which of the following statements are **true**?

I. The presence of vacuoles could be an adaptation that allows the cells to capture more light.
II. High pressures could cause the gas vacuoles to collapse.
III. An H. walsbyii cell in fresh water would require more vacuoles to remain floating at the surface than one in salty water.

A. I only
B. II only
C. III only
D. I and II
E. I and III
F. II and III
G. I, II and III

29	(2 marks; 1,1) The characteristic feature of *H. walsbyi* cells is their shape: they are very thin rectangular prisms, which is an extremely unusual geometry for a cell. Assuming the top surface of the cell is a square, use the following information to calculate the volume and surface area of an average *H. walsbyi* cell. *Average side length = 5 µm* *Average thickness = 0.2 µm* *1µm = 1 micrometre = 1 x 10^{-6} m* Round your answers to the nearest whole number: Volume = 5 μm^3 SA = 54 μm^2
30	(1 mark) It took 24 years after the discovery of *H. walsbyi* for the organism to be successfully grown in the laboratory. Microbiologists found it very hard to create a nutrient solution that would support the growth of the cells. A successful growth solution was eventually prepared which included extremely high concentrations of the chemicals sodium chloride and magnesium chloride. Magnesium (Mg) forms ions with a charge of 2+, and chlorine (Cl) forms ions with a charge of 1-. When ions come together to form a compound, the overall charge on the compound must be zero. What is the formula of magnesium chloride? A. MgCl B. $MgCl_2$ C. Mg_2Cl D. Mg_2Cl_2

31 (1 mark)

A microbiologist is preparing brine solutions.

The following table shows the relationship between mass of salt, volume of water used to dissolve it, and the final volume of the solution.

Mass of salt (g)	**Volume of water (mL)**	**Final volume of solution (mL)**
1	9	9.2
2	8	8.4
3	7	7.6
4	6	6.8
5	5	6.0
6	4	5.2
7	3	4.4

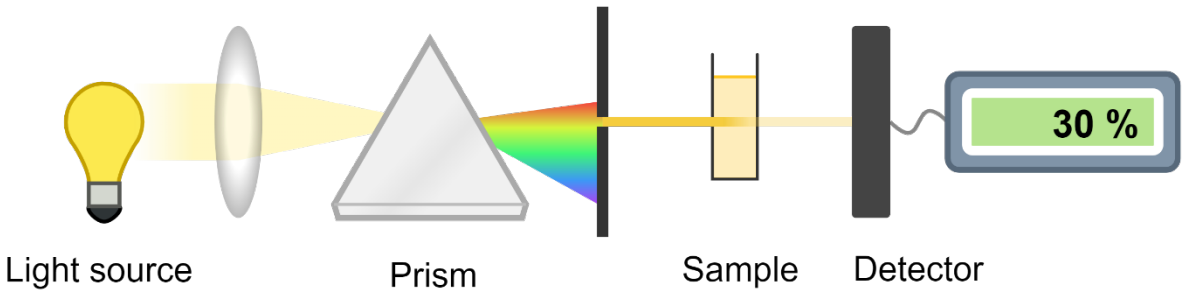
What mass of salt dissolved in 20mL of water will give 23mL solution?

Numerical answer: 15 g

This information relates to the following 3 questions.

A common technique used to monitor the growth rate of microorganisms is to measure the **optical density** of the solution they are growing in. The technique relies on the fact that individual particles present in the water scatter incoming light in all directions, resulting in less light travelling through to the detector.

The equipment for an optical density measurement is set up as shown below.



The prism is used to select different wavelengths of light.

The bacterial growth solution is placed in the light beam and the percentage of light transmitted through the solution to the detector is measured.

The transmission value is converted to an optical density value: a high optical density value means a small percentage of light was transmitted through the sample.

32 (1 mark)

Fahad is using the optical density technique to measure the growth rate of bacterial cells.

In doing so, what assumption is he making?

A. The percentage of light transmitted is directly proportional to the number of bacterial cells present
B. The percentage of light transmitted is affected by the number of bacterial cells present.
C. The percentage of light transmitted is only affected by the intensity of the light source.
D. The percentage of light transmitted is not affected by the number of bacterial cells present.

33	(1 mark) Which of the following would **decrease** the optical density value? I. An increased path length (the distance through the sample that the light must travel) II. An increased concentration of cells III. Cells sticking together rather than remaining separate. A. I only B. II only C. III only D. I and II only E. II and III only F. I and III only G. I, II and III
34	(1 mark) What would Fahad need to do if he wanted to use an optical density measurement to determine the actual concentration of cells (number of cells per millilitre) in the solution? A. Measure the optical density for a series of cell solutions of known concentration and compare the unknown to this data. B. Nothing: the optical density tells you the concentration of cells directly C. Measure the optical density for a known solution with the expected cell concentration. D. Plot optical density versus time and calculate the gradient of the curve.

35 (1 mark)

Geologists use a vast range of techniques to estimate the ages of rocks, fossils and other extremely old artefacts. One of the first dating methods to be developed was **stratigraphy**: the analysis of the relative position of layers of soil and rock to determine which are younger or older.

In early 2024, researchers D. Datta and S. Bajpai reported the discovery of an extremely large snake fossil in Kutch, India. Based on their data, they propose it to be the largest snake that has ever existed.

The diagram is adapted from their paper and shows the rock layers that were excavated to find the snake fossil. The second Eocene thermal maximum, a time at which the Earth's climate was extremely hot, is marked.

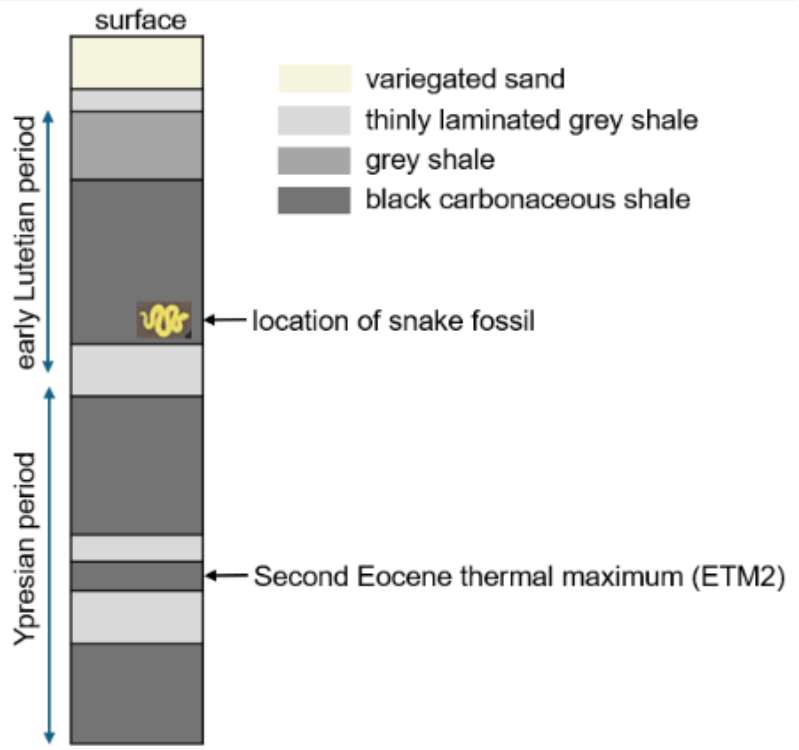


Image adapted from Datta and Bajpai, Scientific Reports 14, 8054 (2024). CC-BY-4.0.

Which of the following statements can be correctly concluded from this diagram?

I. The snake that was preserved as the fossil was alive after the Second Eocene Thermal Maximum.

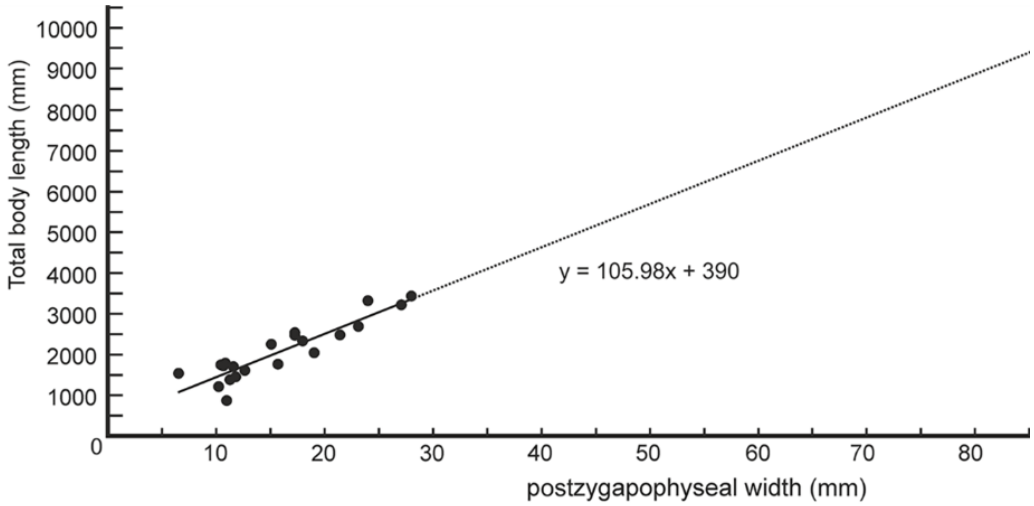
II. The Ypresian period occurred after the Lutetian period.

III. Snakes of this type only existed in the early Lutetian period.

A. I. only

B. II. only

C. III. only

	D. I. and II. E. II. and III. F. I. and III. G. I., II. and III.
36	(1 mark) Datta and Bajpai named the snake *Vasuki indicus*. Evidence suggests it is related to a group of ancient giant snakes that also includes Australian specimens such as *Wonambi naracoortensis* and *Yurlunggur camfieldensis*. The fossil was incomplete, so the exact length of the snake could not be directly measured. However, the relationship between the size of snake vertebra and the total length of the snake has been studied in many existing snake species. The following graph is from Datta and Bajpai's 2024 paper. It shows the relationship between the postzygapophyseal width (a part of the vertebra) and the total body length for snake species existing today. A trendline has been drawn through the data points, and the equation of the trendline is given on the graph.  **Image credit:** Datta and Bajpai, Scientific Reports 14, 8054 (2024). CC-BY-4.0. Given that the postzygapophyseal width for the Vasuki fossil was 110mm, calculate a predicted value for the total body length of *Vasuki*. Give your answer to the nearest whole metre. Body length = 12 m

37 (1 mark)

In everyday language, we often talk of 'warm-blooded' and 'cold-blooded' animals. We think of snakes as cold-blooded, since they aren't able to internally regulate their body temperature like mammals.

Biologists, however, like to be more precise, and have a more detailed way of classifying animals based on the regulation of their body temperature.

- **Homeotherm**: an animal that maintains a stable body temperature regardless of the environmental temperature.
- **Poikilotherm**: an animal that can allow its body temperature to vary as the environmental temperature varies.
- **Endotherm:** an animal that generates its own heat internally.
- **Ectotherm:** mostly relies on external heat sources.

For the first two weeks of their life, gentoo penguin chicks in the extreme climate of Antarctica rely on huddling with their parents to maintain their body temperature.

This makes them:

A. homeothermic endotherms
B. homeothermic ectotherms
C. poikilothermic endotherms
D. poikilothermic ectotherms.

38 (1 mark)

An ecological hypothesis known as Bergmann's Rule predicts that homeothermic animals that inhabit cooler climates are generally larger than close relatives from warmer climates.

A 2024 paper in Nature Communications by Lauren Wilson and colleagues used fossil records of dinosaurs (which were homeothermic) to investigate Bergmann's Rule.

The figure below is from their paper.

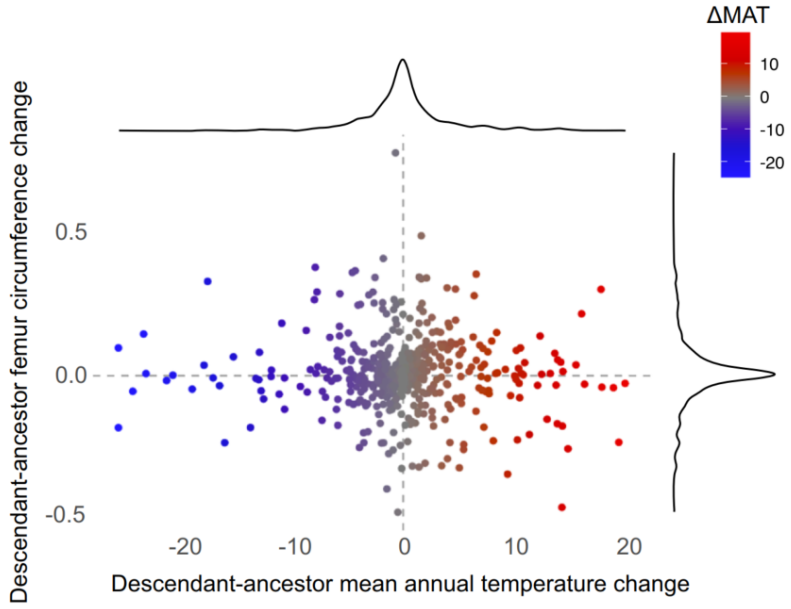


Image credit: Wilson et al (2024) Nature Communications 15:2864; CC BY 4.0

Each dot on the graph represents a pair of related dinosaurs – an ancestor and a descendant. The x-axis represents the *difference in mean annual temperature* (ΔMAT) between the locations where those dinosaurs lived. A positive value means the descendant lived in a warmer location than the ancestor.

The y-axis is a measure of the difference in circumference of the femur (thigh) bone of the animals. A positive value means the descendant had a larger femur than its ancestor. A larger femur implies a larger animal.

In their paper, the authors stated that their data does not support Bergmann's Rule.

If the data *had* supported Bergmann's rule, which of the following correctly describes the trend that would be shown in the graph?

The data would stretch from:

A. Bottom left to bottom right
B. Bottom left to top right

C. Top left to top right

D. Top left to bottom right

39 (1 mark)

Aldemar Acevedo and his colleagues study frogs in the *Pristimantis* genus, which live in central and South America. This is considered to be the world's most diverse genus of vertebrates, containing 596 described species.

One of the features of *Pristimantis* frogs studied by Acevedo is **sexual size dimorphism**, or the difference in size between males and females.

In the graph below, each data point represents one species in the genus. The x- and y-axes represent average size for the females and males respectively.

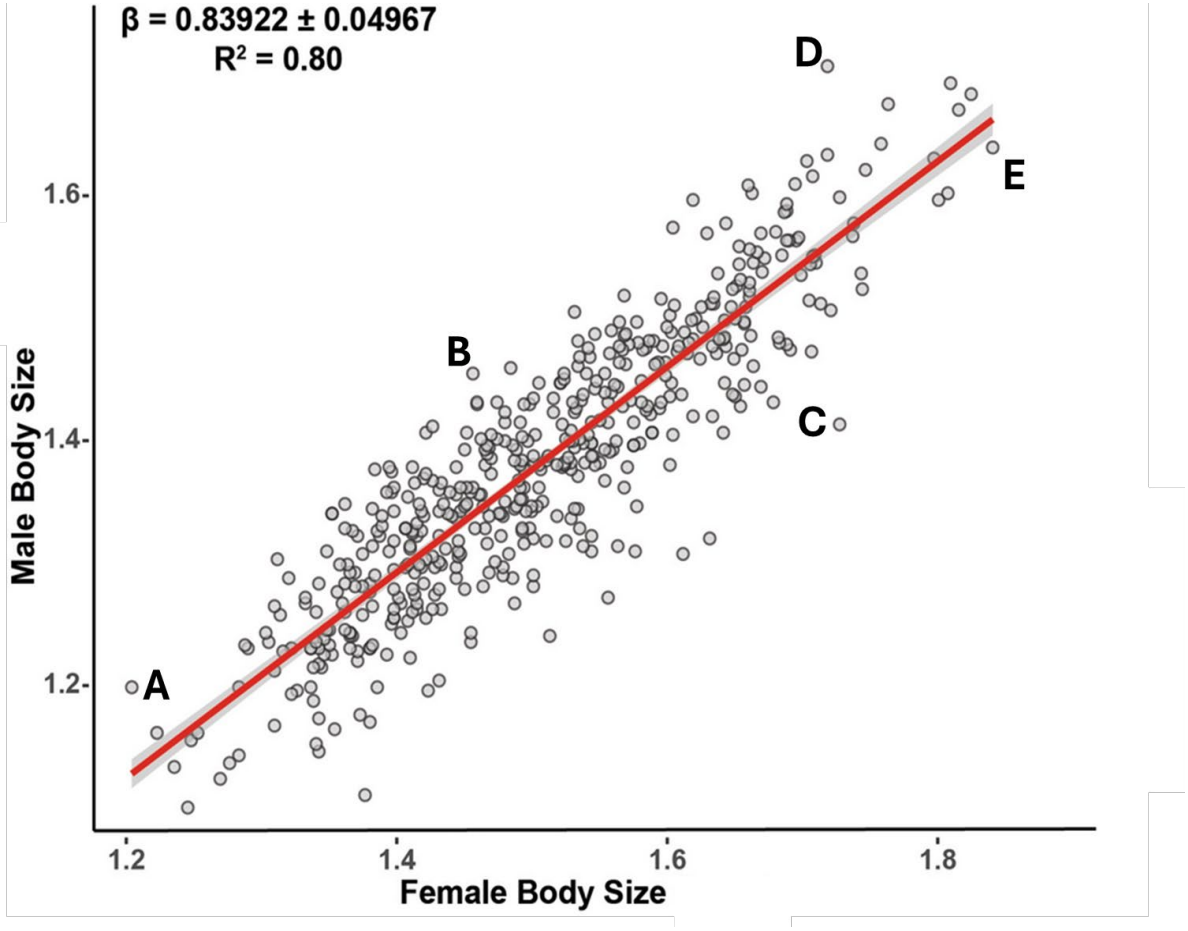
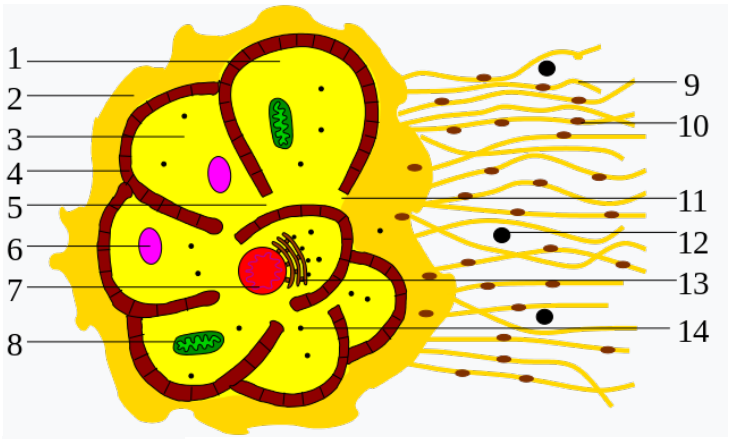
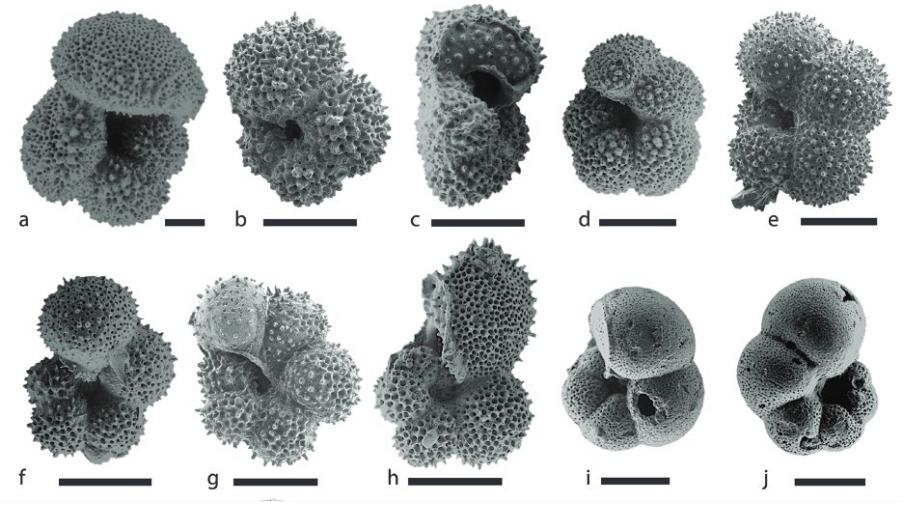


Image credit: Acevedo et al (2022) Scientific Reports, 12:18106, CC BY 4.0

Based on the overall trend of the graph, which statement is true?

	A. Males of a species tend to be bigger than females of that species. B. Females of a species tend to be bigger than males of that species. C. For a given species, males and females are roughly equal in size. D. There is no correlation between male size and female size within species.
40	(1 mark) Consider the five letters (A-E) on Acevedo's graph. Of the five species indicated by the letters, which would show the biggest size difference between males and females? A. A B. B C. C D. D E. E
41	(1 mark) Apart from stratigraphy (which was used to date the *Vasuki* snake), another method of dating extremely old fossils and rocks makes use of the presence of microfossils, such as **foraminifera**. These tiny, abundant and diverse marine organisms have been extensively studied and the time periods during which many species existed are well known. Their presence in a rock provides evidence of the time at which the rock sediment was laid down.  **Image credit:** Franciscosp2; CC BY-SA-4.0, via Wikimedia Commons. The diagram above shows a foraminifera organism.

	Labels: 1 – endoplasm; 2 – ectoplasm; 3 – chamber; 4 – pores; 5 – foramen; 6 - food vacuole; 7 – nucleus; 8 – mitochondria; 9 - granureticulose pseudopodia; 10 – granules; 11 – aperture; 12 - food particle; 13 - Golgi apparatus; 14 - ribosomes. Based on the diagram, the foraminifera is: A. A eukaryote and an autotroph B. A prokaryote and an autotroph C. A eukaryote and a heterotroph D. A prokaryote and a heterotroph
42	(2 marks; 1,1)  **Image credit:** United States Geological Survey; public domain, via Wikimedia Commons. The micrographs above show fossils of ten planktic foraminifera found in sediments from the Eocene era (56 to 34 million years ago). The black scale bar under each micrograph measures 150 micrometres (0.015 cm). a) Which of the foraminifera above is the largest specimen? Select from dropdown: a/b/c/d/e/f/g/h/i/j b) The height of the largest specimen is closest to: A. 1cm B. 0.1cm C. 0.01cm D. 0.001cm

43 (1 mark)

Much research in Earth Science focuses on finding ways to accurately estimate the past climate of the Earth, including periods of extreme heat and cold. One method uses measurements of isotope ratios.

With two fewer neutrons, atoms of the isotope oxygen-16 (O-16) are lighter than those of oxygen-18 (O-18).

Water molecules can contain an atom of either of these isotopes. Water molecules containing O-16 (H_2O-16) require less energy to evaporate than water molecules containing O-18 (H_2O-18).

This means water vapour in the air has a slightly higher proportion of H_2O-16 than the liquid water it evaporated from. Additionally, when precipitation (rain and snow) occurs, the heavier H_2O-18 tends to condense first.

Water vapour in the Earth's atmosphere largely comes from evaporation near the equator. Moist air circulates from the equator to the poles; much of the moisture is removed as precipitation before it reaches the poles.

Based on this information, which of the following statements are true?

I. Water in the oceans has a higher proportion of O-18 than water vapour in the air.
II. Precipitation falling in Antarctica has a lower proportion of O-18 than precipitation falling at the equator.
III. During hotter climate periods, water vapour in the air has a higher proportion of O-18 than during ice ages.

A. Statement I only
B. Statement II only
C. Statement III only
D. Statements I and II
E. Statements II and III
F. Statements I and III
G. All three statements.

44	(1 mark) The global climate includes many feedback loops (positive and negative). In a positive feedback loop, the feedback causes the original effect to increase in intensity, leading to extreme results. In a negative feedback loop, the feedback reduces the original effect, preventing or delaying extreme effects. A thermostat is an example of a negative feedback loop: the thermostat turns the heater on when the room temperature is cold, and turns it off when it is warm. The following three processes are all known to occur on Earth. **Identify which of them represent negative feedback loops.** As the temperature of the atmosphere increases: I. The ocean absorbs heat from the atmosphere. II. Ice melts, decreasing the average amount of sunlight reflected back into space from the surface of the Earth. III. The solubility of CO_2 in the oceans decreases. A. Statement I only B. Statement II only C. Statement III only D. Statements I and II E. Statements II and III F. Statements I and III G. All three statements.
45	(1 mark) Despite all the feedback loops, not every process that occurs on Earth is involved in climate. Which one of the following processes is **not** involved in Earth's climate system? A. The formation of metamorphic rocks. B. The formation of soil. C. The formation of limestone. D. The formation of glaciers. E. The growth of forests. F. The development of permafrost.

46 (1 mark)

The following graph was published in the Sixth Assessment Report of the Intergovernmental Panel on Climate Change in early 2024. It represents the change in probability of hot weather events (i.e. heatwaves) between the pre-industrial climate (before 1800) and the current climate.

The x-axis represents the temperature of the weather events.

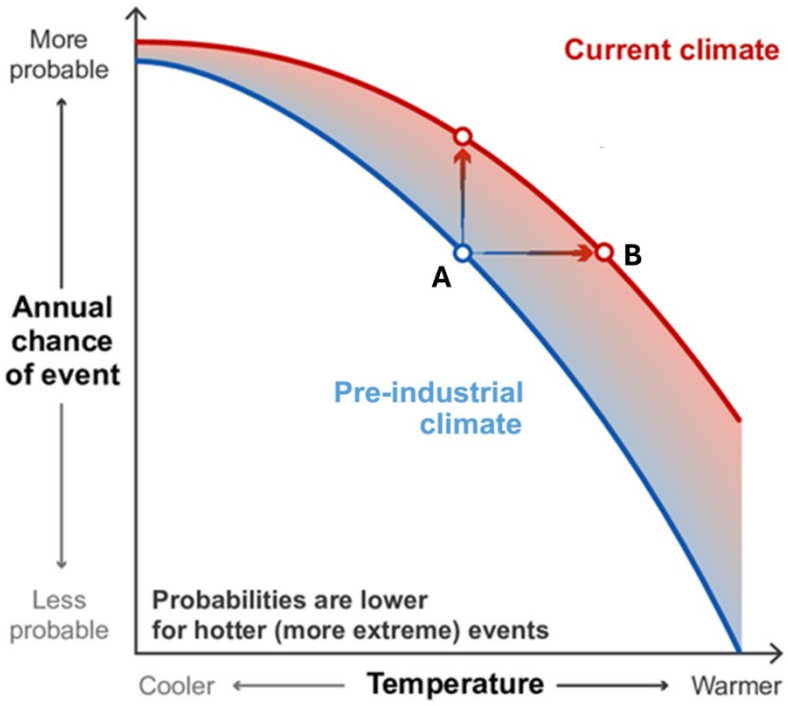


Image adapted from IPCC Sixth Assessment Report, 2024. CC-BY-SA 4.0.

What specific change does arrow A-B on the graph indicate?

A. An extreme heat event of a particular temperature in the pre-industrial climate is more probable in the current climate.
B. A weather event of a certain probability in the pre-industrial climate is warmer in the current climate.
C. An extreme heat event of a particular temperature in the pre-industrial climate is less probable in the current climate.
D. A weather event of a certain probability in the pre-industrial climate is cooler in the current climate.

This information relates to the following 2 questions.

Dengue (pronounced *den-ghee*) fever is a viral disease that is transmitted between humans by several species of mosquito.

People infected with the dengue virus often show mild or no symptoms, but in a small proportion of cases the disease develops into severe dengue, previously known as dengue hemorrhagic fever, which can be fatal.

47 (1 mark)

In the last two years, the incidence of dengue fever in Central and South America has shown a dramatic increase, which is believed to be due to climate change.

The graph below shows the number of deaths (blue columns) and case fatality rate (orange line) due to dengue in Central and South America in the first thirteen weeks of 2024.

$$case\ fatality\ rate = \frac{number\ of\ deaths}{number\ of\ confirmed\ cases} \times 100$$

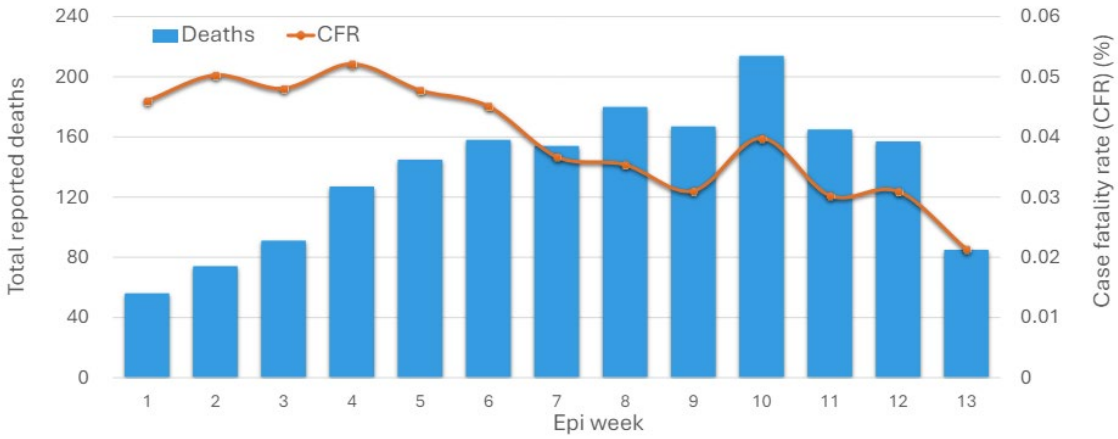
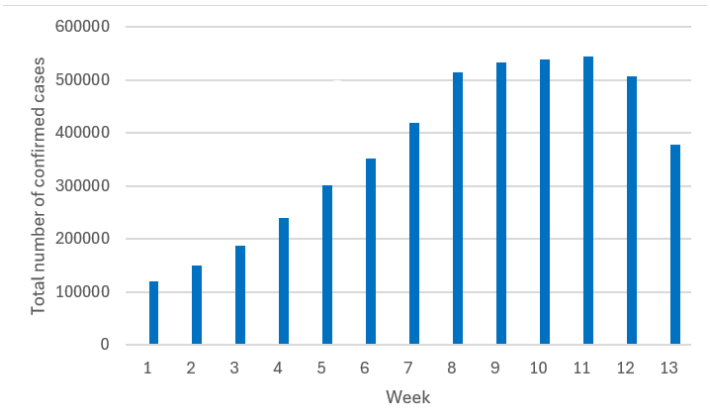


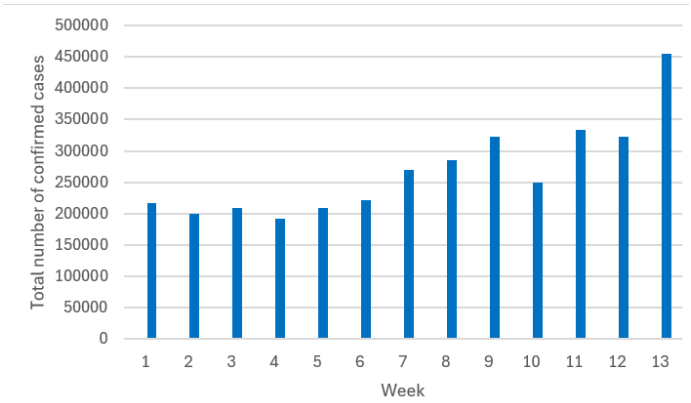
Image credit: Pan-American Health Organisation.

Which of the column graphs below best represents the total number of confirmed cases over this time period?

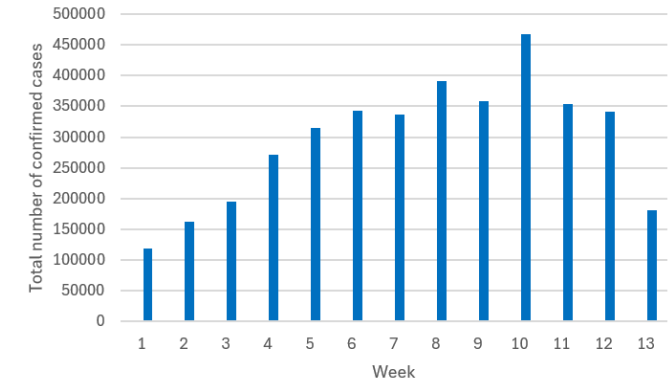
Answer: A.



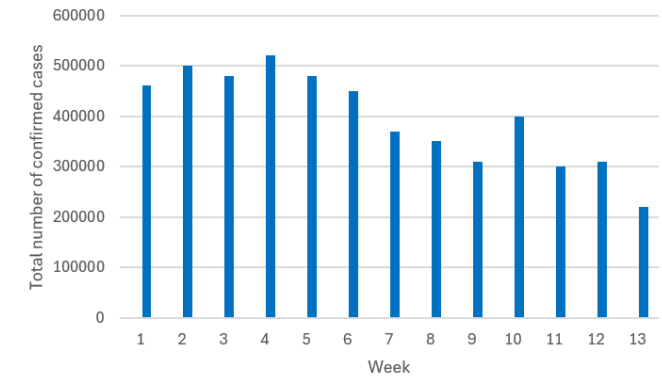
B.



C.



D.



48 (1 mark)

In seeking ways to reduce the transmission of dengue by mosquitoes, scientists are studying the evolutionary relationships between different species.

Scientists use **phylogenetic trees** to represent possible evolutionary relationships between organisms. Modern phylogenetic trees are based on DNA analysis.

By reading a phylogenetic tree, you can determine the most recent common ancestor of two organisms. Species are more closely related if they have a more recent common ancestor.

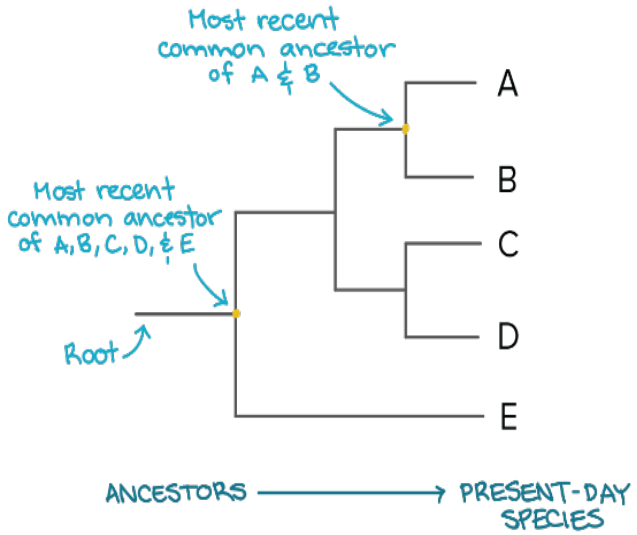
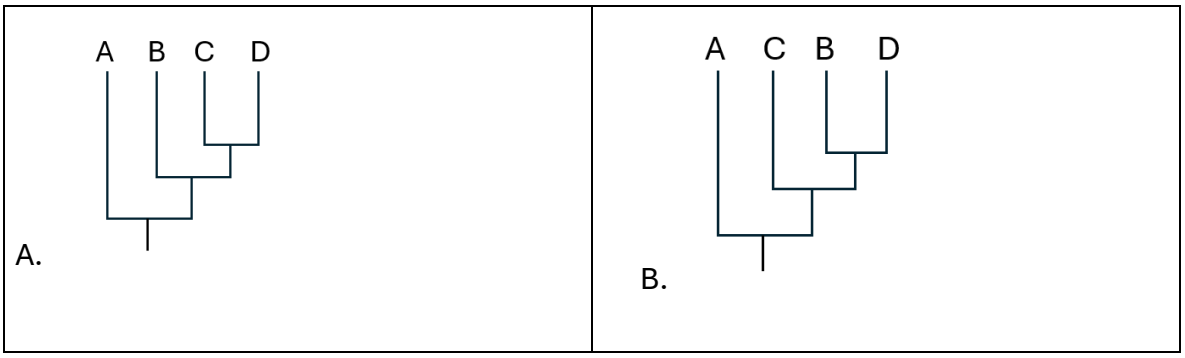


Image credit: Khan Academy, CC BY 4.0

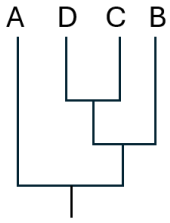
The order in which the species are shown in a phylogenetic tree doesn't matter, as long as the connections within the tree remain the same.

Three of the following four trees are equivalent, showing the same evolutionary relationships. Which is the odd one out?

Answer: B



C.



D.