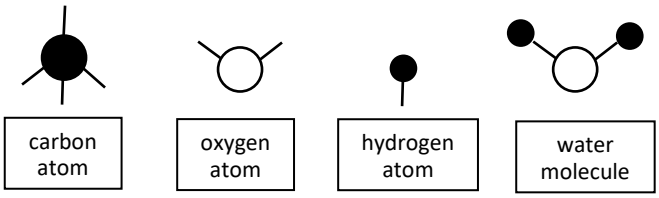
2021 Australian Junior Science Olympiad
Selection Exam

Exam theme: climate change

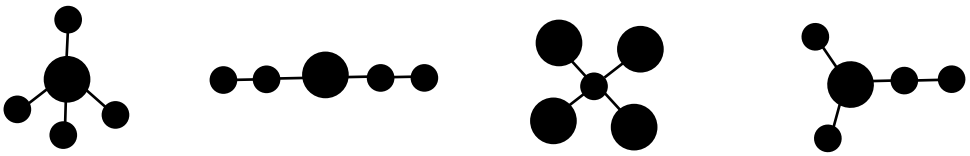
The climate of Planet Earth is a complex system influenced by many factors and involving many feedback loops. Over the 4.5 billion-year history of the planet, the climate has undergone many significant changes, but evidence suggests that it has never changed as rapidly as in the last 200 years.

This is due to human activities such as industry, transport and agriculture which are increasing the concentration of carbon dioxide, methane, nitrous oxide and other greenhouse gases in the atmosphere. The science of climate change is wide-ranging and multi-disciplinary.

1 The diagrams below represent atoms of carbon, oxygen and hydrogen, and also a molecule of water, H_2O. They also show how many other atoms can bond to each atom.



Which of the diagrams below represents a molecule of methane (CH_4)?



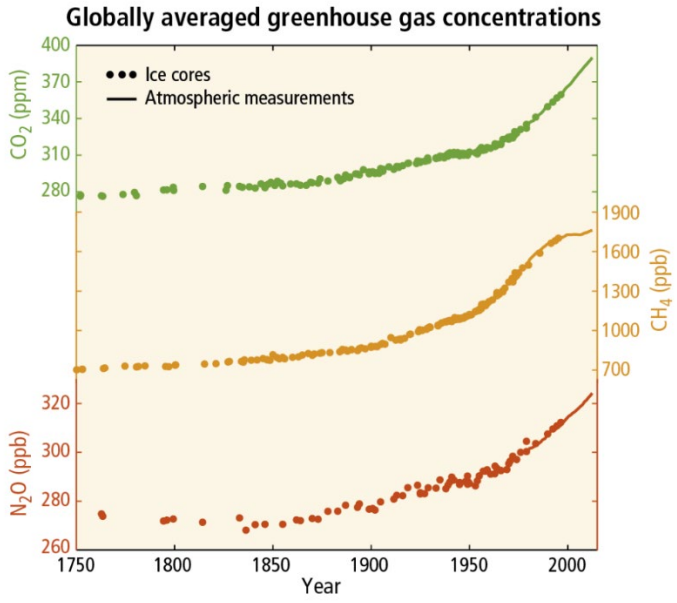
A B C D

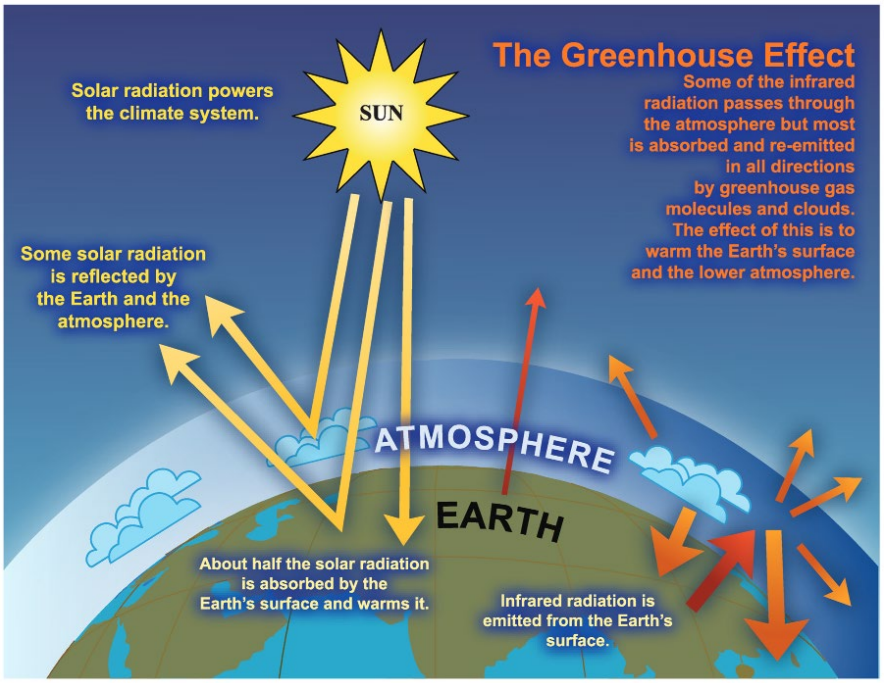
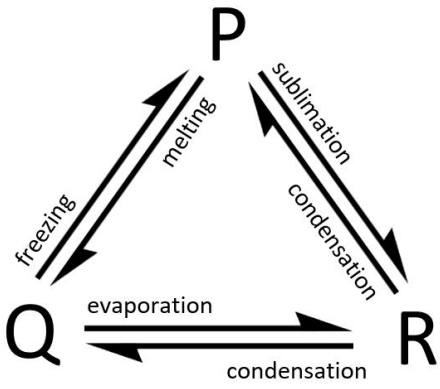
2 Air has the following composition:

Substance	Formula	% of air
Nitrogen	N_2	78.08
Oxygen	O_2	20.94
Argon	Ar	0.93
Carbon dioxide	CO_2	0.04
Other gases	(various)	0.01

Air is best described as:

A. A mixture of compounds and elements, made up of molecules.
B. A mixture of compounds and elements, made up of single atoms and molecules.
C. A mixture of compounds, made up of molecules.
D. A mixture of elements, made up of single atoms and molecules.
E. A pure substance.

3	The concentration of argon in the table in the previous question can also be represented as 9.34 parts per thousand by volume. This is the same as saying that in 1L of air, there is 9.34 x 10^{-3}L of argon. Which of the following correctly represents the number 9.34 x 10^{-3} in standard notation? A. 9.34 B. 0.934 C. 0.0934 D. 0.00934 E. 0.000934
4	The Intergovernmental Panel on Climate Change is an international body which monitors and reports on the global climate situation and recommends strategies to be taken. The following diagram is from their 5th Assessment Report, published in 2014. It shows data on the concentrations of three greenhouse gases over the last two and a half centuries. *Note:* ppm *stands for 'parts per million';* ppb *stands for 'parts per billion'*  According to the graph, which greenhouse gas currently exists in the atmosphere in the highest concentration? A. CO_2 B. CH_4 C. N_2O
5	Refer to the graph of greenhouse gas concentrations in the previous question. The concentration of which greenhouse gas has risen by the greatest proportion since 1800? A. CO_2 B. CH_4 C. N_2O

6	This diagram is from "Climate Change 2007: The Physical Science Basis", published as part of the IPCC 4th Assessment Report. *Note: solar radiation is a combination of ultraviolet, visible and infrared light.* As stated in the diagram, infrared radiation from the Earth's surface is absorbed and re-emitted in all directions by greenhouse gas molecules. In what way does this contribute to warming of the Earth's atmosphere?  A. A smaller proportion of the infrared radiation continues out to space. B. The infrared radiation is distributed more evenly throughout the atmosphere. C. Infrared radiation is trapped and stored by the greenhouse gas molecules. D. The infrared radiation is prevented from reaching the earth.
7	Consider the following scenario: *Sunlight travels through space and through the Earth's atmosphere before being absorbed by and hence warming the surface of the Earth. Air passing over the warmed Earth is itself warmed; this air rises high into the atmosphere, where the air molecules emit their heat energy which is lost to space.* Which of the following lists, in correct order, the heat transfer processes occurring in this scenario? A. Radiation, absorption, conduction, convection, radiation. B. Radiation, absorption, convection, conduction, radiation. C. Convection, absorption, conduction, radiation, convection. D. Conduction, absorption, convection, conduction, radiation.
8	Water is a greenhouse gas, with a complex effect on the climate. It exists in different states under different conditions, and additionally, clouds interact with energy coming into and leaving the atmosphere. The diagram to the right refers to changes of state. Consider the following scenario: *Water evaporated off the ocean, where it gradually became clouds. The water in the clouds formed hailstones, which fell into the ocean.* What is the correct sequence of states that the water went through?  A. Q, R, Q, P, Q B. Q, R, P, Q C. P, R, P, Q D. P, R, P, Q, P

9

Greenhouse gases cause some of the infrared radiation emitted by the Earth to be retained in the atmosphere rather than escaping to space.

Greenhouse gases can undergo chemical reactions that convert them to different substances. As a result, a lifetime can be calculated for each greenhouse gas. This reflects the average amount of time a molecule will stay in the atmosphere before it reacts to form something else or is removed by a natural process. For instance, methane has a lifetime of 12-15 years, while carbon dioxide has a lifetime of 300-1000 years.

Greenhouse gases include carbon dioxide, methane, nitrous oxide and various hydrocarbons, hydrofluorocarbons and chlorofluorocarbons.

Each gas has a different molecular structure, and each type of molecule interacts with infrared radiation in a different way. This means that each gas has a different effect on the warming of the atmosphere.

To compare the effectiveness of different greenhouse gases at warming the atmosphere, scientists have defined a value called the 'Global Warming Potential' (GWP).

To find the Global Warming Potential (GWP) of a gas:

1. Measure the amount of heat energy (infrared radiation) absorbed by a given mass of the gas over a given period of time (call this value E_1).
2. Measure the heat energy absorbed by the same mass of CO_2 over the same period of time (call this value E_2).
3. $GWP = \frac{E_1}{E_2}$

Hence, carbon dioxide is defined as having a GWP value of 1, since it is the reference gas (the gas to which all the other gases are compared).

Below is a list of GWPs calculated over a 100-year period for common greenhouse gases.

Gas	100-year GWP estimates
carbon dioxide (CO_2)	1
methane (CH_4)	25
nitrous oxide (N_2O)	298
difluoromethane (used in air conditioners)	675
fluoroform (used in semiconductor industry for etching) (CHF_3)	14800
sulfur hexafluoride (SF_6)	16300

For each of the following statements, select true or false to indicate whether that factor would affect the estimate of the 100-year GWP for a particular gas.
(Each statement is worth 0.5 marks)

- The molecular mass of the gas
- The chemical structure of the gas
- The rate at which it is being emitted into the atmosphere
- The height above the Earth's surface at which the gas exists
- Its lifetime in the atmosphere
- The probability that it will absorb an infrared photon

Info	The information below is a summary of the experiments reported in the following paper: "Behavioural plasticity under a changing climate; how an experimental local climate affects the nest construction of the zebra finch Taeniopygia guttata." Bridget L. Campbell, Laura L. Hurley and Simon C. Griffith *Journal of Avian Biology*, 2018, vol. 49, issue 4. A study by scientists at Macquarie University in Sydney looked at the nest-building behaviour of zebra finches. In most bird species, successful reproduction depends on the construction of a nest that provides protection and a suitable microclimate for the eggs and nestlings. A variety of studies in the wild had previously observed that in cooler conditions, many bird species tend to build nests with a greater mass of nesting material, presumably to provide better insulation for the eggs. Bridget Campbell and her colleagues wanted to determine whether long-term increases in average temperature due to climate change might cause zebra finches to change the way in which they build their nests. Campbell used a captive population of the Australian zebra finch Taeniopygia guttata. In the wild, zebra finches breed during much of the year, meaning they are exposed to average daily temperatures during breeding that vary from around 10oC to over 26oC. In the summer, temperatures inside the nest can exceed 50oC. They hypothesised that if nest-building behaviour changed with temperature, then a difference in the mass and composition of nests would be observed when finches built nests under different temperature conditions. Campbell and her colleagues set up the experiment as follows. They used 24 pairs of domestically bred zebra finches. One pair of birds was housed in each cage, with six cages to a room. Four rooms were used, two held at constant temperature of 18°C and the other two at 30°C. The birds were kept in their cages for three weeks at the set temperature before the experiment commenced. After the three-week acclimatisation period, each pair of birds was provided with a nest support and three types of nesting material (grass, white cotton thread and emu feathers). The birds then constructed their nests. When eggs were laid, they were removed and replaced with plastic dummy eggs. The birds incubated the dummy eggs, and nine days later the whole nest was removed. The reason for the nine-day period after egg-laying was to ensure that all nest construction was finished before the nest was removed. The collected nests were labelled and stored together for at least six months before processing. During this time they dried under normal indoor laboratory conditions. The birds then switched rooms, with the 18°C birds now moving to 30°C and vice versa. The birds had another three-week acclimatisation period and then the nesting process was repeated. The nests were analysed for total mass, wall thickness, base thickness, and composition. The analysis looked specifically at differences between nests for each individual pair of birds. *The following three questions are based on this information.*

10 Which of the following options correctly states the independent and dependent variables in Bridget Campbell's investigation?

	Independent variable	Dependent variable
A	Average temperature at which nesting takes place	Nest mass and composition
B	Nest mass and composition	Average temperature at which nesting takes place
C	Order in which birds are exposed to cool and warm temperatures	Incubation time
D	Nest mass and composition	Order in which birds are exposed to cool and warm temperatures
E	Long-term change in climate	Nest mass and composition

11 To ensure that the experiment was fair, the scientists identified other variables that might affect the results and controlled them (i.e. they kept them constant for all the birds).

Identify whether each of the following variables was controlled in Campbell's experiment. Select true if it was controlled, and false if it was not controlled.
(Each statement is worth 0.5 marks.)

A. The birds' response may depend on the average temperature in previous weeks.
B. The behaviour of individual birds may be affected by the direction of temperature change(hot to cool or cool to hot).
C. Nest differences may be due to different geographical availability of nesting materials.
D. The droppings of nestlings (baby birds) may be absorbed by the nest, changing its mass.

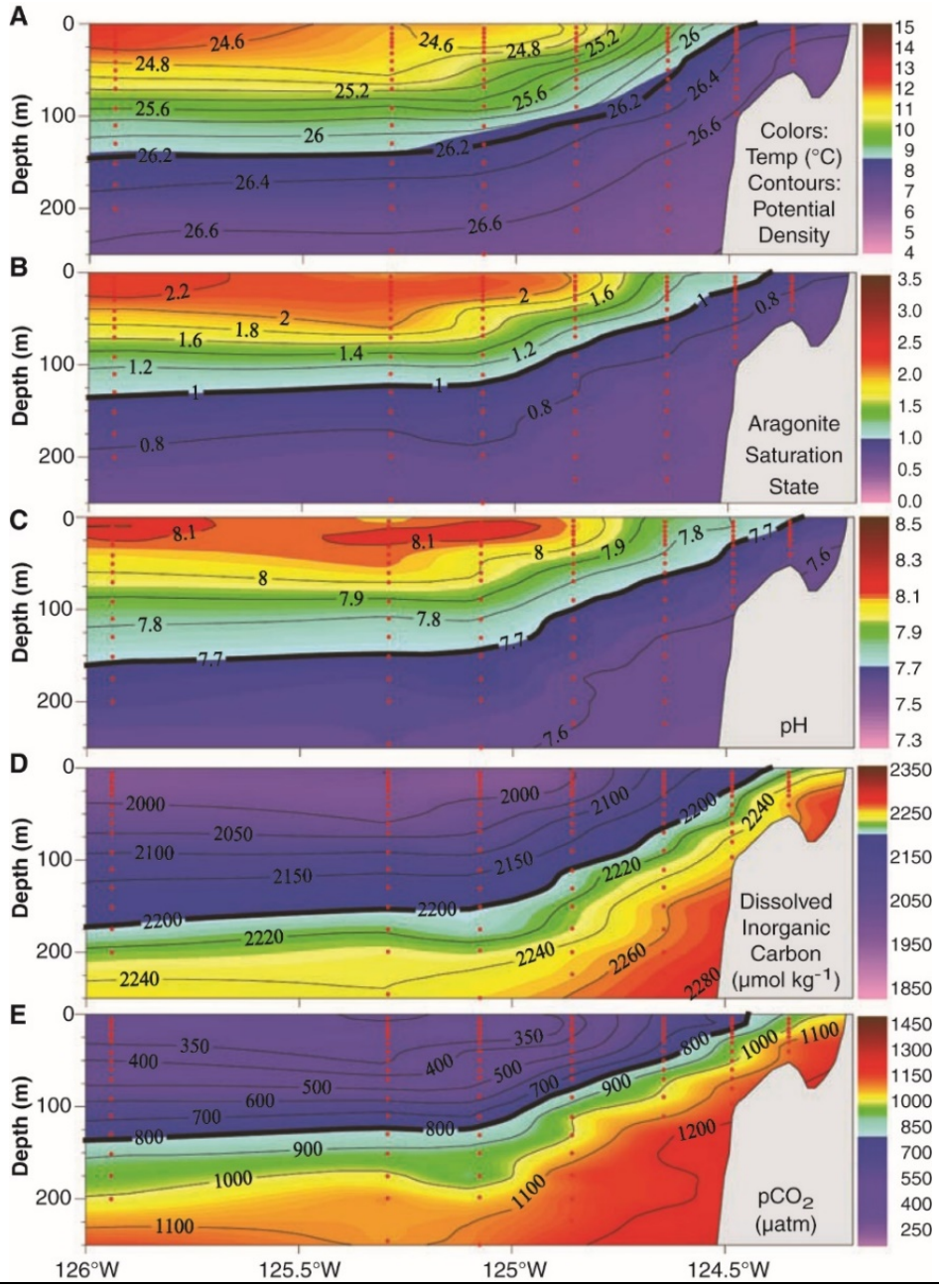
12 The study by Campbell and her colleagues is a **controlled study**. A controlled study is an experiment performed in a laboratory such that the relationship between the independent and dependent variable can be clearly determined. In designing a controlled study, a scientist is trying to determine whether the independent variable **causes** a specific change in the dependent variable. This can only be done if all other variables that might cause the change are eliminated or controlled.

Another kind of scientific investigation is an **observational study**. Observational studies are most useful in large-scale sciences such as ecology, medicine and climate change. An observational study collects data in the real world rather than the laboratory and does not attempt to change the environment in which the study is occurring.

Controlled and observational studies each have their advantages and limitations. For each of the following statements, select 'true' if it describes an advantage of **observational** studies.
(Each statement is worth 0.5 marks.)

- Data is collected from an unaltered natural system
- The study can show the existence of a particular effect or phenomenon in the wild
- It allows rare effects to be easily studied
- Scientists can eliminate or control variables that might affect the phenomenon.
- Scientists can be confident that the organism or system being studied is behaving in its ordinary way
- Scientists can prove that one variable directly causes another.

13	Climate change is causing measurable effects on the world's oceans. Seawater is a solution of salts (ionic compounds) dissolved in water. The most common ions in seawater are sodium ions, chloride ions, magnesium ions, sulfate ions (SO_4^{2-}), calcium ions and potassium ions. Which of the following is true of the **chloride ion**? A. It has a mass number of 17. B. As part of a compound, it exists as diatomic molecules. C. Its valence electrons are in the second electron level. D. It has 18 electrons.
14	Calcium chloride is an ionic compound. A tiny crystal of calcium chloride ($CaCl_2$) contains 100 ions of calcium. How many ions **in total** does the crystal contain? A. 2 B. 3 C. 100 D. 200 E. 300
Info	If the concentration of carbon dioxide in the atmosphere changes, the acidity of the ocean is affected. This occurs because CO_2 gas can dissolve in water. *Note: a substance that is dissolved in water is referred to as 'aqueous'. This is indicated in a chemical equation by the subscript (aq).* Once carbon dioxide has dissolved in the water, some of the **carbon dioxide** molecules react with water molecules to form **carbonic acid**. This is shown in the following equation: $$CO_{2(g)} + H_2O_{(l)} \longrightarrow H_2CO_{3(aq)}$$ Acidity in the ocean causes difficulties for marine organisms that build shells or skeletons from calcium carbonate, such as corals, marine plankton and shellfish. The chemistry involved in the building of shells is complex, but the basis of the problem is that solid **calcium carbonate** reacts with aqueous **carbonic acid** to form **calcium hydrogen carbonate**. While calcium carbonate is insoluble in water (and hence a good shell-building material), calcium hydrogen carbonate is soluble in water. The reaction is shown in the following equation: $$CaCO_{3(s)} + H_2CO_{3(aq)} \longrightarrow Ca(HCO_3)_{2(aq)}$$
15	Determine the charge on the hydrogen carbonate anion. A. -1 B. -2 C. +1 D. +2
16	In the reaction between calcium carbonate and carbonic acid, the more concentrated the acid, the faster the reaction occurs. According to collision theory, for a chemical reaction to occur, the reactant molecules must collide. Which of the following is the best description of why an **increased concentration** would lead to a greater rate of reaction? A. A greater number of reactant molecules causes more frequent collisions. B. A greater proportion of reactant molecules causes a greater proportion of collisions.

	C. More reactant molecules in the same volume causes more frequent collisions. D. More reactant molecules in the same volume increases the chances that any given collision will be successful. E. A greater number of reactant molecules increases the chances that any given collision will be successful.
17	Aragonite is a mineral form of calcium carbonate used by marine organisms to build skeletons or shells. When layers of marine shells accumulate at the bottom of oceans and are compressed over long periods of time, limestone is formed. Limestone is: A. An igneous rock B. A metamorphic rock C. A sedimentary rock D. A type of mineral
18	The diagram below is from a paper published in the academic journal Science in 2008 by Richard Feely and colleagues from the National Oceanic and Atmospheric Administration (NOAA) in the United States of America. 

They were investigating the presence of seawater conditions that would cause the shells of marine organisms to slowly dissolve. This process is referred to as corrosion.

The scientists collected data from the ocean along a transect (straight line) running directly out to sea from Point St George in California. The five graphs above represent a variety of data. The grey area on the right-hand side of each graph represents the coast.

Graph A: temperature (with density measurements superimposed).
Graph B: aragonite saturation
Graph C: pH
Graph D: dissolved inorganic carbon (DIC)
Graph E: pCO2

Notes:

- Aragonite is the form of calcium carbonate used by marine organisms to build skeletons or shells. When the value of the aragonite saturation state (Graph B) drops below 1, it indicates conditions under which the aragonite will slowly dissolve.
- Dissolved inorganic carbon (DIC) (Graph D) includes carbonate ions, hydrogen carbonate ions, and CO_2 molecules, all in the aqueous state.
- pCO_2 (Graph E) refers to the pressure of dissolved CO_2 – this is a way of measuring the concentration of aqueous CO_2.

Based on the information above, indicate whether each of the four following statements is true or false. *(Each statement is worth 0.5 marks.)*

- Higher temperatures and higher pCO_2 values correlate with seawater that is corrosive to shells.

- CO_2 is present in higher concentrations in cold water than in warm water.

- The proportion of carbonate ions and hydrogen carbonate ions in the DIC (dissolved inorganic carbon) is higher in warm water than in cold water.

- A higher concentration of DIC means a higher concentration of carbonate ions, making it easier for marine organisms to construct shells.

Info

Another factor that affects climate is the **albedo** of the landscape. 'Albedo' is a number that represents how well a surface reflects solar energy.

The albedo of a surface varies between 0 and 1. A value of 0 means the surface is a 'perfect absorber' that absorbs all incoming energy. A value of 1 means the surface is a 'perfect reflector' that reflects all incoming energy.

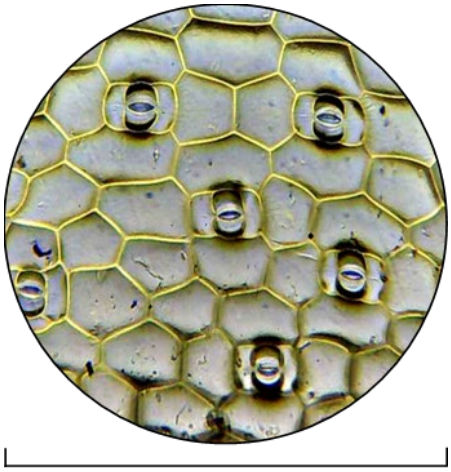
The following table gives albedo values for a range of surfaces on the Earth.

Surface	Albedo range
Fresh snow	0.80-0.90
Old/melting snow	0.40-0.80
Desert sand	0.40
Grassland	0.25
Tundra	0.20
Deciduous trees	0.15-0.18
Coniferous forest	0.08-0.15
Ocean	0.07-0.10

19	Which of the following surfaces absorbs the greatest proportion of the light that falls on it? A. Fresh snow B. Melting snow C. Grassland D. Forest
20	Observations over the last 40 years show clearly that the Arctic is warming, and that the amount of ice in the Arctic region is decreasing. Ocean water has a lower albedo than ice. The long-term effect of the melting of Arctic ice is to: A. reduce Arctic temperatures by transferring thermal energy out of the atmosphere into the meltwater. B. increase Arctic temperatures by increasing the proportion of light energy absorbed by the Arctic region C. increase Arctic temperatures by releasing thermal energy from the exothermic melting of ice. D. reduce Arctic temperatures by reflecting a greater proportion of energy back into space.
21	Artificial turf (fake grass) and real grass have similar albedos. However, on a hot day, artificial turf in full sunlight gets very hot, while grass in full sunlight remains cool. The principal reason for this is the process of evapo-transpiration which occurs in all plants. Which of the following is the underlying chemical reason that evapo-transpiration keeps grass cool? A. Energy absorbed by the leaf increases the kinetic energy of water molecules which then evaporate from the leaf, taking energy with them. B. Energy absorbed by the leaf is stored by water molecules in the leaf, preventing the energy from being released to the surroundings. C. Energy absorbed by the leaf is converted into chemical potential energy stored in water molecules that then evaporate from the leaf. D. Energy absorbed by the leaf is converted to chemical potential energy by photosynthesis.
22	Plants are eukaryotes. Which of the following statements ***best*** describes a difference between prokaryotic and eukaryotic cells? A. Prokaryotic cells do not have the components for autotrophic nutrition. B. Prokaryotic cells do not have a nuclear membrane. C. Prokaryotic cells have membrane-bound organelle structures different from those of eukaryotic cells. D. Prokaryotic cells demonstrate a higher degree of complexity and have more specialised functions than eukaryotic cells.

23

The diagram to the right is the field of vision through a light microscope, showing stomata on a leaf. Stomata are pores that help to regulate gas exchange and water transpiration in plants. During the day, stomata tend to be open, allowing CO_2 to enter the leaf.



As the magnification of a light microscope increases, the diameter of the circular field of vision decreases.

The relationship between magnification and diameter is expressed by the following equation:

$$\frac{magnification\ a}{magnification\ b} = \frac{diameter\ b}{diameter\ a}$$

The diameter of the field of vision in the image is 500 µm, and the magnification is 40 times. If the magnification is increased to 400 times, calculate the **area** of the field of view.

Note:
1µm (micrometre) = 1 x 10^{-6} m
π = 3.14

A. 50 μm^2
B. 157 μm^2
C. 1963 μm^2
D. 7850 μm^2

24

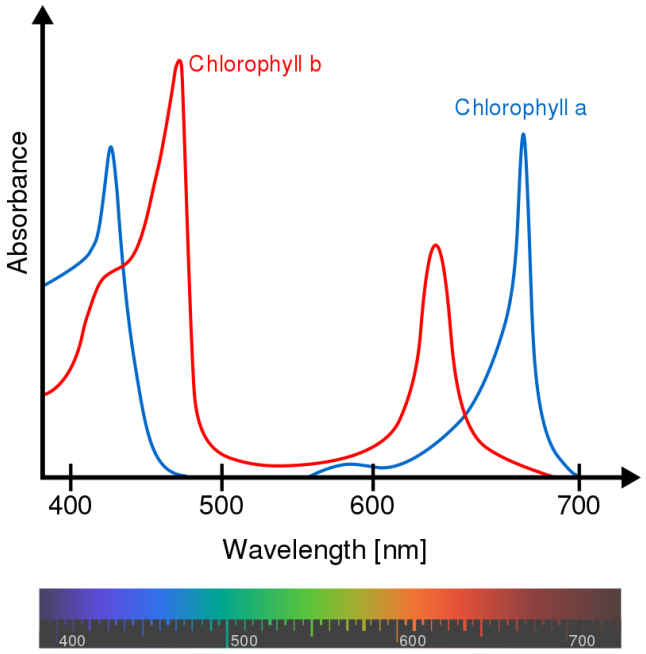
The Earth is approximately 4.5 billion years old. Fossil evidence indicates cells were initially **prokaryotic**, occurring approximately 3.5 billion years ago. **Photosynthetic prokaryotes** evolved approximately 2.5 billion years ago and **aerobic eukaryotic** cells evolved approximately 1.5 billion years ago.

Scientists have determined that initially the Earth had atmospheric conditions very different to the present day. These are outlined in the table below:

Gas	Relative atmospheric levels	
	4.5 billion years ago	current
Nitrogen	High	High
Carbon dioxide	High	Low
Oxygen	Low	High

Which of the following statements best explains the increased levels of **oxygen** in the current atmosphere?

A. Waste from aerobic eukaryotes accumulated in the atmosphere increasing oxygen levels.
B. Waste from photosynthetic prokaryotes accumulated in the atmosphere increasing oxygen levels.
C. Aerobic eukaryotes used up carbon dioxide in cellular processes reducing atmospheric levels of this gas.
D. Photosynthetic prokaryotes used up carbon dioxide in cellular processes reducing atmospheric levels of this gas.

25	Chlorophyll is a chemical substance that absorbs light to allow photosynthesis to occur. There exist several kinds of chlorophyll molecule, and the two main ones in plants are chlorophyll A and chlorophyll B. The two molecules have similar chemical structures but differ in the arrangement of a few atoms. Most plants contain both forms of chlorophyll. The graph to the right shows the **absorbance spectra** for chlorophyll A and for chlorophyll B. An absorbance spectrum represents how strongly a chemical compound absorbs each wavelength of visible light. The x-axis shows the wavelength of light, and the y-axis represents how strongly each wavelength is absorbed. A high absorbance value means the chemical absorbs most of that wavelength of light.  The colour of visible light is determined by its wavelength. Which colour of light is **least** strongly absorbed by chlorophyll? A. Blue B. Green C. Yellow D. Red
26	Which of the following statements about light is true? A. The longer the wavelength of light, the lower its energy B. The higher the frequency of light, the lower its energy C. The longer the wavelength of light, the higher its frequency D. The higher the frequency of light, the brighter it is.
27	A scientist is researching plant growth in a greenhouse. She is aiming to produce fast-growing plants that can be used for the production of carbon-neutral biofuel. She is concerned that her greenhouse is getting too hot from too much light. She decides to shade the greenhouse with coloured translucent plastic sheets. What colour of sheets should she choose to reduce the overall light energy entering the greenhouse, while maximising plant growth? A. Green B. Blue C. Orange D. Any colour will do.

28	The combustion of fossil fuels is the largest contributor to human-produced carbon dioxide in the atmosphere. The most important uses of fossil fuel combustion are coal and natural gas burnt to produce electricity and oil-derived fuels such as petrol, diesel and kerosene that are burnt for transport and heating. Petrol is composed of a mixture of hydrocarbons: chemicals that are entirely made from carbon and hydrogen atoms. The main component of petrol is octane, with the formula C_8H_{18}. The equation below is for the complete combustion of octane. Enter the correct coefficients to balance the chemical equation. *(This question is worth 2 marks).* $C_8H_{18} + O_2 \rightarrow CO_2 + H_2O$
29	Two other common hydrocarbon fuels are methane (CH_4) and ethanol (C_2H_6O). The table below shows the relative masses of molecules of methane, ethanol and carbon dioxide. The relative mass of an atom is determined by assuming a hydrogen atom has a mass of 1 and calculating how many times heavier the atom or molecule is than the hydrogen atom. **Substance** / **Formula** / **Relative mass (no units)** methane / CH_4 / 16 ethanol / C_2H_6O / 46 carbon dioxide / CO_2 / 44 The balanced equations for the combustion of methane and ethanol are shown below. Combustion of methane: $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ Combustion of ethanol: $C_2H_6O + 3O_2 \rightarrow 2CO_2 + 3H_2O$ Calculate the mass of CO_2 produced when 1.0g of each fuel (methane and ethanol) undergoes complete combustion. Give your answer rounded to 1 decimal place. *(This question is worth 2 marks.)* (Numerical entry) 1g of methane produces _____ of CO_2 1g of ethanol produces _____of CO_2
Info	The International Energy Agency released a report in May 2021 entitled "Net Zero by 2050"- a Roadmap for the Global Energy Sector. This report describes a range of strategies that if applied together could bring the world to net zero carbon emissions by 2050. 'Net zero emissions' means that although some human processes will cause the emission of CO_2, other processes will absorb that same amount. One of the ways in which we can make significant changes to greenhouse gas emissions is by replacing vehicles powered by internal combustion engines, which burn fuels like petrol or diesel, with electrified transport, including electric cars, shipping and even electric aeroplanes.

30

Electric motors have much greater initial acceleration than internal combustion engines (such as petrol or diesel engines). A well-known brand of electric car has demonstrated acceleration from 0-100km/h in 2.6s.

The mass of the car is 2250kg.
100 km/h is approximately 28 m/s

Formulae:
$F = ma$
$a = (v - u)/t$

Calculate the average force required to accelerate the car in this way.

(2 marks) Give your answer to the nearest Newton:

(1 mark) Give your answer to correct number of significant figures:

31

An electric car is towing a trailer with a mass of 1000kg. As the car and trailer **accelerate**:

A. The amount of force with which the car pulls against the trailer is equal to the amount of force with which the trailer pulls against the car.
B. The amount of force with which the car pulls against the trailer is smaller than the amount of force with which the trailer pulls against the car.
C. The amount of force with which the car pulls against the trailer is greater than the amount of force with which the trailer pulls against the car.
D. The car's motors are running, so it pulls against the trailer, but the trailer has no motor so it can't pull back against the car.
E. Neither the car nor the trailer exert any force on the other. The trailer moves forward simply because it is attached to the car.

32

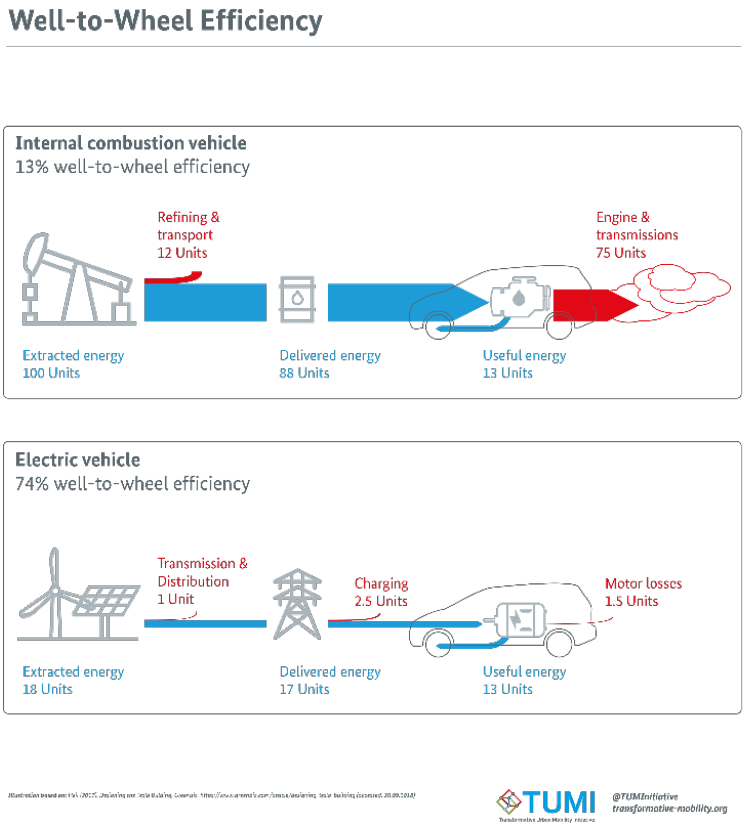
Engines (whether electric motors or internal combustion engines) can be compared by looking at three measures.

	Internal combustion engine	Electric motor
Fuel economy	km/L Distance travelled for the use of 1L of fuel	km/kWh Distance travelled for the use of 1 kWh of electrical energy.
Fuel consumption	L/100km Litres of fuel needed to travel 100km.	kWh/100km Amount of electrical energy needed to travel 100km.
Fuel efficiency	% of chemical energy in the fuel that is converted to kinetic energy of the vehicle.	% of electrical energy in the battery that is converted to kinetic energy of the vehicle.

The Australian Bureau of Statistics reports that the average fuel economy of passenger vehicles **decreased** from 9.4 km/L in 2016 to 9.0 km/L in 2020, largely due to increased sales of larger SUV vehicles.

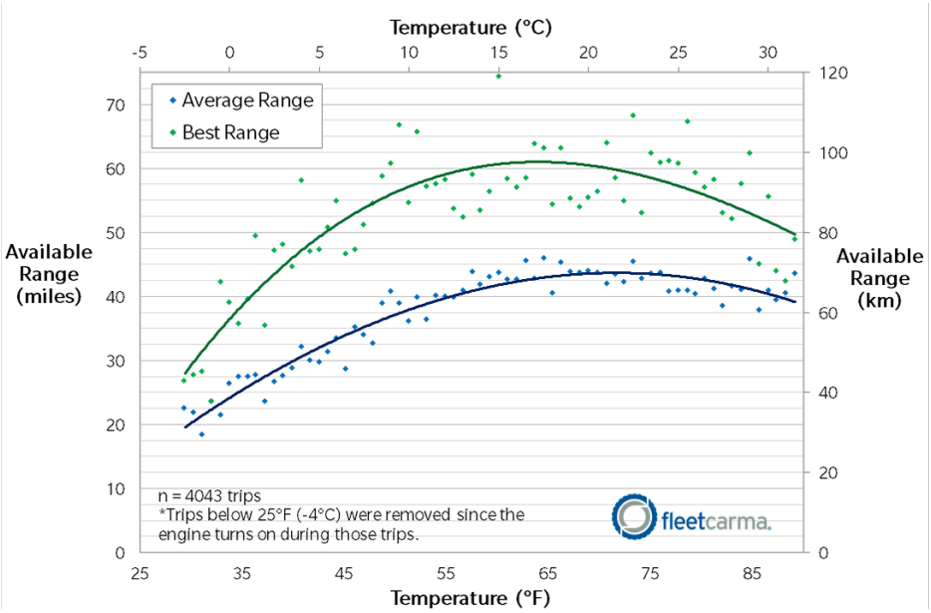
Calculate the fuel consumption (in L/100km) for a vehicle with a fuel economy of 9.0 km/L.
(This question is worth 2 marks.)

(Numerical entry)

33	Which of the following equations would correctly calculate the fuel efficiency of an internal combustion engine? A. (Chemical energy in fuel – kinetic energy of car)/chemical energy in fuel x 100 B. (Kinetic energy of car – chemical energy in fuel)/chemical energy in fuel x 100 C. (Chemical energy in fuel – kinetic energy of car)/kinetic energy of car x 100 D. (Kinetic energy of car – chemical energy in fuel)/kinetic energy of car x 100 E. Kinetic energy of car/chemical energy in fuel x 100
34	The fuel efficiency of a vehicle can also be determined using a broader perspective. The diagram above shows a Sankey diagram illustrating the 'well to wheel' efficiency of an **internal combustion engine vehicle** (ICEV) and an **electric vehicle** (EV).  The 'well' in 'well-to-wheel' refers to the oil well – the original source of the fuel used in the ICEV. The equivalent for an EV is looking at the original generation source of the electricity – here assumed to be wind or solar electricity. Which of the following is the **most significant** reason that internal combustion engine vehicles are **less** efficient than electric vehicles? A. In ICEVs, significant thermal energy losses occur from the engine. B. The ICEV requires more energy to move a certain distance than the EV. C. ICEVs have greater losses due to air resistance and friction than EVs. D. Electricity can be produced from renewable sources such as wind and solar. E. Some energy is lost in refining and transporting the fuel for the ICEV.

35

The graph below shows data collected by owners of a particular model of electric vehicle. The dots are individual measurements; the solid lines are lines of best fit for that set of data.



Which of the following statements is true?

A. Available range is maximised at temperatures of 10-15°C.
B. As temperature increases, available range increases.
C. Available range depends only on temperature.
D. The best range data has a higher uncertainty than the average range data.

Info

One of the concerns relating to rapid climate change is its effect on living organisms. Individual species and the ecosystems they are part of have evolved adaptations to their local climate. Since the process of evolution is generally much slower than the current pace of climate change, it is unclear how ecosystems will change in response.

36

Mosquitos are *ectothermic* -this means that they require the environment to be warm so they can function. Their optimum temperature is approximately 27°C. If the temperature is below 10°C, they cannot function. As global temperatures increase, it is predicted that there will be an increase in mosquito populations.

Many insect species have **alleles** that are temperature sensitive. Fertilised mosquito eggs only develop within specific temperature ranges outlined in the table below.

Genotype	Temperature necessary for development (°C)
EE	10 - 18
Ee	15 - 20
ee	20 - 28

Two mosquitos, both with the genotype **Ee**, mate. Their fertilised eggs (F1) are allowed to develop at 19°C. The F1 mosquitos mate randomly, and the eggs produced are again allowed to develop at 19°C.

What percentage of eggs **produced** by the F1 mating will **not** develop?

A. 25%
B. 50%
C. 75%
D. 100%

37

A population of a particular fish species was founding living in several small shallow lakes up to 50km apart in an area well known for its hot springs.

An initial investigation showed that the temperature range of each of the lake was between 30°C and 35°C. A small number of this species of fish from each of the lakes were tested in the laboratory to find the temperatures they could tolerate. None of those tested survived at temperatures below 27 °C.

Over several years it was observed that the temperature of one of the lakes (Lake A) was falling. A study made 50 years after the initial investigation showed that some members of this species of fish were living in Lake A even though its temperature was now between 21°C and 26 °C.

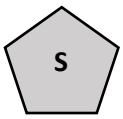
An explanation for this finding would be:

A. Individuals better suited for the colder environment had greater reproductive success.
B. Individuals with favourable characteristics for the environment had longer lifespans.
C. Individuals in Lake A survived by swimming closer to the surface where the water was warmer.
D. Individuals mutated their genomes to have better adaptations for the environment.

38

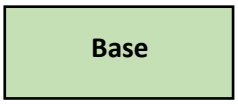
DNA is the molecule that allows information to be passed from one organism to its offspring.

The following diagrams represent the components of a nucleotide. Nucleotides join together in pairs to form DNA molecules.



Sugar

Phosphate

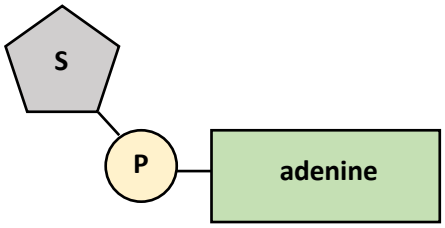


Nitrogenous base

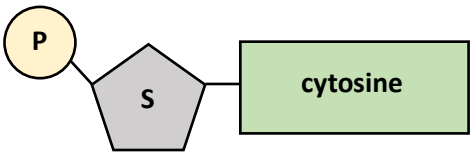
(Adenine, cytosine, guanine, thymine)

Which diagram shows the correct arrangement of components for a nucleotide that would pair with a second nucleotide containing guanine?

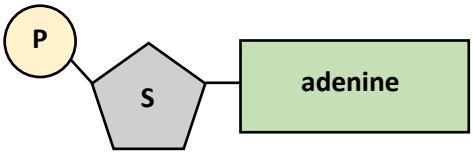
A.



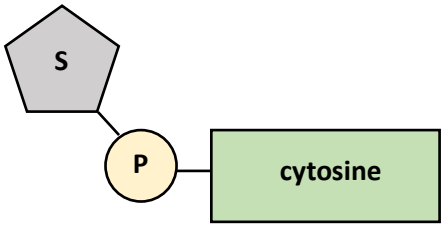
C.



B.



D.



39 Plants are autotrophs: they convert light energy to chemical energy (glucose) according to the following equation.

$$6CO_2 + 6H_2O \xrightarrow{Light} C_6H_{12}O_6 + 6O_2$$

The chemical energy in the glucose is used to drive other chemical reactions in the plant.

Researchers Seymour and Schultze-Motel at the University of Adelaide investigated thermogenesis of the lotus flower (*Nelumbo nucifera)* blooming in the Adelaide Botanical Gardens.

They discovered that the lotus flowers maintained a temperature of 30°C to 35°C, even when the air temperature dropped to 10°C. The plants achieve this by increasing the rate of aerobic respiration (the exothermic breakdown of glucose ($C_6H_{12}O_6$) in the presence of oxygen gas (O_2)). The heat produced by this reaction warms the flowers (thermogenesis). This is expressed by the following equation:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{energy}$$

An investigation was conducted to explore the concentration of CO_2 in the air after it had flowed over *Nelumbo nucifera* during thermogenesis. The control air sample was discovered to have a CO_2 concentration of 330 parts per million (ppm).

Measurements that were made at various air temperatures are recorded in the table below:

Ambient air temperature (°C)	Flower internal temperature (°C)	Concentration of CO_2 (ppm) in the air after it flowed over the plant
05	33	299
15	33	311
25	27	325
35	31	325

Which of the following statements is correct according to the information above?

A. At the air temperature of 05°C the rate of photosynthesis decreases.
B. At ambient air temperatures of 35°C photosynthesis does not occur.
C. At the air temperature of 15°C the rate of photosynthesis is increased but the rate of respiration is decreased.
D. At ambient air temperatures between 25°C and 35°C the rate of photosynthesis plateaus.

40 Seymour and Schultze-Motel hypothesised that the thermogenesis of *Nelumbo nucifera* may be a means of attracting ectothermic pollinators like beetles, bees and flies by providing a warm night shelter and a large pollen reward, thereby aiding lotus flower reproduction. This type of relationship between *Nelumbo nucifera* and these ectothermic insect species is called:

A. Commensalism
B. Mutualism
C. Parasitism
D. Predation

41 The leaf of *Nelumbo nucifera* has been used to treat obesity in China.

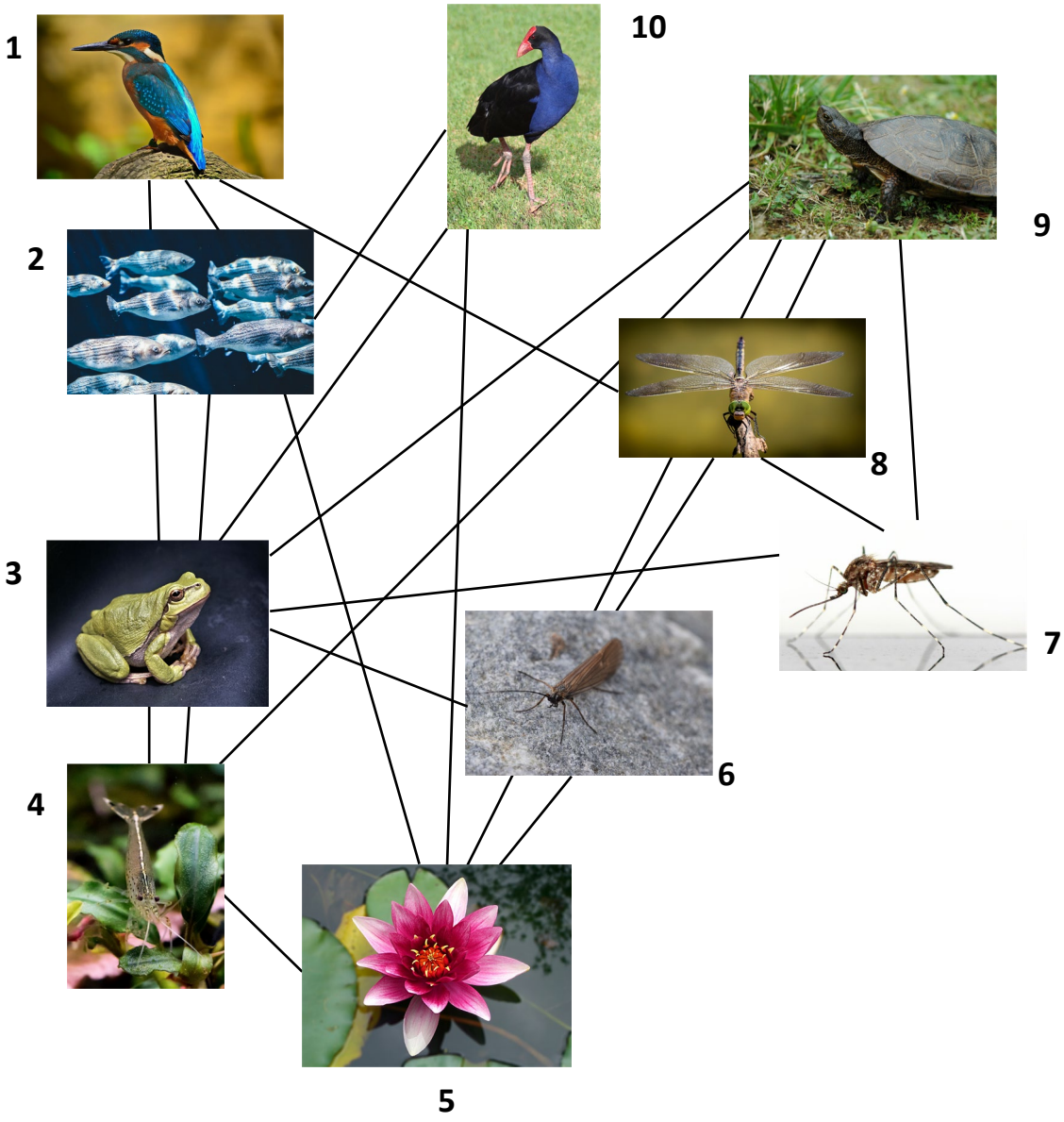
An investigation conducted by Yuka Ono and colleagues in 2006 explored the pharmacological mechanisms of the anti-obesity effect of *Nelumbo nucifera* leaf extract. In mice on a high-fat diet, it was found that the leaf extract reduced the activity of the enzymes α-amylase and lipase.

From this information it can be determined that *Nelumbo nucifera* leaf extract helps to prevent obesity by:

A. Reducing the absorption of starch and fats through the villi of the small intestine into the blood stream.
B. Enhancing the breakdown of starch and fats facilitating their movement into the transverse colon.
C. Enhancing the absorption of starch and fats through the villi of the small intestine into the blood stream.
D. Reducing the breakdown of starch and fats facilitating uptake in the transverse colon.

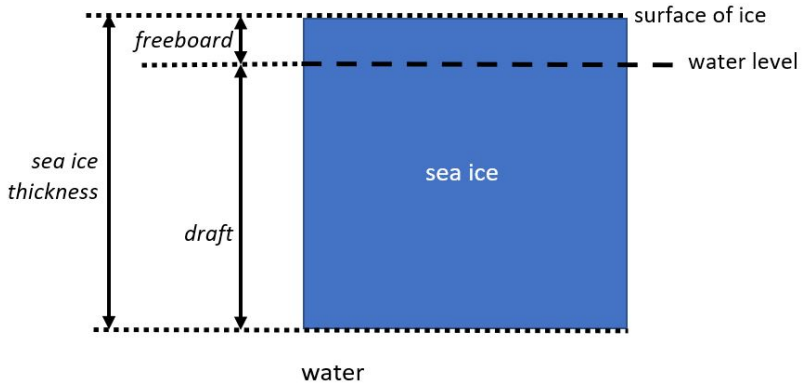
42 The following diagram depicts a food web for a North Queensland aquaculture system used for farming barramundi. The aquaculture system uses lotus flowers to aid in preventing eutrophication: the build-up of nutrients and wastes in the water.

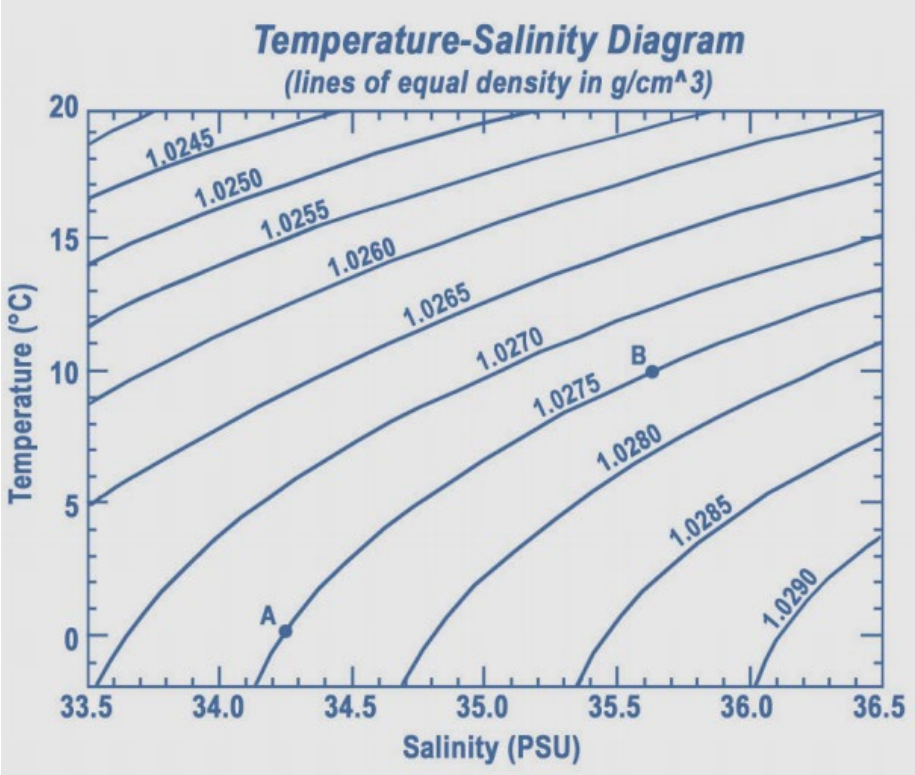
Select the response that correctly identifies the producer in this system and a 2nd order consumer.



A. The producer in this system is image 5, the 2nd order consumer is image 6.
B. The producer in this system is image 2, the 2nd order consumer is image 10.
C. The producer in this system is image 5, the 2nd order consumer is image 3.
D. The producer in this system is image 2, the 2nd order consumer is image 5.

Info	Renewable energy sources such as solar and wind power will play a significant part in our transition to net zero emissions. Because of the intermittent nature of solar and wind power, they must be paired with technology that can store and release the power when needed. Large batteries are part of this storage strategy. So are gravitational energy storage technologies such as pumped hydro, like the Snowy Hydro 2.0 currently being built in the Snowy Mountains of NSW and Victoria. In recent years, some European companies have also been investigating the use of gravity storage towers, or 'towers of power'. Excess electricity from renewable sources is used to drive a motor that raises a giant concrete mass up into the air. When electricity is required again, the mass is allowed to fall in a controlled manner, which spins a turbine, driving an electrical generator.
43	The concrete mass of a gravity storage tower is being lifted up at a constant speed. Consider the following statements: I. The kinetic energy of the concrete mass is constant II. The gravitational potential energy of the concrete mass is constant III. The acceleration of the concrete mass is zero IV. The net force on the concrete mass is zero Select the correct analysis of this situation out of options I-IV: A. Only statements I and II are true B. Only statements I and III are true C. Only statement IV is true D. Only statements I, III and IV are true E. All four statements are true.
44	Here is a list of dimensions and their standard units: Mass is measured in kilograms (kg) Time is measured in seconds (s) Distance is measured in metres (m) Speed is a measurement that is calculated as: $$speed = distance/time$$ Since the standard units for distance and time are metres and seconds respectively, it can be determined from this formula that the standard unit for speed is metres per second (m/s). *** Energy is usually measured in Joules. This unit name commemorates James Prescott Joule, a nineteenth century physicist who studied the nature of heat. However, this unit disguises the 'true' unit of energy. In the same way that the speed unit (m/s) is a combination of the units of distance and time that are used to calculate speed, the energy unit is a combination of distance, mass and time units. Use the following formulae to determine the true unit of energy. $$energy = force\ x\ distance$$ $$force = mass\ x\ acceleration$$ $$acceleration = speed/time$$ A. $kg.m^2/s^2$ B. $kg.m/s^2$ C. $kg.m^2/s$ D. $kg^2.m^2/s^3$ E. $kg^2.m/s^2$

Info	Another area of Earth Science that is crucial for monitoring climate change is glaciology. Glaciologists study the formation and movement of ice, including glaciers, polar ice caps and sea ice. (It is even possible to be an astroglaciologist, specialising in studying the water ice discovered on the Moon, Mars, Europa and Pluto.) The change in the amount of sea ice in the Arctic has been a major area of research in the last few decades, since it is one of the clearest indicators that the climate is changing.
45	The density of pure water at 25°C is 0.997 g/cm^3. Convert this value to kg/m^3. A. 0.000997 kg/m^3 B. 0.997 kg/m^3 C. 99.7 kg/m^3 D. 997 kg/m^3 E. 997 000 kg/m^3
46	Ice is less dense than liquid water. This is unusual, since in most substances, the particles are packed more closely in the solid state than in the liquid state. Which of the following is the principal reason why ice is less dense than liquid water? A. In ice, water molecules are arranged in a hexagonal lattice which takes up more space than the randomly jumbled water molecules in the liquid state. B. It is a general rule that the solid state of a substance will be less dense than the liquid state. C. Water molecules are packed more tightly together in the solid phase than in the liquid phase, making the solid phase less dense. D. Water molecules in the ice phase have less kinetic energy than in the liquid phase, which leads to lower density.
47	Sea ice forms when the surface of the ocean becomes cold enough for freshwater ice to crystallise out of the saltwater ocean. The diagram below represents sea ice (blue) floating in the ocean. The freeboard is the part of the ice that sits above the surface of the water; the draft is the part that sits below the surface of the water.  A floating object displaces the volume of fluid that has the same mass as itself. Calculate the percentage of a block of sea ice that would be freeboard if the density of the seawater is 1.030 g/mL and the density of the sea ice is 0.917 g/mL *(This question is worth 1 mark.)* (Numerical entry)

48	The following diagram shows how the density of water varies with temperature and salinity. The salinity of water refers to the concentration of dissolved salts in it. Salinity is measured using PSU – 'practical salinity units'. The curved lines across the diagram represent the combinations of temperature and salinity at which the density of the water remains constant. Density values are given in g/cm^3.  A sample of seawater has an initial temperature of 5°C and salinity of 33.5 PSU. A change occurs and the density of the water increases by 0.19%. What is the new density of the water? A. 0.00196 g/cm^3 B. 1.0265 g/cm^3 C. 1.0285 g/cm^3 D. 1.0460 g/cm^3 E. 1.2215 g/cm^3
Info	Sea ice in the Arctic is a crucial indicator of changes in the climate. The amount of sea ice in a region can be measured in several ways. Ice concentration: the fraction of an area that is covered by sea ice. Ice concentration is typically reported as a percentage (0-100% ice) or a decimal value (0-1). Ice extent: the area containing ice. This is the total geographical area (in km^2) covered by some amount of ice, including open water between ice floes. A particular area is classified as covered by ice if the ice concentration in that area is greater than 15%. Ice area: total actual area of ice. This is the area of actual ice (in km^2) existing in a region. It can be calculated for a region by multiplying the ice extent by the ice concentration.

49 Consider the following two regions.

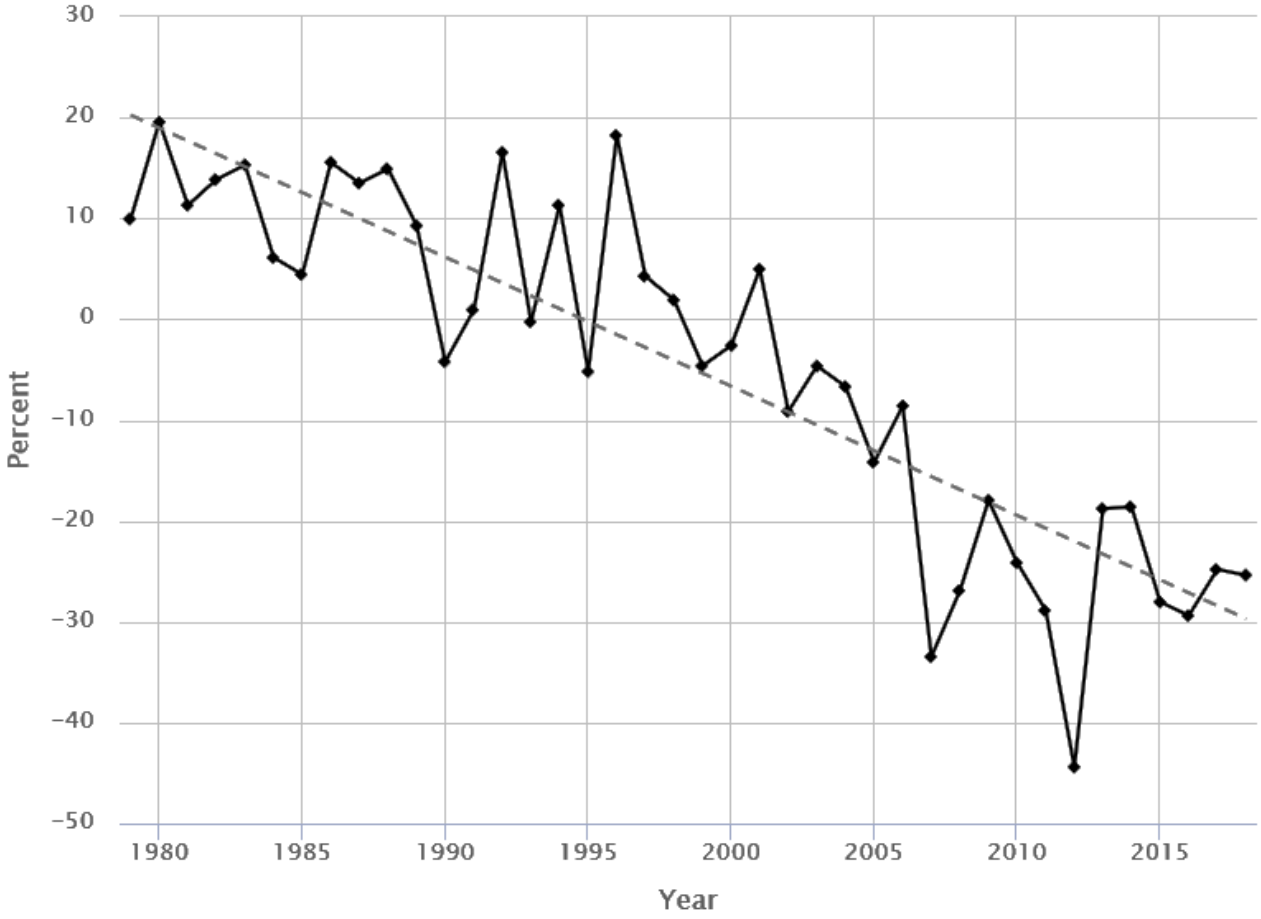
Region 1: 4000 km^2 of ocean completely covered in thick, old sea ice.

Region 2: 10000 km^2 of ocean covered in ice floes like those in the picture below.

(Picture: Esther Dyson; https://creativecommons.org/licenses/by-nc/2.0/)

Select the row in the table below that shows the correct description of Regions 1 and 2 (relative to one another) in terms of ice concentration, ice extent and ice area.

	Region 1	Region 2
A	Higher concentration, lower extent, higher area.	Lower concentration, higher extent, lower area.
B	Higher concentration, higher extent, lower area.	Lower concentration, lower extent, higher area.
C	Higher concentration, lower extent, lower area.	Lower concentration, higher extent, higher area.
D	Lower concentration, higher extent, higher area.	Higher concentration, lower extent, lower area.
E	Lower concentration, higher extent, lower area.	Higher concentration, lower extent, higher area.

Info	The graph below shows data related to the **extent** of sea ice in the Arctic Ocean in September each year from 1979-2018. **Arctic Ice Extent Anomaly Trend (September; 1979-2018),** based on 1981 to 2010 Mean (Average) Ice Extent. *Mean Ice Extent (1981-2010) = 6 400 000 km^2* *Trendline slope = -12.8% per decade*  Data from the National Snow and Ice Data Centre (https://nsidc.org/arcticseaicenews/sea-ice-analysis-tool/). Read the following explanatory notes before attempting the next question. • The y-axis shows the 'anomaly': the percent difference between that year's value and the mean value. • The mean value (shown above the graph) is calculated from 1981-2010 data. • Data points that are positive on the y-axis indicate the sea ice extent is above the 1981-2010 average in that year. • Data points that are negative on the y-axis indicate the sea ice extent is below the 1981-2010 average in that year. • The dotted line is the trendline (line of best fit) calculated from the yearly values (black data points).
50	a) Calculate the average area (in square kilometres) by which the September ice extent is decreasing each decade. Give your answer to the nearest 10000 km^2. *(This question is worth 1 mark.)* (Numerical entry) b) Based on the trendline, in which year was the ice extent for September equal to the mean ice extent for 1981-2010? *(This question is worth 1 mark.)*

	(Numerical entry) c) Based on the trendline, predict the year in which there will be no Arctic sea ice in September. *(This question is worth 2 marks.)* (Numerical entry)