2025 JUNIOR SCIENCE OLYMPIAD EXAM

JUNIOR YEAR 9 & 10

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:

2025 JUNIOR SCIENCE OLYMPIAD EXAM

9 & 10

Time Allowed

Reading Time: 0 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.
- Marks will not be deducted for incorrect answers**.**
- There are four sections to the exam that focus primarily on Biology, Chem, Earth Science and Physics. In real science research, there are no hard boundaries between different disciplines, so you will see questions within each section that cross-over between different sciences. We encourage you to aspire to be an 'all-rounder' in your science understanding!

MARKS

- 1 mark for each question unless otherwise specified
- Total marks for the paper: 50 marks

Integrity of Competition

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

IUPAC Periodic Table of the Elements

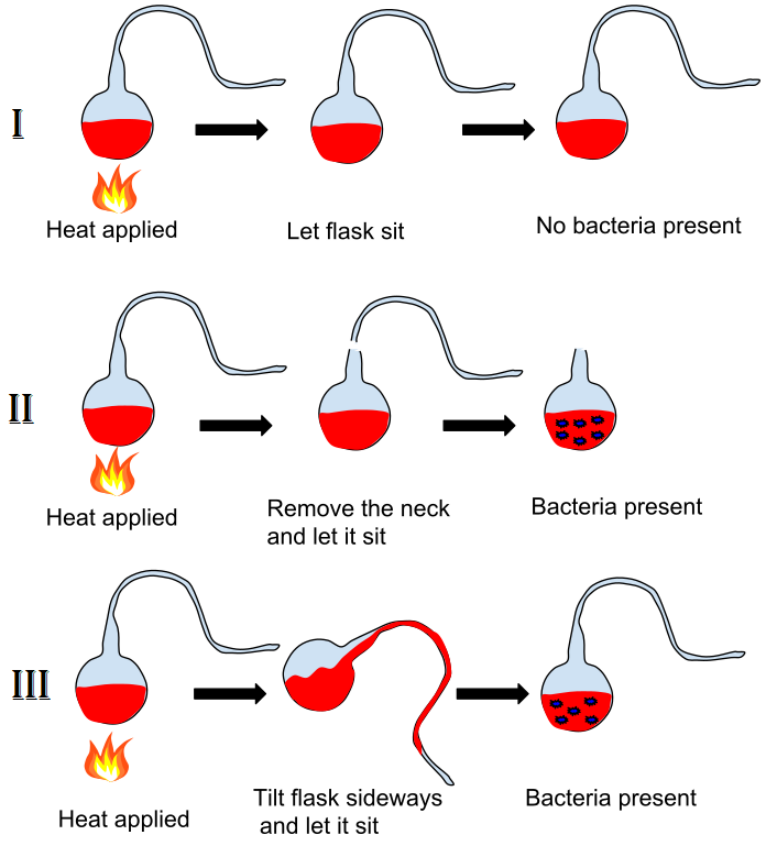
Key: atomic number / **Symbol** / name / abridged standard atomic weight

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** hydrogen 1.0080 ± 0.0002																	2 **He** helium 4.0026 ± 0.0001
3 **Li** lithium 6.94 ± 0.06	4 **Be** beryllium 9.0122 ± 0.0001											5 **B** boron 10.81 ± 0.02	6 **C** carbon 12.011 ± 0.002	7 **N** nitrogen 14.007 ± 0.001	8 **O** oxygen 15.999 ± 0.001	9 **F** fluorine 18.998 ± 0.001	10 **Ne** neon 20.180 ± 0.001
11 **Na** sodium 22.990 ± 0.001	12 **Mg** magnesium 24.305 ± 0.002											13 **Al** aluminium 26.982 ± 0.001	14 **Si** silicon 28.085 ± 0.001	15 **P** phosphorus 30.974 ± 0.001	16 **S** sulfur 32.06 ± 0.02	17 **Cl** chlorine 35.45 ± 0.01	18 **Ar** argon 39.95 ± 0.16
19 **K** potassium 39.098 ± 0.001	20 **Ca** calcium 40.078 ± 0.004	21 **Sc** scandium 44.956 ± 0.001	22 **Ti** titanium 47.867 ± 0.001	23 **V** vanadium 50.942 ± 0.001	24 **Cr** chromium 51.996 ± 0.001	25 **Mn** manganese 54.938 ± 0.001	26 **Fe** iron 55.845 ± 0.002	27 **Co** cobalt 58.933 ± 0.001	28 **Ni** nickel 58.693 ± 0.001	29 **Cu** copper 63.546 ± 0.003	30 **Zn** zinc 65.38 ± 0.02	31 **Ga** gallium 69.723 ± 0.001	32 **Ge** germanium 72.630 ± 0.008	33 **As** arsenic 74.922 ± 0.001	34 **Se** selenium 78.971 ± 0.008	35 **Br** bromine 79.904 ± 0.003	36 **Kr** krypton 83.798 ± 0.002
37 **Rb** rubidium 85.468 ± 0.001	38 **Sr** strontium 87.62 ± 0.01	39 **Y** yttrium 88.906 ± 0.001	40 **Zr** zirconium 91.224 ± 0.002	41 **Nb** niobium 92.906 ± 0.001	42 **Mo** molybdenum 95.95 ± 0.01	43 **Tc** technetium [97]	44 **Ru** ruthenium 101.07 ± 0.02	45 **Rh** rhodium 102.91 ± 0.01	46 **Pd** palladium 106.42 ± 0.01	47 **Ag** silver 107.87 ± 0.01	48 **Cd** cadmium 112.41 ± 0.01	49 **In** indium 114.82 ± 0.01	50 **Sn** tin 118.71 ± 0.01	51 **Sb** antimony 121.76 ± 0.01	52 **Te** tellurium 127.60 ± 0.03	53 **I** iodine 126.90 ± 0.01	54 **Xe** xenon 131.29 ± 0.01
55 **Cs** caesium 132.91 ± 0.01	56 **Ba** barium 137.33 ± 0.01	57-71 lanthanoids	72 **Hf** hafnium 178.49 ± 0.01	73 **Ta** tantalum 180.95 ± 0.01	74 **W** tungsten 183.84 ± 0.01	75 **Re** rhenium 186.21 ± 0.01	76 **Os** osmium 190.23 ± 0.03	77 **Ir** iridium 192.22 ± 0.01	78 **Pt** platinum 195.08 ± 0.02	79 **Au** gold 196.97 ± 0.01	80 **Hg** mercury 200.59 ± 0.01	81 **Tl** thallium 204.38 ± 0.01	82 **Pb** lead 207.2 ± 1.1	83 **Bi** bismuth 208.98 ± 0.01	84 **Po** polonium [209]	85 **At** astatine [210]	86 **Rn** radon [222]
87 **Fr** francium [223]	88 **Ra** radium [226]	89-103 actinoids	104 **Rf** rutherfordium [267]	105 **Db** dubnium [268]	106 **Sg** seaborgium [269]	107 **Bh** bohrium [270]	108 **Hs** hassium [269]	109 **Mt** meitnerium [277]	110 **Ds** darmstadtium [281]	111 **Rg** roentgenium [282]	112 **Cn** copernicium [285]	113 **Nh** nihonium [286]	114 **Fl** flerovium [290]	115 **Mc** moscovium [290]	116 **Lv** livermorium [293]	117 **Ts** tennessine [294]	118 **Og** oganesson [294]

57 **La** lanthanum 138.91 ± 0.01	58 **Ce** cerium 140.12 ± 0.01	59 **Pr** praseodymium 140.91 ± 0.01	60 **Nd** neodymium 144.24 ± 0.01	61 **Pm** promethium [145]	62 **Sm** samarium 150.36 ± 0.02	63 **Eu** europium 151.96 ± 0.01	64 **Gd** gadolinium 157.25 ± 0.03	65 **Tb** terbium 158.93 ± 0.01	66 **Dy** dysprosium 162.50 ± 0.01	67 **Ho** holmium 164.93 ± 0.01	68 **Er** erbium 167.26 ± 0.01	69 **Tm** thulium 168.93 ± 0.01	70 **Yb** ytterbium 173.05 ± 0.02	71 **Lu** lutetium 174.97 ± 0.01
89 **Ac** actinium [227]	90 **Th** thorium 232.04 ± 0.01	91 **Pa** protactinium 231.04 ± 0.01	92 **U** uranium 238.03 ± 0.01	93 **Np** neptunium [237]	94 **Pu** plutonium [244]	95 **Am** americium [243]	96 **Cm** curium [247]	97 **Bk** berkelium [247]	98 **Cf** californium [251]	99 **Es** einsteinium [252]	100 **Fm** fermium [257]	101 **Md** mendelevium [258]	102 **No** nobelium [259]	103 **Lr** lawrencium [262]

INTERNATIONAL UNION OF
PURE AND APPLIED CHEMISTRY

For notes and updates to this table, see www.iupac.org. This version is dated 4 May 2022.

	BIOLOGY
Info	**The information below relates to Questions 1 and 2** A key experiment in our early understanding of cell theory was conducted by Louis Pasteur. In the mid-1800s, Pasteur set up a series of experiments, aiming to show that germs were the likely cause of diseases, and that new cells came from existing cells. Pasteur's experiment entailed heating a growth medium for microorganisms, placing it in different conditions, and determining if any bacterial growth occurred. Pasteur's three main experiments are shown below.  Source: Wikimedia commons. Author: Kgerow16 https://commons.wikimedia.org/wiki/File:Louis_Pasteur_Experiment.svg

1	**(1 mark)** The main role of the heat in this experiment was: A. To add bacteria to the flask B. To provide a source of energy for the growth of microorganisms C. To regulate the temperature of the broth for the effective growth of microorganisms D. To kill any existing microorganisms in the broth, ensuring that any growth is from other microorganisms entering the system
2	**(1 mark)** Which of the statements below best describes the specific purpose of setup "II" in this experiment? A. To test whether bacteria is the microorganism which grows in the medium B. To test whether bacteria present externally can enter a sterile flask, and hence multiply in the growth medium C. To test whether bacteria in the neck of the flask can enter the solution and hence grow in the medium D. To test whether bacteria will grow in the medium if bacterial cells are not allowed to reach the medium at all

This information below relates to Question 3

The Andean Condor is a species of vulture found in various countries in South America.

Source: Thomas Fuhrmann, Wikimedia commons
https://commons.wikimedia.org/wiki/File:Andean_condor_%28Vultur_gryphus%29_at_Colca_Canyon.jpg

A condor feeds primarily on dead and decaying animal carcasses. It builds its nests in elevated regions, such as in the Andes mountains. Condors have a ruff of white feathers around the base of their necks. Some males tend to have white patches on their feathers, whilst female condors tend to be smaller in size than the male.

3 **(1 mark)**

Condors have evolved to have almost no feathers on their head and upper neck. Based on its appearance and lifestyle, what is the most likely benefit of this adaptation?

A. Reduced air resistance and hence ability to reach high heights when flying

B. Greater visibility to spot and hunt prey from a great distance

C. Greater appeal of males to mating females and hence greater chance of reproductive success

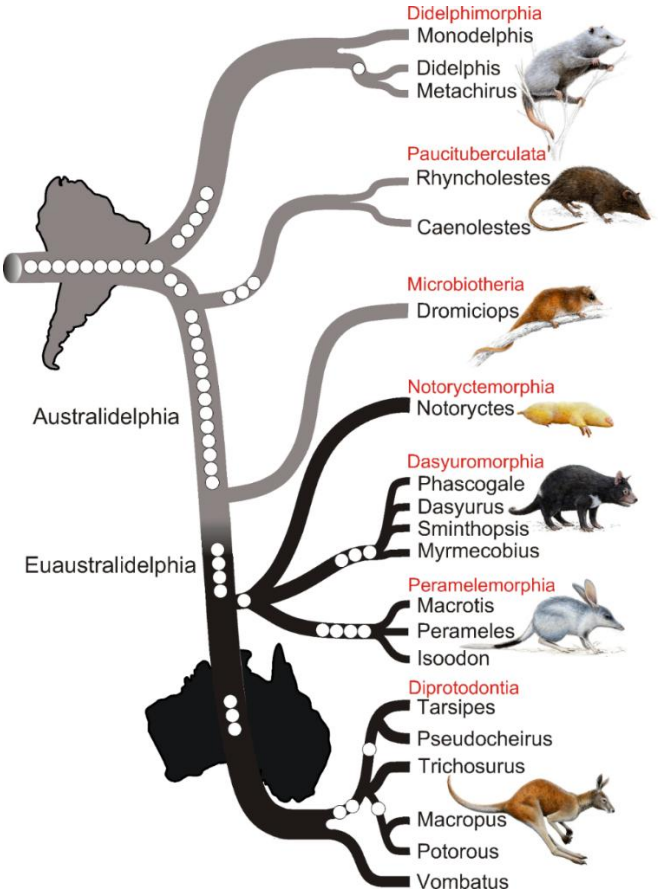
D. Reduced retention of bacteria and other microorganisms when feeding on animal carcasses

Info	***This information below relates to Questions 4 and 5***

Marsupials are a group of organisms found almost exclusively in Australia, including different species of kangaroo (genus: *Macropus*) and wombats (genus: *Vombatus*) and extinct animals such as the Thylacine (Order: *Dasyuromorphia)*.

Examples of marsupials found outside Australia include some species of opossum (order: *Didelphimorphia*) found in the Americas and the tree kangaroo (order: *Diprotontodia*) found in Papua New Guinea. Marsupials are believed to have first evolved in the Americas around 125 million years ago.

Today, the most diverse range of marsupials is found in Australia. The evolution of marsupials in Australia is depicted in the diagram below. Each branch indicates the divergence of a different order, family, genus or species, while the nodes indicate common ancestors.



Source obtained from wikimedia commons: https://commons.wikimedia.org/wiki/File:Phylogenetic_tree_of_marsupials_derived_from_retroposon_data_-_journal.pbio.1000436.g002.png Nilsson, M. A.; Churakov, G.; Sommer, M.; Tran, N. V.; Zemann, A.; Brosius, J. R.; Schmitz, J. R. (2010). "Tracking Marsupial Evolution Using Archaic Genomic Retroposon Insertions". *PLoS Biology* **8** (7): e1000436. DOI:10.1371/journal.pbio.1000436

4	**(1 mark)** Based on the image above, which of the following is the most accurate statement A. The branches “Potorus” and “Vombatus” shared a common ancestor more recently than “Potorus” and “Trichosurus” B. The branches “Dromiciops” and “Notorycytes” are more closely linked to each other than “Isoodon” and “Notorycytes” C. Of all the branches in the image, the order “Didelphimorphia” is likely to show the greatest amount of genetic differences when compared to Australian marsupials D. The order “Diprotodontia” is the only branch which relates to Australian marsupials
5	**(1 mark)** The best explanation for the widespread and diverse occurrence of marsupials in Australia is that A. They originated in the Americas and spread to Australia when the continents were once connected. Over time, they evolved to occupy different roles in Australian ecosystems B. They were introduced in Australia by early colonial settlers and rapidly grew in number and evolved to suit the Australian landscape C. An extinction event wiped out the marsupials in other parts of the world but created opportunities for Australian marsupials D. The introduction of other non-native mammals into Australian ecosystems by colonial settlers caused marsupials to adapt to occupy different functional roles in their ecosystems

Info

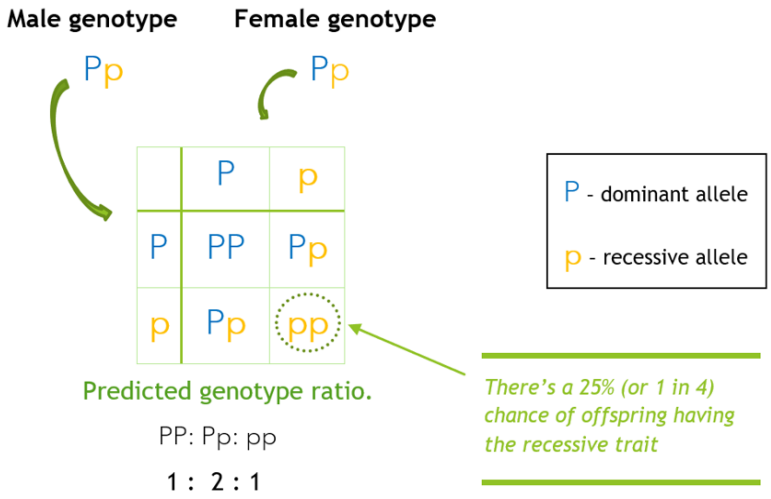
This information below relates to Questions 6 and 7

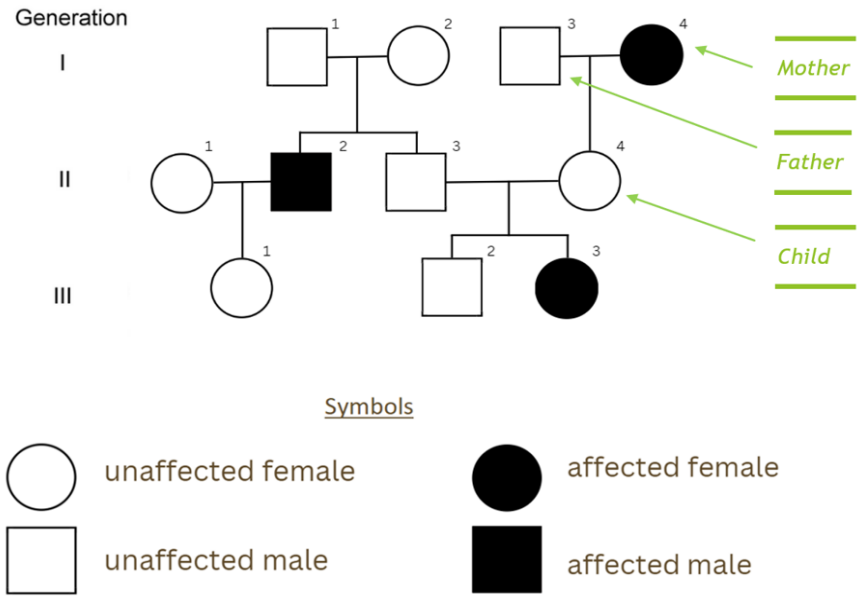
Information about Genetics

Mendelian genetics helps us explain some aspects of the inheritance of traits. Below is a table of terms relating to basic Mendelian inheritance principles. Use this information to answer the questions that follow.

Term	**Definition**
DNA	The biomolecule which contains all the information for traits.
Gene	A section of DNA which codes for a protein or a characteristic.
Alleles	Alternative forms of a gene.
Dominant allele	Any allele which will be expressed, irrespective of what other alleles for that trait are present.
Recessive allele	Any allele which will only be expressed if a dominant allele for that trait is not present.
Mutation	Any change in the DNA sequence, which results in changes to the protein being formed. Mutations MUST affect reproductive cells (sperm or egg) for the characteristic to be inherited.
Genotype	The collection of alleles present in an individual for a particular trait.
Phenotype	The manifestation of the genotype (i.e. what the individual looks like).

6	**(1 mark)** Humans have two copies of most genes (except in the case of rare genetic abnormalities or in relation to the X and Y sex chromosomes). Hence, if a genetically inherited characteristic does not appear in the parent generation, but is seen in at least one of the offspring, it is most likely that: A. The characteristic was acquired from elsewhere B. The characteristic is dominant C. The characteristic is recessive D. The characteristic is a mutation
7	**(1 mark)** When considering basic Mendelian inheritance principles, it is useful to classify individuals as genetic males or genetic females to trace the inheritance of sex-linked alleles. Genetic females have two X chromosomes, while genetic males have an X and a Y chromosome. The X and Y chromosomes contain different genes. Based on this, a trait is likely to: A. Mostly affect females, if it is recessive and on the X chromosome, and only affect males if it is on the Y chromosome B. Mostly affect females, if it is if it is recessive and on the X chromosome, and mostly affect males if it is on the Y chromosome C. Mostly affect males, if it is recessive and on the X chromosome, and mostly affect females if it is on the Y chromosome D. Mostly affect males, if it is recessive and on the X chromosome, and only affect males if it is on the Y chromosome

Info	***This information below relates to Questions 8 and 9*** Punnett squares are a useful tool which can help determine the probability of inheriting a particular allele. Below is a depiction of how a Punnett square is set up to predict the probability of an allele being inherited. Note: In this specific example, neither the dominant nor the recessive trait is more advantageous than the other for the survival of the organism. 
8	**(1 mark)** Based on this Punnett square, which of the statements below is **LEAST** accurate? A. There is a 1 in 2 chance that a child born to these two parents will be genetically identical to the two parents for this trait B. There is a 1 in 4 chance that a child born to these two parents will display a phenotype that wasn't seen in the parent generation C. If a child inherits the recessive allele, there is a 50% chance that the allele came from the father D. There is a greater chance for the dominant allele to be passed on than the recessive allele

9	**(1 mark)** The Punnett square above describes the possible outcomes of a monohybrid cross (i.e. only one trait is being investigated). Hence, there are 4 different genetic combinations, as shown above (4 grid squares). On the other hand, a dihybrid cross (where two traits are being investigated) can be depicted using a Punnett square with 16 grid squares, describing 16 different combinations. How many grid squares would you need to draw if you were exploring a trihybrid cross (i.e. 3 traits). A. 32 B. 64 C. 128 D. 256
Info	***This information below relates to Questions 10*** Pedigrees are another genetic tool which can be used to depict the occurrence of a trait over multiple generations. Below is an example of a pedigree for an autosomal recessive trait. An autosomal gene can be found on any other chromosome besides the sex chromosomes. 

10 **(1 mark)**

If the dominant allele is represented by a "T", and the recessive allele is represented by a "t", what best represents the genotype of individual 4 in generation II (labelled "child").

A. Tt

B. tt

C. TT

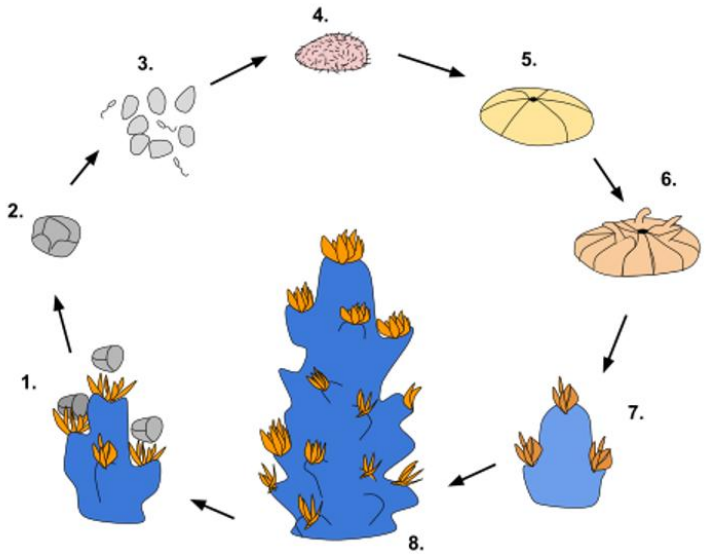
D. Not enough information to determine

Info ***This information below relates to Questions 11 and 12***

The human body maintains homeostasis (a stable internal environment) due to the actions of the nervous and endocrine systems. Below is a table which compares nervous and endocrine signals.

	Nervous	**Endocrine**
Type of message	Electrical impulses.	Chemical signals – hormones.
Transmission pathway	Along a network of neurons as impulses.	Transported in blood plasma (which is mostly water).
Comparing speed of messages	Generally faster.	Generally slower.
Outcome duration	Generally short-lasting.	Generally long-lasting.
Effects	Normally localised to a particular region.	Normally widespread to different regions.

11	**(1 mark)** Based on the information above, which of the following statements is most accurate? A. The nervous system is directly responsible for long term processes such as growth B. The endocrine system is directly responsible for responding to threats such as touching a hot object C. Neurons are more affected by changes in dietary intake than hormones D. Hormones which are insoluble in water are likely to need special carrier molecules to travel in blood
12	**(1 mark)** Endocrine pathways can be affected by negative or positive feedback mechanisms. In a negative feedback mechanism, the signal itself triggers a mechanism which causes a decrease in the intensity of the signal. For instance, an increase in blood glucose triggers the release of insulin, which eventually causes a decrease in blood glucose levels. On the other hand, a positive feedback mechanism will further amplify the signal. Based on this information, which of the following would be most likely to be an example of positive feedback: A. After a baby is born, a decrease in the pressure on the cervix causes a drop in the level of oxytocin, the hormone which was responsible for contractions. B. Blood clotting is caused by a series of chemical reactions which promote each other and the action of platelets to stop excessive blood loss from a wound C. Osmoregulation is initiated when low water levels in tissues triggers the release of the hormone ADH, which increases water reabsorption from the kidneys D. When an individual touches a hot object, they almost immediately retract their hands from the object to prevent damage

Info	***This information below relates to Questions 13 and 14*** Corals are organisms which can employ a range of reproductive strategies. As shown below, sexual reproduction takes place when gametes from separate coral combine to establish new colonies.  Source: Wikimedia commons. Author: Andcelano https://commons.wikimedia.org/wiki/File:Life_Cycle_of_Corals.svg Asexual reproduction normally occurs when polyps develop from mature coral and breakaway to expand or begin new colonies. Alternatively, fragmentation occurs when a section of coral falls away and establishes a new colony.
13	**(1 mark)** When comparing the genetic diversity of offspring and their parents, fragmentation is most similar to A. Polyp based asexual reproduction B. Sexual reproduction C. Equally different from sexual and asexual reproduction D. Not enough information to decide

14	**(1 mark)** Which of the following statements most accurately identifies an advantage and a disadvantage of the specific reproductive strategies mentioned in the statement? A. Advantage of fragmentation - results in the genes from the healthiest part of the coral forming offspring. Disadvantage of sexual reproduction - can result in traits from two separate coral being expressed. B. Advantage of sexual reproduction - results in a greater degree of genetic diversity. Disadvantage of fragmentation - enables a coral to form a new colony in another region, using a small part of its own structure. C. Advantage of sexual reproduction - generally requires more energy and resources. Disadvantage of sexual reproduction - relies on gametes joining together. D. Advantage of asexual reproduction - ensures that beneficial traits are almost certainly passed on to the next generation. Disadvantage of asexual reproduction - limits the amount of genetic diversity in offspring.

	CHEMISTRY
15	**(1 mark)** Sam has accidentally mixed salt, sugar and naphthalene (the main ingredient in mothballs). These three substances have different solubilities in different solvents. Based on the information below, what is the quickest way for Sam to recover the salt from the mixture? **Substance** | **Soluble in water?** | **Soluble in ethanol?** | **Soluble in hexane?** Salt | Yes | No | No Sugar | Yes | Yes | No Naphthalene | No | Yes | Yes Pick the correct words from the drop-down boxes. Add *(water/ethanol/hexane)* to the mixture, stir and filter, and then *(dry/evaporate)* the *(filtrate/residue)*.
16	**(1 mark)** ***Information about Bond Enthalpy*** One of the signs of a chemical reaction is a temperature change. This happens because heat energy is either **absorbed** (making the surroundings cooler) or **released** (making the surroundings warmer.) During a chemical reaction: ● Bonds in the reactant molecules must be broken to free up the atoms (which absorbs energy) ● New bonds are formed between the atoms to make the product molecules (which releases energy) Each type of chemical bond has a specific **bond enthalpy** – this is the amount of energy it takes to break the bond. The same amount of energy is released when that bond is made.

Imagine atoms A and B. A and B can bond together to form three simple diatomic (two-atom) molecules: AB, A2 and B2. The bond enthalpies for these pairs of atoms are shown below.

Bond	**Bond Enthalphy (arbitrary units)**
A-B (a chemical bond between an A atom and a B atom)	300
A-A	280
B-B	140

Which of the following reactions would have the overall effect of cooling the surroundings?

Reaction 1: $AB \rightarrow A + B$
Reaction 2: $2AB \rightarrow A_2 + B_2$
Reaction 3: $A_2 + B \rightarrow AB + A$

A. Reaction 1 only

B. Reaction 2 only

C. Reaction 3 only

D. Reactions 1 and 2

E. Reactions 1 and 3

F. Reactions 2 and 3

G. All three reactions

Info

This information below relates to the following two questions (17 and 18)

The rate of a reaction is how fast it occurs. For instance, explosions – which happen very quickly – are chemical reactions with **high rates**.

A student was studying the reaction between magnesium metal and hydrochloric acid. Their aim was to determine how the concentration of hydrochloric acid affected the rate of the reaction.

They prepared five solutions of hydrochloric acid in beakers. The volumes they used are shown in the table below. They added an identical 0.2g piece of magnesium to each beaker and timed how long it took for the piece of magnesium to disappear. From the time value, they were able to calculate a rate.

They noticed that beakers 1 and 2 became slightly warm. For beakers 3, 4 and 5 it was hard to tell whether a temperature change had occurred.

Their results are shown below.

Experiment	**Volume of hydrochloric acid solution (mL)**	**Volume of water (mL)**	**Time taken for magnesium to disappear (s)**
1	50	0	11
2	40	10	16
3	30	20	20
4	20	30	32
5	10	40	didn't disappear

17

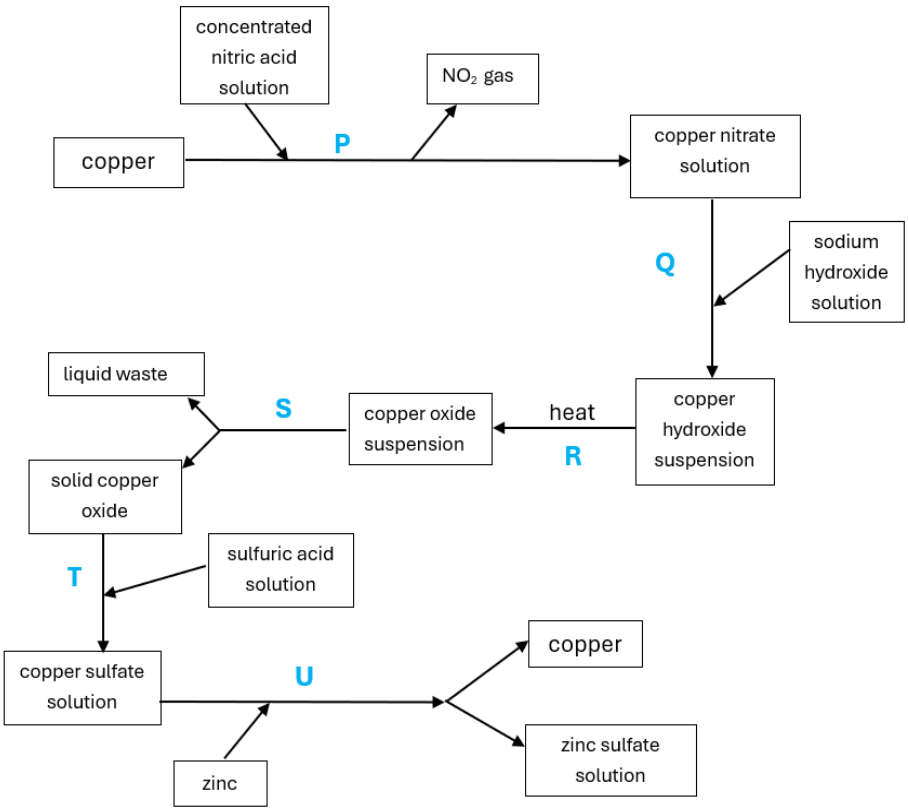
(1 mark)

After determining the rate of the reaction in each experiment, the student wrote a conclusion based on their aim. Select words in the drop-down boxes to make this conclusion accurate.

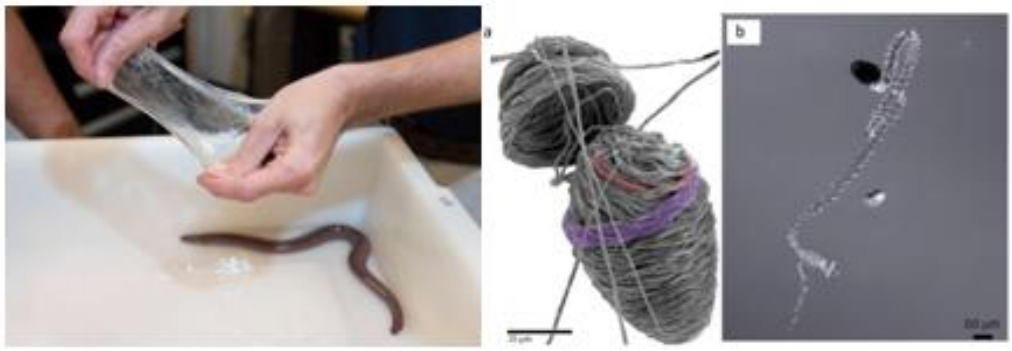
As the *(volume/concentration)* of *(hydrochloric acid/magnesium/water)* *(increases/decreases)*, the rate increases.

18	**(1 mark)** Which of the following statements is/are true for this set of experiments? Statement 1: A 100mL beaker is the most appropriate piece of equipment to measure out the volumes of liquid. Statement 2: When the reactions in experiments 1-4 were complete, the solutions in the beakers still contained some acid. Statement 3: The total volume of the reaction solution is a dependent variable in this experiment. A. Statement 1 only B. Statement 2 only C. Statement 3 only D. Statement 1 and 2 E. Statement 2 and 3 F. Statement 1 and 3 G. All three statements
19	**(1 mark)** ***Information about Nuclear decay*** Two common forms of nuclear decay are alpha decay and beta-minus decay. In alpha decay, the unstable nucleus ejects a helium nucleus (two neutrons and two protons). In beta-minus decay, a neutron in the unstable nucleus transmutes into a proton and an electron; the electron is ejected from the atom and is called a beta-minus particle.

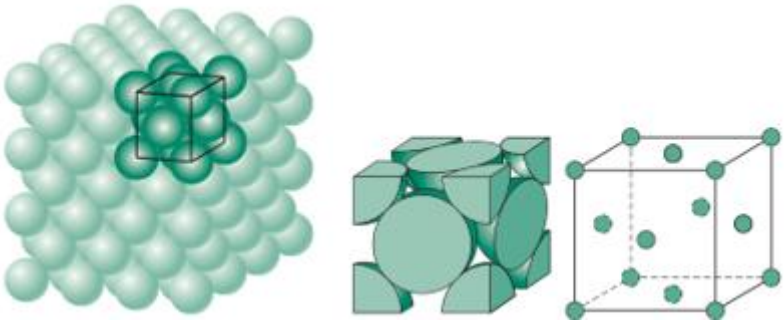
	Astatine is the rarest naturally occurring element in the Earth's crust, occurring only as the decay product of various heavier elements. Astatine-219 can transmute into astatine-215. Which sequence of decays would achieve this transmutation? A. Alpha, beta-minus, beta-minus B. Beta-minus, alpha C. Alpha, alpha D. Beta-minus, beta-minus, beta-minus.
20	**(1 mark)** 1.40g of a substance X was burned in oxygen. This produced 0.95g of water, 3.90g of carbon dioxide and 0.21g of nitrogen as the only products. The mass of O2 used in this combustion reaction was: A. 5.06g B. 3.66g C. 1.40g D. There is insufficient information given to carry out the calculation

Info	***This information below relates to the following four questions (21, 22, 23 and 24)*** The flowchart below shows a series of separations and chemical reactions.  The process starts with copper metal, which goes through steps P, Q, R, S, T and U. During the process, the copper atoms are incorporated into new substances, but when Step U is finished, they are recovered as copper metal again.
21	**(1 mark)** Step P is represented by the following chemical equation. Select the right coefficients to balance the equation. ___HNO_3 (aq) + ____ Cu (s) → ___ $Cu(NO_3)_2$ (aq) + ___ NO_2 (g) + ____ H_2O (l)

22	**(1 mark)** What type of reaction are reactions R and U? Reaction R: (Choose ONE) combination, decomposition, single displacement, double displacement, combustion Reaction U: (Choose ONE) combination, decomposition, single displacement, double displacement, combustion.
23	**(1 mark)** Apart from water, what is the primary substance present in the liquid waste that is separated in step S? A. sodium hydroxide B. sodium nitrate C. copper oxide D. copper hydroxide

24	**(1 mark)** Which of the following could cause a lower mass of copper metal than expected to be produced in Step U? I. Too much nitric acid added in step P II. Not enough NaOH solution added in step Q III. Not enough zinc added in step U A. I. only B. III. only C. II. and III. only D. I., II. and III.
25	**(1 mark)**  Figure 1: hagfish slime Figure 2a: Electron micrograph of protein strand (still coiled) from inside a gland thread cell Figure 2b: A protein strand in the process of uncoiling Source: Slime: Public domain: https://timelessmoon.getarchive.net/amp/media/dr-ryan-kincer-demonstrates-the-elasticity-of-the-authentic-pacific-hagfish-0f1ae8 Gland thread cell: *Cells* **2016**, *5*(2), 25; **https://doi.org/10.3390/cells5020025** When hagfish (also known as slime eels) are alarmed, they can create a large volume of slime around themselves in a very short period of time (Figure 1). They do this by squirting a fluid from special glands into the surrounding water. This fluid contains cells known as gland thread cells.

	Each cell contains an incredibly long strand of protein coiled tightly into the cell (Figure 2a). Released into water, the gland thread cells break open. The protein strands inside uncoil within a fraction of a second (Figure 2b) and tangle together to make a loose gel. • A typical gland thread cell has a volume of about 0.0002 mm^3. • The protein strand has the shape of a very long, thin cylinder with an average radius of 0.6μm (1 μm = 1 x 10-6 m) • The cylinder fills 70% of the volume of the cell • A hagfish can release 20000 cells in a single slime event a) Calculate the total length of protein strands (to the nearest metre) released by a hagfish in a single slime event b) Give your answers to 2 significant figures

26	**(1 mark)** The element iridium is incredibly dense – second only on the Periodic Table to osmium. It is hard, relatively brittle for a metal, and is rare in the Earth's crust. It forms ions of many different charges. One of the many compounds formed by iridium has the formula Sr2MgIrO6. Assuming this is an ionic compound, what is the charge on the iridium ion? Charge on the iridium ion: +6/+5/+4/+3/+2/+1/-1/-2/-3/-4/-5/-6
Info	***This information below relates to the next two questions (26 and 27)*** In iridium metal, the iridium atoms are arranged in a lattice (see Figure a). The geometry of this lattice is called 'face-centered cubic'. The darker atoms in Figure a indicate a single 'unit cell': this is the most basic unit that is repeated to make the larger lattice. However, each of the atoms in this unit cell is shared with at least one neighboring unit cell. If we slice down the faces of the unit cell to reveal only the portion of each atom that is within the unit cell, we get Figure b. Figure c shows the 14 atoms that contribute to one unit cell as small dots.  Figures a, b and c. Diagram: https://www.e-education.psu.edu/matse81/node/2133 CC BY-NC-SA 4.0

27	**(1 mark)** How many whole atoms are represented in a single unit cell? A. 4 B. 5 C. 10 D. 14
28	**(1 mark)** In iridium, each unit cell (Figure b) is a cube with a side length of 383.92 pm (1 picometre = 1 x 10^{-12} m). The mass of one iridium atom = 192.217u (1u = 1.66 x 10^{-24} g) Calculate the density of iridium in g/cm^3. Give your answer to 1 decimal place.

Info

Information about waves

- The speed of waves in matter depends on properties of the medium through which it travels.
- The speed of electromagnetic waves, which consist of oscillating electric and magnetic fields, is given by the speed of light
$$c = 3 \times 10^8 ms^{-1}$$
- The frequency, f, of a periodic wave is determined by how many oscillations (cycles) of the medium occur per second
- The period, T, is the length of time required for one whole oscillation (cycle) to occur.
- The wavelength, λ, of a wave (how far the wave travels in one whole cycle) is related to the velocity and frequency as $\lambda = v/f$

This information below relates to the next two questions (29 and 30)

The wavelengths of light an object reflects determines the colour of the object.
Some objects absorb all visible light wavelengths, so they appear black. Other objects only absorb some wavelengths of light.

Different plant pigments can absorb light with a range of different wavelengths, as shown in the graph below. Note: $1nm = 1 \times 10^{-9}m$.

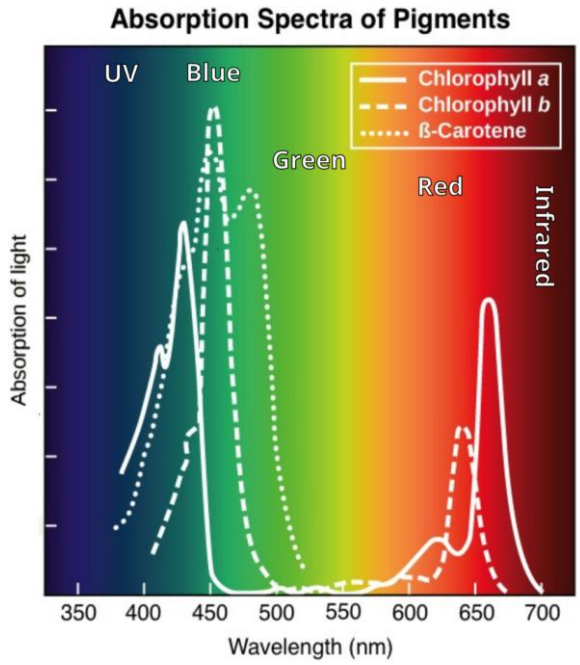
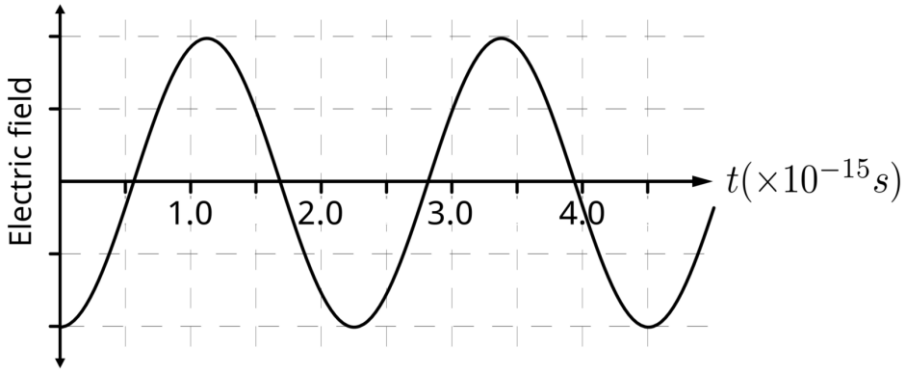


Image modified from "The light-dependent reactions of photosynthesis: Figure 4," by OpenStax College, Biology (CC BY 3.0)

29 **(1 mark)**

The graph below shows the variation in the electric field over time for a particular light wave.



The light waves shown in the graph could be absorbed by:

A. Chlorophyll a, Chlorophyll b and β-carotene

B. Chlorophyll a and Chlorophyll b

C. Chlorophyll a and β-carotene

D. Chlorophyll b and β-carotene

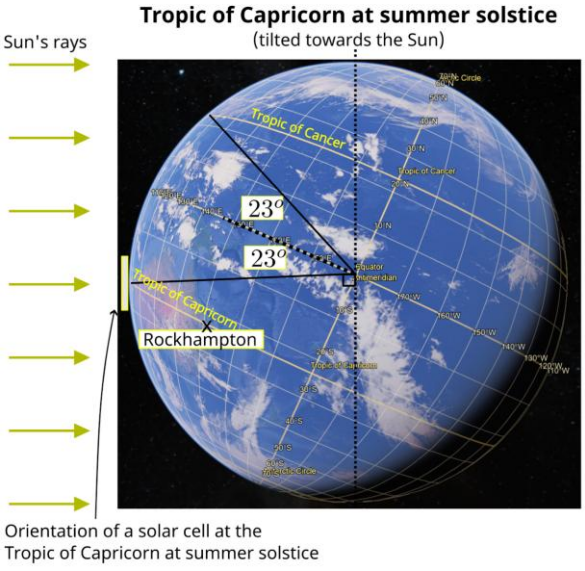
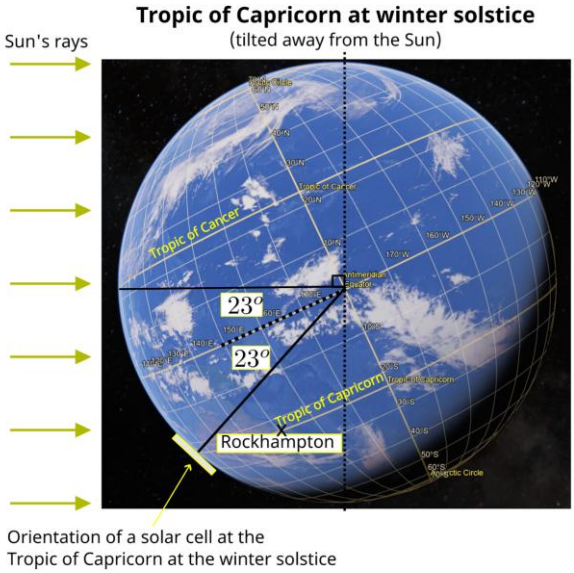
E. Chlorophyll a

F. Chlorophyll b

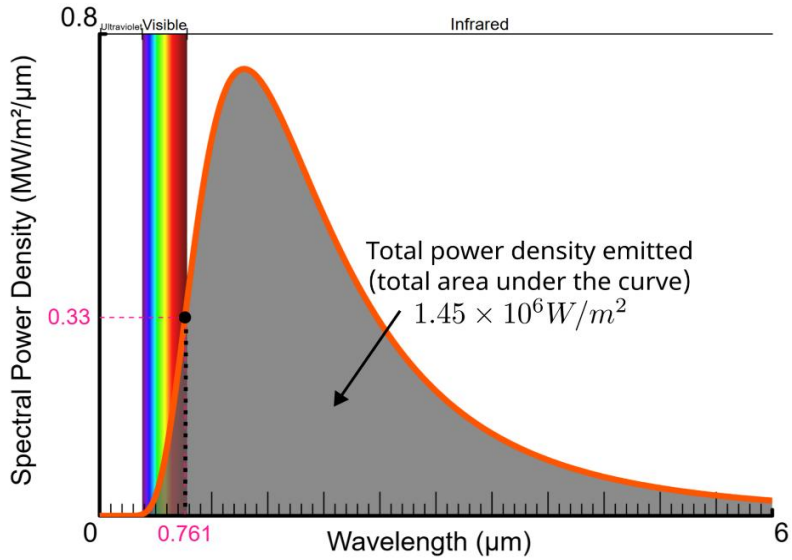
G. β-carotene

H. None of the pigments

30	**(1 mark)** A carrot contains β-carotene but not Chlorophyll pigments. A particular leaf contains Chlorophyll a and Chlorophyll b but not β-carotene. Both the carrot and leaf are illuminated with red light, which has a wavelength of $\lambda = 650nm$. What colour will the carrot and leaf appear to be? **Carrot** (drop down list) Black Blue Red Green Orange **Leaf** (drop down list) Black Blue Red Green Orange
31	**(1 mark)** Energy usage in Australia can be measured in kilowatt hours or joules. 1 kWh is equivalent to the energy transferred to a device that uses 1000 joules every second, if the device runs for 1 hour. A family living in Rockhampton in Queensland uses 25kWh on average each day (close to the Australian average) How many joules of energy does the family use on average each day? Give your answer to the nearest million joules.

Info	**The following information is used for the next question** Apart from energy released inside the earth due to natural nuclear decay processes, all energy input to Earth arrives as electromagnetic radiation from the Sun. The irradiance (power per square meter) varies over the surface of the earth as • the Earth is an oblate spheroid (that can be approximated as a sphere), and • is tilted on its axis at an angle of 23^o   • In the Southern Hemisphere, the summer solstice occurs when the sun is directly over the Tropic of Capricorn, which is located at 23° latitude South, and runs through Australia, Chile, southern Brazil, and northern South Africa. For every place south of the Tropic of Capricorn, the sun is at its highest point in the sky and this is the longest day of the year. • The winter solstice marks the shortest day and longest night of the year. At the winter solstice in the Southern Hemisphere, the sun is directly over the Tropic of Cancer, which is located at 23° north of the equator. Rockhampton (see label in the figure above) is situated close to the tropic of Capricorn. At the summer solstice the irradiance in the middle of the day at the tropic of Capricorn is $1100 W m^{-2}$.

32	(**2 marks)** The family in Rockhampton are considering purchasing solar panels for their flat roof to provide some of their electrical power. The commercial solar cells they plan to buy have an efficiency of 22% and each solar panel is 1.7m long by 1.0m wide. a) (0.5 marks) If one of these solar panels were placed flat on the family's horizontal roof in the middle of the day on the summer solstice, what electrical power could the panels generate? b) (1.5 marks) What percentage of the power you calculated in the previous question would be produced by the same solar cell during the middle of the day on the winter solstice in Rockhampton (when the sun is directly overhead for the topic of Cancer)? Input your answer to the nearest percent.
33	**(1 mark)** In the past, incandescent light bulbs were used for converting electrical energy to light in homes. These devices use electrical energy to heat a wire filament to a high temperature so that it glows, producing electromagnetic waves. Just like the sun, incandescent light bulbs produce electromagnetic waves with a range of wavelengths. However, as a light bulb is cooler than the sun, most energy is emitted in the infrared region of the spectrum and only a small fraction at wavelengths that are visible to humans and useful for lighting. The amount of light energy emitted at different wavelengths by an incandescent bulb operating at a temperature of 2250K is shown below. • The area under the graph over a particular range of wavelengths is equal to the total power emitted in that range of wavelengths per m^2 of the surface of the filament. • The units of the area, MWm^{-2}, are the product of the units on the vertical axis, $MWm^{-2}\mu m^{-1}$ and the units on the horizontal axis, μm.



Credit: https://phet.colorado.edu/sims/html/blackbody-spectrum/latest/blackbody-spectrum_all.html

Use the area on the graph corresponding to visible wavelengths to estimate the efficiency of a light bulb at producing visible light from electrical energy.

A. 0.1%

B. 0.2%

C. 1%

D. 2%

E. 4%

F. 6%

Info

Information about circuits

- The electrical energy transformed to heat and light by an incandescent bulb increases with increasing current through the bulb and increases with increasing voltage difference across the globe.

- Current is the amount of electrical charge that flows past a point per second, while the voltage difference between two points in a circuit is the difference in electrical potential energy per unit charge between those points.

The current that flows through a globe is determined by

$$I = V/R$$

- where V is the voltage difference across the globe and R is the electrical resistance of the globe.

- Any points in a circuit connected by a wire are at the same voltage.

- Around any complete loop in a circuit, the voltage differences across the components add to zero (Kirchoff's loop rule: conservation of energy)

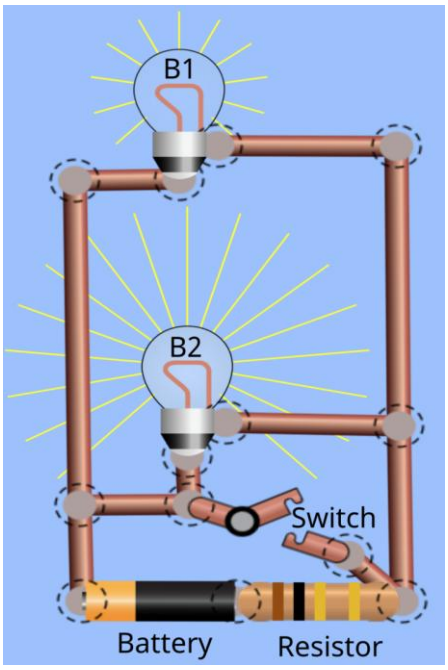
- The sum of currents into any junction in a circuit is equal to the sum of current out of the junction. A corollary is that if there is no junction, the current must remain constant. (Kirchoff's junction rule: conservation of charge).

This information below relates to the next two questions (34 and 35)

Electrical energy is delivered to light bulbs through electrical circuits.

An electrical circuit which uses incandescent light bulbs is shown below.

- Bulb B1 has a different resistance to bulb B2.
- Bulb B2 converts more electrical energy to light per second than bulb B1 (that is, B2 glows brighter than B1)



34 **(1 mark)**

Why is bulb B2 glowing brighter than bulb B1?

A. B2 has a lower resistance than B1 but the same voltage across it.

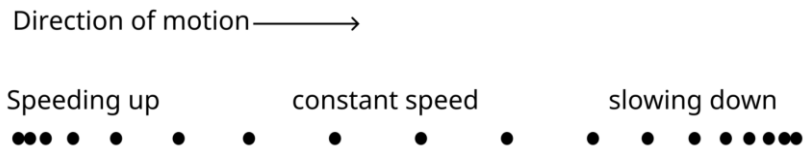
B. B2 has a lower resistance than B1 but the same current flowing through it.

C. B2 has a lower resistance than B1 but has a greater voltage difference across it.

D. B2 has a higher resistance than B1 with the same voltage difference across it.

E. B2 has a higher resistance than B1 but has the same current flowing through it.

F. B2 has a higher resistance than B1 and has a higher current flowing through it.

35	**(1 mark)** If the switch was closed (so that a current flows through it), what would happen to the brightness of the bulbs? A. B1 would go out, but B2 would be unaffected B. B2 would go out, but B1 would be unaffected C. Both bulbs would be unaffected D. Both bulbs would go out E. B2 would become brighter and B1 dimmer F. B1 would become brighter and B2 brighter G. Both bulbs would become brighter
Info	## Information about **motion** • A motion diagram consists of dots showing the position of an object at equal intervals of time. If the distance travelled between dots becomes larger, then the object is speeding up, if the distance becomes smaller the object is slowing down. Example: A motion diagram for someone running is shown below:  The **velocity** (speed with direction) of an object is $$v = \frac{x_f - x_i}{t}$$ • where x_i is the position at the start of a time interval t and x_f is its position at the end of the time interval. The velocity is the slope (gradient) of a position-time graph. An **acceleration** is a change in the speed and/or direction in which an object is moving, and is given by

$$a = \frac{v - u}{t}$$

- where u is the initial speed, v is the final speed and t is the time interval over which the change occurs. The acceleration is the slope (gradient) of a velocity-time graph.
- The acceleration of an object in free-fall is $g = 9.8ms^{-2}$.
- Useful relationships between the initial speed u, final speed v, change in position, s and the time interval t for a constant acceleration a are given below:

$$s = ut + \frac{1}{2}at^2$$

$$v^2 = u^2 + 2as$$

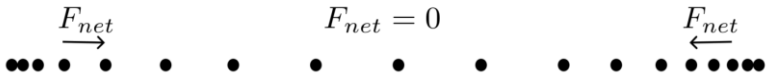
Information about **forces**

An object will accelerate when a **net force** acts on the object, according to Newton's 2nd law

$$F_{net} = ma$$

- where m is the mass of the object and a is its acceleration.

  Example: The direction of the net force acting on someone running can be determined from their motion diagram.



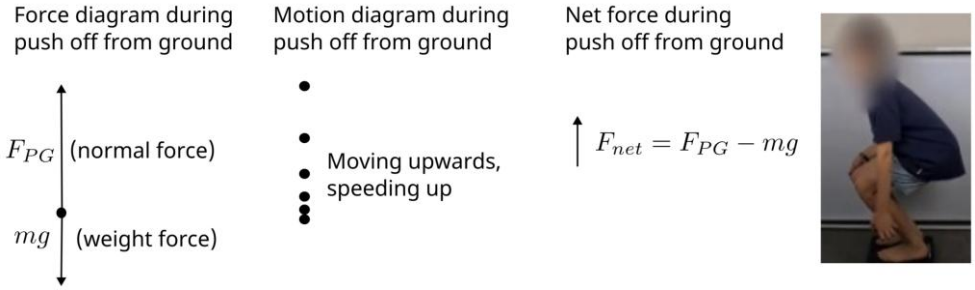
- When more than one force acts on an object the net force is the sum of the forces, taking direction into account. A **force diagram**, which shows the direction and size of the forces acting on the object using arrows is a useful tool for analysing these situations. Force diagrams only include forces.

- A **contact** force acts at any point that the external environment touches an object.

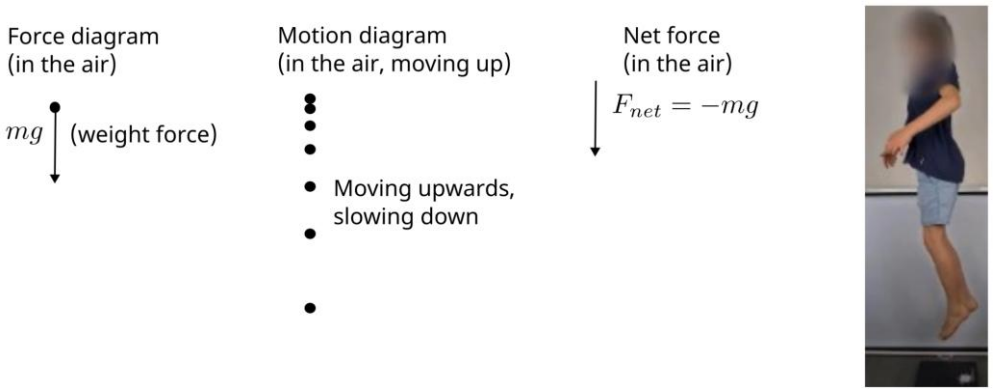
- **Non-contact** forces include the force on an object due to the gravitational attraction between it and the Earth (its **weight**), equal to $F_g = mg$, where $g = 9.8ms^{-2}$.

  Example: The force diagram for a person as they jump upwards is shown below. While they are touching the ground there are two forces on them, a contact force that acts upwards on the person due to the ground, F_{PG}, and a non-contact force mg (their

weight). These add (taking direction into account) to an upwards net force, so the person speeds up in the vertical direction.



Once the person is in the air, if they are not touching anything, then the only force acting on them is the weight force, so they accelerate downwards even though they are still moving up.

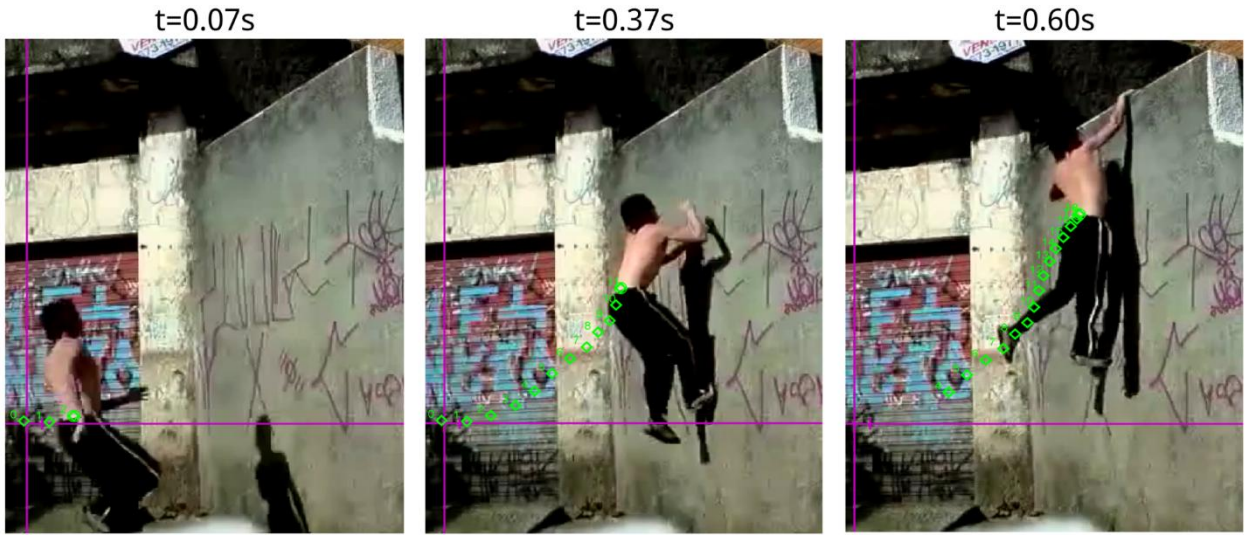


This information below relates to the following six questions (36, 37, 38, 39, 40 and 41)

In the discipline of Parkour, practitioners (traceurs) practice moving between two places in the most efficient way possible with no assisting equipment.

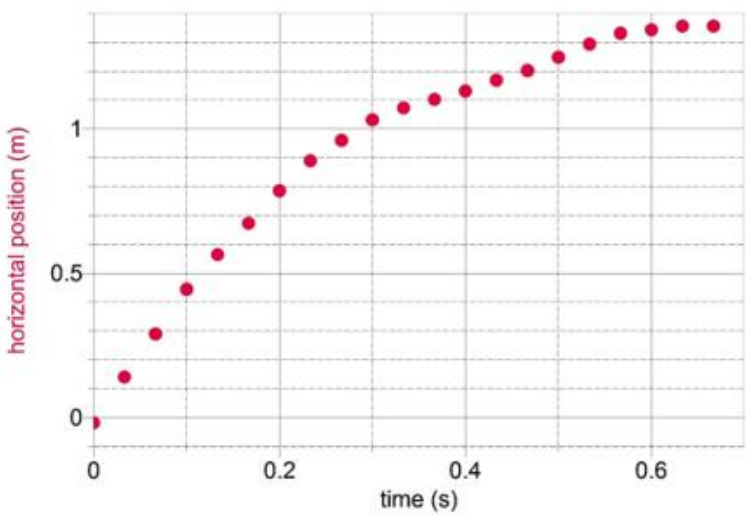
When a traceur performs a 'wall run', they make contact with the wall with their feet and hands during the jump, finishing with their hands over the top of the wall.

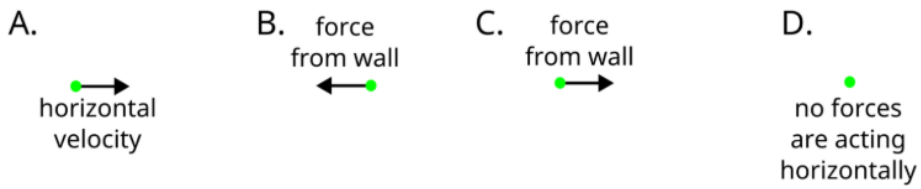
Video analysis has been used in a video of a Parkour wall run to place green markers at equal intervals of time to show the horizontal and vertical position of the traceur's waist, so producing a motion diagram for the traceur as he jumps.

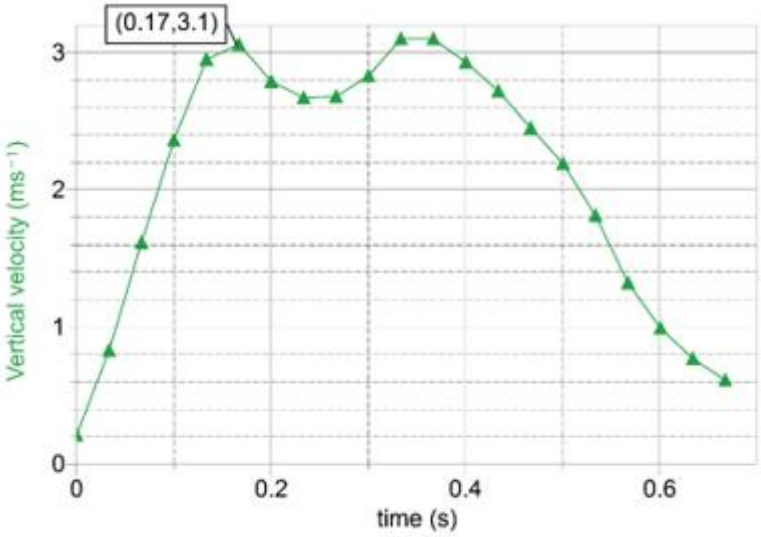


(Credit for original video: Marco Gomes from São Paulo, Brasil, CC BY 2.0 <https://creativecommons.org/licenses/by/2.0>, via Wikimedia Commons https://en.wikipedia.org/wiki/File:Parkour_-_climb_stairs.ogv

Below is the graph of the **horizontal position** of the traceur as he performs the jump. A screenshot from the video at time $t = 0.30s$ is also shown.



36	**(1 mark)** Which of the following statements best describes the **horizontal** velocity of the traceur for the time period shown in the graph? A. It initially increases rapidly, then later increases at a slower rate B. It initially increases at a constant rate then gradually decreases C. It is initially constant. It decreases then briefly increases, then decreases again D. It is initially constant. It increases then briefly decreases, then increases again
37	**(1 mark)** Use information in the graph and photo to determine which of the following force diagrams correctly represents the horizontal force/s acting on the traceur at the time $t = 0.30s$? 

Info	***The following information is used for the next three questions (38, 39 and 40)*** The vertical velocity of the traceur has been obtained by dividing the vertical displacement of the traceur by the time interval in which it occurs. This graph is shown below and is used in the next three questions. The moment the traceur's foot leaves the ground is marked on the graph as the point (0.17, 3.1), and is shown in the screenshot from the video below.  

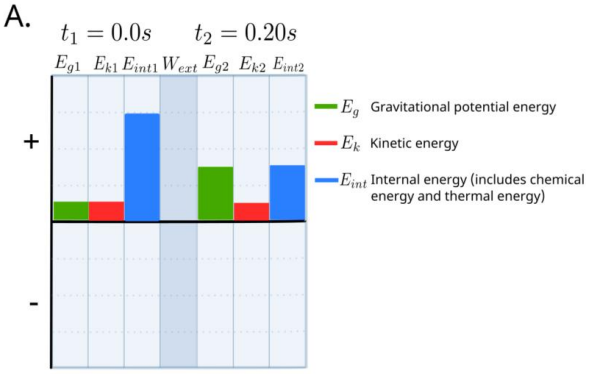
38	**(1 mark)** Between the time the traceur's foot leaves the ground at time $t = 0.17s$ and the time he places his hand on the top of the wall at $t = 0.60s$, his waist undergoes a vertical displacement of $\Delta y_{wall\ run} = 1.13m$. What **additional** vertical displacement does the traceur achieve by pushing on the wall during the jump, above what he could achieve simply by jumping upwards with the same initial speed? A. 0.49m B. 0.64m C. 0.72m D. 0.78m E. 0.83m
39	**(1 mark)** Use information in the graph of the vertical velocity versus time to calculate the average vertical acceleration of the traceur between times $t = 0.0s$ and time $t = 0.17s$ (the time period where he is pushing off the ground). A. $17ms^{-2}$ B. $18ms^{-2}$ C. $19ms^{-2}$ D. $20ms^{-2}$ E. $21ms^{-2}$

40	**(1 mark)** Use the information in the graph of vertical velocity-time to determine the average force the **wall** exerts upwards on the traceur between the times $t = 0.25s$ and time $t = 0.35s$. Take the mass of the traceur to be 70kg. A. 0.40N B. 4.0N C. 28N D. 70N E. 97N F. 280N G. 700N H. 970N
41	**(1 mark)** Energy transformations can be represented using a 'work-energy bar chart' (WEBC). In a WEBC: • the types of energy initially present in a system are shown as vertical bars on the left side of the chart and the types of energy present in a system at the end of a given time period are shown on the right side of the chart. • The height of each vertical bar is proportional to the amount of that type of energy. • Any energy transferred between the system from the environment (or vice-versa) is shown in the central shaded bar. Conservation of energy requires that: $$E_i + W_{ext} = E_f$$ Where:

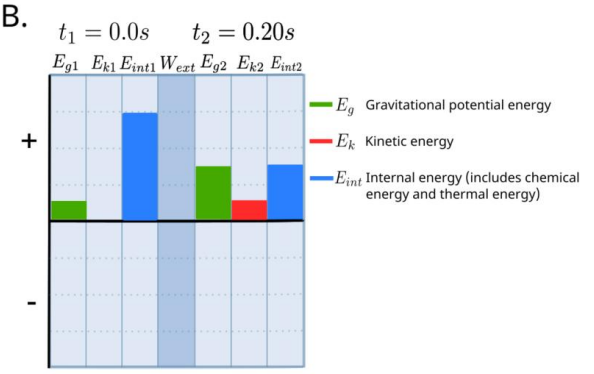
E_i is the sum of all the types of energy in the system at the start of the process
W_{ext} is the energy transferred to or from the system (the 'work' done by external forces)
E_f is the sum of all the types of energy in the system at the end of the process.

Identify which of the following could be a correct representation of the energy transformations that occur in the system consisting of the traceur and Earth between the **times *t*=0.0s and *t*=0.20s.**

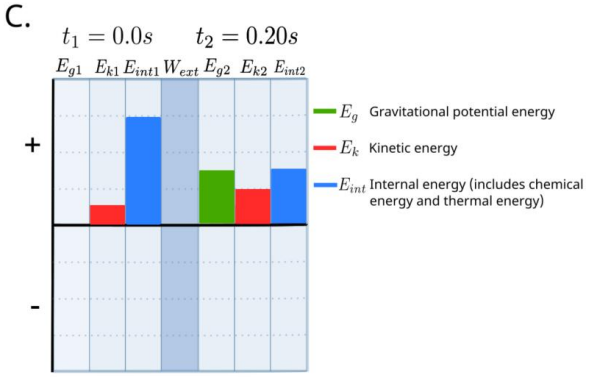
A.



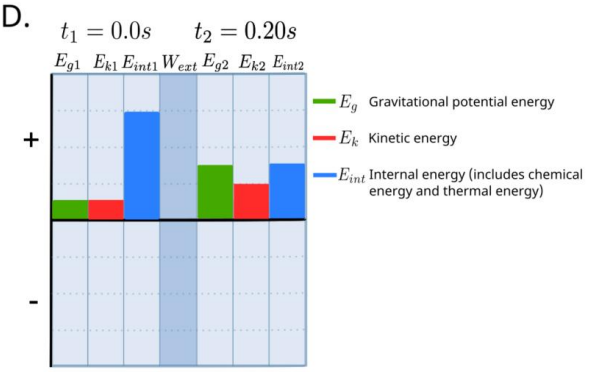
B.



C.

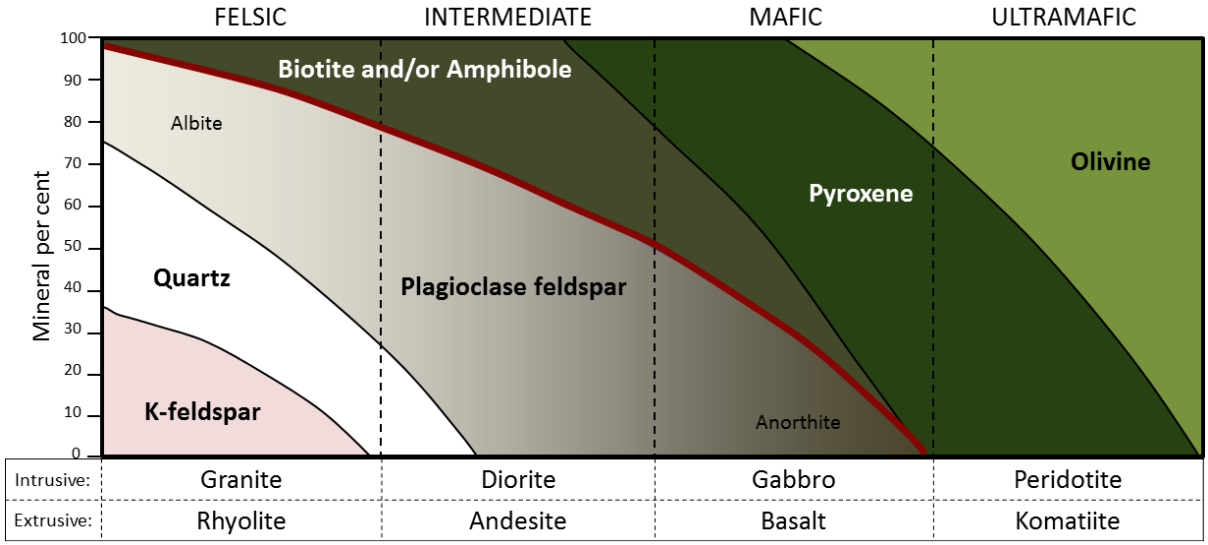


D.



EARTH SCIENCE RESOURCES

Igneous rock classification by mineral composition.



- Volcanic (extrusive) rocks cool quickly at the surface and may not have a chance to develop many minerals to a visible size, with some minerals microscopic and some magmatic material cooling to non-crystalline glass. Gases escaping to the surface often form bubbles in the lava.
- Plutonic (intrusive) rocks cool slowly thousands of metres below the surface, under pressures too high for gases to form bubbles, and all magmatic material develops into visible crystals.
- Colour is not usually a good guide to mineral identification, but Felsic rocks tend to be light colours because quartz is often white or clear and feldspars are usually white or pale pink.
- Mafic rocks tend to be dark colours because pyroxene and amphibole are usually very dark green or black. Lots of dark coloured minerals ‘hide’ the lighter coloured ones.
- Ultramafic rocks are usually distinctly green because olivine is always green or yellow-green.
- Intermediate rocks tend to be grey in colour, in between Felsic and Mafic!

Metamorphic rock table

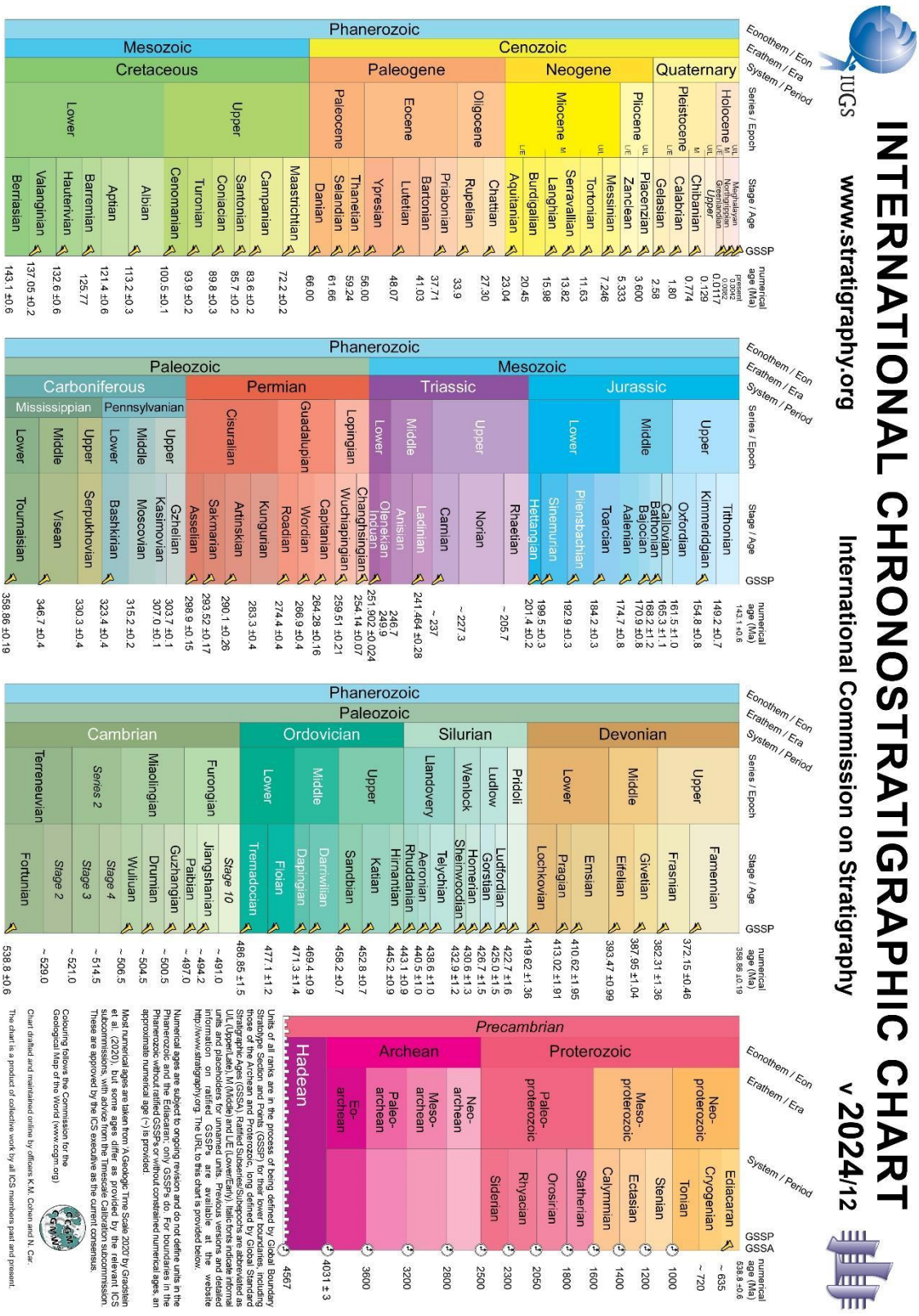
Starting rock		V Low Grade	Low Grade	Medium Grade	High Grade
Mudrock*	Regional Metamorphism	Slate	Phyllite	Schist	Gneiss
Granite		No change	No change	Almost no change	Granite gneiss
Basalt		Greenschist	Greenschist	Amphibolite	Amphibolite
		Regional metamorphic grade is based on a combination of temperatures and pressures, mostly found in tectonic collision zones. The higher the grade the higher both the temperature and pressure.			
Sandstone	Contact Metamorphism	No change	Little change	Quartzite	Quartzite
Limestone		Little change	Marble	Marble	Marble
Mudrock*		No change	Little change	Hornfels	Hornfels
*Shale is a mudrock with obvious layering. Mudstone is mudrock with no obvious layering.		Contact metamorphic grade is based on temperature changes at relatively low pressure, usually found adjacent to large igneous intrusions. The higher the grade the higher the temperature.			

A simplified guide to the types of metamorphic rocks that form from different starting rocks at different metamorphic grades. For example; *Greenschist* is a low grade regional metamorphic rock that forms when Basalt is the starting rock.

Sedimentary rock classification

<table>
<tr><th colspan="2">Granular sediment name</th><th>Grain size diameter</th><th colspan="2">Sedimentary rock name</th></tr>
<tr><td rowspan="3"></td><td>Large boulder</td><td>>630 mm</td><td colspan="2" rowspan="6">Conglomerate
or Breccia*</td></tr>
<tr><td>Boulder</td><td>200 – 630 mm</td></tr>
<tr><td>Cobble</td><td>63 – 200 mm</td></tr>
<tr><td rowspan="3">Gravel</td><td>Coarse gravel</td><td>20 – 63 mm</td></tr>
<tr><td>Medium gravel</td><td>6.3 – 20 mm</td></tr>
<tr><td>Fine gravel</td><td>2.0 - 6.3 mm</td></tr>
<tr><td rowspan="3">Sand</td><td>Coarse sand</td><td>0.63 - 2.0 mm</td><td colspan="2" rowspan="3">Sandstone</td></tr>
<tr><td>Medium sand</td><td>0.2 - 0.63 mm</td></tr>
<tr><td>Fine sand</td><td>0.063 - 0.2 mm</td></tr>
<tr><td rowspan="4">Silt</td><td>Coarse silt</td><td>0.02 - 0.063 mm</td><td rowspan="2">Siltstone</td><td rowspan="3">Mudstone
or
Shale</td></tr>
<tr><td>Medium silt</td><td>0.0063 - 0.02 mm</td></tr>
<tr><td rowspan="2">Fine silt</td><td rowspan="2">0.002 - 0.0063 mm</td><td rowspan="2">Claystone</td></tr>
<tr><td colspan="2">Clay</td><td>≤0.002 mm</td></tr>
<tr><td colspan="5">*Conglomerate has rounded grains; breccia has angular grains.</td></tr>
<tr><th colspan="2">Non-granular sediment name</th><th>Features</th><th colspan="2">Sedimentary rock name</th></tr>
<tr><td colspan="2">Lime-rich mud</td><td>High proportion of calcium carbonate mixed with clays</td><td colspan="2">Marl or Marlstone</td></tr>
<tr><td colspan="2">-</td><td>Mostly calcium carbonate materials from accumulations of shells, corals, etc</td><td colspan="2">Limestone</td></tr>
<tr><td colspan="2">-</td><td>Soluble minerals left behind when water evaporates from lakes and oceans.</td><td colspan="2">Evaporite</td></tr>
</table>

A simplified guide to the types of sedimentary rocks formed from granular material and other sedimentary rocks formed by the accumulation of materials in other ways. For example; a *sandstone* is formed by the compaction of sand grains deposited together by the movement of water or wind but a *limestone* can be formed by the on-site accumulation of carbonate materials, often the skeletons of corals and other marine creatures.



Info

Road trip

Friends Ruby Larenim and Jasper Enost love road trips, especially ones where they find fantastic landforms, geoscapes and fossils along the way. Find out about their latest adventure in the Ruby & Jasper diary: *Drive down-under!*

Excerpts from the travel diary of Ruby & Jasper (written by Ruby)

Drive down-under: Before we start!

What's a contour map? Here's a quick primer:

Contour lines join points of equal elevation, for example points at 10 m above sea level (asl), 20 m asl, etc. A map with set contour intervals will allow observers to discern the topography; valleys, hills and the gradient of slopes (see the example, Figure 1b, below).

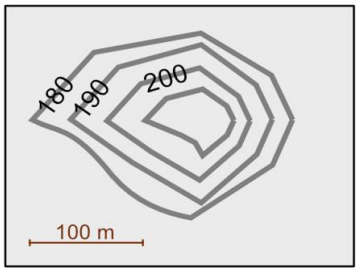


Figure 1a: An example of a contour map. By convention north is at the top of the map unless otherwise specified.

In this example the contour lines are 10 meters apart. The hill represented here is more than 210 m above sea level (asl) but less than 220 m asl. The horizontal scale, shown as a bar, is in metres

Road cuttings

Also, as all Earth Scientists will tell you, road trips are great because engineers love to cut through hills to make the gradients easier for cars and trucks. The 'road cuttings' are wonderful windows into the geoscapes below the landscapes and are often the only places you get to see the geology that is normally covered by soil and forests or farmland crops.

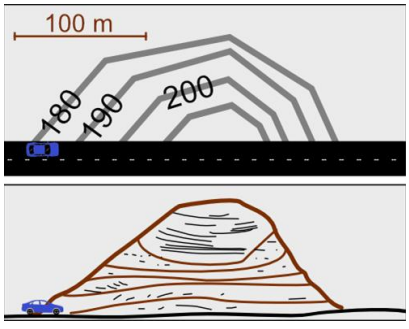


Figure 1b: An example of a road cutting.

The top image is a map, showing a road passing through the hill shown in Figure 1a.

The bottom image shows the road cutting, exposing all the interesting strata below the hill in cross-section. The road is relatively flat, saving all the effort of going up and over the hilltop!

Note: the vertical scale is exaggerated for clarity.

We have decided to ditch the GPS and try navigating by map, just for fun. What could possibly go wrong? Road maps are nice but a bit boring, so we have gone the extra mile (kilometre in Australia!) and purchased topographic maps that show the topography using contour lines as well as all the roads.

Drive down under: Flat or what?

We were told that Australia was flat! So far everywhere we have been there are hills. Even this interesting place we found (see Map, Figure 2, on next page) is hilly! It turns out, Australia isn't totally flat, it just is not as hilly as other places!

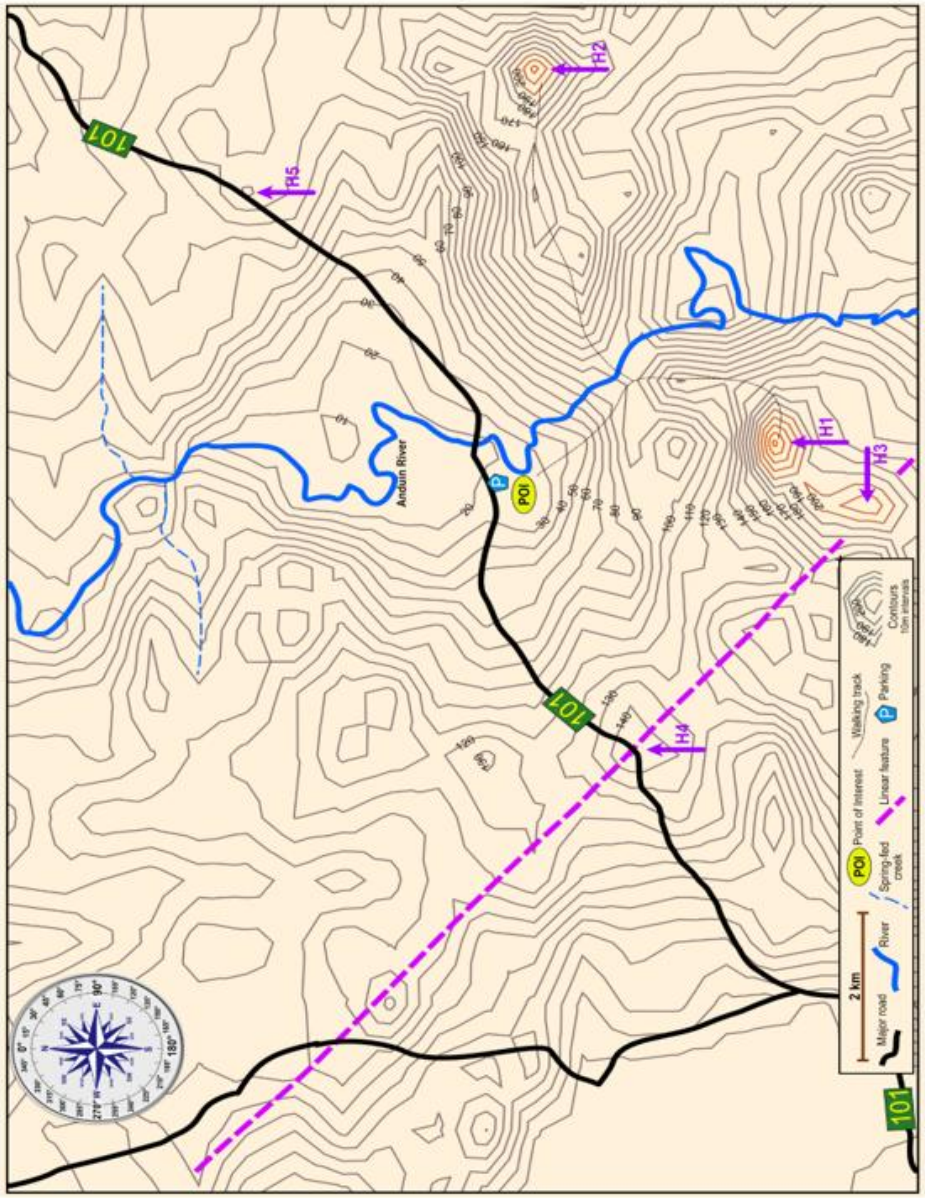


Figure 2: A piece of the Australian landscape Ruby and Jasper quite liked.

42 **(1 mark)**

Travelling Highway 101, we decided to take a break at a picnic spot where the road crosses over the Anduin River (Figure 2). We found a campgrou+nd adjacent to a billabong (also known as an oxbow lake), a natural feature only marked on the map as a Point Of Interest (POI). A sign indicated this billabong is a wetland habitat known to have been in place for many thousands years, based on carbon-14 dates taken on samples retrieved from the lake bottom.

As we ate our picnic lunch, we discussed the intersection of the rock cycle and the carbon cycle that the billabong represents. Jasper challenged me to identify one aspect of the billabong that sinks carbon and one aspect that produces carbon.

What did Ruby correctly state about the billabong's carbon production and carbon storage?

We know that the billabong is usually a still body of freshwater with a low-oxygen or even oxygen-free bottom. In this context ...

A. ... calcium carbonate ($CaCO_3$) from the skeletons of animals, such as shellfish and corals found in the shallows, accumulates in the low oxygen environment at the bottom of the lake - thus storing the carbon in lime mud. In addition, atmospheric CO_2 acidifies rainfall which in turn acidifies the lake. The $CaCO_3$ reacts with the acidic water and liberates CO_2 that bubbles to the surface,

B. ... carbon, in the form of fire ash, falls into the lake and sinks to the bottom. The mud at the bottom of the lake permanently stores the carbon. There is no mechanism in a shallow low oxygen freshwater lake by which any stored carbon can be returned to the atmosphere, making these environments ideal sites for carbon capture and storage.

C. ... all plankton in the water column use atmospheric CO_2 to grow - thus storing the carbon in their tissues. Decomposers, mostly fungi, in the lake bottom mud liberate CO_2 that bubbles to the surface.

	D. … organic matter from plants and animals, living at or near the surface, accumulates in the low oxygen environment at the bottom of the lake - thus storing the carbon in the mud. Anaerobic bacteria that thrive in organic-rich environments at the bottom of the lake produce methane (CH4) that bubbles to the surface.
43	**(1 mark)** After I met Jasper's challenge I challenged him to give an example where the rock cycle produces carbon and one where it stores carbon. **What did Jasper correctly state about the rock cycle and its interactions with the carbon cycle?** *We know that* ● *rain water is actually a solution of carbonic acid, according to the formula: $H_2O + CO_2 \rightarrow H^+ + HCO3-$ so it is no surprise that chemically reactive minerals are affected by rain water* ● *silicate minerals, for example the calcium silicate mineral wollastonite (CaSiO3), react with carbonic acid. Here is the wollastonite reaction formula: $H_2O + 2CO_2 + CaSiO_3 \rightarrow Ca^{2+} + 2HCO_{3-} + SiO_2$.* *and …* A. … silicate-weathering products allow organisms to build skeletons according to the formula $Ca^{2+} + 2HCO_{3-} \rightarrow CaCO_3 + H_2O + CO_2$. The skeletons then form the sedimentary rock limestone, storing the carbon. Igneous volcanic events release carbon to the atmosphere in the form of CO_2. B. … sedimentary rocks store carbon in the form of oil, derived from the buried remains of plants and animals. Limestone weathering releases carbon in the form of CO_2 gas because rain water is a solution of carbonic acid.

	C. … metamorphic rocks store carbon in the form of graphite, derived from the metamorphism of calcium carbonate ($CaCO_3$). Some sedimentary rocks release carbon in the form of CO_2 gas because it is insoluble in the crystals that fill in the gaps between the grains. D. Options A and B E. Options A and C F. Options B and C G. Options A, B and C

44 **(1 mark)**

We were intrigued by the two high hills visible from the picnic area. One, almost due South, we called H1 and the other, almost due East, we called H2 (Figure 2). Both hills looked a bit barren on top. I decided to check out H1 and Jasper went to check out H2. Luckily there was a path to each hilltop with a handy foot bridge over the river for the trek to H2.

We found interesting rocks but we both also came back with some questions about the geological history of the area and how it related to our earlier conversation about the carbon cycle and the rock cycle.

We both noticed weathered granite outcropping on the flanks of the hills and a quick check of geology of the area back at camp revealed these granites are associated with a major tectonic event during the Ordovician period, as shown schematically in Figure 3.

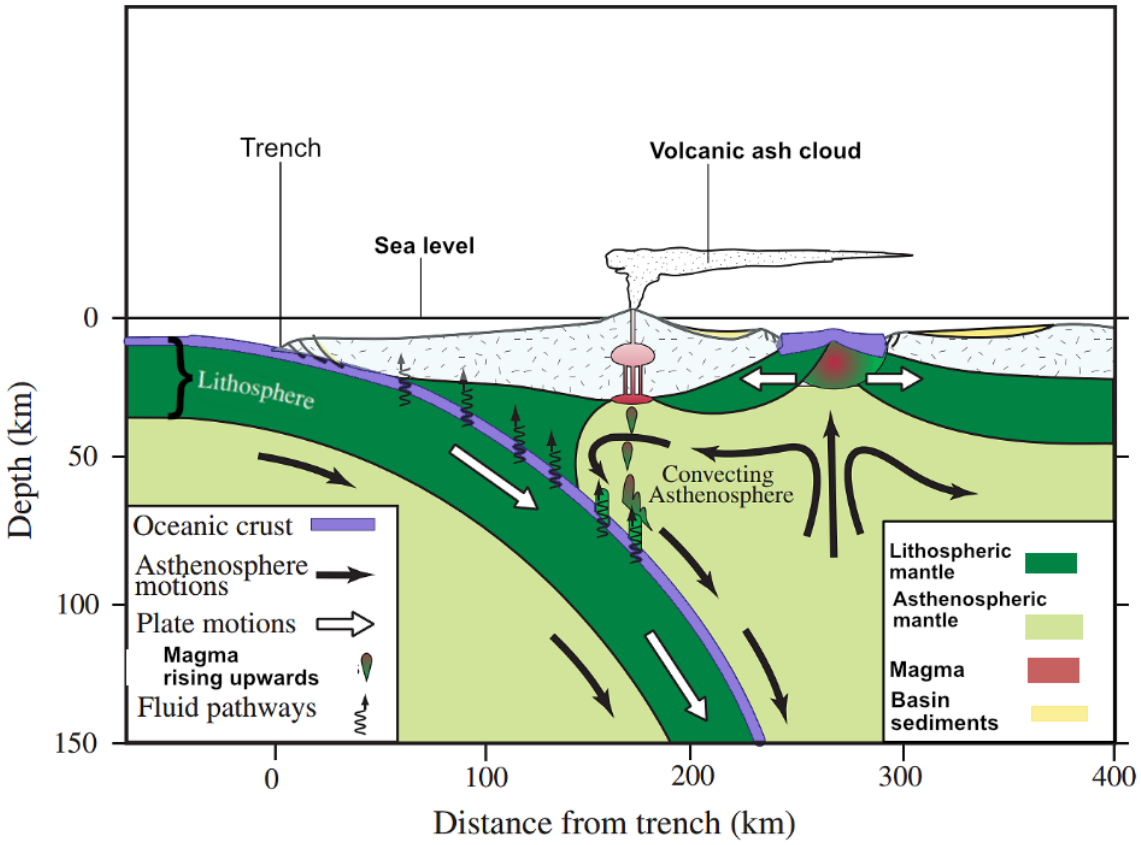


Figure 3: A schematic representation of the possible configuration of the area in question during the Ordovician.

What did they conclude about the tectonic history of the region and its impact on the carbon cycle?

A. Sea floor spreading was responsible for the granite intrusions in the area and submarine volcanoes on the Mid Ocean Ridge released CO_2 into the atmosphere.

B. Subduction zone processes formed the magmas responsible for the granite intrusions and also volcanoes that formed islands and released CO_2 into the atmosphere.

C. Continent-continent collision processes formed the magmas responsible for the granite intrusions and also volcanoes that formed islands and released CO_2 into the atmosphere.

D. Continental rifting formed sedimentary basins that allowed for the burial of organic carbon and also volcanoes that formed islands and released CO_2 into the atmosphere.

E. Transform faulting formed the magmas responsible for the granite intrusions, volcanoes that formed islands and released CO_2 into the atmosphere and sedimentary basins that allowed for the burial of organic carbon.

F. Hotspot magmatism was responsible for the granite intrusions, volcanoes that formed islands and released CO_2 into the atmosphere and sedimentary basins that allowed for the burial of organic carbon.

45 **(1 mark)**

I was thrilled to see the linear feature on the third hilltop, H3 (Figure 2). It was obviously the result of a very black rock that protruded slightly above the surface of the granite outcrops, like a tiny wall about two metres wide. It appeared to be trending NW-SE. Satellite images confirmed this linear feature extended across the landscape (Figure 2) but was not very distinct in most places.

Road cuttings are often good places to see the geology in cross-section, we drove a short distance to a hill on the highway (Figure 2, H4). The best exposure, about 1000 m wide, was on the SE side of the cutting. I was pleased to see the vertical black rock in the outcrop was very obvious, confirming my suspicions that the rock is an igneous dyke (Figure 4).

A dyke of this size, intruding into the cold rocks of the sedimentary sequence, could not heat the rocks enough to cause a wide zone of contact metamorphism. However, we did observe something of interest. See my field notes (Figure 4)!

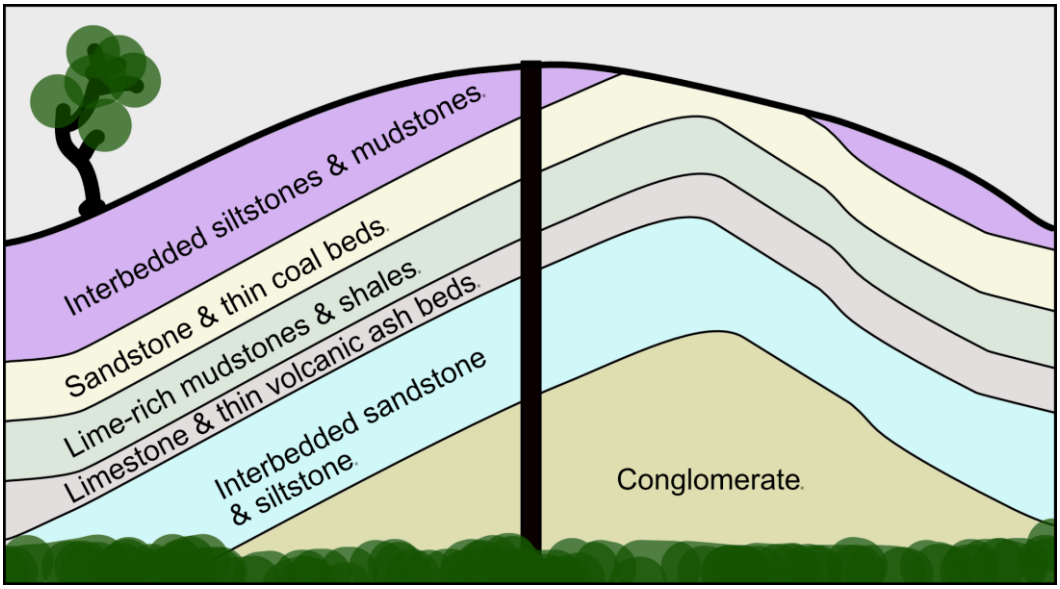


Figure 4: A sketch of the road cutting outcrop, showing the dyke cutting through the folded sedimentary rocks at this location. The limestone unit is ine grained, but we did find layers that contained some Silurian corals. The conglomerate, sandstones and siltstones all contain structures consistent with deposition in river systems.

We continued our discussion about the carbon cycle and decided to list some of the Earth's sphere's (geosphere, biosphere, hydrosphere and atmosphere) interactions that we could see represented in this outcrop.

Which of the following interactions is NOT one they listed because it is not represented in this outcrop, even though it could be a real interaction?

A. Geosphere - Hydrosphere: Sedimentary grains in conglomerates, sandstones and siltstones have been transported by and deposited from water.

B. Biosphere - Hydrosphere: Organisms with calcium carbonate skeletons have chemically extracted calcium ions from the ocean to build their supporting structures.

C. Hydrosphere - Atmosphere: Atmospheric carbon dioxide has reacted with water to form carbonic acid.

D. Hydrosphere - Geosphere: Carbonic acid rainfall has reacted with a limestone to liberate calcium ions into the water column.

E. Biosphere - Geosphere: Mechanical breaking of rock by stone-age miners formed the boulders later washed away in rivers to form the conglomerate.

F. Biosphere - Geosphere: Organic acids from the decomposition of plants in the landscape are reacting with minerals in the outcrop to form weathering products.

46 **(1 mark)**

That evening we camped next to the billabong. It was a very clear night with spectacular views of the Milky Way.

We spent the evening spotting planets, stars, meteors and satellites. We even saw the International Space Station zoom overhead!

Jasper's favourite star cluster, the Pleiades – also known as the Seven Sisters – was especially brilliant. He knew that there are over 800 objects in the cluster but only 6 are normally easy to spot. I was very impressed; especially given I could also see that many of the stars are actually blue in colour.

Credit: NASA, ESA, AURA/Caltech, Palomar Observatory (Public domain)

Jasper explained that the stars are young B-type stars with the brightest, Alcyone, being a giant star around 100 million years old. He added that all the stars in the cluster developed together in time and space.

What else did Jasper correctly say about the cluster of stars known as the Pleiades?

The stars in the cluster all formed at about the same time ....

A. ... during the big bang.

B. ... from a cloud of dust and gas that could have been generated by a supernova.

C. ... as our solar system and from the same nebula that formed the solar system.

D. ... shortly after the big bang, along with the development of the first galaxies.

47 **(1 mark)**

Sitting around the campfire I remembered I had bought a peridot brooch for a friend but had not really looked at it. Peridot is the name for gem quality olivine, so I was pleased to see that it really was a green colour, just like olivine's usually are. However, it came with a silly certificate that said:

Your beautiful peridot is pure olivine, one of nature's most green minerals! It contains iron (great for all blood disorders and circulation) and magnesium (great for muscle aches and postural problems) and your very special stone has a laboratory certified molecular mass of 184.8, the perfect number to ensure good balance in your iron and magnesium auras when you wear this exquisitely crafted brooch.

Jasper and I had a good chuckle about the healing-stone nonsense but were intrigued by the molecular mass claim. Using the handy solid-solution diagram we pulled off the web (Figure 5) and a periodic table we figured out what the brooch's composition really is (assuming the molecular mass is correct).

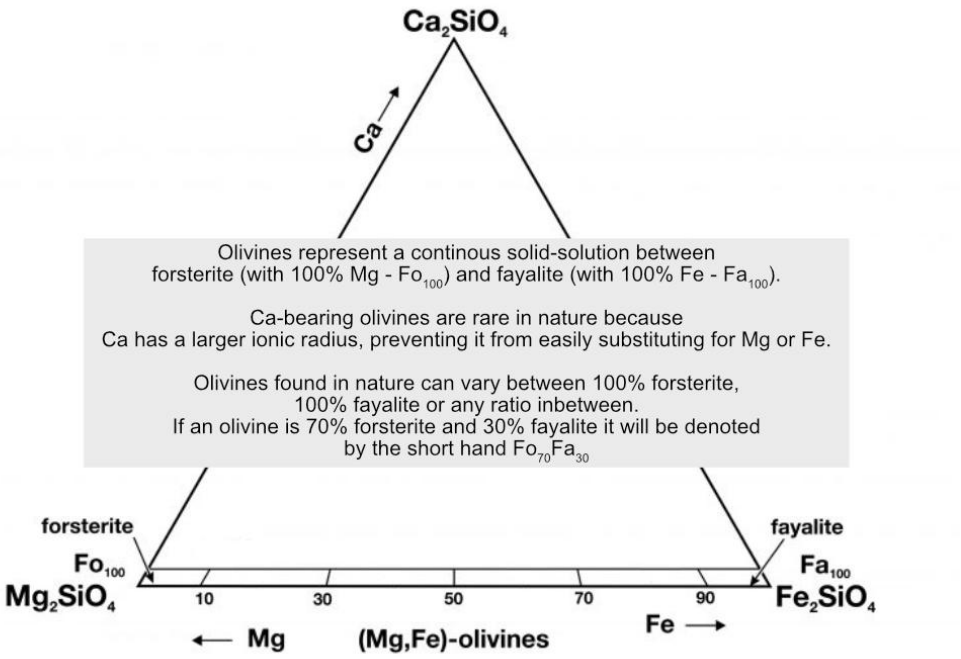


Figure 5: A ternary diagram showing the range of Mg-Fe-Ca 'olivines' commonly found in nature.

What type of olivine is in the peridot brooch purchased by Ruby?

A. The peridot is a fake because that molecular mass is impossible.

	B. The peridot is $Fo_{90} – Fa_{10}$ C. The peridot is $Fo_{80} – Fa_{20}$ D. The peridot is $Fo_{70} – Fa_{30}$ E. The peridot is $Fo_{60} – Fa_{40}$ F. The peridot is $Fo_{50} – Fa_{50}$ G. The peridot is $Fo_{40} – Fa_{60}$ H. The peridot is $Fo_{30} – Fa_{70}$ I. The peridot is $Fo_{20} – Fa_{80}$ J. The peridot is $Fo_{10} – Fa_{90}$

48 **(1 mark)**

We decided to camp longer at the site so we could explore the local geology a bit more, starting at another road cutting we saw on the way here (H5, Figure 2). The cutting is about 1000 m wide and has some wonderful rocks exposed for all to admire (Figure 6).

In the rubble at the bottom of the cutting I found a tropical coral-rich Silurian rock, a Jurassic fern frond in some sandstone and a group of large Permian marine shells sitting in a slab of shale. As we admired the vista, local farmer Herb Petani stopped to ask us what we were looking at.

Jasper explained to Herb that the rock at the bottom of the cutting was a granite intrusion but the rock unit at the very top was especially interesting because it could potentially provide an example of the Cretaceous - Palaeogene (K/Pg) mass extinction that ended the reign of the dinosaurs.

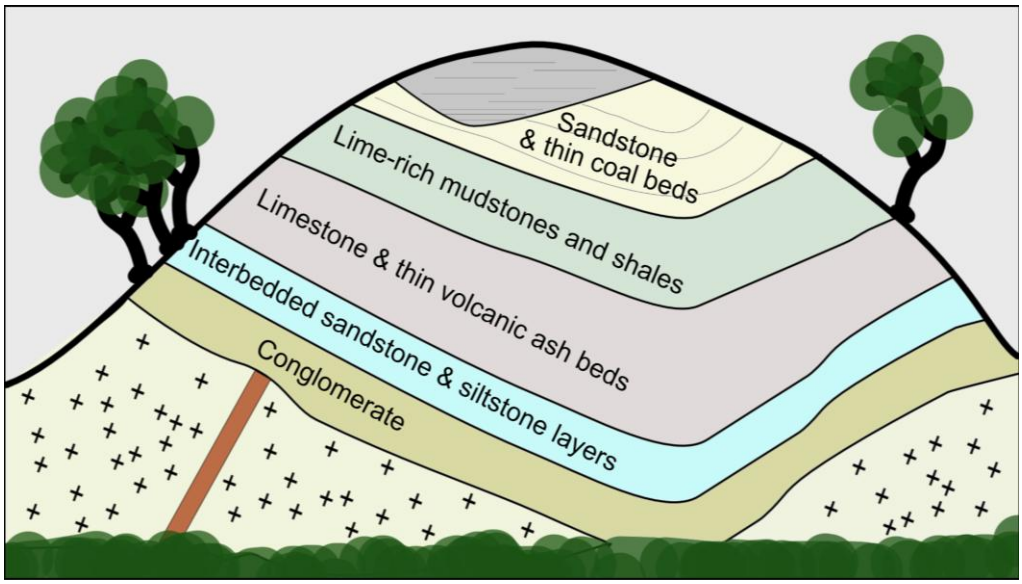


Figure 6: *Road cutting at H5, looking SE. The cutting is about 1000 m in width. The top unit has been deposited after erosion has cut a scour into the underlying Sandstone & thin coal beds unit. The top unit has also had its upper layers eroded away during the formation of the present landscape.*

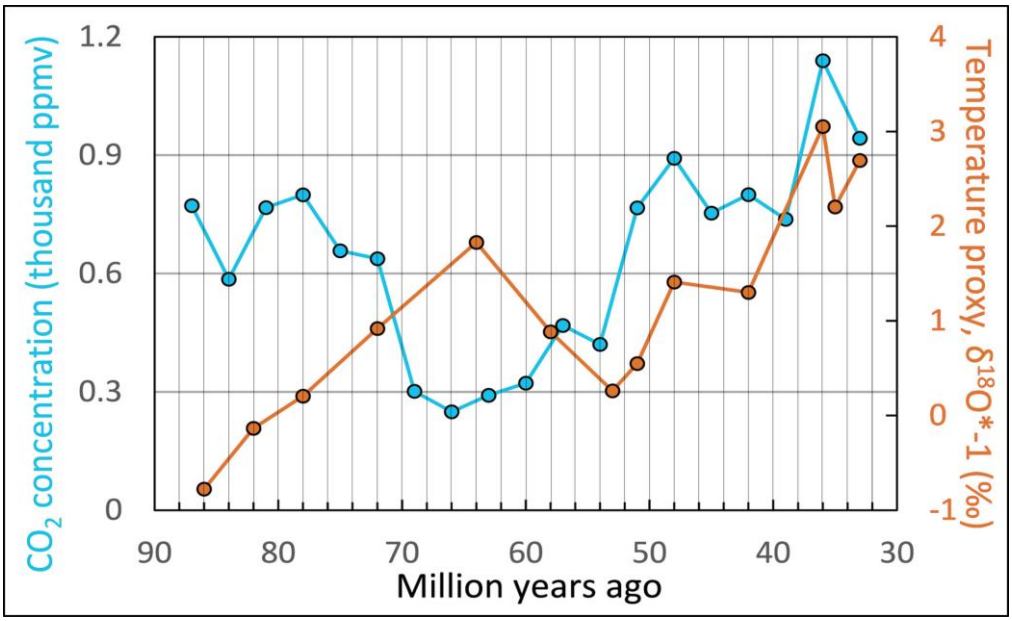


Figure 7: Time series showing the atmospheric concentration of carbon dioxide (CO2, blue curve) and simultaneous temperature proxy (brown curve) over the Cretaceous-Paleogene (K-Pg) mass extinction 66 million years ago. The lines connecting data points in this time series are reasonable interpolations but do not reflect the existence of real data between designated data points. Abbreviations: CO2, carbon dioxide; ppmv, parts per million by volume. The δ18O temperature proxy illustrates the trends in temperature over time, not the actual temperature. The higher the number, the higher the temperature.

What else did Jasper say to Herb about the world during the late Cretaceous to Paleogene while showing him Figure 7?

Between 90 and 30 million years ago the CO_2 concentration in the atmosphere varied a lot (Figure 7). However, the CO_2 concentration ...

A. ... in the atmosphere was in decline for many millions of years before the asteroid impact extinction event, suggesting biogeochemical processes were storing carbon in the geosphere faster than it was being released to the atmosphere by other processes.

B. ... is inversely proportional to the temperature during all time intervals covered by the graph, suggesting temperature is the controlling variable.

	C. … in the atmosphere increased after the asteroid impact event because the temperature declined, suggesting temperature is the controlling variable. D. … decrease appears to be responsible for the extinction event because it rises quickly after the extinction event, indicating a return to high levels of biological productivity and greater storage of carbon in both the geosphere and the atmosphere.
49	**(1 mark)** Given the presence of a tropical coral-rich Silurian rock, a Jurassic fern frond in some sandstone and a group of large Permian marine shells sitting in a slab of shale I was keen to understand more about the very top unit while explaining what I was seeing to Herb. Herb was excited about the possibility of finding dinosaurs but was also keen to know if the impact event was recorded in his local rocks. **What else did Ruby say to Herb about the top unit?** *The concentration of the element Iridium, abundant in some asteroids, is used as an indicator of the dinosaur-killer asteroid's impact horizon because it is rare in most rocks other than the layer deposited around the world as the dust settled. So, …* A. … you could reasonably expect to find dinosaur fossils in all the rocks exposed in the road cutting below the top unit because the iridium layer is certain to be in the top unit somewhere. B. … you could reasonably expect to find dinosaur fossils in the sandstone & thin coal beds unit but only if the iridium layer is found within the top unit. C. … you could reasonably expect to find dinosaur fossils only in the sandstone & thin coal beds unit because the iridium layer must be situated at the base of the top unit given the way the sandstone & thin coal bed layer has been eroded prior to the deposition of the top unit. D. … because the iridium formed during the big bang, which is why it is found in so many asteroids, there might be iridium spikes in other layers so we would need to find other

	evidence to confirm any iridium we find in the top unit is in fact from the dinosaur-killer asteroid. E. … the iridium layer could be anywhere within the top unit unless the erosion between the sandstone & thin coal bed unit and the top unit occurred after the asteroid event or the asteroid event layer has been removed by the erosion of the upper parts of the top unit. F. … the iridium layer is likely within one of the coal beds that contains the fern fossils because the extinction event stored massive amounts of carbon as charcoal from burning plants in the iridium-rich dust layer.