2025 AUSTRALIAN SCIENCE OLYMPIAD EXAM

BIOLOGY

TO BE COMPLETED BY THE STUDENT. USE CAPITAL LETTERS.

First Name: ……..…..…… Last Name…….
Date of Birth: ……/……/...……

□ Male □ Female □ Unspecified Year 10 □ Year 11 □ Other: …….

Name of School: ……..**State:** ……...

Examiners Use Only:

AUSTRALIAN SCIENCE INNOVATIONS

Australian Science Olympiads

2025 AUSTRALIAN SCIENCE OLYMPIAD EXAM
BIOLOGY

Time Allowed
Reading Time: 10 minutes
Examination Time: 120 minutes

INSTRUCTIONS

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

Integrity of Competition

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

MARKS

- **1 mark for each question**
- **Total marks for the paper 85 marks**

1. Which part of the cell contains the genetic material (DNA)?

    a. Cytoplasm

    b. Cell Membrane

    c. Nucleus

    d. Vacuole

2. Homologous chromosomes in a diploid cell usually have the same location and order of _____ along their length:

    a. Epigenetic modifications

    b. DNA replication origins

    c. Gene loci

    d. Nucleotide alleles

3. What is the purpose of cloning in agriculture?

    a. Increasing combinations of alleles in a population

    b. Preserving favourable traits in the offspring

    c. Preserving genetic variability in a population

    d. Increasing the frequency of recessive traits

4. Analysis of DNA shows that adenine and guanine always make up 50% of the total amount of nitrogenous bases in DNA.

    Which **structural feature** of DNA does this provide evidence for?

    a. DNA always has adenine paired with guanine

    b. DNA is always a double-stranded molecule

    c. DNA is made up of equal amounts of nitrogenous bases

    d. DNA is helical in structure

5. Every few months, Steve gets the exact same haircut. The hairdresser takes off a few centimetres of hair each time he visits, to cut it to the same resulting length each time.

   Which of the following is the **closest to** the rate at which his scalp hair grows?

   a. 4×10^{-3} m S^{-1}

   b. 4×10^{-6} m S^{-1}

   c. 4×10^{-9} m S^{-1}

   d. 4×10^{-12} m S^{-1}

6. In a food web, what is the **primary source** of energy for all organisms?

   a. Herbivores

   b. The Sun

   c. Decomposers

   d. Carnivores

7. In a food web, what role do decomposers play?

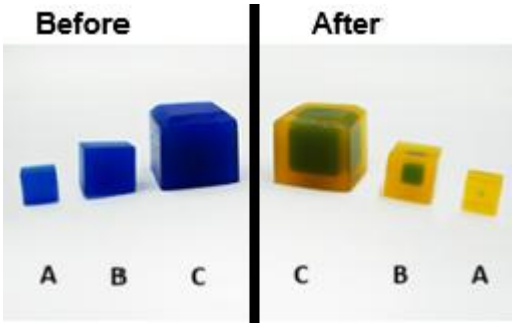
   a. They produce energy from sunlight

   b. They consume only plants

   c. They recycle nutrients back into the ecosystem

   d. They are always at the top of the food chain

8. Animals are restricted in terms of how large they can grow. To explore why this might be, a student designs an experiment comparing the rate of diffusion into three agar blocks containing pH sensitive dye.



Block A: 1 x 1 x 1 cm; Block B: 2x 2 x 2 cm; Block C: 3 x 3 x 3 cm

Blocks were placed in a beaker of sodium hydroxide and after 10 minutes, the outer parts of each cube had changed colour, while the core remained blue.

Which of the following **best explains** why Block A showed the highest proportion of colour change?

a. Block A had the largest surface area; thus, acid entered at a high rate

b. Block A had the smallest total volume; thus, less acid was needed to change its colour

c. Block A had the highest surface area to volume ratio; thus, it had the highest rate of diffusion proportional to its size

d. Block A had a smaller difference in concentration to the acid; thus, more acid was able to diffuse into the block in the given time

9. What is the basic unit of heredity in living organisms?

a. Chromosome

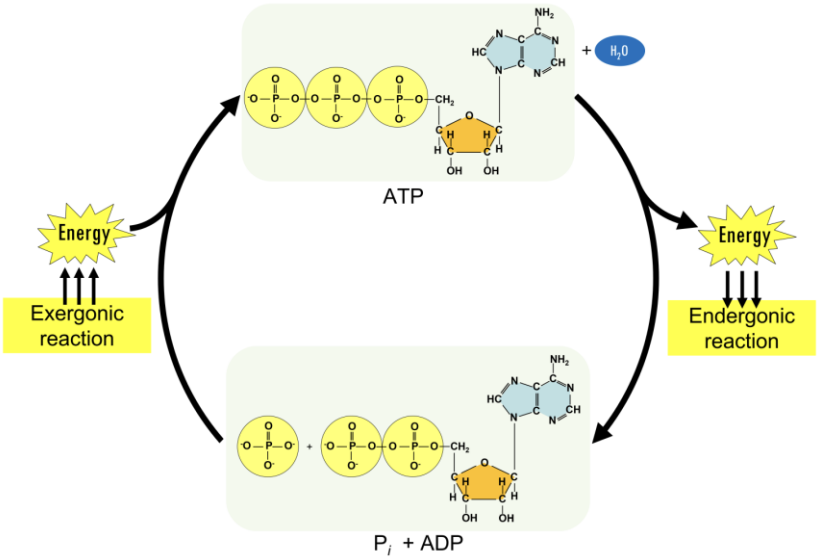
b. Gene

c. DNA

d. Protein

Questions 10 – 13 relate to the following information

Adenosine triphosphate (ATP) is the main form of usable energy in cells. This energy is released when ATP is converted into ADP (adenosine diphosphate) by the removal of one molecule of water. It can be created with, and without, the presence of oxygen through two different processes.



10. When ATP is synthesised without oxygen this is called _____ respiration, and when it is synthesised with oxygen this is called _____ respiration.

    a. Anti-oxy; Pro-oxy

    b. Oxygen independent; Oxygen dependent

    c. Anaerobic; Aerobic

    d. Anoxygenic; Oxygenic

11. Which of the below molecules is ATP **most structurally** similar to?

    a. DNA

    b. RNA

    c. Uracil

    d. Cytosine

12. Which of the following organelles is **primarily responsible** for producing ATP through respiration that requires oxygen?

    a. Nucleus

    b. Nucleolus

    c. Mitochondria

    d. Lysosomes

13. What other organelle can produce ATP through respiration that requires oxygen?

    a. Golgi complex

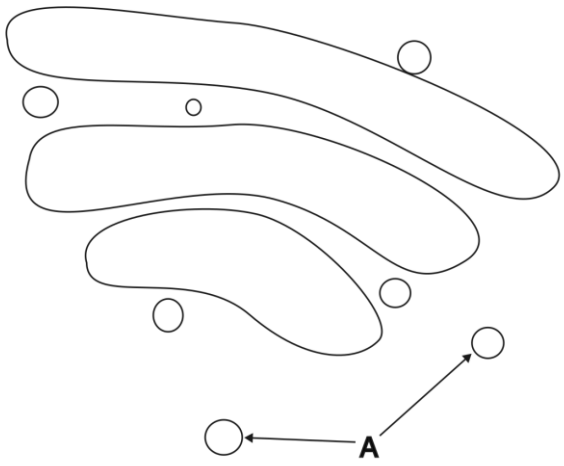
    b. Plasmids

    c. Chloroplasts

    d. Amyloplasts

Questions 14 – 17 relate to the following information

You have decided to investigate the Golgi complex and so have drawn a simple diagram of it from a microscope image you sourced. You know that the Golgi complex consists of a series of flattened, disc-like membranes that are involved in protein post-translational modification and packaging, but you also see several smaller circles which you have labelled as A.



14. What is the **likely** identity of A?

a. Cytoskeleton

b. Lysosomes

c. Vacuole

d. Vesicles

15. What is the **likely** purpose of A?

a. Transport of proteins between the discs of the Golgi complex

b. Stability of the discs of the Golgi complex and keeping them in place

c. Guard molecules that prevent any disruptions to the Golgi complex

d. They are unrelated to the Golgi complex, and are not required for its function

16. In what species could you find Golgi complexes? Select the **most correct** response.

    a. Yeast and Cacti

    b. Cacti and Goldfish

    c. Goldfish and Cacti

    d. Yeast, Cacti and Goldfish

17. The drawing seen above was made from a microscope image of the Golgi complex.

    What type of microscope was **most likely** used?

    a. Scanning electron microscope (shows the surface of the target)

    b. Transmission electron microscope (shows a slice through the target)

    c. Light microscope

    d. Phase contrast microscope

18. A new housing development is being planned near a forested area that is home to a variety of native species, including birds, insects, and small mammals. The development will involve clearing a large section of the forest to build roads, houses, and recreational areas. Environmental scientists are concerned about the potential impact on the local ecosystem, especially the food chains and biodiversity.

    Based on this scenario, which of the following is the **most likely ecological consequence** of the housing development?

    a. An increase in biodiversity due to the introduction of new plant species in gardens

    b. A decrease in native species populations due to habitat loss and fragmentation

    c. Improved soil quality from construction activities and landscaping

    d. A rise in predator populations due to increased availability of prey

19. Many marsupials in Australia, such as the sugar glider and the eastern quoll, rely on large, connected areas of native forest. However, urban development and agriculture have fragmented these habitats into smaller, isolated patches.

    Which of the following is the **most likely** consequence of habitat fragmentation for these marsupials?

    a. Increased genetic diversity due to isolation

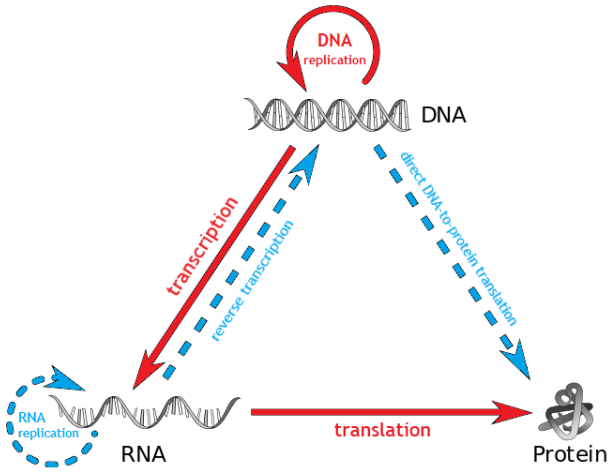
    b. Easier migration between habitats

    c. Reduced breeding success and increased vulnerability to predators

    d. Improved access to human food sources

Questions 20 – 22 relate to the following information

A common incorrect description of the central dogma of molecular biology is that genetic information flows in only one direction, from DNA to RNA to protein.



20. What is an example of a process that breaks this definition?

    a. Eukaryotic unicellular organisms due to their ribosomes

    b. Retroviruses due to their reverse transcriptase enzyme

    c. Archaea due to their RNA polymerases

    d. A newly discovered microRNA in nematode worms

21. Can information flow from protein to RNA or DNA?

a. Yes, from protein to RNA

b. Yes, from protein to DNA

c. No, information in proteins can only be transferred to other proteins

d. No, information in proteins cannot be transferred to DNA, RNA or other proteins

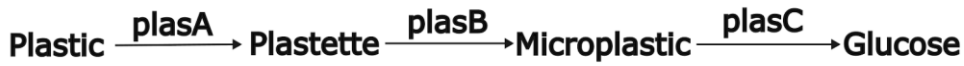
22. DNA, RNA and protein are all types of polymers made up of smaller units called monomers.

What monomers make up these polymers?

	Monomer of DNA?	**Monomer of RNA?**	**Monomer of protein?**
a.	Amino acids	Deoxyribonucleotides	Ribonucleotides
b.	Amino acids	Ribonucleotides	Deoxyribonucleotides
c.	Deoxyribonucleotides	Ribonucleotides	Amino acids
d.	Ribonucleotides	Deoxyribonucleotides	Amino acids

Questions 23 – 27 relate to the following information

Alice has obtained some mutated bacteria from her colleague, Bob, that is normally able to digest plastic. Alice knows the mutation is in the plas operon, which encodes enzymes involved in the metabolic pathway that converts plastic into glucose. She wants to specifically find out which enzyme is non-functional due to mutation. The pathway can be seen below with the intermediate products and enzymes plasA, plasB and plasC.



Alice cultures the mutant and wild type bacteria on 4 different agar plates each (that contain all appropriate nutrients aside from a glucose source): one with just plastic, one with just plastette, one with microplastics and a final one with just glucose. The results of which can be seen below.

Agar plate medium	**Mutant bacteria growth**	**Wild type bacteria growth**
Plastic	-	++
Plastette	-	++
Microplastic	++	++
Glucose	+++	+++

23. Based on these results, which enzyme in the plas operon is **likely** the one to be mutated?

a. plasA

b. plasB

c. plasC

d. plasA and plasB

24. What was the purpose of the glucose agar plate?

a. Positive control for plastic

b. Positive control for strain

c. Negative control for growth

d. Negative control for plas operon

25. The wild type (unmutated) bacteria were tested as a negative control for mutation.

    a. True

    b. False

26. Alice decides she wants to culture more of the mutant bacteria.

    Which type of agar plate should she use to obtain the **greatest growth**?

    a. Plastic

    b. Plastette

    c. Microplastic

    d. Glucose

27. Alice wants to know exactly what type of mutation occurred in this new strain, so she extracts the three plas enzymes from both mutant and wild type bacteria, denatures them so they are linear and of uniform charge density, and runs gel electrophoresis on them to measure the relative lengths. She notices that one of the three enzymes travels a shorter distance on the gel in the mutant compared to the wild type.

    What type of mutation could **not** have caused this?

    a. Silent mutation (no effect)

    b. Missense/point mutation (changes an amino acid)

    c. Nonsense mutation (adds a stop codon)

    d. Frameshift mutation (deletion or insertion that changes the reading frame)

Questions 28 and 29 relate to the following information

Lysosomes are small membrane bound organelles found in some eukaryotic cells that digest and recycle polymers. Being membrane bound allows for compartmentalisation, meaning they can have a different environment to the rest of the cell such as a lower pH and various digestive enzymes.

28. The lysosome can rupture, spilling all its digestive enzymes out of the cell.

    What is the **most likely** outcome from this situation?

    a. The cell will recognise this, and apoptosis will be induced to contain the digestive enzymes.

    b. The digestive enzymes will start breaking down key proteins and other polymers in the cell, leading to cell death.

    c. While the digestive enzymes will break down some of the cell, causing damage, the relative volume of the lysosome being so small compared to the cell means that the damage will be minor.

    d. Nothing will happen, as the digestive enzymes will not function outside the lysosome.

29. Mushrooms are interesting as they have significantly less compartmentalisation between cells compared to animal cells, with a continuous cytoplasm between cells in the hyphae (due to pores in the cross-walls dividing cells).

    Which of the following is **not** improved by a continuous cytoplasm?

    a. Intercellular transport

    b. Intercellular communication

    c. Viral defence

    d. Physical damage defence

Questions 30 and 31 relate to the following information.

Flow cytometry is an advanced technique used to separate cells by different markers. Cells in a sample are focused into a one-cell wide nozzle, where a laser will shine onto the cells and the scattering of light is then observed and used to characterise the cells.

It is used for a variety of purposes, and it is especially useful in sorting and identifying immune cells in the blood as many different parameters can be measured all at the same time. Two of these parameters are the level of forward scattering (FSC) and side scattering (SSC). Forward scattering measures the amount of scattering of the laser in the same direction it is shone, and a higher FSC reading roughly corresponds to a larger size of the cell. Side scattering measures the amount of scattering perpendicular to the direction of the laser, and a higher SSC reading usually indicates a higher granularity of the cell.

30. For which of the following reasons would we expect red blood cells to have a relatively low SSC reading?

    a. They contain relatively small organelles compared to other cells

    b. They contain useful organelles to facilitate gas exchange

    c. They do not contain any organelles

    d. Red blood cells should not have a low SSC reading

31. Neutrophils are white blood cells that are abundant in the human body. They quickly move to sites of infection and undergo phagocytosis (eating pathogens) and release chemicals to combat infections.

    Which of the below is **true**?

    a. An immune cell with a high FSC and high SSC reading must be a neutrophil

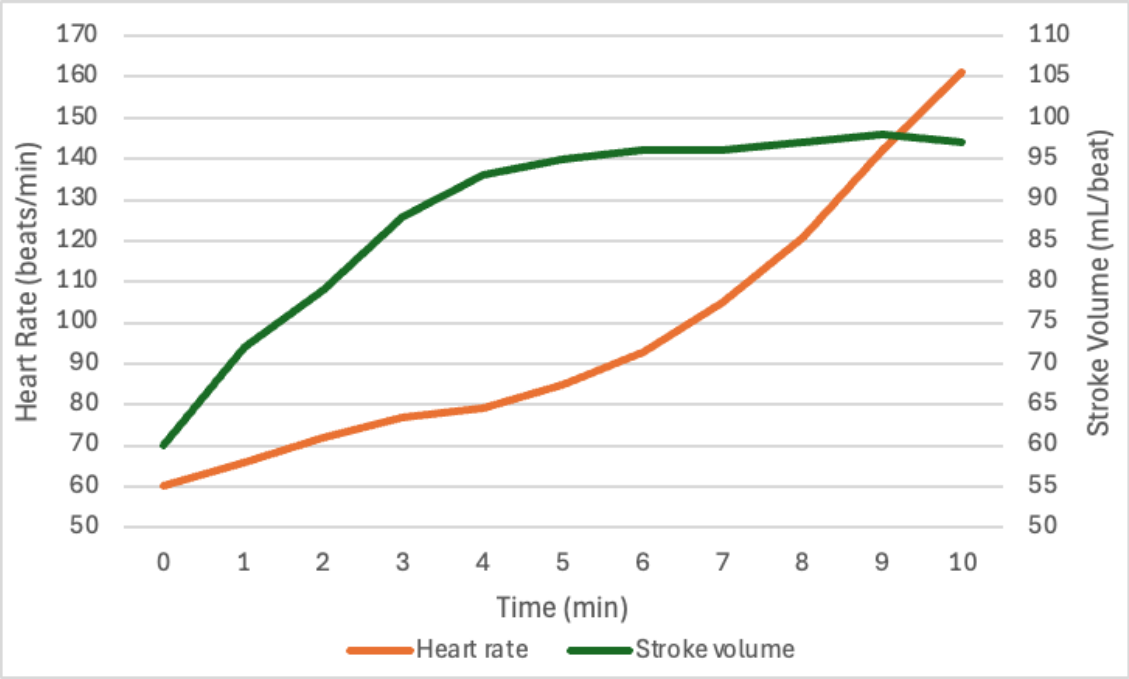
    b. Neutrophils are simple and so have low SSC readings in flow cytometry

    c. Neutrophils tend to have higher SSC readings due to the presence of many vesicles

    d. Neutrophils tend to not have a higher FSC reading than red blood cells

Questions 32 - 34 relate to the following information.

Cardiac output is a measure of the volume of blood pumped, in a unit of time, by the heart, and typically has units of L/min. It can be calculated from the product of heart rate and stroke volume, where stroke volume is the volume of blood pumped by a single beat of the heart. Cardiac output tends to increase with increasing oxygen consumption and is consistent between individuals of the same weight. Below is a graph of the heart rate and stroke volume over time, with measurements taken every minute.



32. What is the cardiac output in L/min closest to at 6 minutes? **2 marks**

a. 7 L/min

b. 9 L/min

c. 7000 L/min

d. 9000 L/min

33. Which of the following factors would **<u>increase</u>** stroke volume?

a. Contractile force

b. Greater volume of left ventricle after contraction

c. Increased heart rate

d. Decreased oxygen consumption

34. The resting heart rate of a trained athlete is significantly lower than the average human.

What outcome would this likely have on cardiac output and stroke volume?

	Cardiac output	**Heart rate**	**Stroke volume**
a.	Reduced	Reduced	Similar
b.	Similar	Reduced	Increased
c.	Increased	Reduced	Increased
d.	Reduced	Reduced	Reduced

Questions 35 and 36 relate to the following information.

Many modern drugs are either directly or indirectly derived from nature.

35. Lisinopril is a drug that is derived from a compound found in the Brazilian pit viper's (*Bothrops jararaca*) venom. The action of this compound results in vasodilation of the blood vessels it is exposed to.

As Lisinopril has a similar function to the venom of the Brazilian pit viper, what symptom might it be used to treat in humans?

a. High blood pressure

b. Low blood pressure

c. Elevated heart rate

d. Reduced heart rate

36. Ozempic is another such drug, this time derived form a compound in the venom of the Gila Monster (*Heloderma suspectum*). Ozempic promotes the growth of β cells in the pancreas, which produce insulin, and inhibits glucagon.

Based on this information, what would be the **likely effect** of taking Ozempic?

a. Increased blood glucose level

b. Reduced blood glucose level

c. Onset of Type 1 Diabetes

d. Onset of Type II Diabetes

Questions 37 and 38 relate to the following information.

Age-specific incidence is a rate that is defined as the number of new disease events within an age group divided by the total number of people in that age group, over a defined period. For the purposes of this question, let each age group equal one year (e.g. all individuals of age 50 are one group). The 'cardiac risk rule' states that the chance of a first-time myocardial infarction (MI) begins to double every six years after individuals reach the age of 50.

37. Suppose the observed incidence of first-time MIs at age 60 is exactly 0.010 first-time MIs per person-year. Under the 'cardiac risk rule' which of the following values should be **closest** to the expected incidence at age 69? **2 Marks**

    a. 0.020

    b. 0.028

    c. 0.032

    d. 0.040

38. For individuals of ages above 90, the observed age-specific incidence of first time MIs is in fact lower than the expected incidence that would be predicted by the 'cardiac risk rule'.

    Which of the following explanations is **most likely** to account for this divergence?

    a. Very old adults are frailer than suggested by the rule

    b. Incidence of MI fluctuates randomly with age

    c. Cardiac deaths dominate at younger ages, leaving a 'hardier' subset at very old ages

    d. Lifestyle factors (e.g. ability/opportunity to exercise) worsen after age 90

Questions 39 and 40 relate to the following information.

Epidemiological models of infectious disease divide a population into compartments of different infection statuses, as follows:

S	'susceptible'	Proportion of individuals who are uninfected and can be infected
I	'infected'	Proportion of individuals who are currently infected and therefore more contagious
R	'recovered'	Proportion of individuals who have cleared the infection and are currently immune to reinfection

- The proportions sum to 1 (i.e. S + I + R = 1)
- Disease transmission involves an individual moving from S to I.
- Disease recovery involves moving from I to R.

For some diseases, immunity is largely permanent after recovery; whereas for other diseases, immunity can wane and recovered individuals can become susceptible again, moving from R to S.

A key threshold quantity is the basic reproduction number (R_0), defined as the average number of people one infectious individual would infect in a completely susceptible population. If $R_0 > 1$, an introduced case can spark an outbreak, while if $R_0 \leq 1$, the pathogen cannot establish itself in a population.

39. Assuming a closed population where births = deaths and $R_0 > 1$, which outcome only occurs when immunity can wane (i.e. it is possible to go from R to S)? **2 Marks**

a. The pathogen ultimately dies out

b. The system settles into an equilibrium with a persistent non-zero fraction of infected individuals

c. The epidemic peak is higher than when immunity is permanent, but pathogen extinction still follows

d. The herd immunity threshold is lower because immunity wanes faster

40. Disease X is a highly contagious viral infection with a basic reproduction number $R_0 = 20$. A new single-dose vaccine for disease X prevents infection in 80% of those who receive it and confers lifelong protection in those individuals.

    For a vaccine that is not perfectly effective, the 'effective immune fraction' (E) in the population is:

    $E = p \times Ve$
    Where:

- p = the proportion of people vaccinated, and
- Ve = the vaccine efficacy = 0.80 in this case

    Herd immunity is achieved when E meets or exceeds the herd-immunity threshold H_c, which is calculated as follows:

    $H_c = 1 - (1 / R_0)$

    Which of the following statements is most accurate? **2 Marks**

    a. Vaccinating 95% of the population would be sufficient to stop sustained transmission

    b. Herd immunity can be reached if exactly 80% of the population is vaccinated, because Ve = 0.80

    c. Any vaccine coverage above 50% drives the effective R_0 below 1 regardless of vaccine efficacy

    d. Eradication of disease X by this vaccination is not attainable

Questions 41 and 42 relate to the following information.

Consider a study in which field biologists compared sentinel behaviour (time spent scanning for predators) in four social species.

One classic theory ("many-eyes") predicts that the fraction of time that each animal devotes to vigilant scanning, Vpred, is inversely proportional to group size.

i.e. $V_{pred} = V_1 / N$

- V_1 = the solitary scan fraction, i.e. the percentage of time a single, isolated individual would spend actively scanning the environment for predators
- N = the group size.

This equation reflects the fact that as group size increases, individuals in the group can each devote a smaller fraction of time to scanning for predators than when alone.

Suppose that in all species studied, the single-individual (solitary) scan fraction was observed to be V_1 = 50%. In a group of size N = 10, the V_{pred} = 5%.

The biologists gathered observations of 10-member groups in the four species and found the following actual (observed) scan fractions:

Species	Scan fraction
Meerkats	18%
Black-tailed prairie dog	9%
Rock pigeon	5%
Canada goose	3%

41. Which of the following statements is **<u>most correct</u>**?

a The variability between species is likely to predominantly reflect sampling error

b The mixed pattern of deviations from the predicted scanning fraction of 5% suggests the presence of species-specific cooperative strategies (e.g. altruistic sentinels, selfish free-riding, or perfect sharing)

c The estimate of solitary vigilance was too low for all four species

d The higher than predicted vigilance in meerkats and prairie dogs demonstrates that group size does not influence vigilance very much; individuals simply maintain their solitary behaviour regardless of group membership

42. Which of the following statements is the **most plausible** biological interpretation of the results? **2 Marks**

a. The Canada goose's lower-than-predicted scan fraction suggests that the "many-eyes" benefit is enhanced in this species due to superior individual predator detection capabilities that allow for greater-than-expected reduction in per-individual vigilance

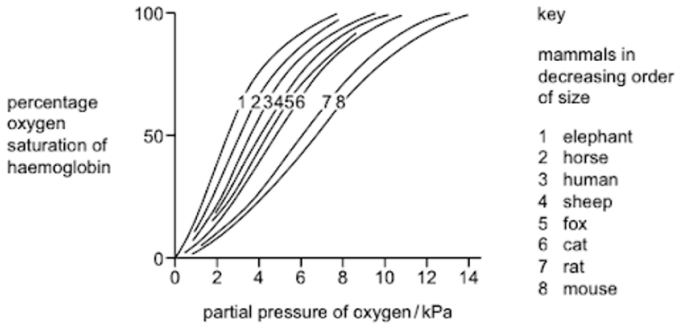
b. The rock pigeon matches the predicted value of V because it is the only species of the four whose primary food source requires continuous head-down foraging, leading to a mathematically optimal trade-off between vigilance and feeding behaviours

c. The high vigilance of meerkats and prairie dogs suggests that the "many-eyes" theory is fundamentally flawed, as it fails to consider that larger group sizes invariably attract a disproportionately larger number of predators

d. The data suggests that the solitary scan fraction (V_1) for meerkats and prairie dogs is much higher than 50%, and lower for Canada geese

Questions 43 and 44 relate to the following information

Haemoglobin (Hb) is a quaternary protein that carries oxygen in the bloodstream. The figure below presents oxygen dissociation curves for blood in muscle capillaries for eight species of mammal (ranked in order of decreasing body mass).



Po_2 = partial pressure of oxygen in kilopascals (kPa) (indicating the amount of oxygen present)

Assume the following experimental conditions apply identically for each species:

- Alveolar Po_2 at rest or during recovery is 13 kPa, so arterial blood is ~100% saturated in all species.
- During a strenuous treadmill trial, venous Po_2 falls to 4 kPa.
- Each species has the same haemoglobin concentration (150 g L^{-1}).
- Fully saturated Hb binds 1.34 mL O_2 g^{-1}.

Cardiac output (Q) scales with body mass (M, in kg), as follows:

$Q = 190\ M^{0.75}$ mL min^{-1}

Maximal whole-body oxygen consumption (Vo_2max) can be estimated using the Fick equation, as follows:

Vo_2 = Q x (arterial – venous O_2 content)

43. Suppose a researcher assumes that the arteriovenous O_2 content difference is exactly 50 ml O_2 L^{-1} blood for all mammals.

    Using the curves and the information above, for which of the above species would this assumption of fixed arteriovenous O_2 difference cause the greatest **underestimation** of the true Vo_2max? **2 Marks**

    a Elephant

    b Sheep

    c Cat

    d Mouse

44. The P_{50} is the Po_2 at which a given Hb is 50% saturated with O_2.

    Hb-O_2 dissociation curves are sigmoidal in shape, so the Hb-O_2 dissociation curve is steepest near its P_{50}, and shallower at Po_2 conditions that are further from the P_{50}. The magnitude of the change in haemoglobin saturation over a given Po_2 interval therefore depends on how close the working Po_2 is to the P_{50}.

    During an intense sprint, tissue Po_2 in active muscle can transiently fall from 4 kPa to 3 kPa. Using the curves provided, which species would experience the **largest decrease** in Hb-O_2 saturation when muscle Po_2 falls from 4 kPa to 3 kPa? **2 Marks**

    a. Elephant

    b. Human

    c. Cat

    d. Mouse

Questions 45 to 47 relate to the following information.

The reactions that occur in cells are extremely complicated, quick and invisible to the naked eye. Our contemporary understanding of how the cell works is one of the greatest accomplishments of science and can be credited to things like advancements in microscopes. However, our understanding of the cell has also been assisted by robust theoretical models which give simple specifications for a cell's behaviour. To construct such a model, we need to reason about how the cell behaves to make simplifications to our model (best of luck trying to make a mathematical simulation that accurately represents a cell in every way). For example, when reasoning about complex reactions in a cell with multiple reactants we often assume that this occurs in a sequence in which only 2 reactants react at a time.

45. Choose **the best** reasoning for this assumption.

a. Nothing in the real world is instant, everything takes multiple steps and some even perceptibly small amounts of time

b. Common parts of the reactions in cells like enzymes and receptors are incapable of binding with more than one substrate

c. The math for three or more reactants combining at a time is far too complex to make a useful model out of

d. The probability of 3 reactants colliding correctly at one time is significantly less than that for 2 reactants

46. Michaelis-Menten kinetics is a mathematical model for how enzymes behave. Unfortunately, it is meant to model just enzymes with a single substrate and product. This can be represented by the following equation:

    $E+S \leftrightharpoons ES \rightarrow E+P$

    where:

- The two-way arrow expresses that the equation is reversable (you might be used to just seeing a right arrow for chemical equations).
- ES represents the enzyme that has bonded to the substrate.

    In Michaelis-Menten kinetics we only care about how fast the enzyme goes between binding and not binding with the substrate, and how fast it goes from binding with the substrate to spitting out the product.

    In which of the more complex situations could Michaelis-Menten kinetics be used **without having to modify** the underlying model at all?

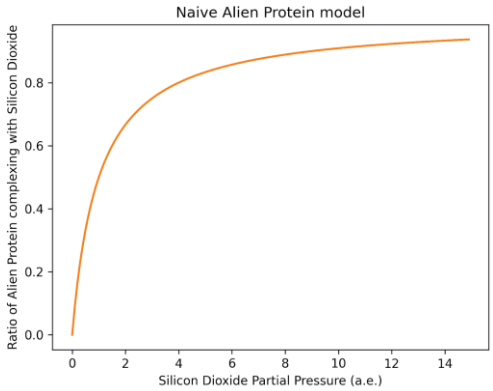
    a. 2 substrates are needed to make the product

    b. The enzyme can catalyse two of the substrates at the same time

    c. The enzyme makes multiple products

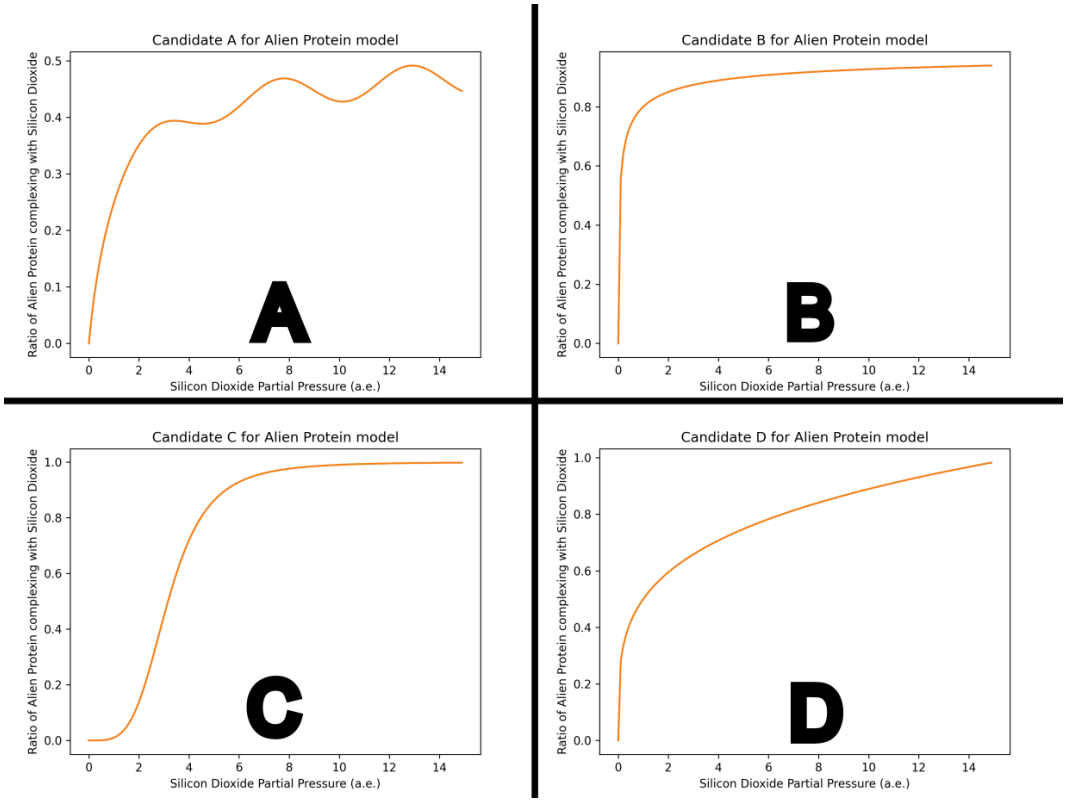
    d. The enzyme can catalyse two different substrates at different times into the same product

47. Consider a protein found in alien life called Alien Protein, which is able to attach up to 3 silicon dioxide molecules to itself and does so at sites that form the vertices of an equilateral triangle. Then, Alien Protein can be in four possible states based on how many silicon dioxide molecules are attached to it: No silicon dioxide molecules, 1 silicon dioxide molecule, …, 3 silicon dioxide molecules. The Alien Protein constantly shifts between consecutive states by accepting or rejecting silicon dioxide molecules. However, Alien Protein becomes more receptive to collecting silicon dioxide molecules the more molecules it already holds onto. If we were to model this situation using the standard Michaelis-Menten kinetics most reasonably we would end up with the following (we count an Alien Protein with 2 silicon dioxide molecules as ⅔ of an Alien Protein complexing with silicon dioxide).



Where the slope is steep, the effect of increasing silicon dioxide to give the Alien Protein more silicon dioxide to complex with is dominating. Where the slope is flat the Alien Protein cannot bind to any more silicon dioxide. This omits a key complexity.

Which of the following graphs is a **<u>better representation</u>** of the true system?



a. A

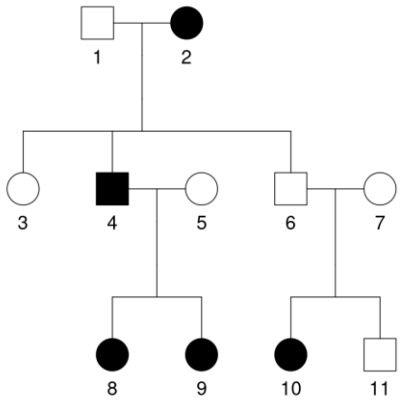
b. B

c. C

d. D

Questions 48 to 51 relate to the following information

You are studying a sex linked, heritable genetic disorder found in chickens. As an accomplished geneticist, you know that chickens do not have the same XY sex chromosome system as humans, instead having Z and W chromosomes. Male chickens (roosters) are ZZ, and female chickens are ZW. You decide to make a pedigree chart of one of the lineages of chickens to attempt to understand the identity of the genetic disorder, where male chickens are squares, females are circles, and coloured in means they are affected.



48. Based on the pedigree chart, what type of genetic disorder is it **most likely** to be?

a. Z-linked dominant

b. Z-linked recessive

c. W-linked dominant

d. W-linked recessive

49. Which chickens are carriers for the disease?

a. 1

b. 3

c. 4

d. None of the chickens are carriers

50. If chickens 6 and 7 were to have another child, what is the probability the child will have the disease?

a. 25%

b. 50%

c. 75%

d. 100%

51. If chickens 6 and 7 were to have another child, and it was known to be a girl, what is the probability that the girl would have the disease?

a. 0%

b. 50%

c. 75%

d. 100%

Questions 52 - 54 relate to the following information.

The Baltimore classification is a system for classifying viruses based on how they store their genetic information, and how they replicate it. Viral mRNA can be positive-sense, where it can be directly translated into viral proteins, and negative-sense, which can be used to produce a complimentary positive-sense strand.

52. Baltimore V includes viruses that contain negative-sense mRNA. Why might this be evolutionarily favourable over just containing positive-sense mRNA?

    a. It protects the mRNA from self-defence mRNAases in the host cell

    b. It means that proteins can be produced at a greater rate, as the positive-sense mRNA encoding them is continuously produced

    c. The positive-sense mRNA produced is larger than the original negative-sense mRNA, thus more mRNAs can be packed into the virus if negative-sense mRNA is used

    d. This is not actually evolutionarily favourable, evolution does what works, not what is best

53. Retroviruses are a part of Baltimore VI, which are viruses that contain RNA that is used to transcribe DNA, which is then incorporated into the host genome. This effectively inserts the viral genes into the host cell's genome.

    Which of the following is **not a benefit** of this approach, from the perspective of the virus?

    a. Disrupting of existing genes in the cell, leading to cancer and rapid cell growth

    b. Permanent, reoccurring infections

    c. Increased lifespan of genetic material

    d. More enzymes required means that it is harder to produce antivirals

54. CRISPR-Cas9 is a defence mechanism in some bacteria against viruses, effectively allowing bacteria to recognise and cleave a viral DNA sequence. However, Cas9 can be directed to target other specific recognition sequences, making it a useful tool for biotechnology.

    Which of the following could be done with a targeted Cas9, and only a targeted Cas9?

    a. Specifically cleaving a Baltimore VI classified virus gene that has been inserted into a cell's genome

    b. Specifically cleaving Baltimore V classified virus genetic material

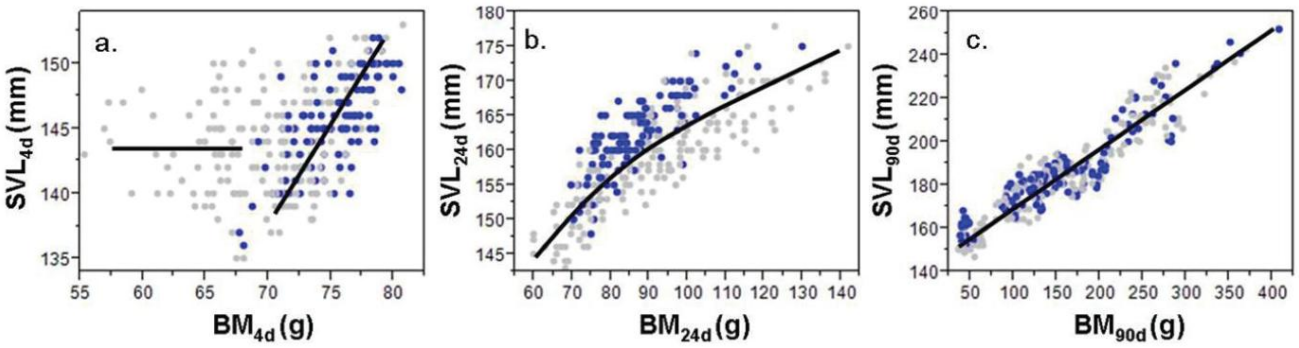
    c. Reducing gene translation by specifically cleaving transcribed mRNA

    d. Cleaving Baltimore IV classified virus genetic material

Questions 55 and 56 relate to the following information.

A number of species that have multiple offspring, have juveniles which experience a condition known as 'Failure to Thrive' (FTT), where some individuals show inadequate growth and may die. This phenomenon was studied in crocodiles (*Crocodylus porosus*) that were raised in controlled conditions.

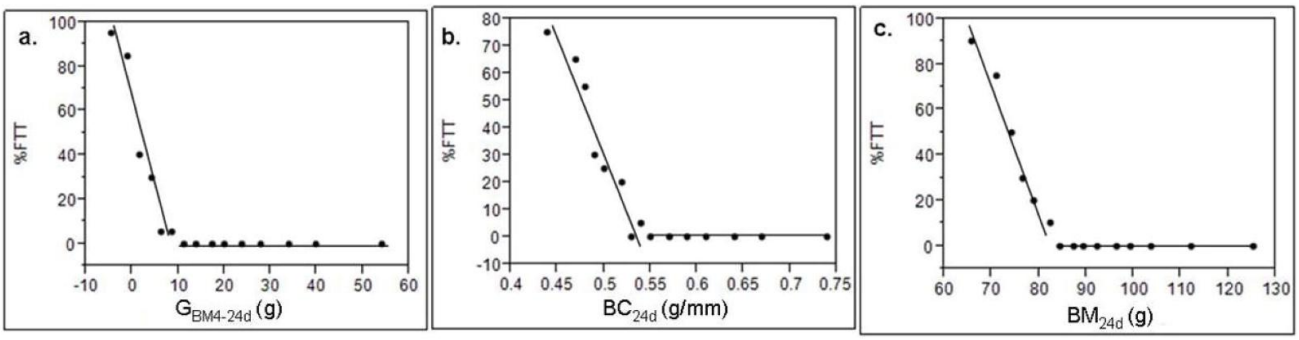
The snout-vent length (SVL), Body Mass (BM) at 4 days, 24 days and 90 days and time of birth (early or late in the season) were recorded. The data are plotted below.



Relationship between BM and SVL of hatchling *C. porosus* (n=300) at different ages.
Relationship at a) 4d, b) 24d, and c) 90d for hatchlings born early (n=120; blue) and late (n=180; grey) in the year.

All animals that died up to 300 days post-hatching were recorded. Of these, 55 (72% of mortalities) were seriously afflicted by FTT, did not respond to efforts to stimulate feeding, and died or were euthanized.

The figure below shows the probability of avoiding FTT and surviving to 300 days for hatchling *C. porosus* in relation to a) growth in body mass ($\mathbf{GB}_{M4\text{-}24d}$), b) body condition ($\mathbf{BC}_{24d}$), and c) body mass ($\mathbf{BM}_{24d}$).



Source: https://doi.org/10.1371/journal.pone.0100276

55. From these data, what can be concluded about the relationship between BM and SVL of hatchling *C. porosus*?

a. At 4 days, there is no relationship between BM and SVL of the hatchlings born late, but a linear relationship between BM and SVL for hatchlings born early

b. At 24 days, the SVL can be used to predict BM only for those hatchlings that were born early

c. At 90 days, the longer the SVL the greater the BM of the hatchlings

d. Both a and c can be concluded

56. Which of the following statements (a – d) is **incorrect**?

a. FTT was clearly indicted within 24 days of hatching by the extent of growth in body mass, body condition and body mass

b. The length of the hatchlings did not affect the likelihood of FTT

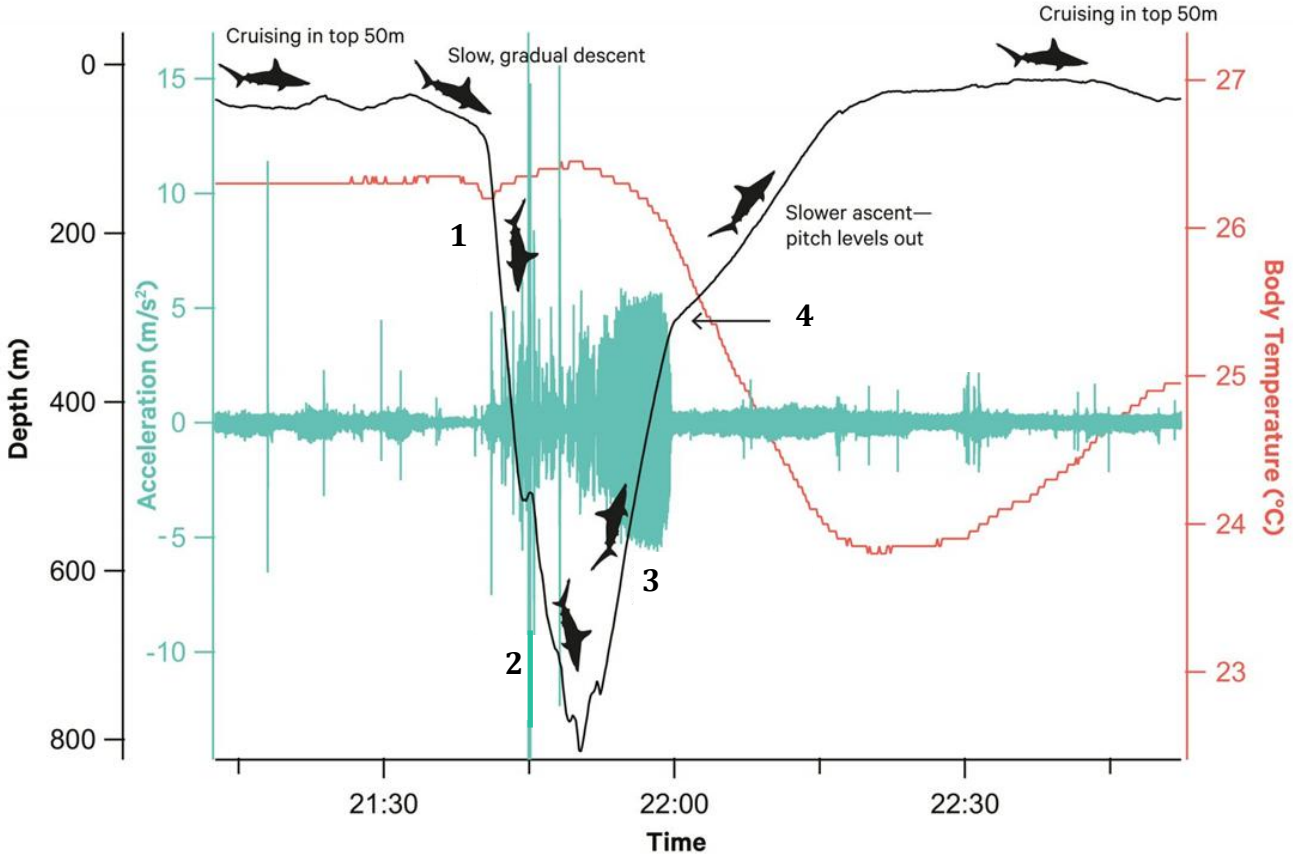
c. FTT did not occur in hatchlings that grew more than 8.2g in the 24 days post-hatching

d. Hatchlings that reached a body mass of 81.7g by 24 days post-hatching did not show FTT

Questions 57 and 58 relate to the following information.

Sharks are cold-blooded, and yet they can maintain a constant body temperature when they are hunting their prey in the freezing cold of the ocean depths. A study by scientists tracking hammerhead sharks off Hawaii (Royer *et al.* 2023) found that they do this by closing their gill slits as they begin to descend steeply, minimising heat transfer between the water and their tissues. Their gills open again during the later part of their ascent when the pitch levels out. Functionally, these sharks hold their breath during dives to facilitate access to prey in deep, cold waters.

The figure below shows the scalloped hammerhead's swimming behaviour and body temperature during a deep dive. Shown here are depth (black), intramuscular body temperature (red), and acceleration of the shark's tail (green).



Source: Royer *et al.* 2023, Science, Vol 380, Issue 6645 pp. 651-655.

57. Below are 4 descriptions (not in any particular order) of the sharks' swimming behaviour in a deep dive.

I. Rapid change in depth at a steep pitch angle with bursts of tail movement.
II. Rapid change in depth at a steep pitch angle with continuous sprinting movement.
III. Fast tail beats with bursts of tail movement and prey capture.
IV. Abrupt change from sprinting movement to a slower change in depth.

Considering the diagram, which of the options A – D is the **correct order** for the way the shark behaves in a deep dive.

a. I., II., III., IV.

b. I., II., IV., III.

c. I., III., II., IV.

d. II., I., III., IV.

58. What is the **best conclusion** that can be drawn about the intramuscular body temperature of the shark during a deep dive?

a. The body temperature of the shark during a deep dive is entirely due to the heat generated from muscle movement as the shark beats its tail

b. The body temperature of the shark is due to the depth of the dive and the ambient water temperature

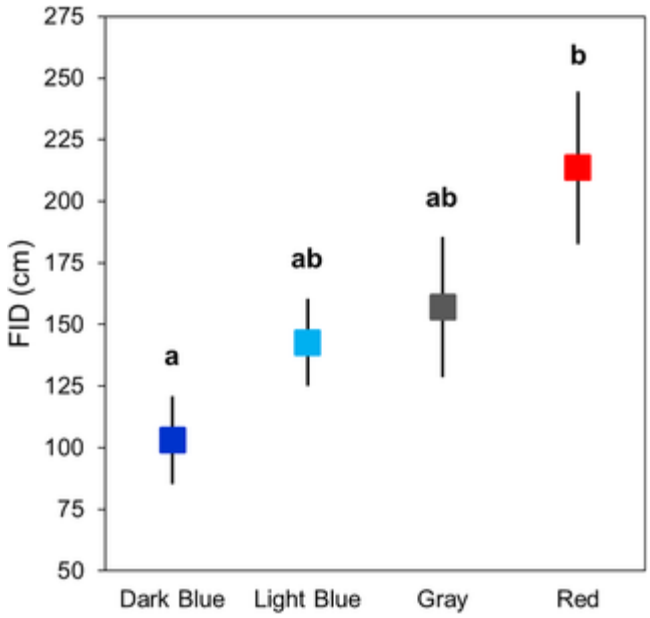
c. The shark is unable to maintain its body temperature during the deepest part of the dive

d. The body temperature of the shark only decreases substantially in the latter parts of the ascent, when the gills are open

Questions 59 and 60 relate to the following information.

Animals often view humans as predators, which can affect their behaviour. Even something simple like the observer's clothing colour may affect an animal's behaviour. The 'species confidence hypothesis' suggests that birds are attracted to colours found on their bodies and repelled by non-body colours. Animals that are repelled by colours will escape at the earliest opportunity. The distance between a human and an animal when the animal moves away is called the 'Flight Initiation Distance" (FID).

To expand this idea beyond birds, scientists quantified the effects of four T-shirt colours on FID in western fence lizards (*Sceloporus occidentalis*), while accounting for detectability against the background environment. The FID data is displayed below. Letters show statistically significant differences between colours – data with the same letter have statistically insignificant differences when compared with each other.



Source: Putman et al (2017). Fear no colors? Observer color influences lizard escape behaviour. PlosOne

59. What is the **most accurate** conclusion to be made from these data?

a. Red T shirts attract lizards

b. Light Blue and Gray T shirts could be as attractive as Red T shirts to lizards

c. Lizards allow people wearing Dark Blue T shirts significantly closer than people wearing Red T Shirts

d. Lizards allow people wearing Dark Blue T Shirts significantly closer than people wearing Red, Gray or Light Blue T shirts

60. To find out whether the blue T-shirts resembled the lizards' ventral blue patches, a value called '**just noticeable difference values**' (JNDs) was calculated between all T-shirts and parts of the lizards' body and environment. A JND value less than 1 indicates that two regions cannot be discriminated while a JND greater than 1 indicates that the regions are visually distinct, with higher values indicating greater contrast.

Contrast type	Comparison region	T-shirt color			
		Dark blue	Light blue	Gray	Red
Chromatic	Throat	3.0 ± 1.5	2.3 ± 1.0	3.4 ± 1.8	8.2 ± 1.7
	Abdomen	7.2 ± 1.2	7.2 ± 1.3	7.6 ± 1.5	9.8 ± 1.1
	Background environment	10.3 ± 3.4	6.9 ± 3.2	3.6 ± 1.0	59.2 ± 6.4
Luminance	Throat	1.4 ± 1.2	3.6 ± 1.7	7.5 ± 1.7	5.1 ± 1.7
	Abdomen	5.2 ± 2.4	2.0 ± 1.0	11.7 ± 2.4	9.3 ± 2.4
	Background environment	7.6 ± 6.8	16.6 ± 10.5	13.9 ± 8.1	8.2 ± 7.1

https://doi.org/10.1371/journal.pone.0182146.t001

Review the following statements, with reference to the table above.

I. All T shirt colours were 'noticeably different' from the background environment.
II. All T shirt colours were 'noticeably different' from all parts of the lizard.
III. The Red T shirts stood out the most from everything tested.
IV. The dark blue T shirt stood out the least from everything tested.
V. There was no significant difference between the 'noticeable difference' of any T shirt and the environment.

Which statements are **true**?

a. None of the statements are true

b. I, and II only

c. I, III, IV, and V only

d. I, II, III, and IV only

61. Dr James Estes and his colleagues at the University of California, Santa Cruz have been studying sea otter populations for over 20 years. They noticed that the sea otter populations inhabiting several of the Aleutian Islands had declined as much as 90% in fewer than 10 years (1990 – 1996) and suspected killer whales would have to had eaten 40,000 sea otters in six years! How many killer whales would it take to eat this many sea otters? We know that killer whales travel in groups ranging from five to 25 individuals. This is an important question to answer to determine whether killer whale predation could account for all the missing sea otters.

Estimated number of Aleutian Island Sea otters eaten, 1990 - 1996	40,000
Adult sea otters	
average caloric content	1.81 kcal/gram wet weigh
average mass, male	34 kg
average mass, female	23 kg
Killer whales	
average field metabolic rate	55 kcal/kg/day
average mass, male	5600 kg
average mass, female	3400 kg

Data from Estes, J.A., M.T. Tinker, T.M. Williams, and D.F. Doak. 1998. "Killer whale predation on sea otters linking oceanic ecosystems." *Science* 282: 473-476.

Using data provided in the table above, **estimate** how many whales, maintaining their weight and feeding exclusively on sea otters would it take to eat 40,000 over the period of decline (assuming the otter population is not breeding). **2 marks**

a. 2 whales

b. 4 whales

c. 10 whales

d. 30 whales

Questions 62 to 68 relate to the following information.

Ethology is a branch of Biology that is focused on studying the complex behaviour of animals. It is often studied with relation to evolutionary fitness, where organisms logically take actions that increase their own ability to survive and reproduce. However, there is a subset of behaviours, called altruistic behaviours, which seemingly contradict this belief. This is because these behaviours reduce an individual's own fitness while increasing the fitness of the receiving organism.

62. Which one of the following behaviours listed below would be **<u>least appropriate</u>** to classify as an altruistic behaviour?

    a. A bee ventures out of the hive to forage for flowers

    b. A plant provides a fungus with carbohydrates in return for phosphorus

    c. Red squirrels taking care of related squirrel children

    d. A humpback whale protecting a seal from an orca

63. Hamilton's rule offers a simplified explanation of why altruistic behaviours may arise in evolution. It states that an altruistic act will be favoured in natural selection if it fulfils the criteria that:

$$rB - C > 0$$

    Where *r* is the degree of relatedness between the recipient organism and the altruistic organism, that is the proportion of genes that are shared between the two. *B* is the reproductive benefit that the receiver gains, that is the number of additional offspring they would have due to the act, and *C* is the reproductive cost to the altruistic organism.

    Given that for a certain altruistic act, the proportion of genes shared between the two organisms is 78% and that the reproductive benefit is 0.12. What is the **largest value of C**, ***rounded to 2 decimal places***, such that this act will be favoured by natural selection by Hamilton's rule?

    a. 0.90

    b. 6.50

    c. 0.09

    d. 0.15

64. We can also study why certain behaviours are chosen in ethology by modelling these behaviours as a series of games. In its most simple form, we consider two players or animals, each with two choices. Consider a hypothetical situation with two predators, each with the choice/strategy of either hunting a rabbit or a lamb. We can then summarise the outcomes of the choices in a payoff table:

		Predator 2	
		Hunt Lamb	Hunt Rabbit
Predator 1	Hunt Lamb	(10,10)	(4,2)
	Hunt Rabbit	(2,4)	(3,3)

The left number in each entry corresponds to the amount of energy gained by Predator 1 and the right entry corresponds to the amount of energy gained by Predator 2. Assume that gaining energy increases the fitness of the organism.

Assume that each predator will choose to hunt a lamb or rabbit such that changing its choice respective to the other predator's choice will not lead to an increase in its own fitness.

What will each predator choose to do?

a. Predator 1 will hunt the lamb and predator 2 will hunt the lamb

b. Predator 1 will hunt the lamb and predator 2 will hunt the rabbit

c. Predator 1 will hunt the rabbit and predator 2 will hunt the lamb

d. Predator 1 will hunt the rabbit and predator 2 will hunt the rabbit

65. Now consider a different payoff table that describes a hypothetical situation where two monkeys may either choose to fight for a pile of food or share it. If they decide to fight, they expend c/2 amount of energy. The payoff table is shown below:

		Monkey 2	
		Fight	Share
Monkey 1	Fight	$(2-\frac{c}{2}, 2-\frac{c}{2})$	$(3, -1)$
	Share	$(-1, 3)$	$(2, 2)$

Assuming the same conditions as the previous question, what is the **largest whole number value** of c such that both monkeys always choose to fight? (**2 marks**)

a. 4

b. 5

c. 6

d. 7

Questions 66 to 69 relate to the following information.

Scientists used this technique in another scenario between two hawks to analyse the choices they would make. Each hawk can choose to either dive for a prey in the water, potentially having to fight other hawks, or yield. They calculate that the optimal choice for each hawk is to independently choose to dive 80% of the time.

Then they decided to observe the interaction of 100 pairs of hawks and noted the occurrences of each of the choices made by the hawks. The results are summarised below:

	Frequency
Both Hawks Dove	68
One Dove and One Yielded	14
Both Yielded	18

Using the table above and previous information, ***determine whether each statement is true or false***:
(Note: Questions 66, 67 and 68 must all be answered correctly to receive the three (3) marks).

66. Hawks chose to dive independently of the other hawk.

    a. True

    b. False

67. The hawks chose to both yield more than expected.

    a. True

    b. False

68. The hawks chose to dive more than expected.

    a. True

    b. False

69. The Chi-squared test allows scientists to measure how close experimental results are to their hypothesised expected results. The Chi-squared value is calculated as follows:

$$\chi^2 = \sum \frac{(O_i - E_i)^2}{E_i}$$

Where O_i and E_i are the observed and expected occurrences of each entry, and where χ^2 is the chi-squared value. The Σ refers to summing across all the entries.

What is the Chi-squared value, ***rounded to the nearest 2 decimal places***, for the results of the experiment done on 100 pairs of Hawks? (**2 marks**)

	Frequency
Both Hawks Dove	68
One Dove and One Yielded	14
Both Yielded	18

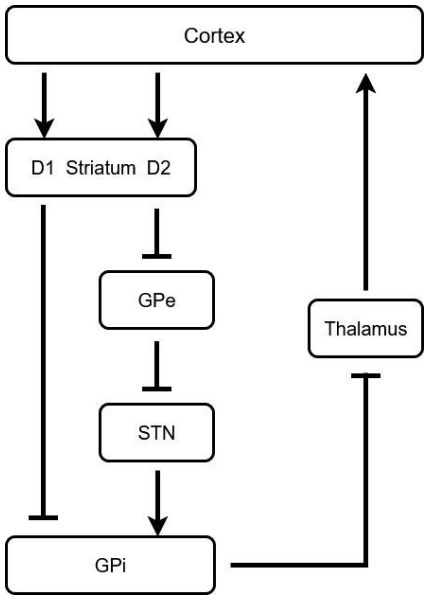
a. 3.00

b. 3.19

c. 13.88

d. 59.38

70. The initiation and suppression of movement involves many regions of the brain. Signals begin in the cortex when the body decides whether to start a movement. After processing and planning of the action by other brain regions, signals that are sent back to the cortex are executed. Below is a simplified diagram representing the direct and indirect pathways of the motor circuit, which pass through D1 and D2 receptors respectively. Arrows represent excitatory signals, while flat ends represent inhibitory signals.



Huntington's disease is a neurodegenerative condition which is characterised by excessive, involuntary movements.

Which statement **best explains** this symptom?

a. Damage to D1 receptors leading to increased excitation of thalamus

b. Damage to D2 receptors leading to reduced inhibition of thalamus

c. Damage to D2 receptors leading to decreased excitation of thalamus

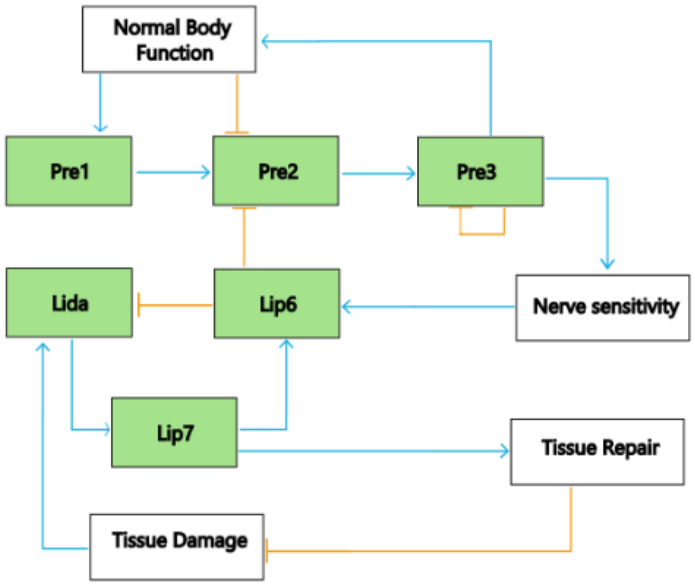
d. Damage to thalamus leading to excitation of cortex

71. Victor is interested in creating a cure to the chronic Chiltzers disease which arises from a defunct metabolic pathway in the tissues of those afflicted. The disease is caused by a mutation in one protein which leads to chronic pain for the individual, deterioration of body tissue throughout their life and muscular spasms as the only known non cognitive symptoms. Victor has made a schematic of the metabolic pathways in the tissue of an individual without Chiltzers. These pathways only highlight the proteins and processes Victor understands are related to the disease.

Proteins are placed as green boxes, biological processes are placed as white boxes, a pointed arrow pointing from protein A to protein B means that compound A activates compound B and a flat arrow from protein A to protein B means that compound A inhibits compound B. It is important to recognise that in this case the degree of activation of a protein is a spectrum-i.e. a protein is not just activated or inactivated but has a level of activation between 0 and 1. Here is an example schematic.

Where protein A activates protein B which in turn inhibits protein A. Protein B also activates Process C. This pathway is a simple way to activate Process C that prevents over activation.

Victor's schematic for the metabolic pathway of an individual without Chiltzers is illustrated below.



Which of the following would result in the **strongest symptoms** associated with Chiltzers?

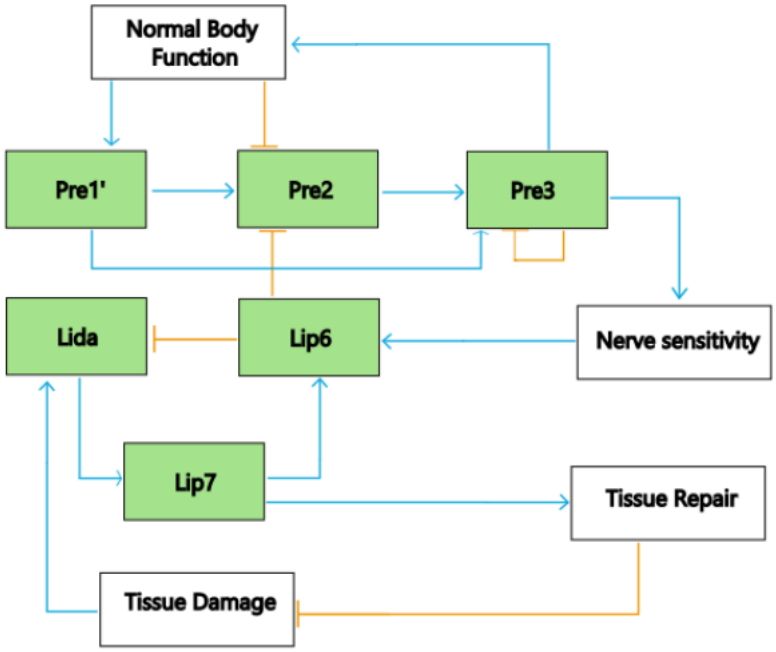
a. A defunct Lida which will have no effect on Lip7

b. A conglomerate complex of Pre2 and Pre3 that maintains all functionality of the original two proteins except that it can no longer interact with the Normal Body Function, Lip6 and itself

c. A mutant version of the ddf3 protein associated with the firing of nerves that suppresses Pre3

d. A defunct version of Lip6 that inhibits Pre2 less effectively

72. In reality, the metabolic pathway in an individual inflicted with Chiltzers resembles the schematic below.



Which of the following explains why this change to the metabolic pathway results in the symptoms of Chiltzers?

a. Pre3 is now being activated twice as much, resulting in more nerve sensitivity, resulting in more active Lip6, resulting in less active Lida, resulting in less active Lip7, resulting in less repair of damaged tissue

b. Pre3 will be more active, resulting in more nerve sensitivity, resulting in more active Lip6. However, since Pre3 is more active, more Lip6 activity will be used up inhibiting Pre 2, resulting in overall less active Lip6 to regulate Tissue Repair

c. The inhibition of Pre3 by Normal Body Function and Lip6 is now less effective, resulting in more Pre3 activity, resulting in more nerve sensitivity, resulting in more active Lip6, resulting in less tissue repair

d. Less Pre2 is needed to activate Pre3, resulting in more Lip 6 activity, resulting in more nerve sensitivity and tissue repair

73. Victor's plan is to use gene therapy as a treatment for Chiltzers. His plan is to insert DNA coding for a protein that will help regain the correct regulation in the metabolic pathway of an individual with Chiltzers. The protein is called Ctk11. To successfully complete gene therapy Victor needs to isolate the gene coding for Ctk11 and find a way to insert this DNA into patients using what is called a vector. If the DNA is small enough it is common to use viruses as vectors since viruses are naturally adept at inserting the DNA contained within it. A common choice for this is a desVirus which will insert its DNA into random parts of the cell's DNA. However, Victor wants to use the vector modified Adeno Associated Virus (vmAAV) instead. This virus instead delivers its DNA without incorporating it into any chromosomes. This DNA will never degrade in the cell, but it will also never replicate.

    Choose the **best** evaluation of Victor's decision below.

    a. Victor is incorrect. Using a desVirus is desirable because DNA that is not within chromosomes will not be expressed.

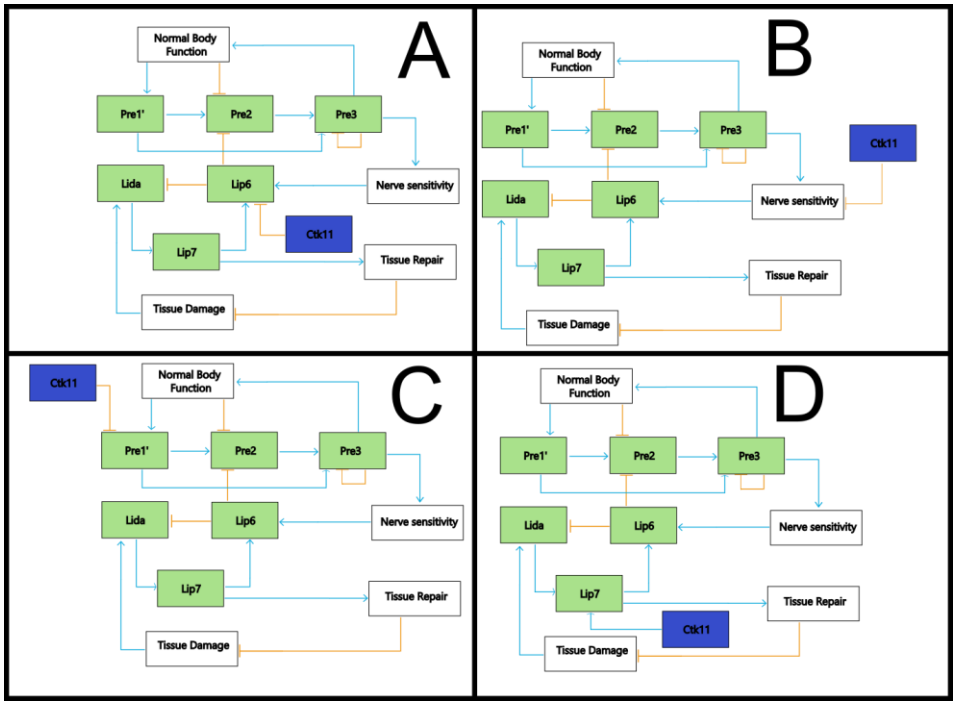
    b. Victor is incorrect. For the Ctk11 protein to interact effectively with the metabolic pathway it needs to be located close to the genes coding for the other proteins in the DNA.

    c. Victor is correct. The DNA inserted by vmAAV will not degrade so it will be a more effective long-term treatment.

    d. Victor is correct. vmAAV is less likely to have problematic side effects.

Questions 74 and 75 relate to the following information.

Below are four potential metabolic pathways relating to Chiltzers that involve Ctk11, which is placed in the blue box (The position of the blue box is the only thing that is changing in these images).



74. Choose the **correct** metabolic pathway that includes Ctk11 that will treat Chiltzers.

a. A

b. B

c. C

d. D

75. Which of the possible pathways will **make things worse** for a Chiltzer's patient?

a. A

b. B

c. C

d. D

END OF EXAM

We would like to acknowledge the contribution and inspiration to this paper by the New Zealand International Biology Olympiad