

**2021 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:

2021 AUSTRALIAN SCIENCE OLYMPIAD EXAM
BIOLOGY

Time Allowed

Reading Time: 10 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.**

Examination Time: 120 minutes

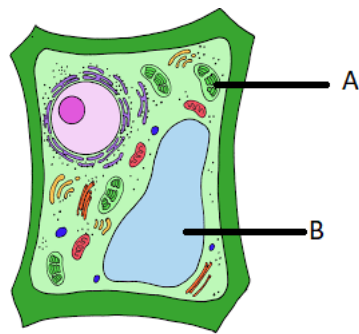
MARKS

- **1 mark for each question**
- **Total marks for the paper 65 marks**

Integrity of Competition

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

Questions 1 – 4 relate to the following image of a cell.



1. This cell is best described as what type of cell?
 - a. white blood cell
 - b. prokaryotic cell
 - c. plant cell
 - d. animal cell
 - e. epithelial cell

2. What is the name of the organelle labelled A?
 - a. Golgi apparatus
 - b. Chloroplast
 - c. Ribosome
 - d. Mitochondria
 - e. Nucleus

3. What does organelle A produce when functional in a cell?
 - a. Carbon dioxide
 - b. Starch
 - c. Oxygen
 - d. ATP
 - e. Glucose

4. The organelle labelled B plays a role in the structural integrity of the cell. When filled with water, ions, minerals, and nutrients this organelle exerts a pressure to maintain the structural integrity. The term that relates to this pressure is:
- a. Osmotic pressure
 - b. Turgor pressure
 - c. Cell pressure
 - d. Hydrostatic pressure
 - e. Structural pressure
5. In Australia, the 25th of April is ANZAC day. ANZAC Day is a national day of remembrance and honours all who served and died in all wars, conflicts, and peacekeeping operations.

In the United States however, the 25th of April is National DNA Day. The day commemorates the completion of the Human Genome Project in 2003 and the discovery of DNA's double helix structure in 1953.

The human genome is?

- a. All of our genes
 - b. All of our DNA
 - c. All of the DNA and RNA found in the nucleus of a cell
 - d. All of our RNA
6. If a length of DNA comprises 10,000 nucleotides of which 26% is adenine, what is the predicted number of cytosine bases?
- a. 48
 - b. 96
 - c. 1200
 - d. 2400
 - e. 4800

7. Which of the following is found in RNA but not in DNA?
- a. Thymine
 - b. Guanine
 - c. Uracil
 - d. Phosphate group
 - e. Cytosine
8. When a gene is 'expressed' it is?
- a. Transported around the body to make proteins
 - b. Replicated within the cell
 - c. Used as a blueprint to assemble the protein it codes for
 - d. Used as a blueprint to assemble the peptide it codes for
9. Pathogens are agents which infect humans and cause disease. Molecular mimicry occurs when foreign pathogens contain molecules that look like human molecules. When infected by such a pathogen, the body's immune system attacks the pathogenic molecule.

However, after the infection is cleared, the immune system may then mistakenly attack our own self-molecules.

Molecular mimicry could occur because:

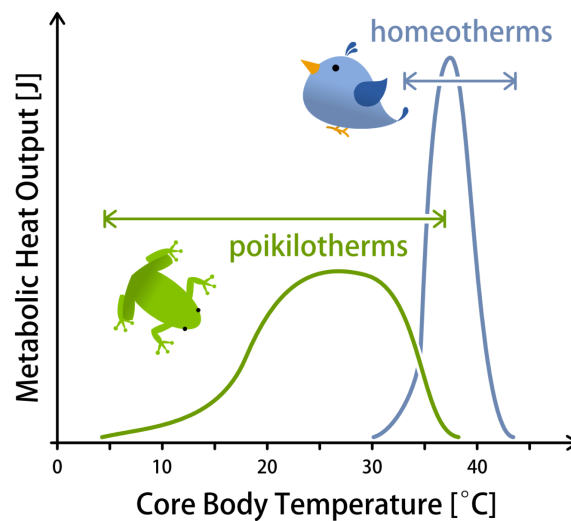
- a. pathogen proteins resemble host proteins
- b. pathogens activate specific host cytokines
- c. pathogens activate specific host cell metabolism
- d. pathogens mimic specific host genes
- e. pathogens change their molecules to look like human molecules during an infection

10. Which of the following may be pathogenic organisms?

- I. Bacteria
 - II. Viruses
 - III. Prions
 - IV. Fungi
 - V. Protozoa
-
- a. I and II
 - b. I, II and V
 - c. I, IV and V
 - d. I, II, IV and V

Questions 11 and 12 relate to the following information.

A Poikilotherm is an organism whose internal temperature varies considerably with their environment. In comparison, a homeotherm is able to maintain a stable internal body temperature regardless of external influence.



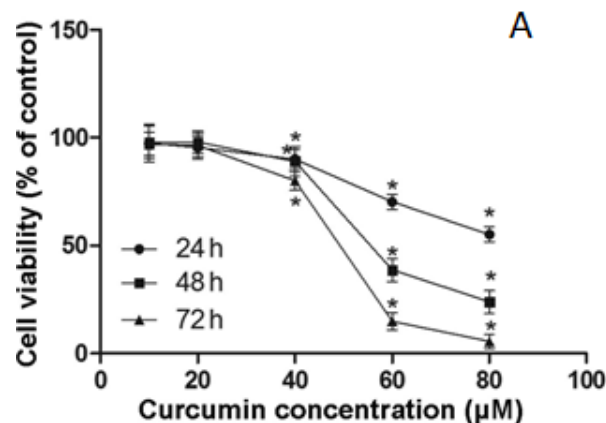
11. Biochemical reaction rates vary with temperature. To function, poikilotherms may have four to ten enzyme systems that operate at different temperatures for an important biochemical reaction. Compared to homeotherms in similar ecological niches, poikilotherms are likely to have:
- a. more complex organ systems
 - b. larger, more complex genomes
 - c. enzymes that are significantly more resistant to denaturation
 - d. enzymes that may perform very different functions depending on the temperature
12. Homeotherms and poikilotherms generally have different energy requirements per body mass. Which response is correct?
- a. A given food source can support a greater density of poikilothermic animals than homeothermic animals
 - b. In niches with limited food, homeotherms tend to out compete poikilotherms
 - c. Poikilotherms require more energy than homeotherms to reproduce
 - d. A given food source can support the same density of poikilothermic and homeothermic animals
13. The Great Barrier Reef is among the world's most awe-inspiring and unique ecosystems. It spans more than 2,000 kilometres, has more than 600 types of coral, 1,600 types of fish and is of immense cultural significance, especially for traditional owners of the land.

The species of coral *Acropora digitifera* is unable to produce cysteine as it lacks the gene for an essential enzyme. However, the same organisms that give the coral its colour (dinoflagellates) also provide the organism with cysteine. This is an example of what kind of relationship?

- a. Commensalism
- b. Predator-prey
- c. Mutualism
- d. Parasitism

Questions 14 – 19 relate to the following information.

Turmeric is a flowering plant, *Curcuma longa* of the ginger family, Zingiberaceae. It has a very long history of medicinal use, dating back nearly 4000 years. In the last 25 years, over 3000 new publications have been released regarding the health effects of turmeric. The primary compound in turmeric is curcumin, which has been purported to have anti-inflammatory and antioxidant effects. Scientists conducted a study investigating the effect of varying concentrations and length of exposure of curcumin on adipocytes from a human cell line. Figure A shows the effect of curcumin concentration on the viability of a population of adipocytes.



Further investigation showed that the effect on viability was due to changes in the regulation of apoptosis. Caspases are known to play essential roles in apoptosis and are an important regulator of this process is the Bax protein, which causes the release of cytochrome c.

14. Apoptosis is a process known as:

- a. programmed cell death
- b. mitosis
- c. transcription
- d. cellular injury

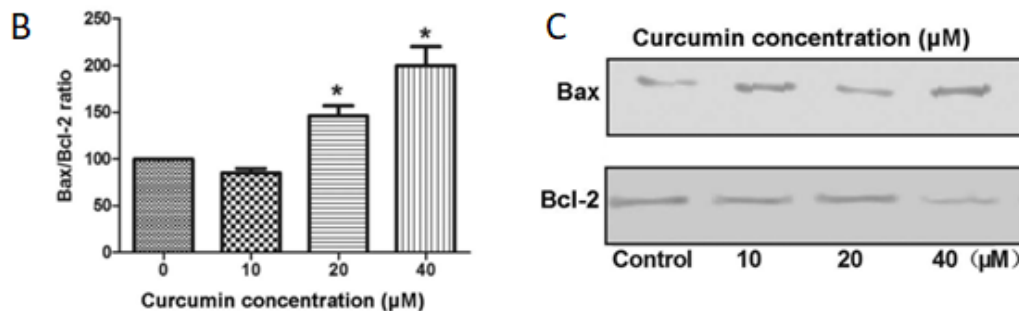
15. Which organelle releases cytochrome c?

- a. Mitochondrion
- b. Nucleolus
- c. Smooth endoplasmic reticulum
- d. Golgi apparatus

16. Cytochrome c:

- a. Initiates the release of caspases from the mitochondria
- b. Interacts with DNA, leading to nuclear fragmentation
- c. Activates the first caspase of an enzymatic cascade
- d. Is an integral protein

Bcl-2 is a protein that prevents the release of cytochrome c. The Bax/Bcl-2 ratio determines the balance of apoptosis. Figure B shows the effect of 0, 10, 20 and 40 μ M curcumin for a 24h period on the Bax/Bcl-2 ratio. An asterisk (*) denotes a statistically significant result. Figure C shows the result of a western blot.



17. Curcumin:

- a. stimulates the growth of fat cells by increasing the production of Bcl-2
- b. inhibits the growth of fat cells by increasing the expression of Bax relative to Bcl-2
- c. inhibits the growth of fat cells by decreasing the synthesis of Bax
- d. inhibits the growth of fat cells by increasing the expression of Bcl-2 relative to Bax

18. The concentration of (1) in the cytoplasm of the cells treated with (2) μM of curcumin compared to those treated with (3) μM is (4).

Which of the following options does **NOT** make the sentence above true?

	(1)	(2)	(3)	(4)
a.	Cytochrome c	10	0	Higher
b.	Cytochrome c	20	0	Higher
c.	Cytochrome c	20	40	Lower
d.	Bax	20	40	Lower
e.	Bcl-2	0	40	Higher

19. Results of the present study suggest that curcumin may be a promising therapeutic agent for:

- a. Heart disease, by increasing adipocyte numbers surrounding the heart
- b. Obesity, by increasing adipocyte numbers through the induction of adipocyte apoptosis
- c. Obesity, by decreasing adipocyte numbers through the induction of adipocyte apoptosis
- d. Cardiovascular health, by decreasing a person's fat free mass

20. When someone loses weight by "burning fat", where does most of the mass of the fat go?

- a. It is excreted in the faeces
- b. It is converted into energy according to $E=mc^2$, where E is energy, m is mass and c is the speed of light
- c. It is exhaled as carbon dioxide
- d. It is lost in sweat and urine

21. The brain is a vitally important organ that has evolved a multitude of protective barriers, including the skull, cerebrospinal fluid, and the meninges.

Another protective element is the blood–brain barrier, which separates the blood in the circulatory system from the cerebrospinal fluid of the central nervous system. The blood–brain barrier was discovered in the late 19th century, when Paul Ehrlich, a German physician, injected a blue dye into the bloodstream of a mouse. All of the tissues in the mouse turned blue, with the exception of the brain and spinal cord. The effectiveness of the blood–brain barrier depends on the cells that line the interior of blood vessels. In capillaries that form the blood-brain barrier, these cells are packed more closely together than in other capillaries.

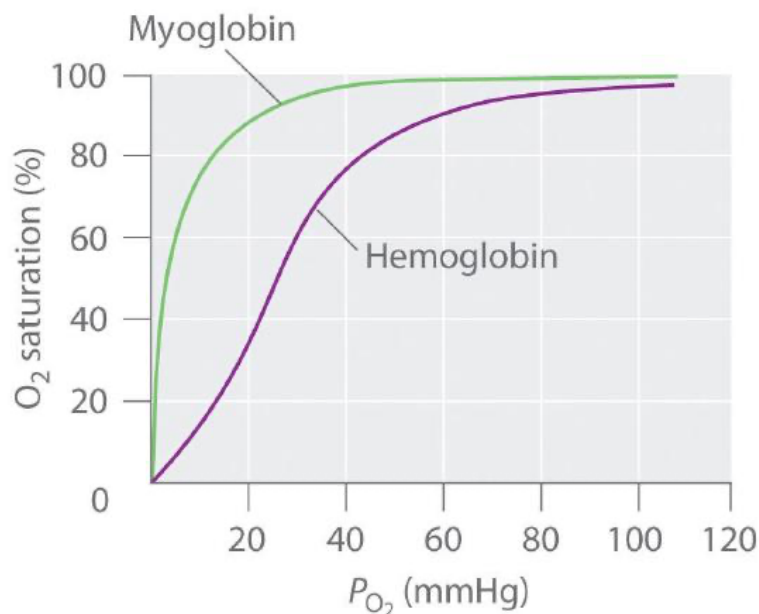
Which of the following statements is true?

- a. The blue dye was composed of large hydrophilic molecules which were unable to diffuse across the blood-brain barrier
- b. The cells of the brain and spinal cord do not have a specific receptor for the dye to bind; therefore, it did not cause a colour change in these tissues.
- c. The molecules of blue dye were transported through the blood bound to large proteins, which were unable to diffuse across the blood-brain barrier.
- d. Cells that make up the capillary wall lack a phospholipid bilayer; therefore, the dye was unable to diffuse across the blood-brain barrier.

Questions 22 – 24 relate to the following information.

Hemoglobin and myoglobin are proteins that have oxygen-carrying capacity. Hemoglobin is found in red blood cells and myoglobin is found in muscles. Hemoglobin can bind to four oxygen molecules at any point in time. In the lungs, where there is a high oxygen concentration, hemoglobin binds to oxygen forming oxyhemoglobin. Oxyhemoglobin then circulates the body in blood and unloads oxygen to tissues with a low oxygen concentration, reforming hemoglobin. Myoglobin stores oxygen in the muscle tissue and only releases oxygen when the partial pressure of oxygen has fallen drastically. Myoglobin is only found in the bloodstream after muscle injury.

The oxygen dissociation curve, depicted below, describes the relationship between the partial pressure of oxygen (x axis) and the oxygen saturation of hemoglobin or myoglobin (y axis).



22. The partial pressure of O_2 in the lungs is around 100mmHg. In the lungs, the % O_2 saturation of hemoglobin is:
- a. 90%
 - b. 95%
 - c. 100%
 - d. 110%

23. As hemoglobin unloads oxygen:

- a. It becomes easier to unload more oxygen
- b. It becomes harder to unload more oxygen
- c. Unloading oxygen continues at the same rate
- d. Carbon dioxide is exchanged for oxygen on hemoglobin

24. In intense exercise, muscles produce lactic acid. This increase in acidity within the muscle helps hemoglobin unload more oxygen. How would this change the oxyhaemoglobin dissociation curve?

- a. The curve would shift to the left
- b. The curve would shift to the right
- c. The curve would shift up
- d. The curve would shift down

25. Androgens and oestrogens are steroid (lipid) hormones that affect specific populations of cells in the human body. Which one of the following statements about this action is correct?

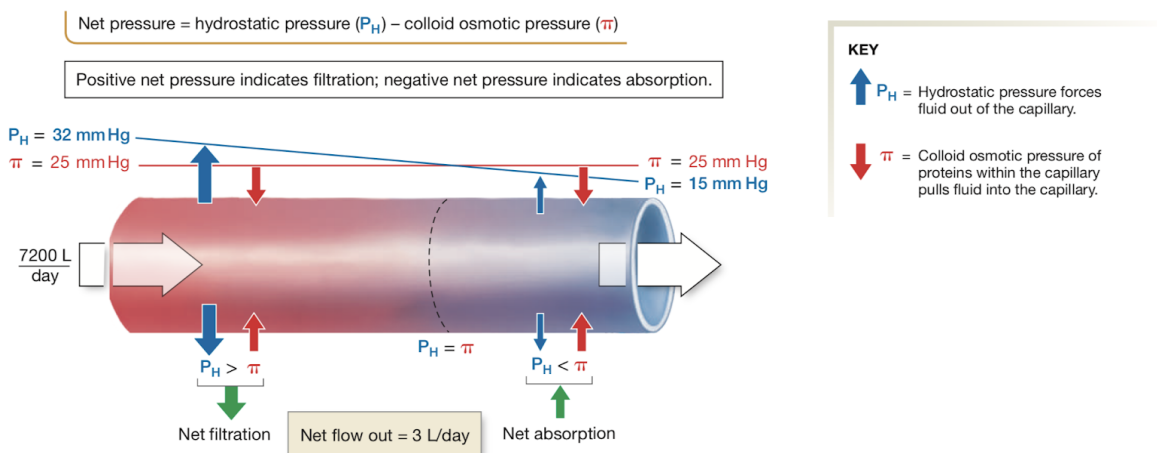
- a. Oestrogen receptors and androgen receptors are found in identical regions of the body
- b. The steroid hormones act by binding to receptors concentrated on the plasma membrane
- c. Androgen and oestrogen signalling control only one pathway in the body
- d. The lipid solubility of steroid hormones means that all cells in the body are exposed to circulating steroid hormones
- e. Androgen and oestrogen can dissolve in water and thus travel in blood plasma without a reliance on protein carriers

26. An antibody, also called immunoglobulin (Ig), is a protective protein produced by the immune system in response to the presence of a foreign substance. Antibodies are specific to one foreign molecule. They help the immune system to target and destroy the foreign material. With modern technology, scientists are now designing antibodies called monoclonal antibodies (mAbs). These are made to target specific proteins, ultimately to treat diseases.

Which of the following is true:

- mAbs provide protection against a wide range of common infections
 - mAbs can be used as the sole therapy to treat immunodeficiency in patients
 - mAbs are designed for the treatment of patients with a cancer or disease caused by a specific pathogen
 - mAbs can be used in place of intravenous IgG (IVIg) as a treatment for people who have antibody deficiencies
 - mAbs can bind to two different molecules
27. Capillary hydrostatic pressure is the pressure exerted by the blood on the walls of capillaries, forcing fluid out of the capillary. Colloid osmotic pressure is exerted by proteins within the blood and draws fluid back into the capillary via osmosis.

As blood travels from the arterial to the venous end of the capillary, capillary hydrostatic pressure decreases as fluid leaves, while colloid osmotic pressure increases as the concentration of plasma proteins increases due to the loss of fluid. Therefore, there is net filtration at the arterial end of the capillary but net absorption at the venous end. Overall, across the entire capillary, there is generally more filtration than absorption. The diagram below summarises this information.



Peripheral oedema or swelling occurs when excessive fluid exits the capillaries and accumulates in the interstitial spaces.

Which of the following options could cause peripheral oedema?

- a. Liver disease, which decreases production of the plasma protein albumin
- b. Heart failure, where the heart is unable to pump sufficient blood to the rest of the body, leading to increased venous pressure
- c. Deep vein thrombosis, where a clot forms in the veins of the legs and obstructs venous blood flow
- d. Lymphatic filariasis, caused by worms such as *Wuchereria bancrofti* which may obstruct lymphatic vessels
- e. All of the options above would cause peripheral oedema

28. What would cause increased capillary hydrostatic pressure?

- a. Hypotension
- b. Increased fluid volume
- c. Decreased fluid volume
- d. Increased diameter of the capillary

- $$\begin{array}{c} \text{R}^1 \\ | \\ \text{H}_3\text{N}^+-\text{CH}-\text{C}-\text{OH} \\ || \\ \text{O} \end{array} + \text{H}-\text{N}-\text{CH}-\text{COO}^- \begin{array}{c} \text{H} \\ | \\ \text{R}^2 \end{array}$$
- $$\xrightarrow[\text{H}_2\text{O}]{\text{H}_2\text{O}}$$
- $$\begin{array}{c} \text{R}^1 \quad \text{H} \quad \text{R}^2 \\ | \quad | \quad | \\ \text{H}_3\text{N}^+-\text{CH}-\text{C}-\text{N}-\text{CH}-\text{COO}^- \\ || \quad | \\ \text{O} \quad \text{O} \end{array}$$

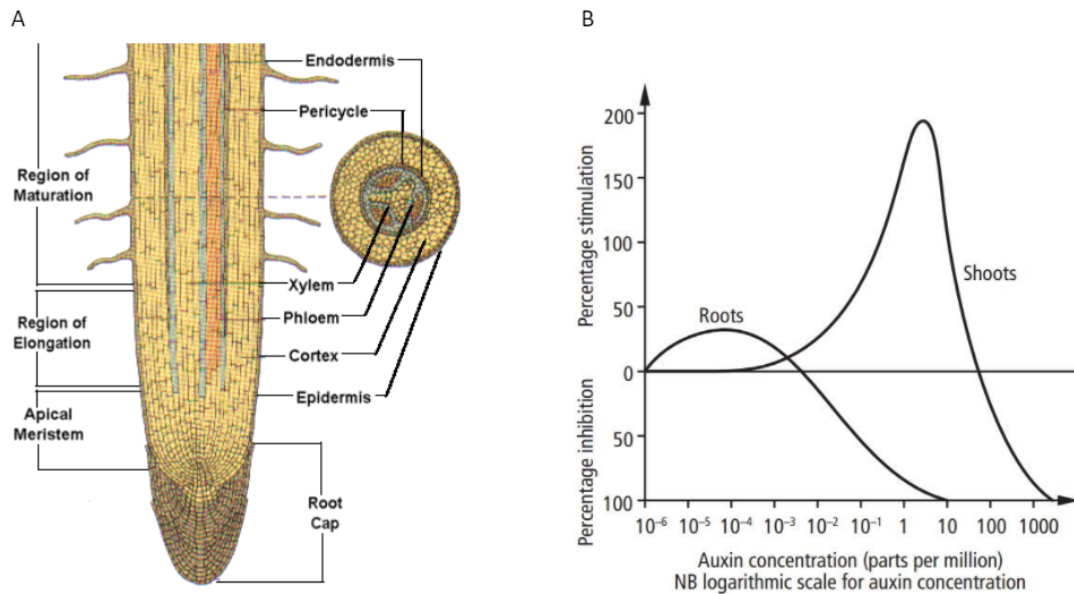
What is the molecular formula of a polypeptide chain composed of one hundred (100) glycine molecules?

- Page 16 of 42
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Questions 30 – 32 relates to the following information.

Auxin (IAA) is a hormone produced primarily in shoot apical meristems and young leaves. Root apical meristems also produce some auxin, although the root depends on the shoot for much of its auxin. Amongst its many functions in plant growth, auxin plays an important role in gravitropism.

Figure A shows the anatomy of a root. Figure B shows the relationship between auxin concentration and growth of roots and shoots.



30. What concentration/s of auxin leads to a percentage stimulation of shoot growth closest to 50%?

- 10^{-1} parts per million
- 10^{-1} parts per million and 10 parts per million
- 10^{-2} parts per million and 10 parts per million
- 2×10^{-2} parts per million and 30 parts per million
- 6×10^{-2} parts per million and 70 parts per million

31. Which of the statement/s is/are true?

- I. At low concentrations, auxin stimulates the root cap to elongate.
- II. The effects of auxin are confined to the regions in which it is synthesised.
- III. Auxin stimulates gravitropism in root hairs.
- IV. Auxin is transported through the plant in an active, cell-to-cell manner.

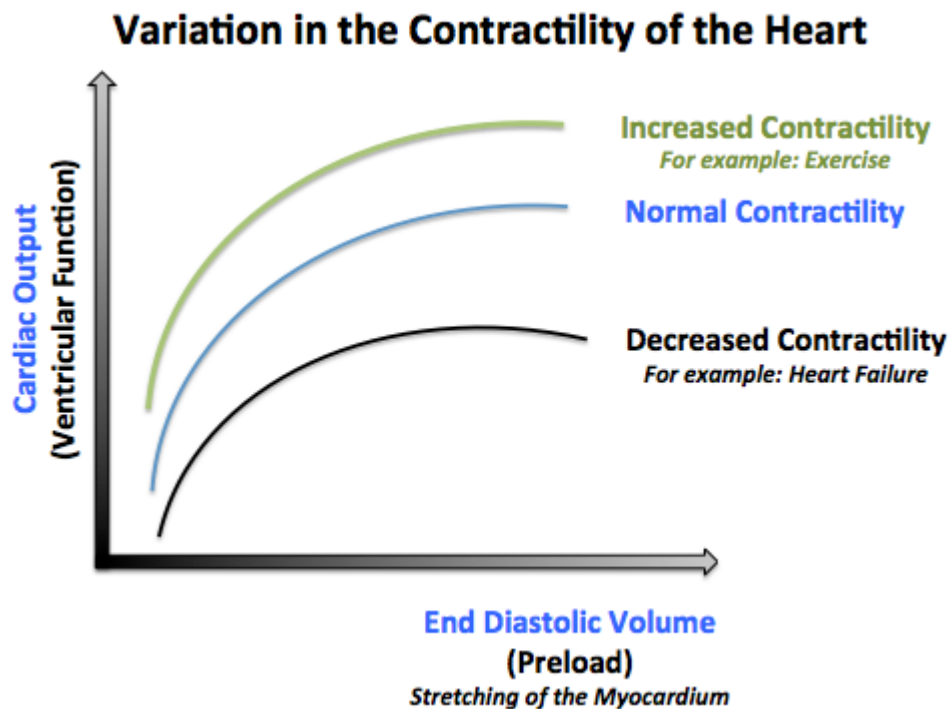
- a. I only
- b. I and II
- c. II and III
- d. I, III and IV
- e. IV only

32. Which of the following statements is true?

- a. The concentration of auxin in the roots is inversely proportional to the concentration of auxin the shoots.
- b. Maximal shoot growth occurs at auxin concentrations of less than 1×10^3 parts per billion.
- c. Maximal shoot growth occurs at auxin concentrations of less than 1×10^{-7} parts per billion.
- d. At a given concentration, auxin may not stimulate growth of both shoots and roots.
- e. At a given concentration, auxin may inhibit the growth of both shoots and roots.

Questions 33 - 35 refer to the following information.

The left ventricle of the heart pumps blood around the body. The amount of blood pumped out of the heart during one contraction is called the cardiac output. The cardiac output varies according to end diastolic volume (see diagram below). The end diastolic volume, also known as the preload, is the volume of blood in the left ventricle before contraction. The cardiac output is also influenced by contractility, which is the ability of the heart muscle to contract.



33. Which of the following would increase cardiac output?

- I. Increased contractility
- II. Increased preload
- III. Weakened heart muscle
- IV. Decreased blood volume
- V. Fight or flight response

- a. I and II
- b. I, II and III
- c. I, II and IV
- d. I, II, and V
- e. I, II, III and IV

34. What would NOT result from an increased end-diastolic volume?

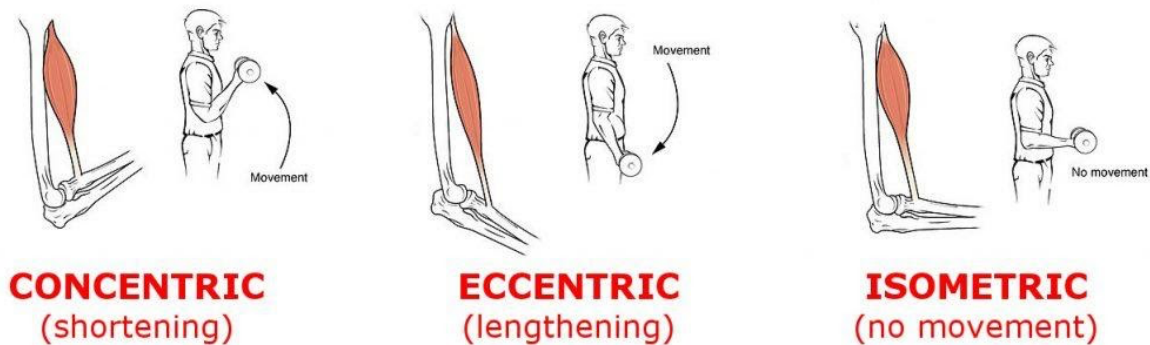
- a. Increased stretching of the left ventricle.
- b. Weaker contraction of the left ventricle.
- c. Increased preload.
- d. Increased cardiac output.
- e. Increased volume of blood in the left ventricle before contraction.

35. This graph depicts the Frank-Starling law. The Frank-Starling Law is the description of cardiac function as it relates to myocyte stretch and contractility.
Which of the following best describes the Frank-Starling law of the heart?

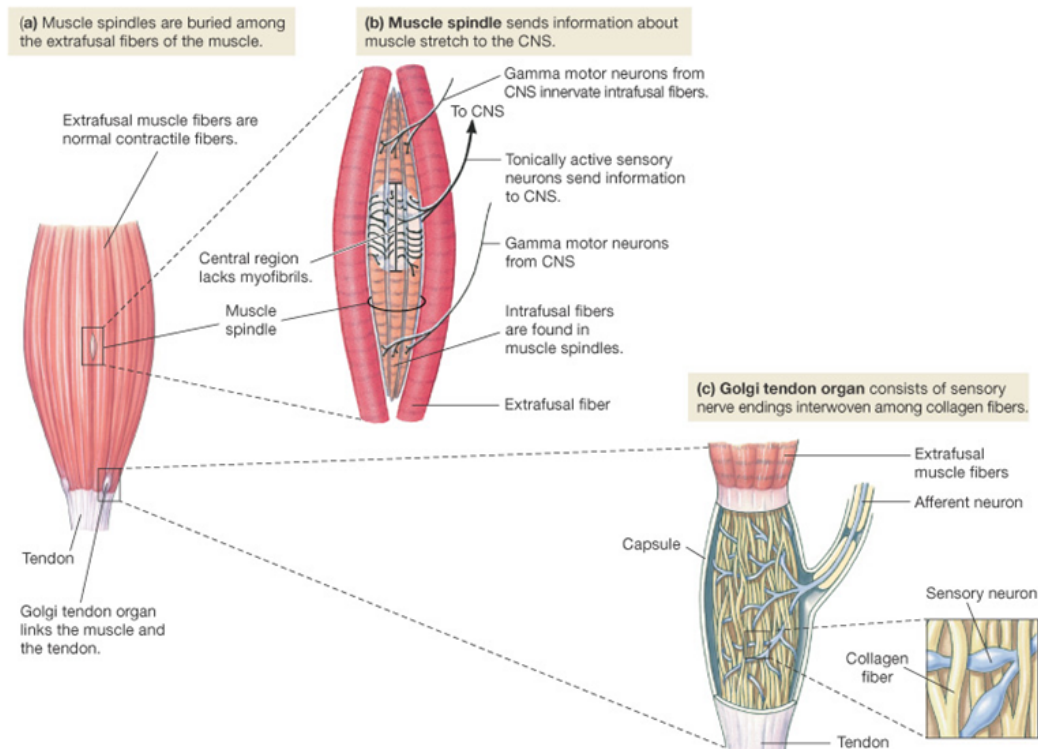
- a. Increase in end-diastolic volume results in an increased cardiac output.
- b. Increase in end-diastolic volume results in an increased heart rate.
- c. Increase in end-systolic volume indicates an increased cardiac output.
- d. End-systolic volume equals end-diastolic volume.
- e. Increase in cardiac output results in an increase in end-diastolic volume.

Questions 36 and 37 refer to the following information.

There are three types of muscle contraction, see diagram below. All these muscle contractions occur against a load. Concentric contraction occurs when a muscle shortens against a load. Eccentric contraction occurs when muscle lengthens against a load. Finally, isometric contraction occurs when muscle does not shorten or lengthen against a load.



Within a muscle, there are two types of receptors: muscle spindles and golgi tendon organs, see diagram below. Muscle spindles are found within the belly of a muscle. These are activated when the muscle stretches. Golgi tendon organs are found in the tendon of a muscle. A tendon attaches muscle to bone. Golgi tendon organs are activated when the muscle contracts and shortens. This information is sent to the central nervous system via sensory neurons.



36. What happens to sensory neuron activity during concentric contraction?
- a. Muscle spindle nerve activity increase, Golgi tendon organ nerve activity decrease
 - b. Muscle spindle nerve activity decrease, Golgi tendon organ nerve activity decrease
 - c. Muscle spindle nerve activity increase, Golgi tendon organ nerve activity increase
 - d. Muscle spindle nerve activity decrease, Golgi tendon organ nerve activity increase
 - e. Muscle spindle nerve activity stays the same, Golgi tendon organ nerve activity stays the same
37. After drinking coffee, a person slowly lowers a mug down to the table. What happens to sensory neuron activity during this action?
- a. Muscle spindle nerve activity increase, Golgi tendon organ nerve activity decrease
 - b. Muscle spindle nerve activity decrease, Golgi tendon organ nerve activity decrease
 - c. Muscle spindle nerve activity increase, Golgi tendon organ nerve activity increase
 - d. Muscle spindle nerve activity decrease, Golgi tendon organ nerve activity increase
38. Energy can be stored in the body in different ways. Glucose and glycogen yield approximately 17 kJ of energy per gram while lipids (fats) yield 37 kJ per gram. If the average person has stored 5 g of free glucose in their blood, 480 g total glycogen in their muscles and liver, 15 kg of lipids in their adipose tissue and has an energy requirement of 8700 kJ per day, approximately how many days could they theoretically survive under starvation conditions?
- a. 25 days
 - b. 35 days
 - c. 45 days
 - d. 55 days
 - e. 65 days

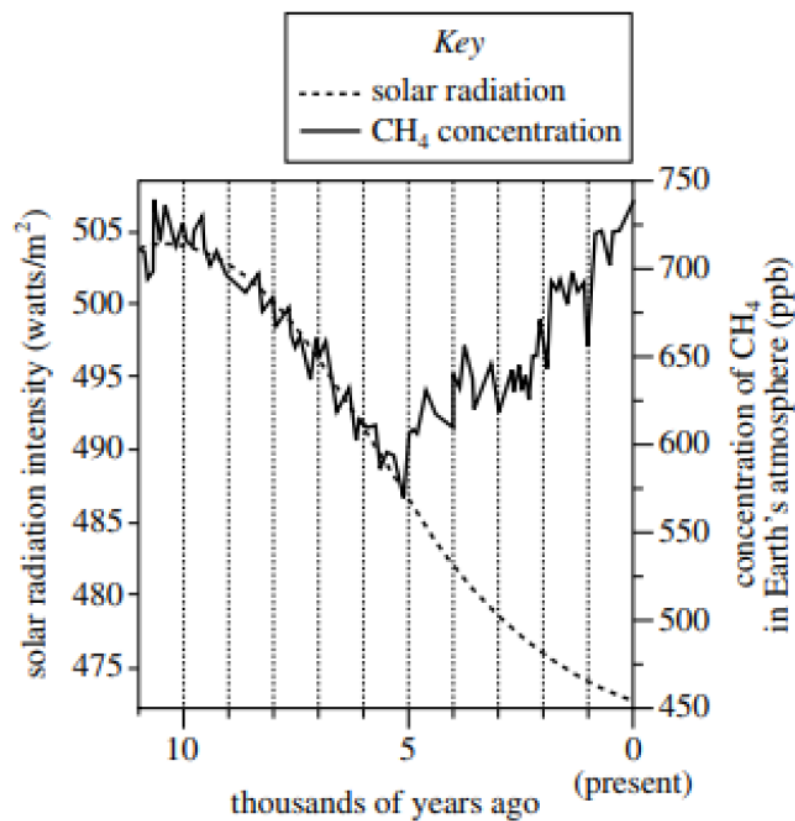
39. The picture below shows a white-light microscopy image of *Paramecium*, a unicellular organism which is commonly found in freshwater environments.

Given that the scale bar represents 120 μm , approximately how many identical organisms can fit length-to-length across a petri dish with a 100 mm diameter?



- a. 17
- b. 30
- c. 58
- d. 80
- e. 108

40. The graph below shows the concentration of methane (CH_4) in the Earth's atmosphere alongside the intensity of solar radiation over the past few millennia.



According to the graph, if the trend of CH_4 concentration had continued to match the trend on solar radiation intensity, the concentration at present would most likely be:

- a. Less than 500 ppb.
- b. Between 500 and 550 ppb.
- c. Between 550 and 600 ppb.
- d. Between 600 and 700 ppb.
- e. Above 700 ppb.

Questions 41 and 42 refer to the following information.

A spectrophotometer is a machine that measures how much light is absorbed or transmitted when passed through a solution. The result depends on the colour and clarity of the solution as well as the wavelength (colour) of light passed through it. Zijlstra & Buursma (1997) examined the absorptivity of four derivatives of haemoglobin (the pigment that makes blood red) for humans and cows (bovines) (Figure 1).

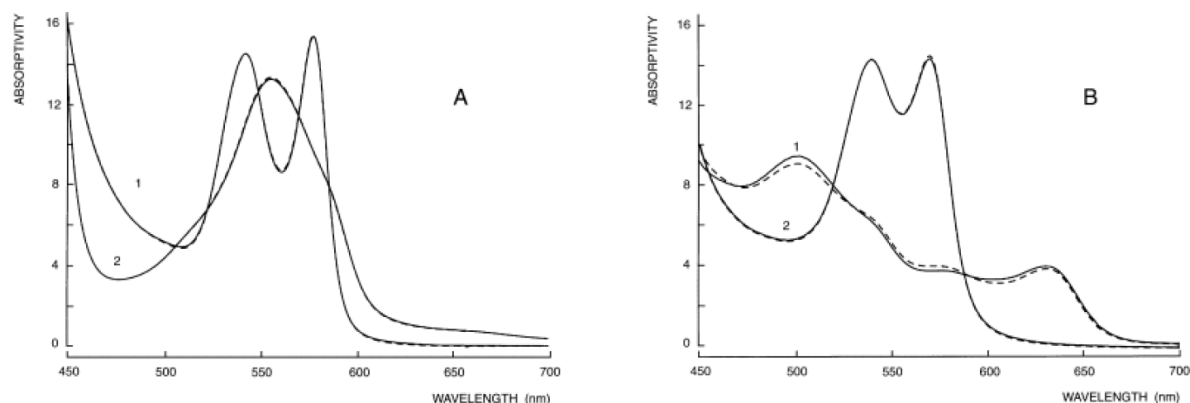


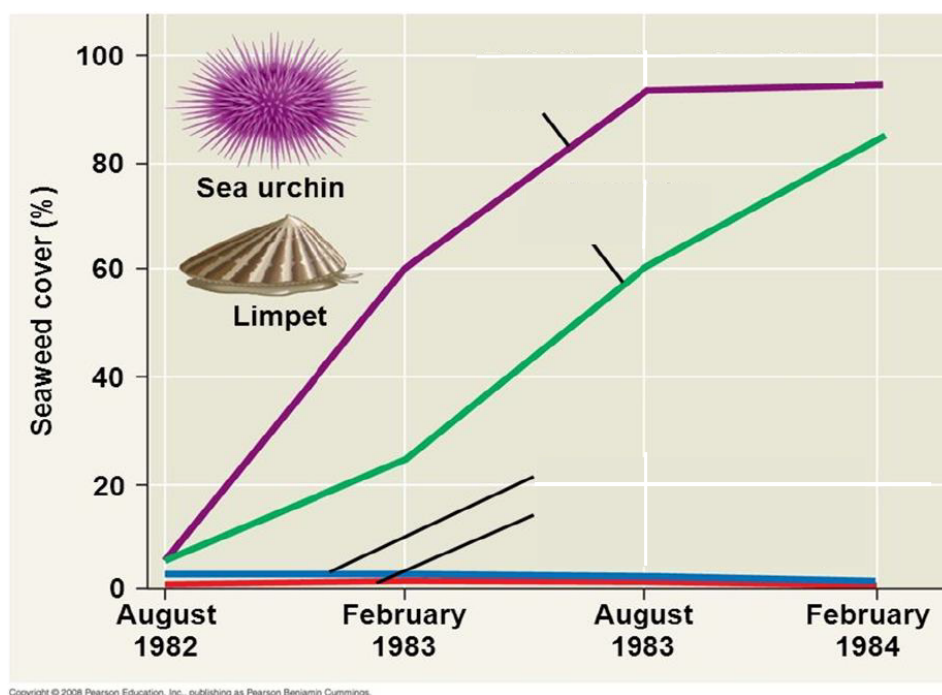
Figure 1. Absorption spectra of the common derivatives of cow (—) and human (---) haemoglobin in the visible range. (A) oxyhaemoglobin, O₂Hb (1) and deoxyhaemoglobin, HHb (2); (B) methaemoglobin, Hi (1) and carboxyhaemoglobin, COHb (2). The absorptivity is expressed in L mmol⁻¹ cm⁻¹.

41. What is the approximate absorptivity of methaemoglobin for humans at 550nm?
- 4 L mmol⁻¹ cm⁻¹
 - 6 L mmol⁻¹ cm⁻¹
 - 8 L mmol⁻¹ cm⁻¹
 - 10 L mmol⁻¹ cm⁻¹
 - 12 L mmol⁻¹ cm⁻¹
42. Which of the following can be concluded from the data contained in the graphs?
- There is a statistically significant spectral difference between bovine and human Hi.
 - For HHb, O₂Hb, and COHb there are only minute spectral differences between bovine and human haemoglobin.
 - In the O₂Hb spectrum the minimum at 560 nm is slightly higher for bovine than for human haemoglobin.
 - At 508 nm the absorptivity of bovine haemoglobin is slightly lower than that of human haemoglobin.

- e. In the COHb spectrum the α -peak around 569 nm is somewhat higher for bovine haemoglobin, and in the minimum near 496 nm the spectrum of bovine haemoglobin lies a little above that of the human.
43. Betsy and Bob are both high-risk carriers of a hereditary illness, X. After receiving genetic counselling, they were told that the probability of any child they have inheriting X is 12%. The illness affects boys and girls equally, both in terms of severity and in the probability of inheritance. Betsy and Bob plan to have two children.

Calculate the probability that they will have two healthy (non-affected) sons.

- a. 11.4%
- b. 12%
- c. 19.4%
- d. 44%
- e. 77.4%



Unfortunately, the labels of the plot lines have disappeared. In no particular order, the labels are:

1. No limpets or urchins removed (Control)
2. Both limpets and urchins removed
3. Only urchins removed
4. Only limpets removed

Which of the following options correctly labels each line?

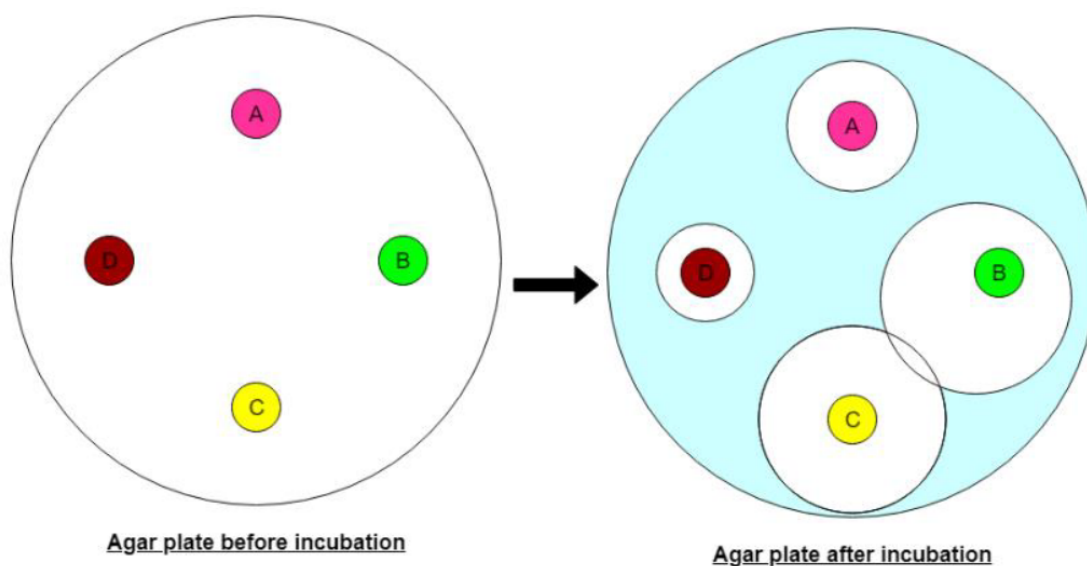
- a. Purple – 1, Green – 3, Blue – 4, Red - 2
 - b. Purple – 2, Green – 3, Blue – 4, Red – 1
 - c. Purple – 2, Green – 4, Blue – 3, Red - 1
 - d. Purple – 2, Green – 3, Blue – 1, Red - 4
 - e. Purple – 1, Green – 2, Blue – 3, Red - 4
45. Differential staining is an important technique used in bacterial microbiology. One such stain is the Gram stain, which uses a crystal violet dye that binds to a cell wall layer called peptidoglycan. Thick layers of peptidoglycan stain dark purple in Gram-positive bacteria because the stain is retained. Thinner layers of peptidoglycan do not retain the stain effectively in Gram-negative bacteria and are therefore not stained the same deep purple. This is important because the staining result and subsequent classification inform medical staff on how best to treat an infection with this bacterium.

Based on the information about differential staining, choose the CORRECT answer:

- a. A Gram-negative and a Gram-positive bacterium will stain the same
- b. Gram-positive bacteria are harder to kill
- c. Gram-positive bacteria can be identified by a thick purple stained cell wall
- d. Gram-negative bacteria have no peptidoglycan layer in their cell wall
- d. The gram stain can be used to classify bacteria by their genus as well as their cell wall properties

46. With the rise in drug-resistant bacteria, it is crucial that antibacterial drugs are effective and prescribed appropriately to prevent selecting for resistance in the bacteria. We also need to understand their effect on other bacteria cohabiting the human body to prevent development of resistant strains of these other bacteria.

The Kirby-Bauer disk diffusion method is one technique used to assess the resistance of a bacterium to a drug. The bacteria are cultured on plates and small disks impregnated with specific antibiotics placed on the surface (coloured and labelled A-D below). The antibiotic from the disk diffuses into the growth medium as the bacteria on the surface of the plate replicates. Susceptible bacteria cannot grow in the presence of the antibiotic, resulting in a clear zone of inhibition around the disk. In contrast, resistant bacteria can replicate freely around the disk and there is no clear zone seen, just a 'lawn' of bacteria. The size of the inhibition zone is indicative of the effectiveness of the antibiotic impregnated in that disk. Zones of antibiotic diffusion should not overlap: if they do so a repeat of the experiment is required to determine their effectiveness.

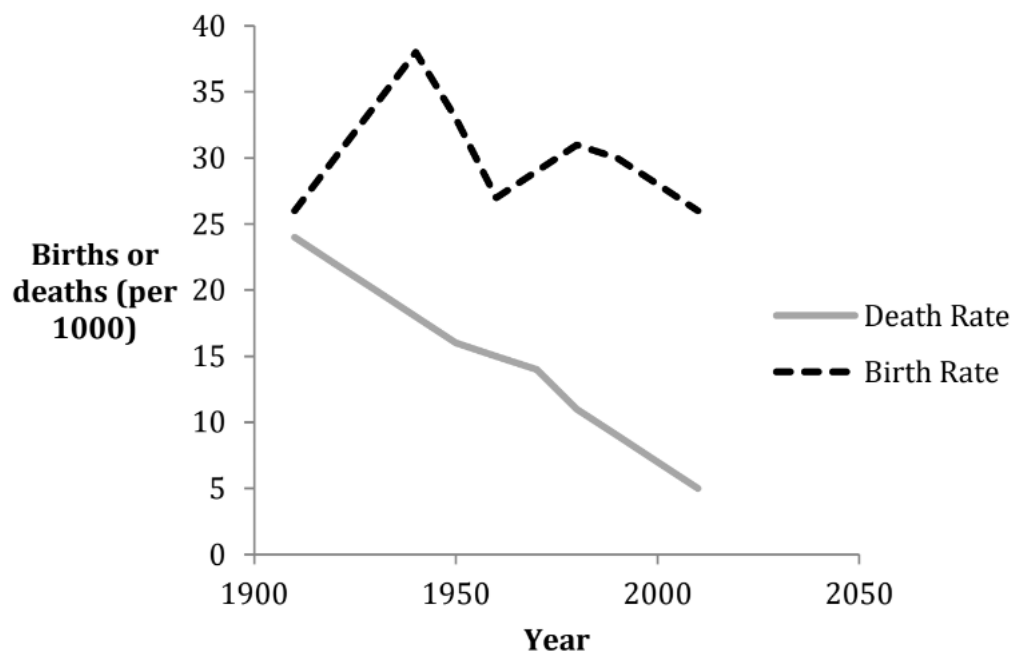


Which of the following statements is INCORRECT?

- a. Antibiotics B and C require a repeated experiment to determine their effectiveness
- b. Antibiotic D is the best inhibitor of the growth of this bacterium
- c. The incubation process caused the differential growth of this bacterium species
- d. Antibiotic A is effective against this bacterium, although antibiotics B and C are potentially more effective than A
- e. Antibiotic B has not diffused evenly from disk B

47. Anna's father has five daughters: 1. Nana, 2. Nemu, 3. Nino, 4. Nomi. What is the name of the fifth daughter?
- a. Nune
 - b. Nume
 - c. Nunu
 - d. Numu
 - e. Anna

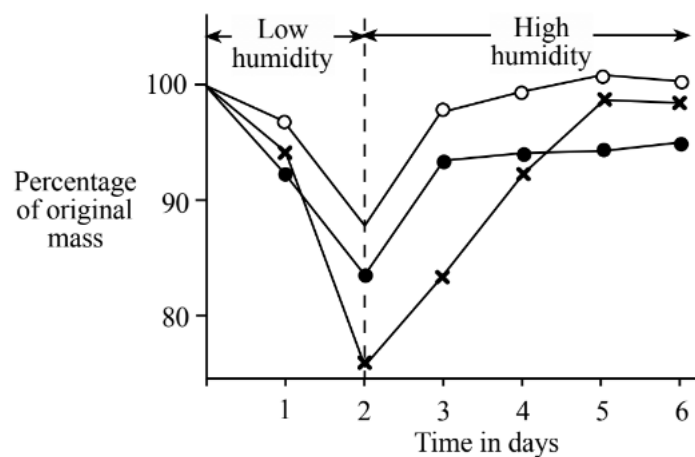
48. The graph shows the birth rate and death rate for a population of kangaroos over a 100-year period.



Assuming equal emigration and immigration, from 1900 to 2000, the population has:

- a. Increased
- b. Decreased
- c. Stayed the same
- d. Increased until 1930, then decreased
- e. Decreased until 1930, then stayed the same

49. The graph shows changes in mass of three individual kangaroo ticks when they were removed and kept for two days at low humidity and then four days at high humidity.



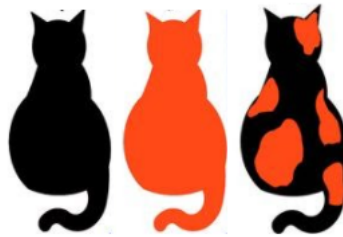
The best deduction from these data is that:

- a. At high humidity ticks absorb water from the atmosphere
- b. At day 6 the ticks have recovered their body water
- c. The loss of mass during the first two days is due to starvation
- d. Individual ticks contain different amounts of water
- e. Individual ticks lose water at the same rate when held in low humidity conditions

Questions 50 and 51 refer to the following information.

Like many mammals, cat species use the XY sex-determination system where males have the sex chromosomes XY and females have the sex chromosomes XX. In a specific breed of cats called tortoiseshell cats, the major gene for fur colour is located on the X-chromosome. There are two fur colour alleles for this gene: one for orange fur and one for black fur.

In a specific litter of kittens, there are three kittens born with the following fur colours: pure orange fur, pure black fur, and one with both orange and black fur.



50. Which of the following statements is most likely to be true?
- a. The kitten with both orange and black fur is female
 - b. The kitten with both orange and black fur is male
 - c. The pure colour kittens (the pure black fur and pure orange fur) are male
 - d. The pure colour kittens (the pure black fur and pure orange fur) are female
 - e. The kitten's sexes are randomly determined so cannot be determined
51. An orange fur female tortoiseshell cat was crossed with a black fur male tortoiseshell cat and had a litter of six kittens. Which of the following offspring colours are most likely?
- a. 3 black fur male kittens and 3 mixed fur (orange and black fur) female kittens
 - b. 4 orange fur male kittens and 2 mixed fur female kittens
 - c. 2 black fur kittens, 2 orange fur kittens, 2 mixed fur kittens
 - d. 1 mixed fur male kitten, 5 orange female kittens
 - e. All kittens will be of a mixed fur pattern

Questions 52 and 53 refer to the following information.

Julie noticed an introduced species of weed disrupted the growth of native plant seedlings in the local park. She also recalled that symbiotic bacteria in the soil play a role in native plant seedling growth. Julie took two soil samples from an area where the weed species were growing ('Affected' soil samples) and sterilised ONE sample using ultraviolet light. She then obtained another two soil samples from an area without any evidence of the weed species ('Unaffected' soil samples) and sterilised one sample as well. She then planted some native seedlings in each soil sample and let them grow for 3 months. At the end of 3 months, she removed all the roots, stems, and leaves of the seedlings and weighed the biomass of the collected plant material.

She repeated this experiment 5 times with five different sets of soils and documented the results in a table:

Soil category	Weighed seedling biomass (g)				
	First set	Second set	Third set	Fourth set	Fifth set
Affected	6	11	1	2	4
Unaffected	141	149	139	128	140
Sterilised affected	3	7	5	2	5
Sterilised unaffected	10	21	9	7	14

Julie also examined the soil samples with and without the weed species under a light microscope to examine the symbiotic bacteria present in the soil.

Soil category	Number of symbiotic bacteria viewed per mm ² under the microscope				
	First set	Second set	Third set	Fourth set	Fifth set
Affected	6	7	11	6	8
Unaffected	515	534	501	456	466

52. Which conclusion is most supported by the data results?

- The symbiotic bacteria in the soil are a shared resource that the weed species outcompetes the native seedlings for
- The presence of symbiotic bacteria supports the growth of the introduced weed species by forming a mutualistic relationship
- The native seedlings promote symbiotic bacteria growth in the soil, which then inhibits the growth of the introduced weed species
- The data shows there is no relationship between the symbiotic bacteria, introduced weed species, and native seedlings
- The weed species suppresses native seedling growth by decreasing the number of symbiotic bacteria in the soil

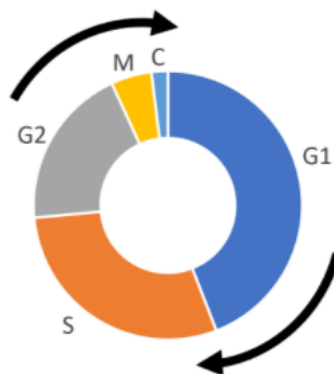
53. How could Julie best increase the validity of her experiment?

- a. Increase the number of times she repeated the experiment and collect more numerical data, and then average the results
- b. Introduce a friend to repeat her experiment and check Julie's data collection
- c. Dry out the seedling biomass samples in a dehydrator before recording the weight
- d. Count the number of seedlings instead of weighing them
- d. Recording biomass weights to two decimal points, rather than rounding them to the nearest gram

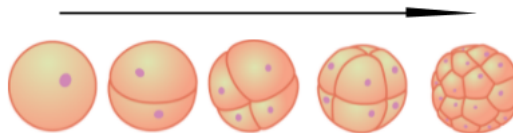
Questions 54 and 55 refer to the following information.

When eukaryotic cells divide, they pass through the 'cell cycle', which can be subdivided into a series of phases. This is depicted in the picture below. Cells that begin to prepare for cell division enter the G1 phase ('Gap 1' phase). In the G1 phase, cellular and cytoplasmic contents are produced in preparation for cell division (such as proteins, organelles, and the cytoplasm itself). After this phase, the cell progresses into the S phase ('Synthesis' phase) where DNA replication occurs, and then into the G2 phase ('Gap 2' phase) where the cell grows further by producing and assembling the cytoplasmic materials for mitosis and cytokinesis. Finally, the cell enters the mitotic phase (labelled 'M') and cytokinesis (labelled 'C') and completes cell division.

Phases through the Cell Cycle



54. Liam is using x-ray radiation to induce mutations in a strain of animal cells in his laboratory. At which phase of the cell cycle is a cell most likely to mutate when exposed to radiation?
- a. G1
 - b. S
 - c. G2
 - d. M
 - e. C
55. Anna is a scientist who looked through the microscope at a dividing animal embryo. She noticed that in the early stages of embryo development, the cells undergo cell division in quick succession and the daughter cells become smaller with each division, as depicted in the image below. Unlike regular cell division, embryo cells divide through a modified cell cycle known as 'cleavage' where some phases of the cell cycle are shortened or skipped entirely.

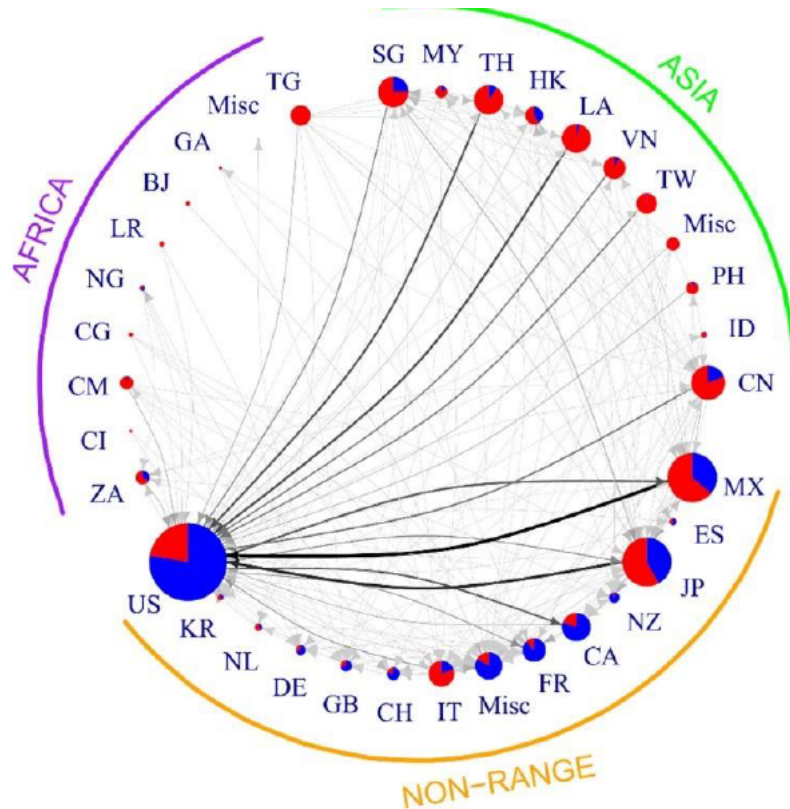


Which phase of the cell cycle is shortened the most in 'cleavage' division?

- a. S and G1 phases
- b. G1 and G2 phases
- c. M and C phases
- d. G2 and M phases
- e. M and S phases

56. The pangolin is an endangered mammal, with 4 species native to Africa and another 4 species native to the Asian continent. Pangolins are protected by CITES, the Convention on International Trade in Endangered Species of Wild Fauna and Flora. CITES aims to ensure that the international trade in wild animals and plants does not threaten their survival.

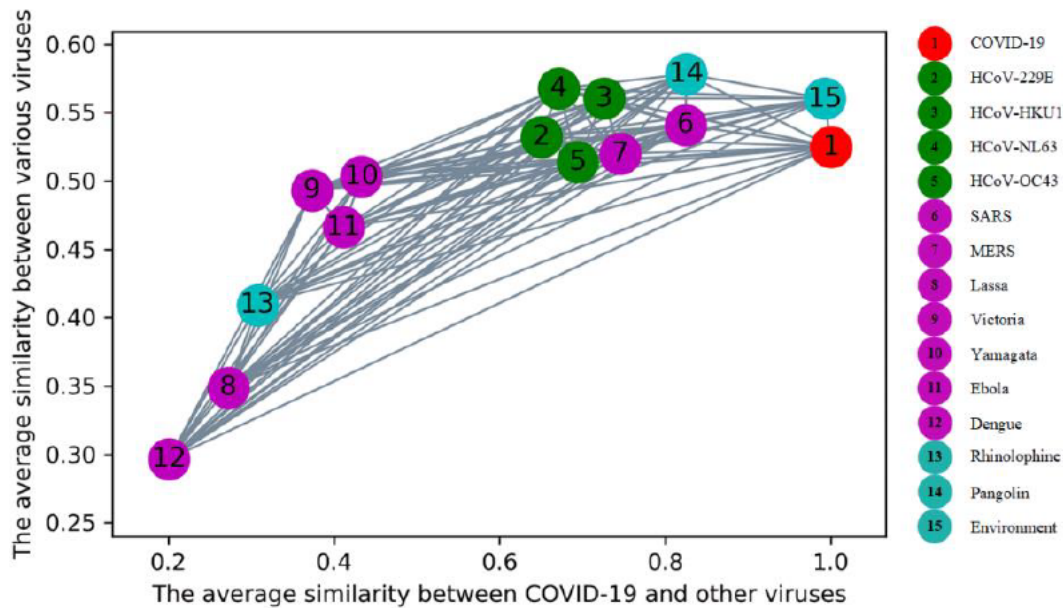
CITES records of intercepted pangolin trades (1977-2014) are summarised below. Red sectors in the pie graphs indicate that a country was the origin of an exported pangolin, blue indicates that a country was the destination for an imported pangolin. The width of the arrow and diameter of pie graphs indicate the relative size of the trade.



Which of these statements is NOT supported by the data?

- New Zealand (NZ) is involved in the illegal trade of pangolins
- The USA (US) is the main destination for imported pangolins
- More pangolins are exported from Asia than Africa
- Italy (IT) exports more pangolins than the USA (US)
- Asian countries are involved in both the importation and exportation of pangolins

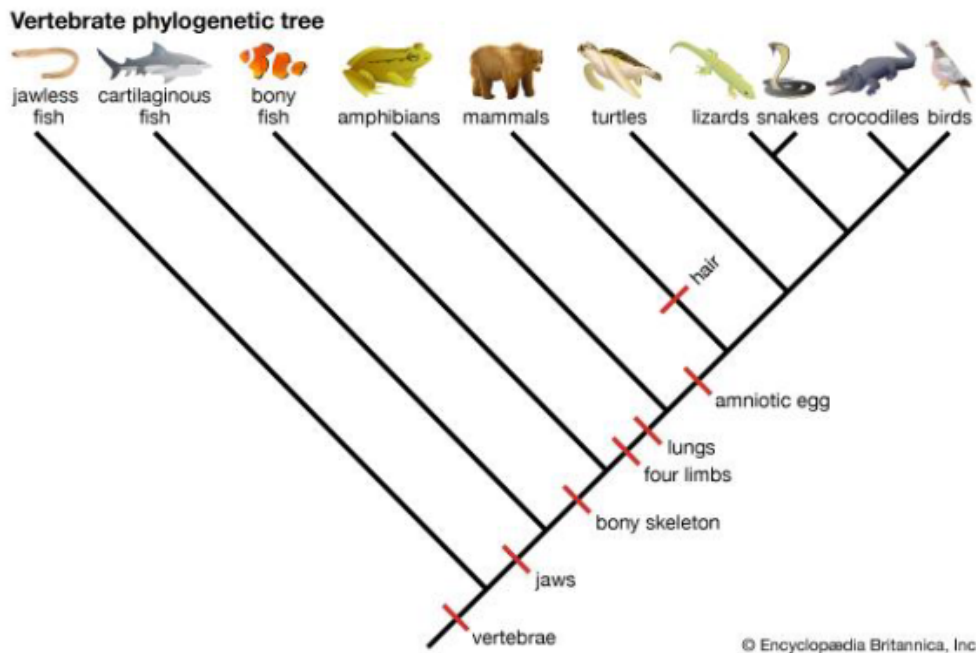
57. The genetic sequence of the virus that causes COVID-19 was compared with virus samples from different non-human hosts and from environmentally collected strains and all samples were plotted against the average similarity of the group. The COVID-19 virus found in the environment is very similar to that from humans, likely reflecting the current high levels of transmission within the human population and shedding into the environment.



From the list below, what is the best inference that can be made from these data? The COVID-19 virus

- a. evolved spontaneously in the environment, with no clear host
- b. has its closest evolutionary link to a pangolin virus
- c. has its closest evolutionary link to a bat (Rhinolophine) virus
- d. has its closest evolutionary link to a Dengue virus
- e. evolved from the common cold virus (HCoV – 229E)

58. A phylogenetic tree is a diagram that shows the evolutionary relationships of living things that have descended from a common ancestor. Each branching point in this phylogenetic tree represents the divergence of two groups from a common ancestor.



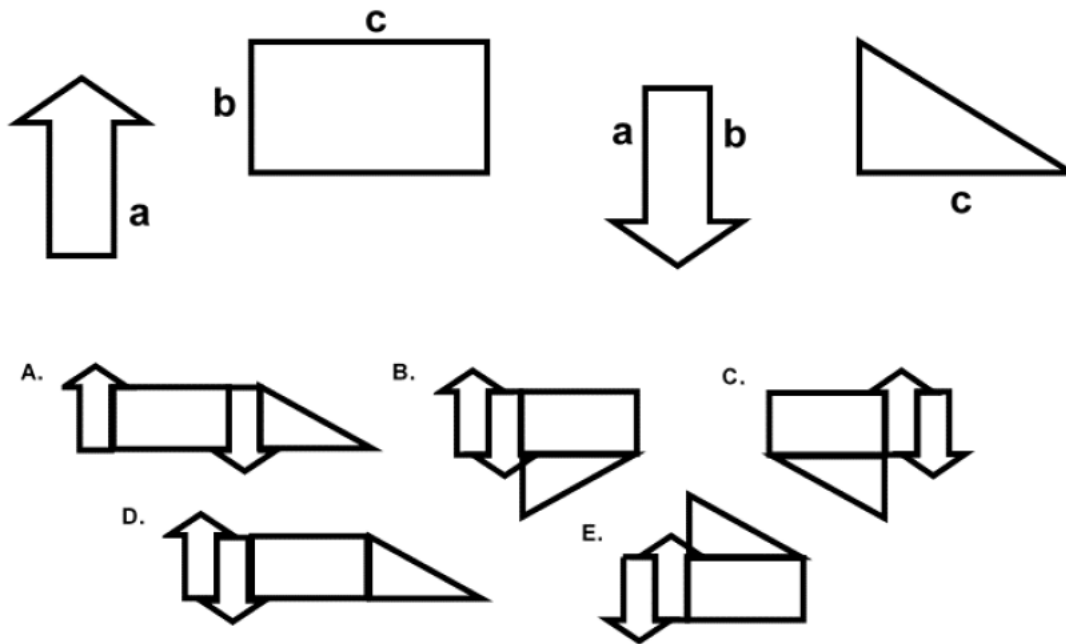
Considering the vertebrate tree above, which of the following options correctly orders vertebrates from the least to the most number of branching points experienced in total since the evolutionary divergence that resulted in vertebrates?

- Jawless fish < cartilaginous fish < crocodiles < birds
- Bony fish < amphibians < snakes < lizards
- Amphibians < mammals < turtles < birds
- Lizards < turtles < amphibians < birds
- Lizards < snakes < crocodiles < birds

59. All vertebrates show some sort of bilateral symmetry. What advantage does this provide?

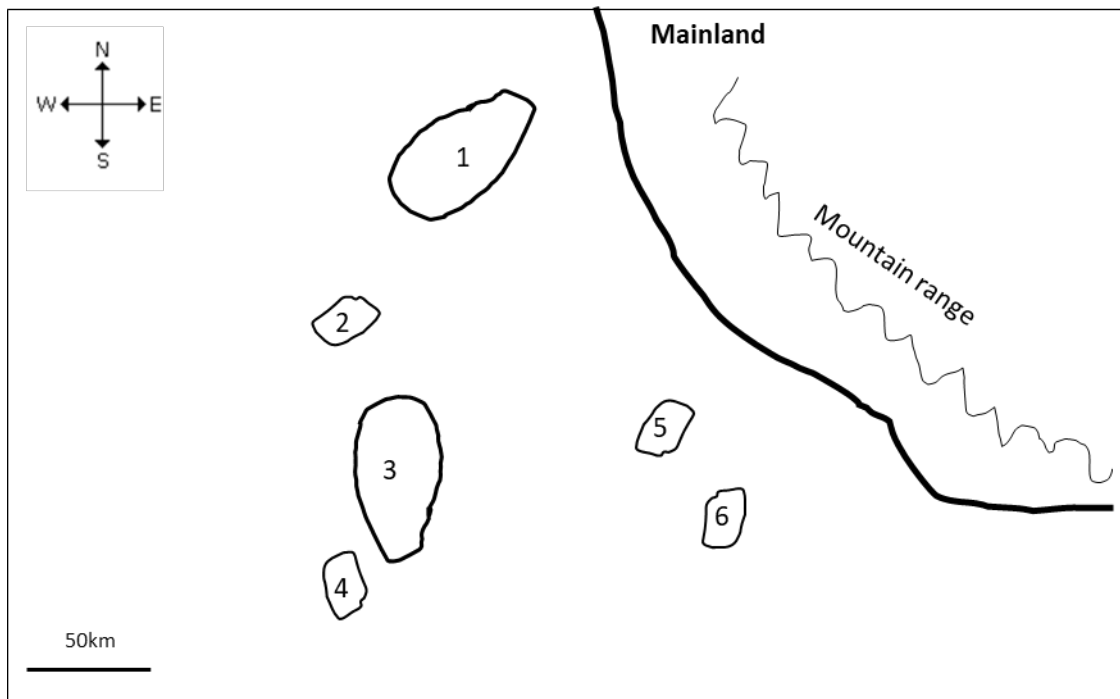
- Concentration of most sensory organs are in the head
- Walking on land
- Flying
- Development of bones
- Ability to give birth to live offspring

60. Join all of the shapes below together matching the letters. Which shape (A – E) will this make?



Questions 61 - 65 refer to the following information.

Review the following map and answer the 5 subsequent questions.



Ecologists have been studying the small archipelago shown in the map above. They have been comparing the ecology of the mainland with those on the nearby islands and have come up with a few discoveries. The area has not been known to have been inhabited by humans, so it remains very natural. The mainland contains a low mountain range approximately 50km inland from the coast (highest peak approximately 400m above sea level) and the prevailing winds are westerlies.

61. Which Island is expected to contain the greatest species diversity?

- a. 1
- b. 5
- c. 3
- d. 2
- e. 6

62. After investigating all of the vegetation types on each region the ecologists identified an area that would fit the description of a rain shadow. Where would the rain shadow be most likely to have been identified?
- a. East of the mountain range on the mainland
 - b. West of the mountain range on the mainland
 - c. Island 3
 - d. Island 6
 - e. Island 1
63. The ecologists monitor the number of geckos on Island 3 and find that their birth rate equals 0.2 per annum. When the ecologist counted them this year there were 110 geckos on the island.
How many will there be at the same time next year?
- a. 55
 - b. 132
 - c. 22
 - d. 165
 - e. 172
64. Considering the smaller islands only, which one would be expected to have the greatest biodiversity?
- a. 2
 - b. 4
 - c. 5
 - d. 6
 - e. 0 (they would all be equal)

65. The ecologists studying the biodiversity on the islands notice that the geckos on island 3 look darker than those on island 1, even though genetic analysis shows that they are the same species.

What is most likely to produce this phenomenon?

- a. Radiant heat differs on each island
- b. The islands differ in their gecko prey availability
- c. Predation pressure
- d. Genetic bottleneck
- e. Low reproduction rates

END OF EXAM

SOURCES

Question 1 - 4: Image sourced: [Cpb-us-e1.wpmucdn.com/](http://cpb-us-e1.wpmucdn.com/)

Question 10 - 11: Images sourced: <https://overallscience.com/differences-between-poikilothermic-and-homeothermic-animals/>

Question 13 - 18: Adapted from: Zhu, L., Han, M.B., Gao, Y., Wang, H., Dai, L., Wen, Y., & Na, L.X. (2015). Curcumin triggers apoptosis via upregulation of Bax/Bcl-2 ratio and caspase activation in SW872 human adipocytes. Molecular Medicine Reports, 12, 1151-1156. <https://doi.org/10.3892/mmr.2015.3450>

Question 27: Image sourced: Human Physiology: An Integrated Approach 7e (Dee Unglaub Silverthorn)

Question 29: Image sourced: Principles of Biochemistry (Lehninger 6e)

Question 30 – 32: Images sourced: <http://www.robinsonlibrary.com/science/botany/anatomy/roots.htm/>.

Question 33 - 35: Image sourced: https://www.wikidoc.org/index.php/File:Variation_in_the_Contractility_of_the_Heart.png.

Question 36 - 37: Images sourced: <https://fitblissfitness.com/2020/08/07/concentric-eccentric-isometric-tempo-what-does-it-all-mean/> AND http://memex.cc/Skeletal_muscle.

Questions 40: Image sourced and modified: William Ruddiman, 'Plows, Plagues & Petroleum'

Questions 41 and 42: Image sourced: <https://www.sciencedirect.com/science/article/pii/S0305049197002307>.

Question 44: Image sourced: Campbell Biology (10th edition), Copyright © 2008 Pearson Education Inc.

Question 59: Source: <https://kids.britannica.com/students/assembly/view/235364>

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