

2016 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 SECTIONS A and B on the MULTIPLE CHOICE and TRUE/FALSE ANSWER SHEETS PROVIDED. Use a pencil.**
- **Answer SECTION C in the answer booklet provided. Write in pen and use pencil only for graphs.**
- **Ensure that your diagrams are clear and labelled.**
- **All numerical answers must have correct units.**
- **Marks will not be deducted for incorrect answers.**
- **Do not write on this question paper. It will not be marked.**

MARKS

SECTION A	40 multiple choice questions	40 marks
SECTION B	12 sets of true/false questions	12 marks
SECTION C	19 written answer questions	48 marks

Total marks for the paper 100 marks

SECTION A
USE THE ANSWER SHEET PROVIDED

1. In Science, an educated guess is called a/an
 - a. observation
 - b. conclusion
 - c. question
 - d. hypothesis

2. In an experiment, the factor whose value depends on that of another is called the
 - a. independent variable
 - b. controlled variable
 - c. conclusion
 - d. dependent variable

3. Genetic material is contained within the _____ of the cell.
 - a. ribosomes
 - b. cytoplasm
 - c. nucleus
 - d. nucleolus

4. The main structural component of plant cells is:
 - a. sodium chloride
 - b. glycogen
 - c. cellulose
 - d. glucose

5. A solution that has a higher concentration of solute than another solution is called:
 - a. hypertonic
 - b. hypotonic
 - c. isotonic
 - d. concentration

6. Equilibrium is reached in an aqueous solution when
- Random motion stops
 - Water molecules and dissolved molecules are moving at the same rate
 - The dissolved molecules or ions are equally distributed throughout the solution
 - There are the same number of water molecules as dissolved molecules
7. A contractile vacuole is an organelle that pumps excess water out of many freshwater protozoan cells. A freshwater protozoan was placed in solution A and observed to form contractile vacuoles at a rate of 11 per minute. The same protozoan was then placed in solution B and observed to form contractile vacuoles at a rate of 4 per minute. Based on this information, which of the following statements is correct?
- Solution A is hyperosmotic to solution B
 - Solutions A and B are isosmotic
 - Solution B is hyperosmotic to solution A
 - Solutions A and B are isosmotic to the protozoan cell
8. Which of the following is a unicellular organism?
- earthworm
 - hydra
 - yeast
 - mushroom
9. A disc X is punched out of a leaf from a growing plant, then dried at 110 °C and weighed. A week later another disc Y is punched out of the leaf of the same growing plant using the same punch, dried at 110 °C and weighed. Leaf disc Y is found to have a greater dry weight than leaf disc X; this is because leaf Y has:
- increased in area
 - more water in it
 - produced more carbohydrate
 - transpired at a greater rate

10. Enzymes

- a. are not very specific in their choice of substrates
- b. are needed in large quantities because they are used up during a reaction
- c. lower the activation energy of a reaction
- d. none of the above

11. The organelle responsible for producing ATP in the human body is the:

- a. nucleus
- b. mitochondria
- c. endoplasmic reticulum
- d. golgi apparatus

12. Which of these is not used by the body for energy?

- a. fat
- b. carbohydrate
- c. protein
- d. water

13. Just prior to cell division, the diploid human body cell contains ____ chromatids.

- a. 23
- b. 46
- c. 69
- d. 92

14. An individual who has two of the same allele is said to be

- a. homozygous
- b. heteromologous
- c. heterozygous
- d. diplozygous

15. Which of the following represents a dihybrid?
- a. WWSs
 - b. WwSS
 - c. WwSs
 - d. WWss
16. DNA replication is called semiconservative because _____ of the original double helix is conserved in each new DNA molecule.
- a. none
 - b. a quarter
 - c. a half
 - d. most
17. The subunits of nucleic acids which consist of a sugar, phosphate group, and nitrogenous base are referred to as a
- a. Nucleolus
 - b. Histone
 - c. Nucleotide
 - d. Phospho-carbohydrate
18. In a population of wildflowers, the frequency of the allele for red flowers was 0.8. What was the frequency of the white allele, the only other allele for flower colour?
- a. 0.8
 - b. 0.4
 - c. 0.2
 - d. 0.1
19. A previously unknown virus has been isolated from the Brazilian rainforest. Analysis of its genome reveals that it is composed of a double stranded DNA molecule containing 14% T (thymine). Based on this information, what would you predict the %C (cytosine) to be?
- a. 14%
 - b. 28%
 - c. 36%
 - d. 72%

- 20.** A scientist measures the circumference of gum nuts in a population of eucalypts and discovers that the most common circumference is 2 cm. What would you expect the most common circumference(s) to be after 10 generations of stabilising selection?
- a. 2 cm
 - b. Greater than 2 cm or less than 2 cm
 - c. Greater than 2 cm and less than 2cm
 - d. Can't tell from the information given
- 21.** During their early stages of development, the embryos of reptiles, birds, and mammals look very similar. This suggests that reptiles, birds, and mammals
- a. have a common ancestor
 - b. live in the same types of environments
 - c. have undergone parallel evolution
 - d. are no longer undergoing evolution
- 22.** What types of events are typically seen in the fossil record?
- a. speciation
 - b. successive change in structures
 - c. extinction
 - d. all of these are typical of the fossil record
- 23.** Which of the following chemicals enter living organisms primarily from the atmosphere rather than from rocks or soil?
- a. calcium
 - b. sulphur
 - c. sodium
 - d. carbon
- 24.** Which trophic level is incorrectly identified?
- a. Carnivores – secondary or tertiary consumer
 - b. Decomposers – microbial heterotrophs
 - c. Herbivores – primary consumer
 - d. Omnivores – moulds, yeasts and mushrooms

Questions 25, 26 and 27 are based on the following food chain (Figure 1)

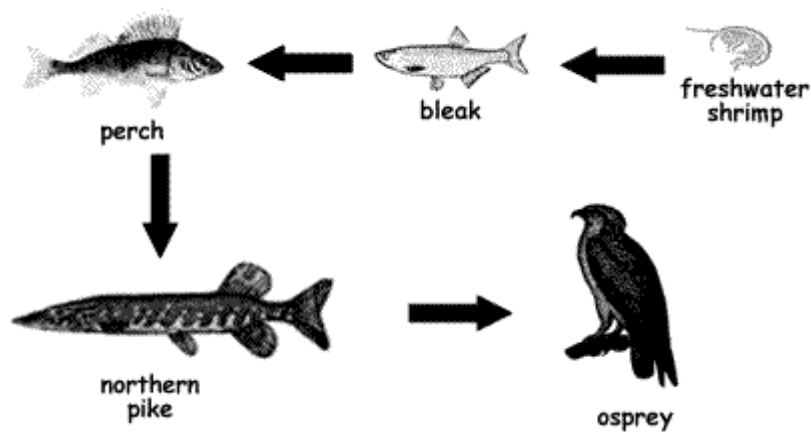


Figure 1

<http://www.sciencegeek.net/Biology/review/U7Review.htm>

25. Of the organisms depicted above, the one that would likely be found in the smallest number within the ecosystem is the
- freshwater shrimp
 - osprey
 - perch
 - northern pike
26. Missing from the food chain above are
- consumers
 - heterotrophs
 - carnivores
 - producers
27. Wastes and dead organisms from this food chain will be fed upon by
- autotrophs
 - herbivores
 - tertiary consumers
 - detritivores

Questions 28 and 29 relate to the following figure (Figure 2)

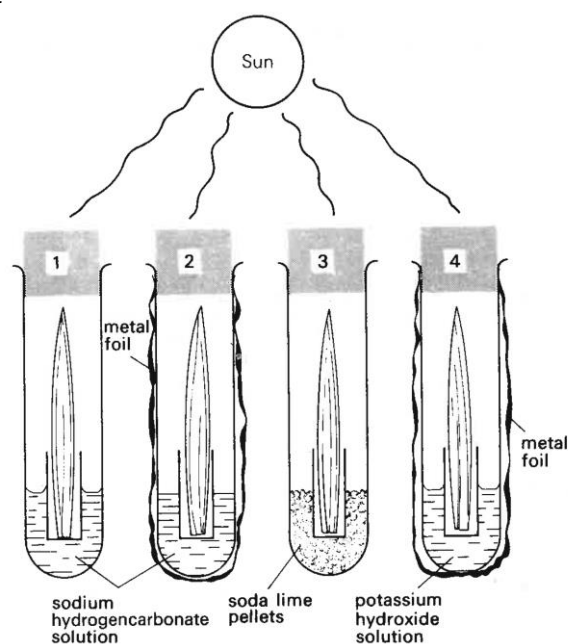


Figure 2

28. Each tube in Figure 2 contains an iris leaf in a small cup of nutrient solution. Tubes 2 and 4 are blacked out with metal foil. Tubes 1 and 2 contain sodium hydrogencarbonate, whilst tube 3 has soda lime pellets, and tube 4 has potassium hydroxide solution.

After one hour the leaves are tested for glucose which is found to be present in one of the following.

- a. Tube 1
- b. Tube 2
- c. Tube 3
- d. Tube 4

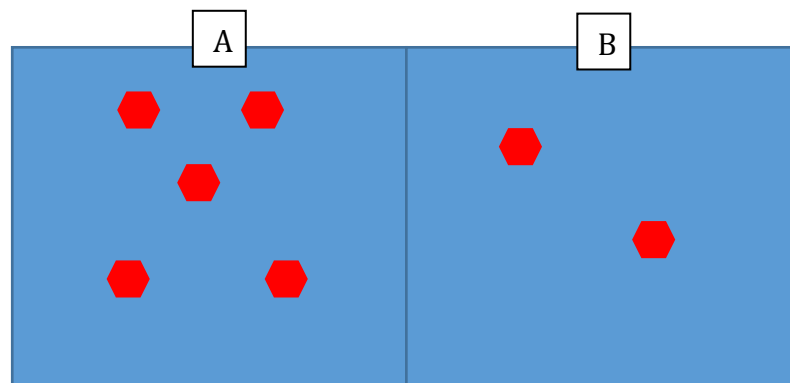
29. Which tube in Figure 2 was deprived of more than one essential requirement for photosynthesis to occur?

- a. Tube 1
- b. Tube 2
- c. Tube 3
- d. Tube 4

30. Assuming independent assortment, the probability of obtaining an offspring with genotype AABbCcdd from two parents with genotypes AabbCCDd and AaBbCcDd respectively is:
- a. 0
 - b. $\frac{3}{4}$
 - c. $\frac{3}{16}$
 - d. $\frac{1}{64}$
 - e. $\frac{3}{128}$
31. A red pigment is extracted from a marine alga. Which best supports the hypothesis that the pigment is involved in photosynthesis? The red pigment
- a. has an absorption spectrum similar to that of chlorophyll
 - b. is also found in land plants
 - c. has a molecular structure similar to that of chlorophyll
 - d. has an absorption spectrum similar to the photosynthetic action spectrum for that same marine alga.
32. Prior to the Rio Olympics there were concerns about the quality of water at the outdoor sailing, rowing, and open-water swimming venues. Independent tests were conducted that detected the presence of contaminants at harmful levels, whereas those conducted by the Rio authorities and the International Olympic Committee detected no such harmful organisms. The tests conducted by the IOC and Rio organisers featured a mesh sieve calibrated for organisms the size of bacteria. Which organisms are most likely to be responsible for the difference in results observed between the independent and sanctioned tests?
- a. Protozoans
 - b. Viruses
 - c. Bacteria
 - d. Prions

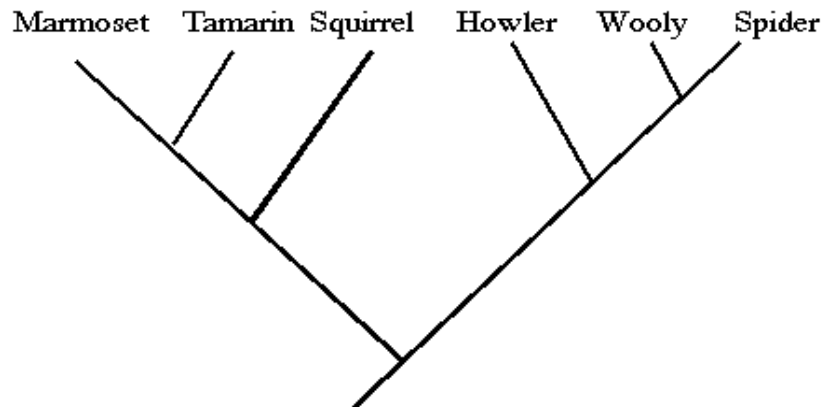
33. Olympic medallists tend to be highly specialised athletes, often neglecting certain aspects of fitness and athletics in order to better develop those relating to their individual disciplines. Over time there has been a trend of “the weird getting weirder,” for instance gymnasts have become smaller and lighter whereas weightlifters are heavier and stockier of build. This is a modern example of:
- a. Artificial selection
 - b. Natural selection
 - c. Genetic drift
 - d. None of the above
34. Which of the following is also a common aquatic environmental pollutant?
- a. Carbon monoxide
 - b. Methane
 - c. Sulphur dioxide
 - d. Nitrate fertilisers
35. A vet was called to a large cattle property due to an unknown disease outbreak. He was able to obtain bacteria in samples from the infected cattle. Which of the following would allow him to most confidently say that this bacterium is causing the disease?
- a. The same bacteria are not found in healthy cattle
 - b. Inoculation of healthy cattle with the bacteria caused those cattle to get the disease
 - c. The same bacteria cause a similar disease in humans
 - d. The same bacteria are found in healthy cattle.
36. Which of the following would most easily cross a cell's phospholipid membrane?
- a. H₂O
 - b. H⁺
 - c. K⁺
 - d. Na⁺

37. In the diagram below, the red hexagons indicate sugar dissolved in water. Indicate which way net water would move over the semi-permeable membrane between the two solutions:



- a. A to B
 - b. B to A
 - c. Water would move both ways
 - d. Water would not move between these two solutions
38. The effects of natural selection may be countered by
- a. Gene flow
 - b. Genetic drift
 - c. Mutation
 - d. Inbreeding

The following cladogram refers to Question 39



39. A valid taxonomic group for this cladogram would include:

- a. Tamarin + Squirrel
- b. Tamarin + Squirrel + Howler
- c. Squirrel + Howler + Woolly
- d. Woolly + Spider

40. In relation to natural selection, evolution is the

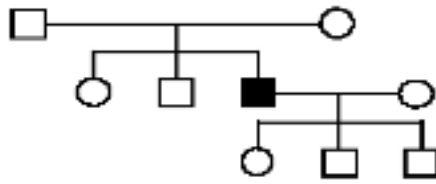
- a. Process
- b. Outcome
- c. Mechanism
- d. Purpose

41. What is the ultimate source of genetic variability?

- a. Mutation
- b. Migration
- c. Genetic drift
- d. Non-random mating

42. Habitat fragmentation through deforestation and excessive hunting have impacted severely on endangered maned three-toed sloth in Eastern Brazil (e.g., estimated drop in population from 80000 to 800). In an effort to help preserve the species, scientists caught 20 sloths and used them to start a new population in the northwest Brazil. Which of the following factors would most likely have the least impact in this new population?
- a. Habitat deterioration
 - b. Random mating
 - c. Reduced genetic variability within the population
 - d. Exposure to a range of diseases
43. The theory of population genetics and how evolution occurs includes all but which one of the following
- a. Mating must be random
 - b. The size of the population is small
 - c. There is no influx of genes from other populations
 - d. No genotype has selective advantage over another
44. Which statement most accurately reflects what population geneticists refer to as "fitness"?
- a. Fitness is the measure of an organism's adaptability to various habitats.
 - b. Fitness reflects the number of mates each individual of the population selects.
 - c. Fitness refers to the relative health of each individual in the population.
 - d. Fitness is a measure of the contribution of a genotype to the gene pool of the next generation.
45. A strain of bacteria living in a hospital is found to have a plasmid containing two genes: one for sex pilus construction, and one for tetracycline resistance. If these bacteria were to undergo conjugation with bacteria lacking this plasmid, and thus transferred the plasmid to the other bacteria, the most likely result would be:
- a. A genetically identical clone of bacteria containing the same plasmid
 - b. Rapid spread of tetracycline resistance to other bacteria in the hospital
 - c. The subsequent loss of tetracycline resistance in the initially resistant strain
 - d. The bacteria will no longer be found in the hospital

46. Given the following pedigree:



What is (are) the possible mode (s) of inheritance?

- I. Autosomal dominant***
- II. Autosomal recessive***
- III. X-linked dominant***
- IV. X-linked recessive***

- a. II only**
- b. I or III only**
- c. II or IV only**
- d. All four modes of inheritance (I, II, III and IV)**

47. Which of the following is not a function of the urinary system?

- a. Removal of waste products from the bloodstream.**
- b. Storage and excretion of urine.**
- c. Regulation of leukocyte and platelet production.**
- d. Regulation of blood volume and, indirectly, blood pressure.**

48. A physiologist wants to find out the rate of filtration in the glomeruli of the kidneys. The best experimental design would be to inject a substance which:

- a. cannot pass through the glomerular capillaries**
- b. can pass through the glomerular capillaries but is totally reabsorbed in the renal tubules**
- c. can pass through the glomerular capillaries and is partially reabsorbed in the renal tubules**
- d. can pass through the glomerular capillaries and is not reabsorbed in the renal tubules.**

- 49.** After a period of intense physical exercise the concentration of solutes in the blood rises above a certain level causing
- a.** more water to be reabsorbed in the kidney tubules
 - b.** less water to be reabsorbed in the kidney tubules
 - c.** more salt to be reabsorbed in the kidney tubules
 - d.** less glucose to be reabsorbed in the kidney tubules
- 50.** Colour-blindness is a recessive, X-linked trait. A couple, who are both blood type A and who both have normal vision, have a son who is blood type O and colour-blind. What is the probability that their next child will be a daughter who is blood type O and has normal vision?
- a.** $1/2$
 - b.** $1/4$
 - c.** $1/8$
 - d.** $1/16$

SECTION B

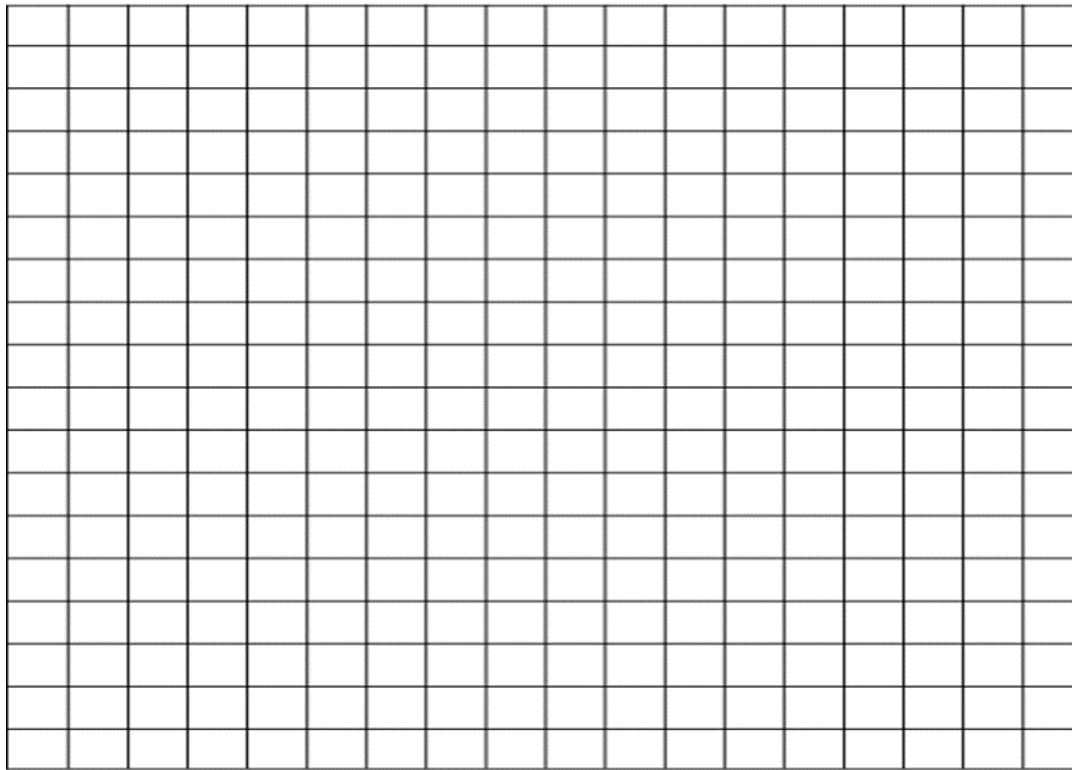
Question 1

There is debate over to what degree genetic traits impact athletic performance. At the 2016 Rio Olympics, all entered male marathon runners were screened for abnormalities in the genes responsible for determining lung capacity. The lung capacity of each athlete was then measured and an average running time calculated for each capacity. This gave rise to the following data:

Lung capacity (litres)	Average marathon time (mins)
5	2:45
5.5	2:30
6 (average)	2:25
6.5	2:15
7	2:10

a) Graph the data on the grid provided using appropriate axis and titles.

Title: _____



b) If an athlete was measured to have a lung capacity of 6.25L what would be the expected average marathon time for this individual?

Answer _____ (2 marks)

c) It was found that 40% of athletes had a mutation that resulted in increased lung capacity. These athletes ran times ranging from 2:10 to 2:30 with roughly equal numbers of individuals in each group. Comment on this finding (2 marks).

Question 2

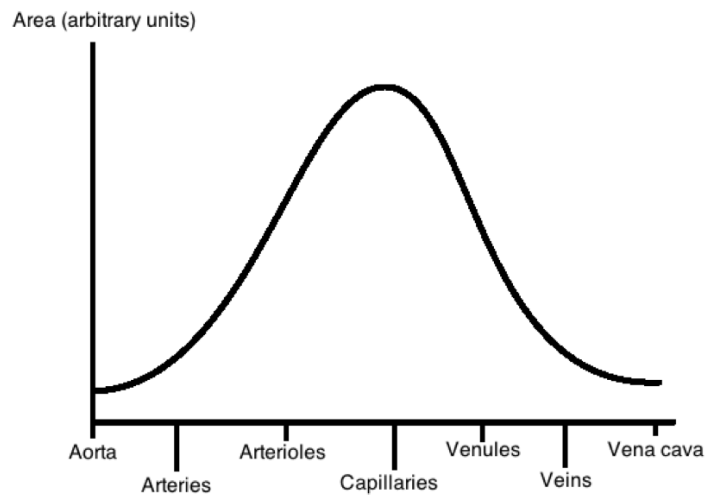
PART A:

The flow of ideal fluids in a closed system of tubes abides by the continuity equation:

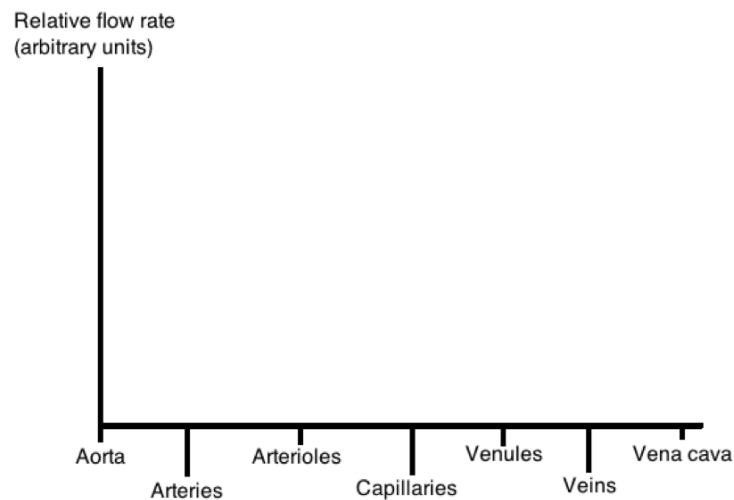
$$Av = \text{constant}$$

Where: A = cross-sectional area of the tube at a point (m^2)
 v = fluid velocity past that point (m/s)

The following graph represents the total blood vessel cross-sectional area of an Olympic athlete's circulatory system, at various points.



a) Given this graph and the above information regarding the relationship between cross-sectional area and fluid velocity, represent on the following set of axes the relative blood velocity at different points in the athlete's circulatory system (this should be a line graph as above). (Ignore any effects of blood pressure and viscosity.) (2 marks)

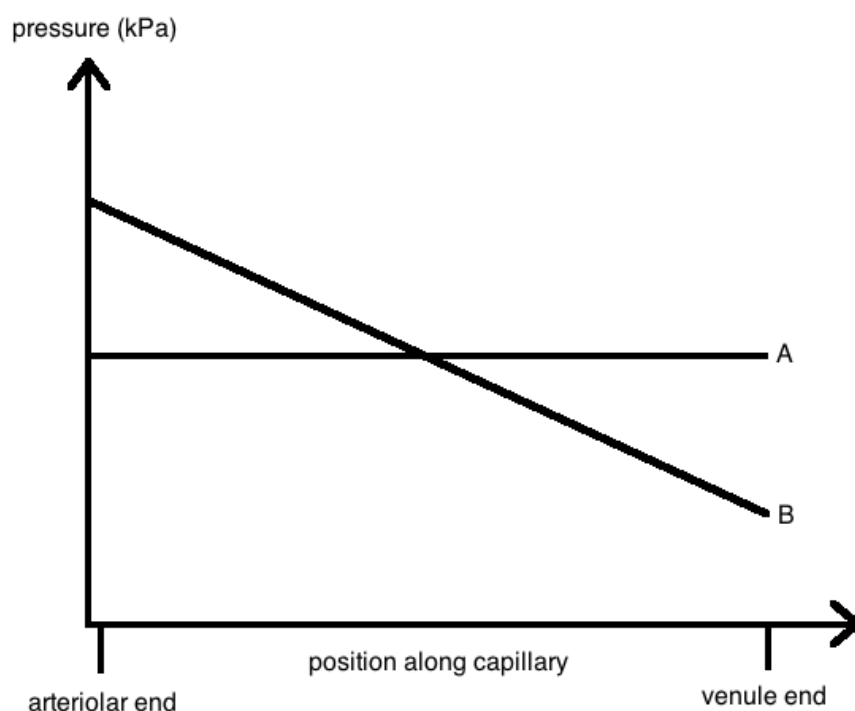


PART B: Capillaries form the meshwork of tiny blood vessels that infiltrate the various tissues of the body. The cross sectional area of each individual capillary is very low, often with room for only a single file of red blood cells. (The total cross sectional area shown in part (a) is very high only because capillaries are so numerous.)

Fluid movement across the very thin capillary wall is governed by Starling's forces – the balance of hydrostatic and osmotic pressures, as depicted in the graph below. This movement of fluid across capillary walls is essential for maintaining a continuous exchange of oxygen and carbon dioxide between the body's cells and the blood supply.

Hydrostatic pressure derives from the pumping action of the heart and serves to push fluid out of the capillaries, while osmotic pressure derives from the higher protein concentration of the blood plasma relative to the interstitial fluid, and serves to draw fluid back into the capillary.

At the arteriole end of the capillary, the hydrostatic pressure exceeds the osmotic pressure and so there is a net movement of fluid out of the capillary; the converse occurs at the venule end to balance this, and so there is no net increase in interstitial fluid.



A: osmotic pressure (pushing from interstitial fluid to capillary fluid)

B: hydrostatic pressure (pushing from capillary fluid to interstitial fluid)

b) When tissues are damaged, mast cells release inflammatory molecules such as histamine that increase the permeability of capillary walls to cells and proteins. Indicate on the graph above how this would affect the balance of forces. (How would A and/or B change, if at all?) (4 marks)

c) How would the changes affect the fluid balance in the surrounding tissue? (1 mark)

d) Briefly suggest how this process (inflammation) could be of benefit to the damaged tissue. (2 marks)

Question 3

Feijoada is popularly considered to be the national dish of Brazil, especially in the Olympic host city Rio de Janeiro and its surrounds. It is, in essence, a bean stew with pork and beef, and is derived from the traditional cuisine of Brazil's Portuguese settlers.

Callum the Chef works at the Olympic athletes' village and thus has a vested interest in food safety. He wishes to test the bacterial load of a sample of raw pork mince.

Callum suspends 0.84g of the meat in sterile diluent (fluid used to dilute) to make an 8.4mL suspension. He takes 0.1mL of the suspension and adds it to 9.9mL of fresh diluent, then further dilutes 0.1mL of this new suspension into 9.9mL of diluent. A 0.5mL sample of the final suspension is plated on nutrient agar. After a period of incubation, 389 colonies are counted on the agar plate.

a) Each colony on the plate arises from a single viable bacterium from the original meat sample, referred to as a colony-forming unit (CFU). Calculate the number of CFUs per gram in the sample. (4 marks)

b) Callum considers the mince to be safe for consumption if there are less than 10^6 CFU/gram. Would the sample meet his standard? (Is the meat safe?) (1 mark)

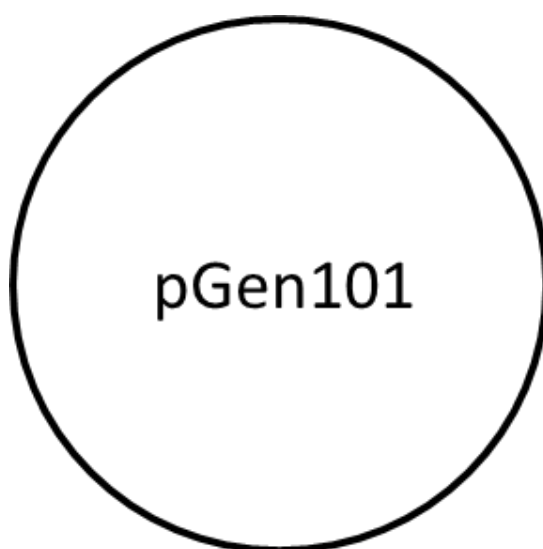
c) What is the practical advantage obtained by diluting the suspension, as opposed to plating up the initial undiluted suspension? (1 mark)

Question 4

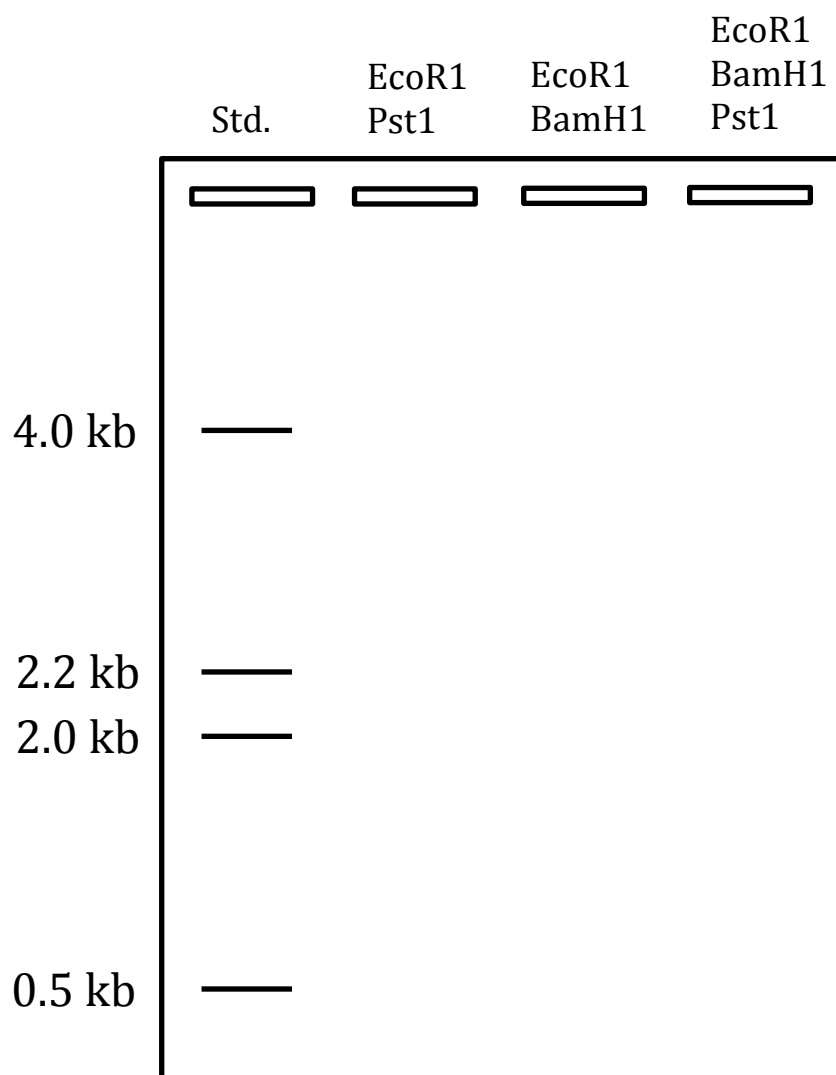
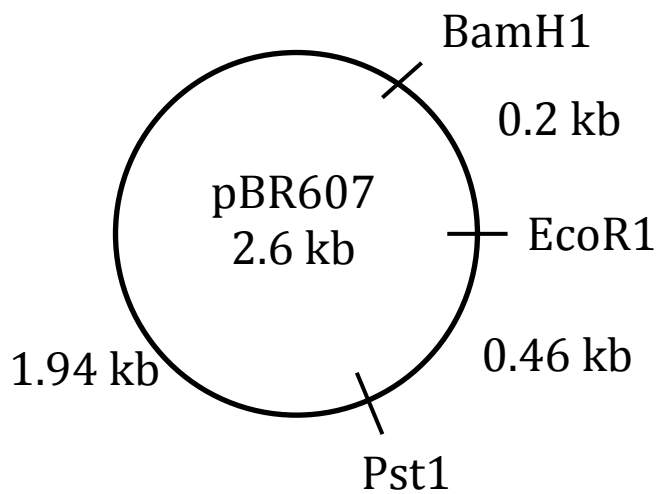
Genetic engineering is made possible by a class of bacterial enzymes called restriction endonucleases. These enzymes recognise and cleave the DNA at specific sites called restriction sites, and are naturally produced by bacteria to resist invasion by foreign DNA. Scientists may extract and use specific restriction enzymes to process DNA in the lab.

pGEN101 is a 20 kb DNA plasmid (loop). Digestion with the restriction enzyme EcoR1 results in one fragment. Digestion with BamH1 results in three fragments of the following sizes: 12 kb, 2 kb and 6 kb. A combination digest with EcoR1 and BamH1 results in 4 fragments: 8 kb, 4 kb, 2 kb and 6 kb.

a) Develop a map of the plasmid with the restriction digests given. (In other words, mark the cutting sites and label the distances between them.)



The restriction map for a different plasmid pBR607 is shown below. Draw and label the locations of the proper bands on the gel below.



Question 5

The total blood volume of a human averages 60cm^3 per kilogram of body weight, and the average glomerular filtration rate is $125\text{cm}^3 \text{ minute}^{-1}$. (6 marks total)

a) Calculate the total blood volume of a person who weighs 120kg. **Show your working.**

Answer _____ (2 marks)

b) Calculate the volume of glomerular filtrate produced per day by this person. **Show your working.**

Answer _____ (2 marks)

c) How many times each day will the person's blood be filtered by the kidneys? **Show your working.**

Answer _____ (2 marks)

Question 6

Diagram A below shows the different phases during the cell cycle of a eukaryotic cell. **Diagram B** shows the amount of DNA present during the different phases. G₁ and G₂ represent the gap phases during which cell growth may occur. S is an intermediate phase.

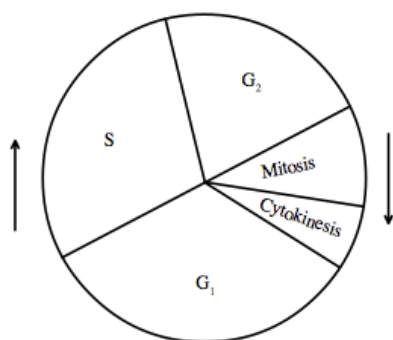


DIAGRAM A

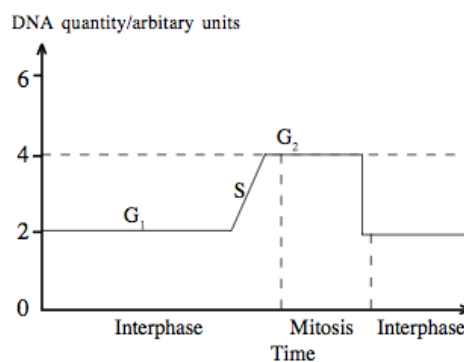


DIAGRAM B

a) List any four general characteristics that distinguish prokaryotic cells from eukaryotes. (2 marks)

b) Describe how the quantity of DNA in cells is increased during phase S. (2 marks)

c) What will be the quantity of DNA in arbitrary units at the end of mitotic cell division? (1 mark)

d) How is the quantity of DNA returned to this level? (3 marks)

e) What would be the quantity of DNA in arbitrary units at the end of a meiotic division? (1 mark)

Question 7

A student noticed that large numbers of daisies and common sedge grew on a pasture. The student used random quadrats to determine whether the two species of plant tended to grow together (in association) or tended to grow separately (not in association). The student obtained the following results:

Plants present	No. of quadrats
Daisies and common sedge	78
Common sedge only	6
Daisies only	7
Neither daisies or common sedge	9
	Total = 100

The student proposed the null hypothesis that ‘there was no association between daisies and sedge’. A Chi squared test was carried out to test the null hypothesis statistically.

The results were arranged into the following contingency table:

	Daisies	No daisies	Row total
Common sedge	(O) = 78 (E) = 71.4	(O) = 6 (E) =	84
No common sedge	(O) = 7 (E) = 13.6	(O) = 9 (E) =	16
Column total	85	15	100

The formula for calculating Chi squared is:

$$\chi^2 = \sum \frac{(O - E)^2}{E}$$

O = observed results. E = expected results

The expected numbers may be calculated by the formula:

$$E = \frac{\text{Row total}}{\text{Total}} \times \frac{\text{Column total}}{\text{Total}} \times \text{Total}$$

a) Calculate the missing E numbers on the table and insert them in the table. Show your working. (2 marks)

b) Calculate the value of χ^2 . Show your working.

Answer _____ (2 marks)

The number of degrees of freedom (n) is given by the equation:

$$n = (\text{no. of rows} - 1) (\text{no of columns} - 1)$$

c) How many degrees of freedom are there?

Answer _____ (1 mark)

d) The critical value for χ^2 with these degrees of freedom is 3.84 at a 5% significance level. Does your value enable you to accept or reject the null hypothesis? Explain your answer. (2 marks)

END of EXAMINATION

