

2015 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	10 sets of true/false questions	40 marks
SECTION C	6 written answer questions	45 marks
	Total marks for the paper	125 marks

SECTION A: MULTIPLE CHOICE
USE THE ANSWER SHEET PROVIDED

1. Of the following biological levels of organisation, which one represents the smallest or lowest level?
 - a. organs
 - b. organelles
 - c. cells
 - d. organisms

2. You are conducting an experiment to test the hypothesis that dairy cows will give more milk if they listen to classical music while being milked. Your 20 experimental cows listen to classical music during milking; you collect all their milk and measure how much there is. Your 20 control cows should have all experimental conditions identical to the experimental cows except
 - a. they should listen to classical music at a louder volume
 - b. they should listen to classical music all the time, not just during milking
 - c. they should listen to a different type of music, like heavy metal
 - d. they should not listen to any music

3. A successful scientific experiment will result only in
 - a. rejection of one or more hypotheses
 - b. proving a hypothesis
 - c. accepting many hypotheses
 - d. confirming predictions

4. Homologous structures among animals provide evidence for evolution in that these structures are
 - a. different in different animals, but are modifications of the same basic structure
 - b. similar in function, but of different basic structure
 - c. all shown in the fossil record
 - d. all produced by the same gene

5. The study of the way individual traits are transmitted from one generation to the next is called
 - a. ecology
 - b. genetics
 - c. cell biology
 - d. homology

6. Which of the following is not a property of life?
 - a. moulding or adapting to one's environment
 - b. regulating materials that enter and leave the system
 - c. responding to stimuli
 - d. reproducing, passing hereditary material to the next generation

7. Plant cells differ from animal cells in that plant cells have
- an endoplasmic reticulum
 - a central vacuole
 - Golgi apparatus
 - Vesicles
8. When separated by a selectively permeable membrane a net gain of water tends to occur in
- a hypoosmotic solution from an isosmotic solution
 - an isosmotic solution from a hyperosmotic solution
 - a hyperosmotic solution from a hypoosmotic solution
 - a hypoosmotic solution from a hyperosmotic solution
9. In a lipid bilayer the lipids have their.
- water repelling heads facing inward
 - water repelling tails facing inward
 - hydrogen bond forming heads facing inward
 - hydrogen bond forming tails facing inward

10. The universal energy currency of all cells is

- a. ATP
- b. NAD⁺
- c. ADP
- d. O₂

11. Enzymes

- a. make endergonic reactions proceed spontaneously
- b. lower the activation energy of a reaction
- c. are not very specific in their choice of substrates
- d. are needed in large quantities because they are used up during catalysis

12. To what category of macromolecules do most enzymes belong?

- a. carbohydrates
- b. lipids
- c. proteins
- d. nucleic acids

13. The usefulness of fermentation as a means of deriving energy is limited because
- a. it cannot generate enough ATP
 - b. it produces too much NH_2
 - c. the end products are toxic to the producer
 - d. it uses more energy than it produces
14. Organisms that do not have the ability to produce or synthesise their own food are called
- a. anaerobic
 - b. autotrophs
 - c. exergonic
 - d. heterotrophs
15. Water vapour exits and CO_2 enters a leaf through the
- a. stomata
 - b. grana
 - c. stroma
 - d. photons

16. Sexual reproduction favours

- a. genetic stability
- b. highly successful species
- c. stable populations
- d. genetic diversity

17. Which of the following are mismatched?

- a. haploid- n
- b. somatic cells- $2n$
- c. zygote- n
- d. sperm cell- n

18. The ratio often referred to the Mendelian ratio is

- a. 1:3:3:1
- b. 3:1
- c. 1:3:1
- d. 1:1

19. Which of the following represents a testcross?

- a. $Ww \times WW$
- b. $ww \times WW$
- c. $Ww \times Ww$
- d. $WW \times WW$

20. An actively dividing bacterial culture is grown in a medium containing radioactive adenine (A^*). After all the adenine is labelled, the bacteria are transferred to a medium containing nonradioactive adenine (A). Following one round of DNA replication in the nonradioactive medium, the DNA is analysed. Which of the following sequences could represent this DNA?

- a. $A^*A^*TTGA^*TC$
 $TTAACTAG$
- b. A^*ATTGA^*TC
 TTA^*A^*CTAG
- c. $AATTGATC$
 $TTAACTAG$
- d. $A^*A^*TTGA^*TC$
 $TTA^*A^*CTA^*G$

21. Mutations that impact evolution must occur in

- a. the fossil record
- b. somatic cells
- c. sperm cells
- d. germ-line cells

22. Which of the following populations is most likely to go extinct?

- a. A very small population in an unstable environment.
- b. A large population with abundant resources.
- c. A large population with lots of genetic variability.
- d. All would likely go extinct. Or as sentence fragments without capitals

23. The formation of seeds greatly improved plants' adaptation to land by:

- a. enabling offspring to disperse further away from the parent plant
- b. allowing survival during adverse conditions
- c. providing nourishment following germination
- d. all of the above

24. How many principal organ systems does the human body contain?
- a. 11
 - b. 4
 - c. 23
 - d. it varies from individual to individual
25. Materials are exchanged between the blood and the surrounding tissues in the
- a. arteries
 - b. veins
 - c. capillaries
 - d. lymphatic system
26. Which types of feedback systems are more common in vertebrates to maintain homeostasis?
- a. positive
 - b. negative
 - c. a and b, are both common
 - d. a and b are both extremely rare

27. The cell cycle is made up of four main phases. The genetic material of a cell is replicated in S phase while cell division occurs in M phase. Cells from different tissues will cycle at different rates, some continuous while others are capable of entering a resting state. Cells from which tissue are likely to cycle continuously?

- a. skin
- b. liver
- c. brain
- d. kidney

28. A human cell has 46 chromosomes. This cell replicates its DNA and undergoes cell division into two identical daughter cells. What is this process called and how many chromosomes are found in each daughter cell?

- a. Mitosis, 23
- b. Meiosis, 23
- c. Mitosis, 46
- d. Meiosis, 46

29. The kidneys function to filter the blood to produce urine for excretion. This process occurs in millions of tiny structures called nephrons within the kidney. The substance exiting the blood and entering the nephron is called filtrate (F). This filtrate is modified by the nephron via two mechanisms; secretion (S) of substances into and reabsorption (R) of substances out of the filtrate. The final product is excreted (E). Which equation correctly summarises this process?
- a. $F - (R \times S) = E$
 - b. $F - (R + S) = E$
 - c. $F + R + S = E$
 - d. $F - R + S = E$
30. Certain vaccines function by introducing a weakened variant of a pathogen into the human body. Which of the following statements is incorrect?
- a. Vaccines can be made from a particular segment of a pathogen
 - b. The immune response to the vaccine will be 'remembered' if the active pathogen is ever encountered
 - c. The vaccine lacks virulence factors that cause disease
 - d. Protection similar to vaccination cannot be attained from previous infection

31. Haemoglobin is a protein in human blood that collects oxygen from the lungs and delivers it to tissues. Myoglobin is similar to haemoglobin in structure and functions to store oxygen in muscle tissue. Which of the following concerning protein affinity for oxygen is correct?

- Foetal haemoglobin > maternal haemoglobin
- Maternal haemoglobin > paternal haemoglobin
- Adult haemoglobin > adult myoglobin
- Maternal haemoglobin > foetal haemoglobin

The following information refers to questions 32 - 34

Chromosomal abnormalities occur during meiosis, a process that produces gametes (eggs and sperm) within human bodies. Abnormalities occur when there is an uneven split of chromosomes into each gamete. The following table shows 6 of the most common syndromes associated with chromosomal abnormalities.

Syndrome name	Chromosome Affected	Incidence per 10, 000 births	Type of mutation
Polyploidy	Extra complete set of chromosomes	Fatal, doesn't reach full term	Addition
Patau syndrome	13	2	Addition
Edwards syndrome	18	3	Addition
Down syndrome	21	15	Addition
Klinefelter syndrome	23	10 (<u>affects only males</u>)	Addition
Turner syndrome	23	2 (<u>affects only females</u>)	Deletion

32. Following 30,000 of **all** births, how many children would be predicted to have Turner syndrome?
- a. 0
 - b. 3
 - c. 4
 - d. 6
33. What is the sex chromosome makeup of a child with Klinefelter syndrome?
- a. XO
 - b. XY
 - c. XXY
 - d. XX
34. The incidence of Down's syndrome increases with maternal age, and not significantly with paternal age. What may reasonably explain this trend?
- a. failure of muscular contractions to correctly fuse the two gametes.
 - b. gradual accumulation in germ-line chromosomal mutations throughout reproductive age.
 - c. maternal oocytes have a longer period of meiosis than paternal spermatozoa, and thus there are more opportunities for mutations to develop.
 - d. maternal mitochondrial DNA is mutated in Down's syndrome.

35. Sports exert a heavy physiological toll on the body, particularly martial arts. When exposed to a dangerous situation the body releases adrenaline, triggering a fight or flight response. Which of the following would you NOT expect to observe in the pair of fighters below?



- a. Increased pulse
- b. Decreased blood flow to the muscles
- c. Altered release of typical body hormones such as testosterone and oestrogen
- d. Increased blood pressure

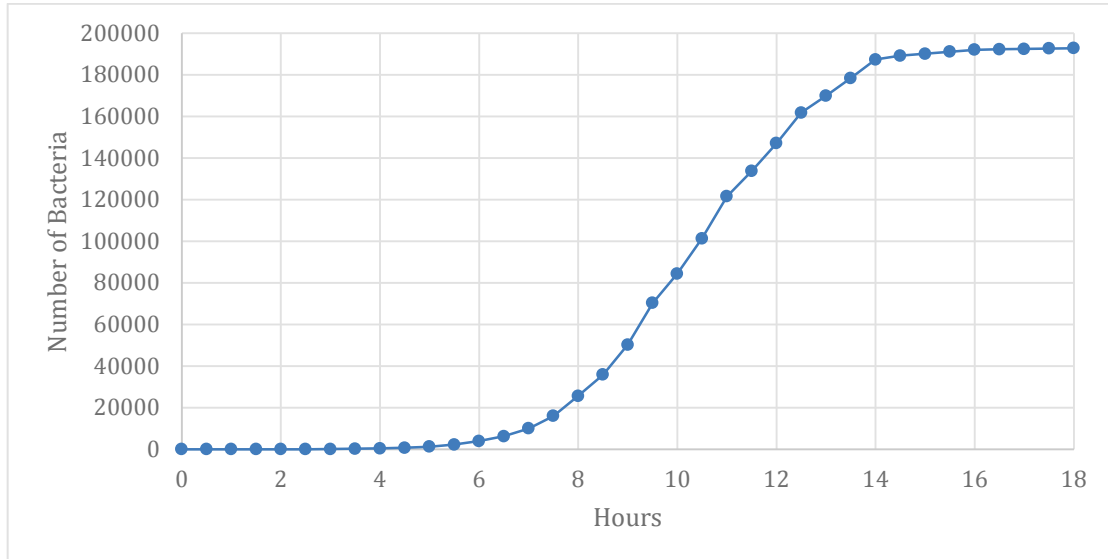
36. Another sport that puts a high degree of strain on the body is artistic gymnastics. Due to the high number of hours these athletes spend training they are at increased risk of a variety of detrimental conditions. Which of the following does NOT explain this relationship?



- a Excessive stretching of muscles can also stretch ligaments, leading to joint instability.
- b Overtraining may lead to micro-tears in muscles which if left untreated can cause larger tears to occur.
- c Having a higher than average level of muscle tone puts athletes at increased risk of malnutrition and broken bones.
- d Increased exercise can lead to compression of the discs between vertebrae in the back leading to pain and inflammation.

The following information refers to Questions 37 and 38

Dr Vitali is growing bacteria in a liquid broth in his lab. He measures the growth of bacteria over time and graphs it, showing the trend below:



37. Past about 12 hours the growth of the bacteria seems to change. What is a plausible reason for this occurring?

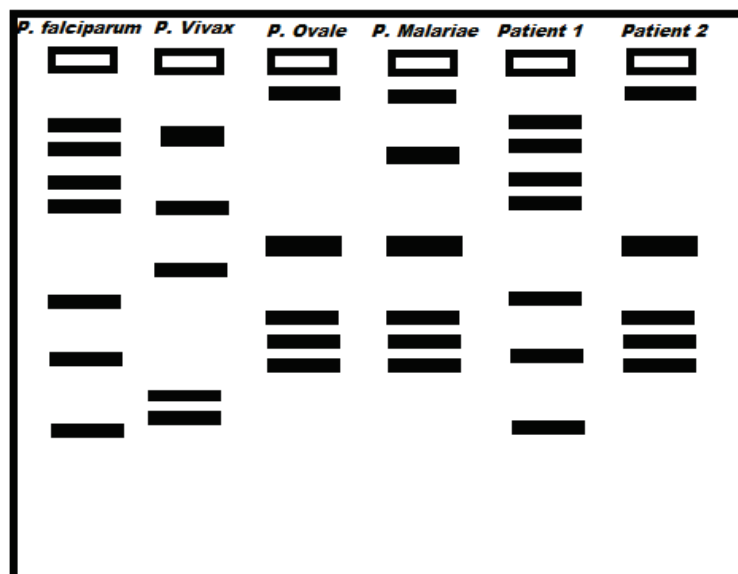
- Antibiotics in the nutrient broth begin to take effect around this time and inhibit growth.
- Waste products toxic to the bacteria have accumulated and inhibit growth.
- The bacteria ran out of space.
- The temperature for growth was now optimal and the bacteria grew faster.

38. Dr Vitali would like to repeat the experiment by taking a sample of bacteria out of the culture when they are in large numbers AND still growing quickly. At what time would it be best for him to take his sample?

- a. 4 hours
- b. 8 hours
- c. 10 hours
- d. 12 hours

The following information refers to Questions 39 – 40

The disease Malaria is caused by parasitic protozoa of the genus *Plasmodium*. Different species of *Plasmodium* are found in different regions of the world. Dr Plos sees a patient (Patient 1) who shows the symptoms of malaria, however this patient has been on a round the world tour and so Dr Plos is not sure which Malaria stain the patient has. To find out Dr Plos takes the *Plasmodium* DNA and cuts it up with a restriction endonuclease enzyme. This produces a characteristic “DNA fingerprint” which can be matched to standards from different Malaria species.



39. From the DNA gel above, what malaria stain is Patient 1 infected with?

- a. *Plasmodium falciparum*
- b. *Plasmodium Vivax*
- c. *Plasmodium Ovale*
- d. *Plasmodium Malariae*

A week later a friend of patient 1 (patient 2) presents to the doctor because they are also feeling ill. To figure out where they both contracted the disease Dr Plos looks at the mosquitos which carry each of the *Plasmodium* species.

The main vectors for each *Plasmodium* species are:

Malaria Species	Mosquito vector	Distribution in Asia
<i>P. falciparum</i>	An. dirus	East and West China, Vietnam, Laos, Thailand and Japan
<i>P. Vivax</i>	An. farauti	India, Pakistan, South Afghanistan, New Guinea and Northern Australia
<i>P. Ovale</i>	An. minimus	Vietnam, Cambodia, Laos, Thailand and Malaysia
<i>P. Malariae</i>	An. stephensi	Philippines, Malaysia, Indonesia and New Guinea

40. Assuming the two friends were infected in the same location while they travelled together, and given the above distribution of malaria vectors, where were they infected?

- a. West China
- b. East China
- c. India
- d. Laos

SECTION B: True/False
USE THE ANSWER SHEET PROVIDED

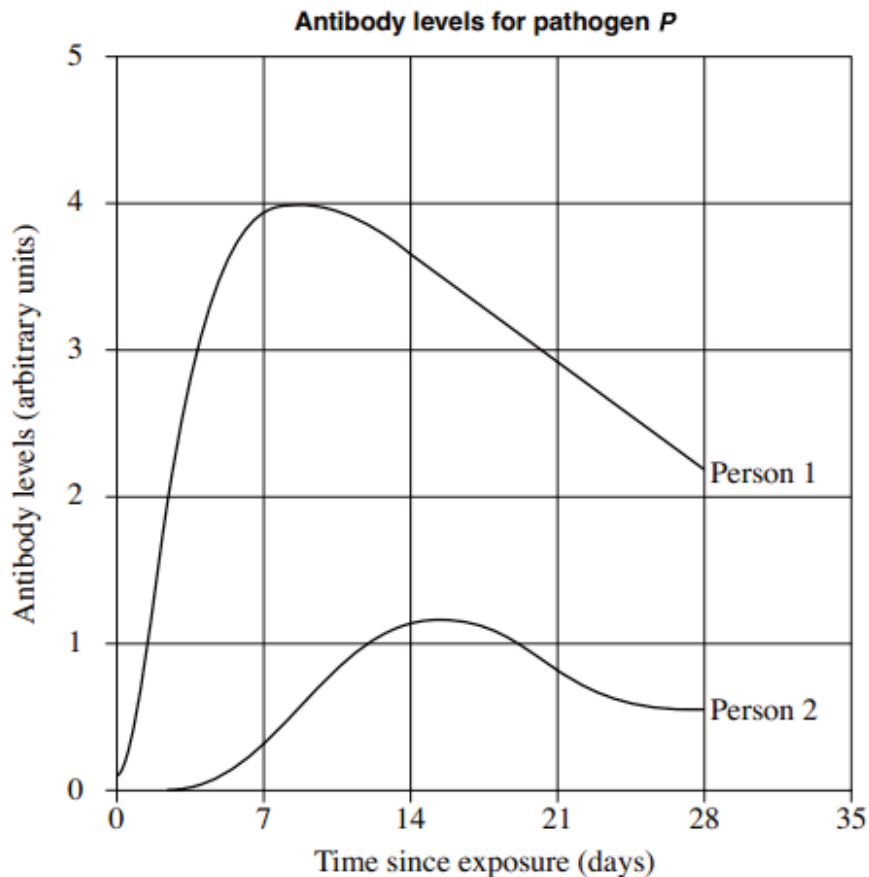
41. Australia has the world's highest incidence of melanoma, a form of skin cancer characterised by abnormal cell growth. As with many diseases, it is affected by several environmental and genetic factors. Determine whether the following statements are true (T) or false (F).

- a. If the DNA of a cell is damaged then it is more likely to grow irregularly which may increase the risk of developing melanoma.
- b. It is easier to cure damage to DNA once it has occurred than to prevent the damage initially.
- c. Individuals born with a genetic predisposition to melanoma will develop the condition at some point in their lives.
- d. The incidence of melanoma is correlated with lifestyle factors such as sun exposure, diet, and exercise.

42. Determine whether the following statements are true (T) or false (F).

- a. Plants display no response to environmental stimuli.
- b. The reaction describing photosynthesis is:
$$\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + \text{O}_2$$
- c. The visible portion of a fungi or mushroom represents only a small percentage of the entire organism.
- d. Since plants cannot carry out photosynthesis without sunlight, at night they are metabolically inactive.

43. The following figure displays the relationships between time and antibody levels for a specific phage (P) over a month. With reference to the information below, determine whether the following statements are true (T) or false (F).



- a. Person 1 is likely to have been exposed to the phage before since they have higher levels of antibodies overall.
- b. Person 2 is likely to have been exposed to the phage before since they have lower levels of antibodies overall.
- c. Both graphs display similar trends in antibody levels
- d. Since every individual is different the timing of the immune response is different for every individual.

44. In regards to genetics, determine whether the following statements are true (T) or false (F).

- a. Hybridisation is the mating/crossing of two true-breeding varieties.
- b. All genetic crosses follow Mendelian ratios.
- c. For each character, an offspring will receive only one copy of a gene.
- d. Traits segregate independently of each other.

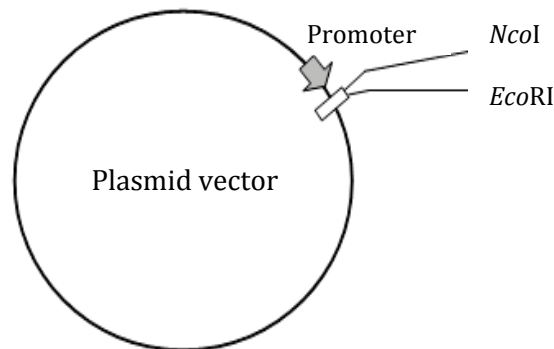
45. Determine whether the following statements are true (T) or false (F).

- a. Vacuoles are membrane-bound organelles which are only found in plant cells.
- b. Plant cells and fungal cells both possess cell walls.
- c. Chloroplasts are essential to the synthesis of sugars in cells, and so are found in all living cells.
- d. The Golgi complex is only found in secretory cells.

46. Determine whether the following statements are true (T) or false (F).

- a. The genomes of viruses can be composed of DNA or RNA.
- b. All viruses have a protein coat surrounding their genetic information.
- c. Phages are viruses that specifically infect bacteria only.
- d. Bacteriophages are only able to attach to their hosts if the bacteria possess features or receptors on its surface to which the virus can bind.

47. You plan to insert the gene *PhoQ* from *Tobibacterium* sp. into a plasmid vector containing an artificial promoter followed by a restriction site for *Nco*I (CCATGG) and a restriction site for *Eco*RI (GAATTC).



To conduct this procedure you are required to design forward (the sense strand) and reverse (antisense strand) primers. Part of the 561 nucleotide long coding sequence is shown below.

5'-ATGCGACAGTTCATCACCGA... _____GCGGGACCGGACTGGGGTAA-3'

Determine whether the following statements are true (T) or false (F).

- The use of two different restriction sites avoids wrong orientation of the inserted fragment.
- A possible forward primer for amplification and insertion of *PhoQ* gene will have the following sequence:
5' - GATCCCATGGATGCGACAGTTC - 3'
- A possible reverse primer for amplification and insertion of *PhoQ* gene will have the following sequence:
5' - GATCGAATTCAATGGGGTCAGGCC - 3'
- The final gene product will consist of at least 189 amino acids

48. Plant xylem transport can be understood only by invoking biomechanics. Conduit diameter and length have major consequences for conducting efficiency, which agree with the Hagen–Poiseuille formula as follows:

$$\text{volumetric flow rate} = \frac{\pi r^4}{8 \times \text{viscosity}} \times \frac{\Delta \Psi_p}{L}$$

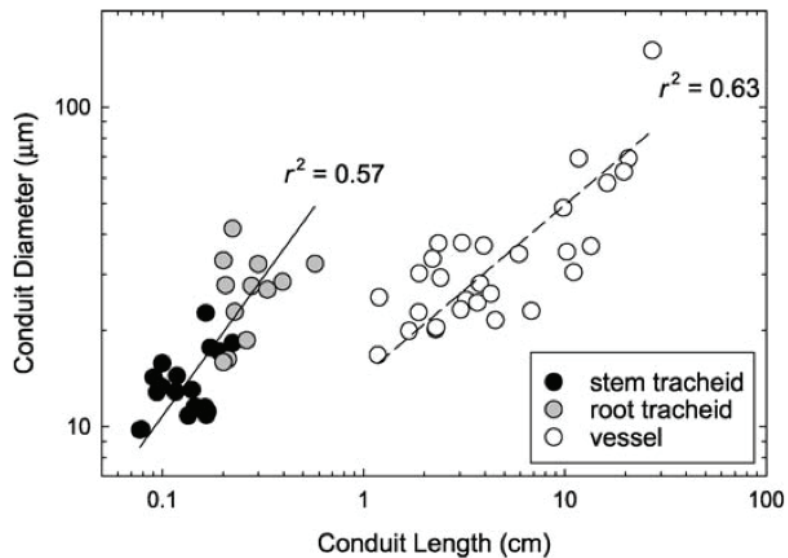
whereas:

r = radius

Ψ_p = pressure potential

L = length

The figure below shows the range of conduit diameter and length of tracheid in gymnosperms and vessels in angiosperms.



Determine whether the following statements are true (T) or false (F).

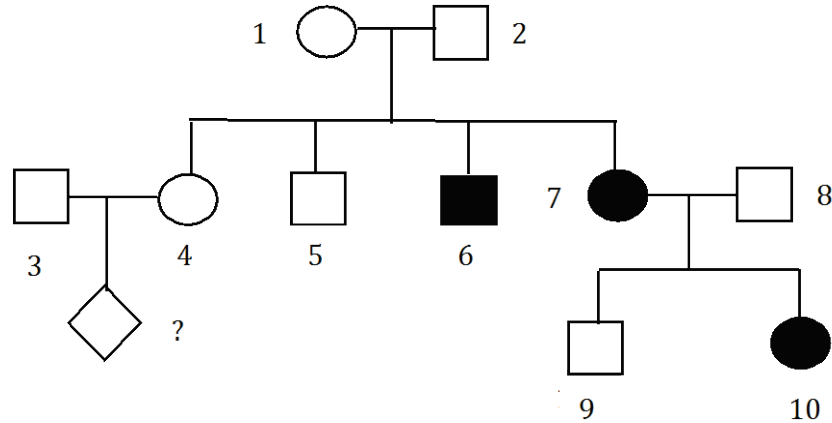
- The largest difference between vessels and tracheids is in the length, rather than the diameter.
- Movement rate in vessels is approximately equal to that in stem tracheids.
- Root tracheids can be wider than stem tracheids because they do not need as much reinforcement to hold up the foliage and to resist bending of the axis.
- The bigger the diameter of vessels, the smaller its frictional resistance.

49. Growth hormone (GH) is important for humans that raises the concentration of glucose and free fatty acid and promotes postnatal growth through direct and indirect effects on many tissues.

Determine whether the following statements are true (T) or false (F).

- a. Hyperglycaemia can stimulate the release of GH secretion.
- b. Exercising will increase GH production which in turn increases lipolysis.
- c. The effects of GH are enhanced by circulating androgens (e.g. testosterone) at puberty.
- d. Administration of GH will stimulate bone mass and muscle growth.

50. The pedigree of a family is shown below in which some members (shown in black) are affected by a genetic disease with a prevalence of 9% in the population. The phenotype of the individual marked with ? is unknown.



Determine whether the following statements are true (T) or false (F).

- The disease is most likely caused by autosomal recessive allele.
- Individual 5 is heterozygous with a probability of 50%.
- Under the assumption that the disease-causing allele is in Hardy-Weinberg equilibrium, individual 3 is heterozygous with a probability of 46%.
- If affected individuals had a reduced fertility, the disease-causing allele would be eliminated from the population.

