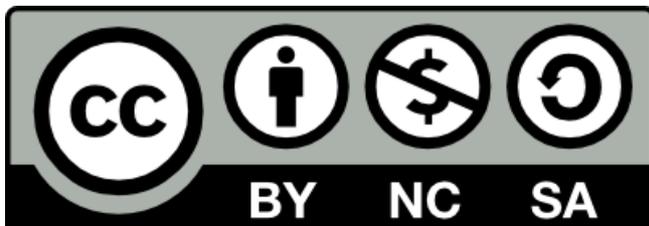




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23rd INTERNATIONAL BIOLOGY OLYMPIAD

8th – 15th July, 2012

SINGAPORE



THEORETICAL TEST – PAPER 2

Write all answers in the **ANSWER SHEET**

Dear Participants

- You have a total of 3 hours (180 minutes) for answering this theory paper.
- Use the **Answer Sheet**, which is provided separately, to answer all the questions.
- The answers written in the Question Paper will **NOT** be evaluated.
- Write your answers legibly. **Note that there may be more than one correct/incorrect answer and every cell should be filled.**

For example:

a	b	c	d	e
x	✓	x	x	✓

- **NOTE**: Some of the questions may be marked “Skipped” / “Deleted”. DO NOT attempt these questions. Also, read the question completely before attempting it as some questions may continue from one page to the next.
- The maximum number of points for this paper is **91.8**.
- Stop answering and put down your pen IMMEDIATELY when the bell rings.
- Your Answer Sheets as well as the Theoretical Test question paper will be collected at the end of the test period.

Good Luck! 😊

CELL BIOLOGY

1. Four mixtures of microorganisms were collected from different sites around a school and each microbial mixture was inoculated into a medium that contained all essential elements (in the form of ionic compounds) except carbon. The medium was at first clear (i.e., not turbid), and this was left to be cultured with agitation in the dark for 24 h (Stage I). The culture was subsequently continued in bright light for 24 h (Stage II) and then a further 24 h in the dark (Stage III). The turbidity of the four samples was monitored at the end of each stage and the following results were obtained.

Sample	End of Stage		
	I	II	III
1	Clear	Clear	Clear
2	Clear	Slightly turbid	Slightly turbid
3	Slightly turbid	More turbid	Very turbid
4	Slightly turbid	Slightly turbid	Slightly turbid

Which of the following organisms (a-d) are likely to be present in samples 1 to 4? Use a tick (✓) to indicate presence and a cross (✗) to indicate absence **in the Answer sheet**. (3.2 points)

- photoautotrophic microorganisms
- chemo-organotrophic microorganisms
- microorganisms that carry cellular storage granules such as inclusion bodies
- microorganisms that carry thylakoid membranes in their cells

2. A rod-shaped bacterial cell is observed to have numerous pili and fimbriae growing all over its surface. These structures appear to be able to lengthen and shorten. Indicate the correct function(s) (a – d) of these structures with a tick (✓) and incorrect answer(s) with a cross (✗). (1 point)
- a. recombination
 - b. attachment to surfaces
 - c. active motility in solution
 - d. for defence
3. Two bacterial cells were cross sectioned, and Bacterium A showed a single membrane covering its cell, while Bacterium B is covered by two membranes which are separated by a narrow space containing peptidoglycan material. Identify which bacterium is Gram positive and Gram negative respectively **in the Answer sheet**. (0.4 points)

4. Research was conducted to examine the presence of regulator element in the upstream of transcription start site from eukaryotic gene. As a preliminary study, a researcher performed *in silico* analysis by multiple alignment of nucleotide -37 to -26 from 900 different genes. The resulting homology percentage data are shown in the table below.

		-37 (5')											-26 (3')
Base frequency (%)	A	21	16	4	91	0	95	67	97	52	41	16	24
	C	23	39	10	0	0	0	0	0	0	9	35	37
	G	28	35	3	0	0	0	0	3	12	40	38	30
	T	28	10	83	9	100	5	33	0	36	10	11	9

- 4.1. Based on the given data, predict the most likely nucleotide sequence -35 to -29 within the conserved area which is essential for its regulator function. **In the Answer Sheet**, fill the boxes with A, C, T, and G, at the appropriate positions. (1.4 points)
- 4.2. Deletion of nucleotides -50 to -26 of several genes resulted in dramatically decreased RNA polymerase binding within the gene. Which type(s) of sequence element may be represented by nucleotides -50 to -26? Indicate appropriate answer(s) with a tick (✓) and inappropriate answer(s) with a cross (✗) **in the Answer Sheet**. (1.0 point)

5. Hormones regulate physiological processes in various specialised cells. Match the hormones listed below (a – e) with the physiological processes (I – VII) that they regulate. Note: some processes can be regulated by more than one corresponding hormone. (2.8 points)

Hormone	Physiological process
a. insulin	I. gluconeogenesis
b. cortisol	II. glycogenesis
c. glucagon	III. glycogenolysis
d. thyroid hormone	IV. lipolysis
e. epinephrine	V. lipogenesis
	VI. protein catabolism
	VII. protein anabolism

6. Which of the following allow(s) cell membranes to remain fluid under cold temperatures? Indicate correct answer(s) with a tick (✓) and incorrect answer(s) with a cross (✗). (0.8 point)
- a. by using active transport
 - b. by co-transport of glucose and proton
 - c. by increasing the percentage of unsaturated phospholipids in the membrane
 - d. by decreasing the number of hydrophobic proteins in the membrane

7. Cellular abnormality can often lead to manifestation of disease or disorders in our body. Match the following cellular abnormalities (I – V) each with their most likely disorder (a – e). (1.5 points)

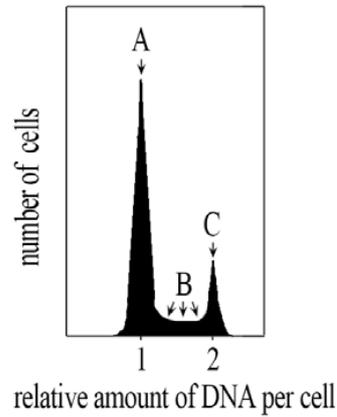
Cellular abnormalities:

- I. altered cellular receptor
- II. uncontrollable cell division
- III. abnormal membrane transport protein
- IV. enzyme absence
- V. absence of structural protein

Disorders:

- a. A child has chronic respiratory infections; secretions of the gut and lung are thick in this child, and his sweat is altered, with high Na^+ and Cl^- levels.
- b. A young man has pain in his chest and biopsy test demonstrates presence of abnormal, unspecialized, metastatic cells.
- c. A phenotypically normal boy is diagnosed as having androgen insensitivity; his chromosomes are 46, XY.
- d. A young boy has progressive weakness and muscle wasting atrophy of calf muscles.
- e. Affected children gradually lose skills and sight; have massive accumulation of lipid in brain cells. Death occurs at young age. There is no treatment.

8. A replicating cell population was stained with a dye that became fluorescent when bound to DNA. The DNA content of its individual cells was then determined by fluorescence-activated cell sorting (FACS) which is shown in the graph below.



- a. From the graph, which group of cells (A – C) are in the S phase of the cell cycle? (0.9 point)
- b. Which group of these cells (A – C) are in the LONGEST phase of the cell cycle? (0.9 point)

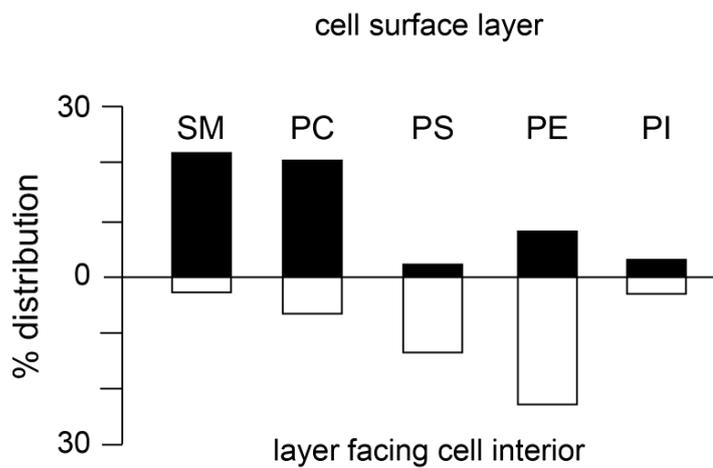
Indicate appropriate answer(s) with a tick (✓) and inappropriate answer(s) with a cross (✗).

9. Phospholipids are a class of lipids that are a major component of all cell membranes as they can form lipid bilayers.

9.1. Indicate true statement(s) with a tick (✓) and false statement(s) with a cross (✗). (0.8 point)

- a. The hydrophobic tails are oriented towards the interior of the cell membrane.
- b. The fatty acids present in the membrane do not have double bonds.
- c. Once phospholipids are incorporated they remain in the cell membrane permanently.
- d. The bilayers are randomly interspersed with proteins.

9.2. Mammalian plasma membranes are characterized by the presence of different types of phospholipids (SM, PC, PE, PS and PI). The graph below shows the percentage distribution of each phospholipid across the plasma membrane of human erythrocytes.



Indicate the correct statement(s) with a tick (✓) and incorrect statement(s) with a cross (✗).

The numbers indicated are approximate figures. (0.8 point)

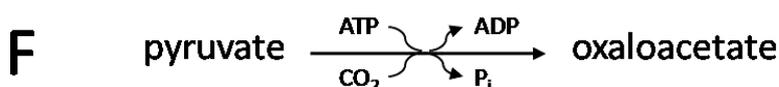
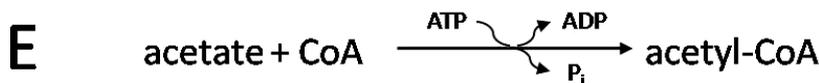
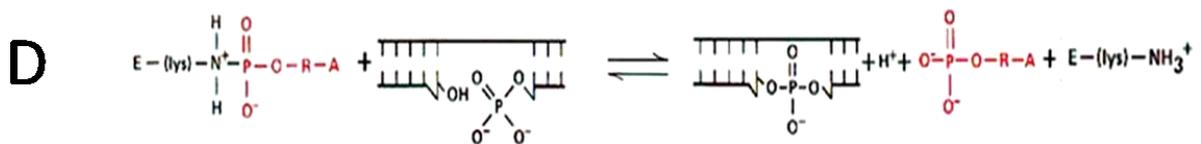
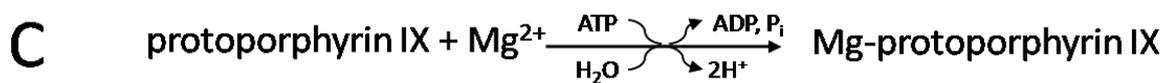
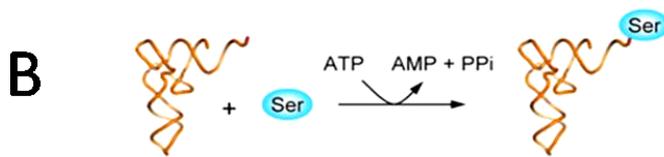
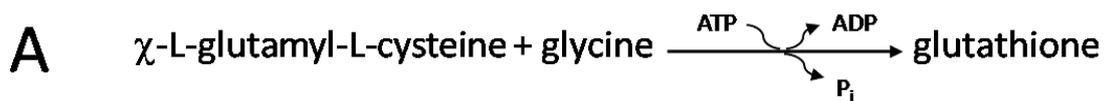
- a. Membranes, in general, can be concluded to be asymmetric.
- b. 24% of the total membrane phospholipids contain SM and 4% contain PI.
- c. 80% of the inner total membrane phospholipids contain PE and 16% contain PC.
- d. Most PC is confined to the outer surface of the erythrocytes while most of the PE and PS are confined to the inner surface of the erythrocytes.

10. In a study of a rice plant, it is found that gibberellins (GA) play an important role in the growth of seedlings. The GA repressor protein (GARP) controls the expression of GA induced genes. This protein contains two domains: (i) regulatory domain (DELLA) and (ii) the repressor domain (GRAS). GA bound to its receptor, attaches to DELLA domain and facilitates association of repressor domain with 'SCF ubiquitin ligase complex'. It results in GARP getting targeted and degraded by proteasome. This leads to GA induced gene expression and seedling growth. Based on this information, indicate growth of the seedlings with a loss of function mutation in the DELLA domain or the GRAS domain with a tick (✓) under the presence or absence of gibberellins, and use a cross (✗) if no growth is predicted **in the Answer Sheet**. (1.2 points)

11. The following enzymes(1 – 6) catalyse the formation of the chemical bonds, I to VI.

Enzyme	Chemical bond
1. DNA ligase	I. Carbon-oxygen bond
2. magnesium chelatase	II. Carbon-sulfur bond
3. acetate-CoA synthase	III. Carbon-nitrogen bond
4. amino acid-tRNA synthase	IV. Carbon-carbon bond
5. pyruvate carboxylase	V. Phosphoric ester bond
6. glutathione synthase	VI. Nitrogen-metal bond

Reactions that the enzymes catalyse are listed below:



Match the enzyme and corresponding enzymatic reactions with the respective bond types. (2.4 points)

PLANT ANATOMY AND PHYSIOLOGY

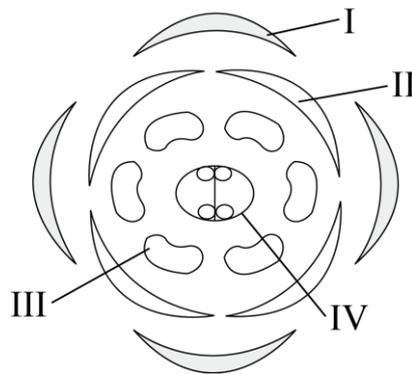
12. The cell wall in plants limits cell expansion. Growing cell walls extend faster in acidic conditions and a group of proteins called expansins are key regulators of wall extension during growth. In an experiment, excised cucumber hypocotyls of the same length were subjected to the following treatments (1 – 4) before being attached to an extensometer and the extension of the hypocotyl measured.

	Treatment protocol
1	Treated with fusicoccin (a drug which activates H ⁺ -ATPase in the plasma membrane) and placed into a buffer at pH 7
2	Treated with fusicoccin (a drug which activates H ⁺ -ATPase in the plasma membrane), heated, and placed into a buffer at pH 4.5
3	Heated, then placed in a buffer at pH 4.5
4	Heated, then placed in a buffer pH at 4.5 with the addition of an homogenate extracted from a region just behind the growing tip of another cucumber hypocotyl

The length of the hypocotyl can either increase or remain the same. Indicate the outcomes with an arrow (↑) for an increase in length and an equal sign (=) for the same length for the different treatments. (1.2 points)

13. The ABC model explains how three homeotic genes control floral organ identity:

- activity of gene A alone specifies sepals
- activity of both gene A and B is required for the formation of petals
- activity of genes B and C results in the formation of stamens
- activity of gene C alone specifies carpels
- gene A and gene C mutually repress each other



Indicate what the floral parts (I – IV) develop into in a mutant with a loss of activity of its B gene?

Write the resultant outcome **in the Answer Sheet**. (1.2 points)

- sepal
- petal
- stamen
- carpel

14. Indicate the type of cell division involved in the organ/cell formation and the ploidy of the cells.

Use I for mitosis and II for meiosis. (2 points)

15. Delves et al. (1986) studied the influence of different organs on nodulation phenotype. To analyze whether shoot or root factors have a regulatory role in the nodule formation, they grafted *wildtype* plant (Bragg cultivar) with two plant mutants (*nts382* and *nts1116*). The grafts were inoculated with *Bradyrhizobium japonicum* strain USDA110 and harvested 9 weeks later. Nodules were picked and counted from each plant and dry weights obtained. The results are summarized in Table 1.

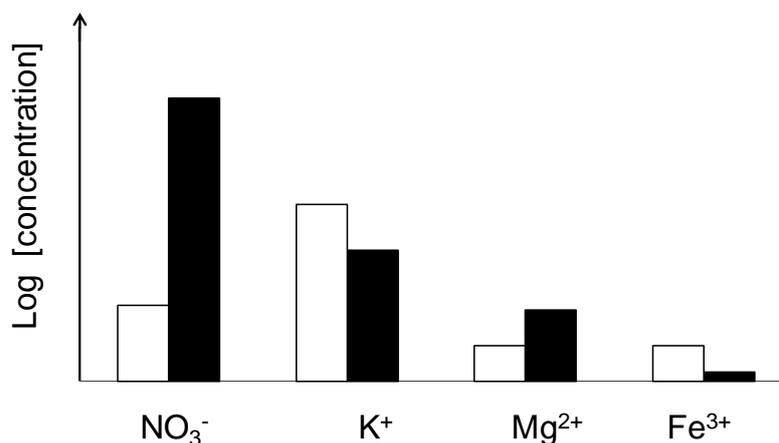
Table 1. Supernodulation control by Bragg cultivar

Graft (Shoot/Root)	Nodule No. per Plant	Nodule Mass <i>mg dry wt nodule</i> <i>g⁻¹ dry wt plant</i>
<i>nts382/nts382</i>	249 ± 90	139 ± 101
<i>nts1116/nts382</i>	71 ± 18	110 ± 5
Bragg/nts382	11 ± 5	2 ± 1
<i>nts382/nts1116</i>	251 ± 46	182 ± 16
<i>nts1116/nts1116</i>	64 ± 6	14 ± 5
Bragg/nts1116	8 ± 3	3 ± 1
<i>nts382/Bragg</i>	182 ± 35	56 ± 28
<i>nts1116/Bragg</i>	48 ± 4	9 ± 2
Bragg/Bragg	8 ± 1	2 ± 1

Indicate correct deduction(s) with a tick (✓) and incorrect deduction(s) with a cross (✗). (1.8 points)

- Genetic factors expressed in the shoot are affecting the number of nodules present in the root.
- Genetic factors expressed in the root are affecting total nodule mass.
- Grafts are compensating an increased number of nodules with a lower mass per nodule.

16. The bar chart shows the concentrations of various minerals in the nutrient solution (\square) and in the root cells (\blacksquare) after 2 weeks of plant growth. Based on the graph given below, indicate appropriate answer(s) with a tick (\checkmark) and inappropriate ones with a cross (\times) **in the Answer Sheet**. (2.4 points)



17. Chemical Z, produced in germinating barley (*Hordeum*) seeds plays a role in the α -amylase synthesis by the aleurone layer cells. To investigate the role of Z more closely, the promoter of the α -amylase gene was fused with the gene for β -glucuronidase (enzyme producing blue product with certain substrate). The transgenic plants were then tested under various conditions for the presence of blue color in the aleurone layer cells, upon addition of the β -glucuronidase substrate. The results are shown in the table below:

Experimental condition	Aleurone layer cells with blue colour
Normal seed	Present
Seed with embryo removed	Absent
Seed without embryo + Z	Present
Isolated protoplasts of aleurone layer cells	Absent
Isolated protoplasts of aleurone layer cells + Z	Present

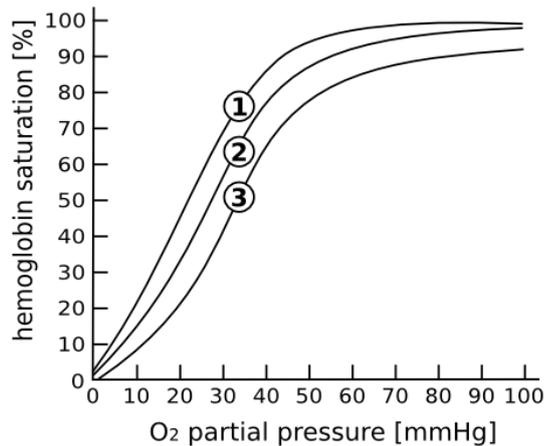
Indicate correct deduction(s) about Z with a tick (✓) and incorrect deduction(s) with a cross (✗).

(1.0 point)

- a. It is likely to be a transcription factor for the α -amylase gene in barley.
- b. It is produced in the aleurone layer.
- c. It is produced in the embryo.
- d. It is produced in the pericarp.
- e. It is likely to be ethylene.

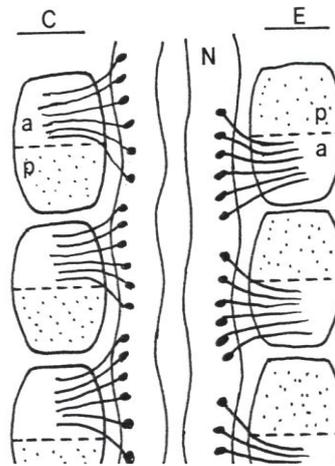
ANIMAL ANATOMY AND PHYSIOLOGY

18. The O₂-affinity curve for human haemoglobin at the physiological blood-pH of 7.4 is represented by (2). Under various conditions, the curve would shift towards (1) or (3). Indicate the appropriate curve (1 or 3) under the conditions listed in the table in the Answer Sheet. (2 points)



19. Tom ran after a snatch thief and caught him after a 80m chase. Which of the following biochemical pathways was important in his muscles during the chase? Indicate the correct answer with a tick (✓) and incorrect answers with a cross (✗). (1 point)
- fatty acid oxidation
 - glycolysis
 - gluconeogenesis
 - glycogenolysis
 - proteolysis

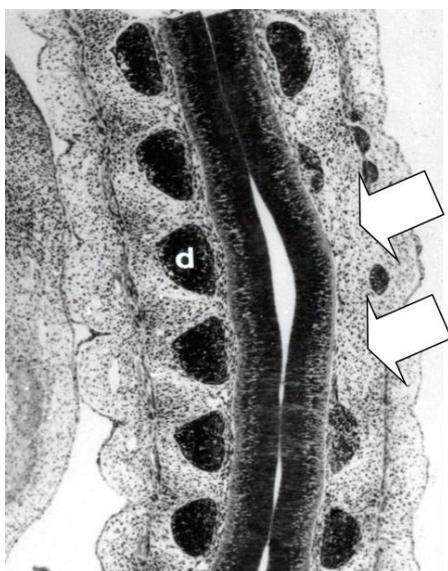
20. The schematic drawing below was traced from the horizontal section of a chick embryo showing the axon outgrowth pattern of the motorneurons after an experimental manipulation. N is the neural tube which will normally develop into the spinal cord. The segmented structures flanking the neural tube are the somites which will contribute to the muscles and vertebrae development. Somites are subdivided into anterior (a) and posterior (p) segments. The control side (C) has somites in the original orientation whereas the experimental side (E) has some somites surgically rotated. The objective of the experiment was to determine if the outgrowth pattern of the motor axons is dependent on the orientation of the somites.



Based on the above figure, indicate correct deduction(s) with a tick (✓) and incorrect deduction(s) with a cross (✗). (2 points)

- The axons grow out of the neural tube regardless of the orientation of the somites.
- The axons preferentially grow through the anterior segment of the somite.
- The axons preferentially grow through the posterior segment of the somite.
- The segmented axon outgrowth pattern is an intrinsic property of the motor neurons.
- The somite segmentation pattern determines the motor axon segmentation pattern.

21. Dorsal root ganglia are formed by neural crest cells migrating away from the neural tube during embryo development. The crest cells forming the ganglia differentiate into sensory neurones. In an experiment, a two-day old chick embryo had the anterior part of two somites surgically removed (arrowed) and allowed to develop until the dorsal root ganglia (d) had formed in day 5. In the image below, the right side of the embryo was the experimental side (E) and the control side (C) is to the left. Note the 'ganglia' scattered on the E side of the embryo (next to the arrows).



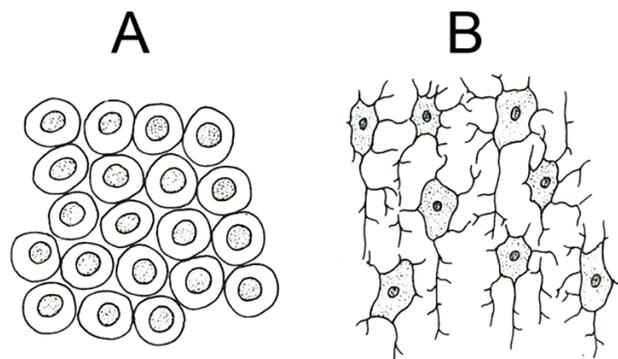
Based on the image above, indicate correct deduction(s) with a tick (✓) and incorrect deduction(s) with a cross (✗). (1.6 points)

- The ganglia segmentation pattern is secondary to the somites segmentation.
- The ganglia segmentation is dependent on the presence of the anterior part of the somite.
- Ectopic ganglia formed possibly because of somites lacking the anterior segments disrupted the normal crest cell migration pathway.
- The somites can regenerate after surgical interference.

22. Combining the observations and deductions derived from **Questions 20** and **21**, it is quite obvious that the anterior segment of the somites are conducive for the outgrowth of motorneurons and the migration of neural crest cells. Indicate valid inference(s) with a tick (✓) and invalid inference(s) with a cross (✗). (1.5 points)

- The anterior segments of the somites are likely to express extracellular matrix molecules that guide the axons and the crest cells.
- The molecules expressed in the anterior segments of the somites are likely to be adhesive proteins for contact inhibition.
- The posterior segments of the somites may produce repulsive molecules that axons and crest cells avoid.

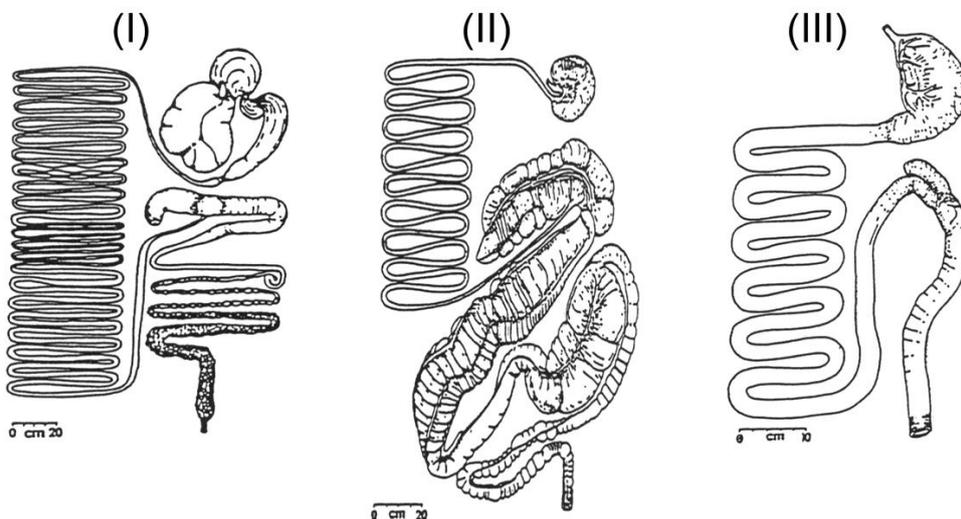
23. A transverse section through the spinal cord is examined under high magnification of the microscope. Indicate which figure (A or B: not drawn to scale) corresponds to grey and white matter respectively. (0.6 points)



24. Blood glucose concentration is regulated by homeostasis. Indicate the concentrations at which the following responses are elicited. Use tick (✓) and a cross (✗) for high and low blood glucose concentrations respectively. (1.2 points)

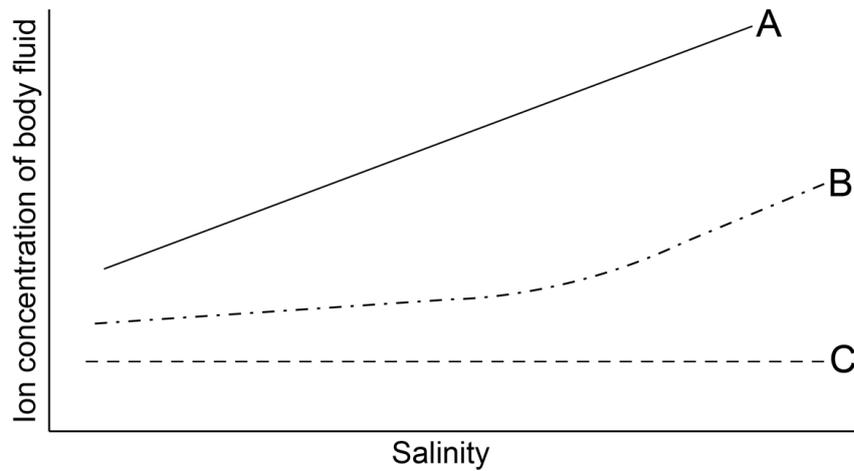
- a. detected by α -cells in islets of Langerhans
- b. increase in insulin secretion
- c. convert glycogen to glucose
- d. speeds up rate of glucose uptake by cells from blood
- e. promotes fat synthesis
- f. stimulates formation of glucose from amino acids

25. Match the digestive systems (I – III) with the corresponding animal feeding adaptation (a – c). (1.5 points)



- a. carnivore with limited post-gastric fermentation
- b. herbivore with extensive post-gastric fermentation
- c. herbivore with extensive pre-gastric fermentation

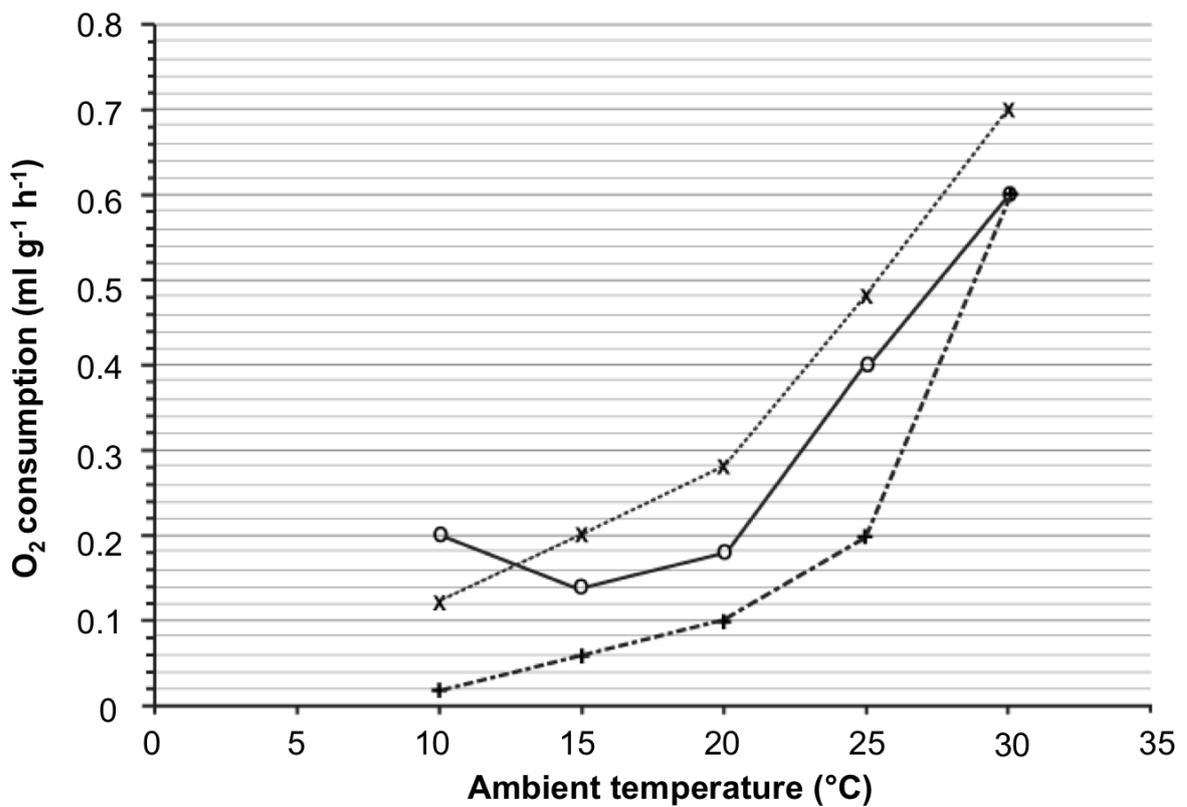
26. The graph below shows the different responses of marine animals to salinity changes.



An extremely heavy and sustained week-long rainfall resulted in the salinity at a river mouth to fall from 28 ppt to 8 ppt. This caused many soft-bodied intertidal organisms to die. Which group of organism survived best? Write your answer **in the Answer Sheet**. (1 point)

27. Q_{10} values are often used to describe the effects of temperature on the rate of many reactions involved in biological processes. The Q_{10} value is the ratio of the velocity constants k_1 (at $t + 10$ °C) and k_2 (at t °C), $[k_1/k_2]$.

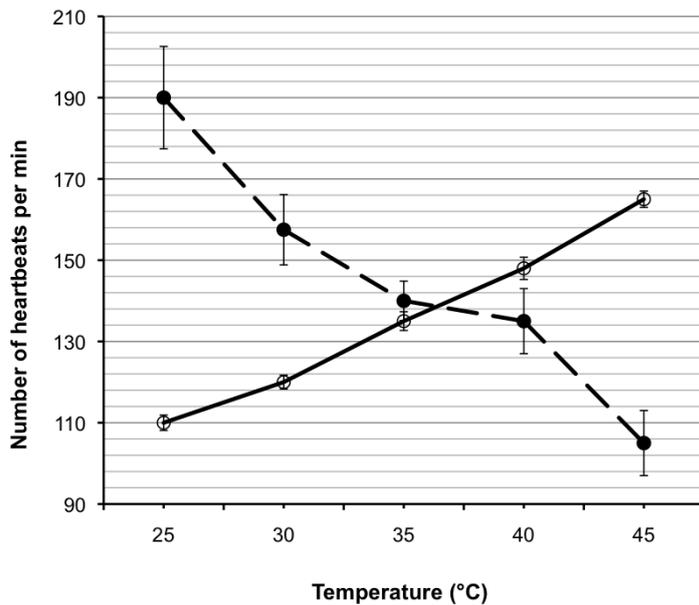
27.1. Using the data on the oxygen consumption of the three organisms below, calculate the Q_{10} values for temperature intervals of (i) 10 – 20 °C, (ii) 15 – 25 °C, and (iii) 20 – 30 °C. (3.6 points)



Note: A: --- X--- B: — O — C:----- +-----

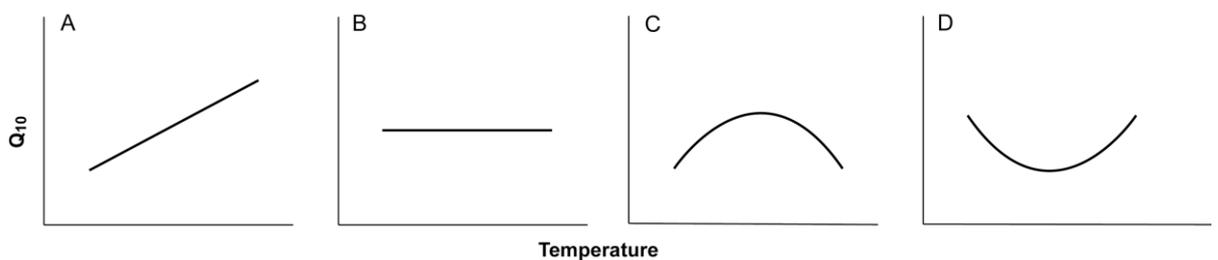
27.2. Classify the organisms (A – C) as ectotherm(s) or endotherm(s). (0.9 point)

28. Ghost crabs (*Ocypode ceratophthalmus*) are common on tropical shores, with the adults being nocturnal (staying in their burrows in the day) and the juveniles, diurnal in activity behaviour. Adult crabs generally excavate burrows higher up the shore than juveniles. Heart beat rates of juvenile and adult ghost crabs were measured at various temperatures.

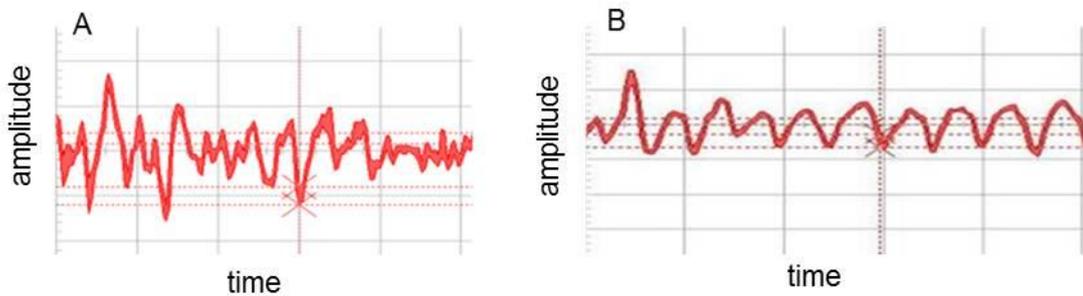


● juvenile crabs; ○ adult crabs

28.1. Graphs (A – D) below represent the trend of typical physiological response of organisms to temperature change as measured by Q_{10} values. Identify the correct graph for the two stages of crab development. (1 point)



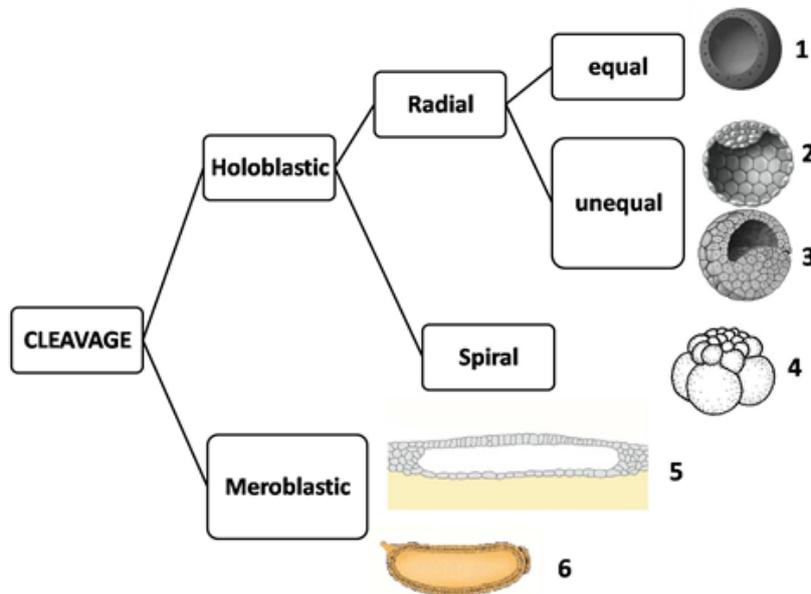
28.2. The heart beat patterns of the crabs at 30 °C over a period of 5 s are shown in the figure below. Match the patterns with the correct stage of crab development. (1 point)



28.3. Indicate correct statement(s) with a tick (✓) and incorrect statement(s) with a cross (✗).
(1.6 points)

- As heart rate and metabolic rate are strongly correlated, this study provides evidence that smaller organisms have higher basal metabolisms regardless of temperature.
- The higher heart rates of juvenile crabs are compensated by more heat lost via the proportionately larger surface area to volume ratio.
- Adult crabs show endogenous nocturnal activity as they are not so heat tolerant, preferring to stay in their burrows during the day.
- Physiological responses to thermal stress remain constant as ghost crabs mature.

29. The types of cleavage pattern and blastulas (1 – 6) for some animal embryos are shown below:



29.1. Match the cleavage patterns and blastulas (1 – 6) with the corresponding animals.

Indicate P for protostome and D for deuterostome. (1.2 points)

29.2. Identify the main factor that influences the cleavage. (1 point)

- a. the ratio of the egg cytoplasm to nucleus
- b. the thickness of the egg membrane
- c. the amount of the yolk content
- d. the overall volume of the zygote

ETHOLOGY

30. Vervet monkeys (*Cercopithecus aethiops*) warn fellow monkeys by producing unique warning signals according to the type of predators such as eagles, leopards and snakes. Depending on the type of signals, monkeys in the group choose the appropriate method to escape. A newborn Vervet monkey is capable of producing all of these signals but it does not know which signal should be used in each case. If a baby monkey produces the signal for eagles when a sparrow is flying over, adult monkeys look up at the sky and then ignore the signal. However, if an eagle is indeed hovering, the entire group joins in the warning. Sometimes, baby monkeys are punished by their mothers for producing wrong signals.

Which of the following learning types are associated with the warning signal development in baby monkeys? Indicate the correct answer(s) with a tick (✓) and incorrect answer(s) with a cross (✗) in the table provided **in the Answer**

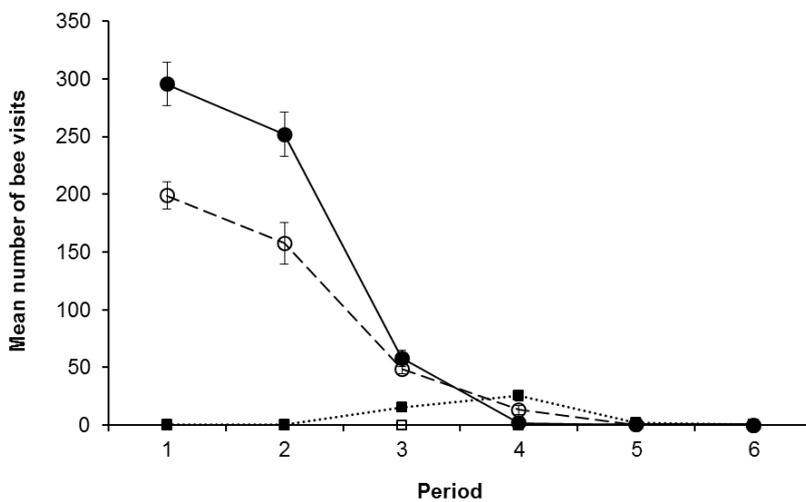
Sheet. (0.8 point)

- a. imprinting
- b. associative learning
- c. problem solving
- d. social learning

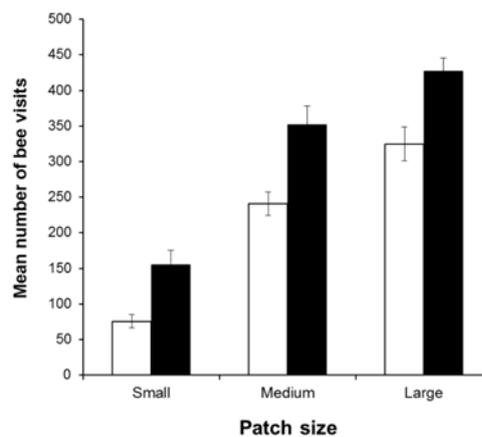
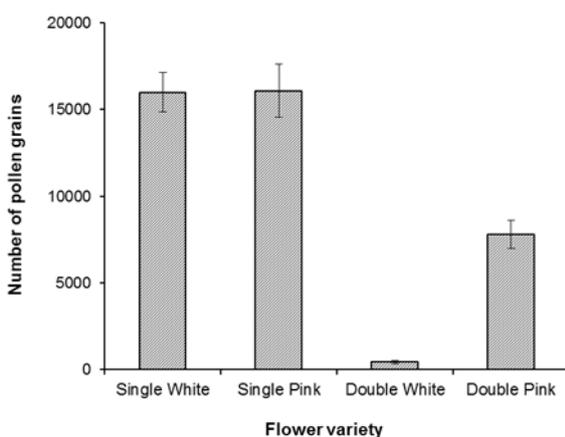


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31. The Asian honey-bee, *Apis cerana* is the primary pollinator of *Portulaca grandiflora*. Bees' pollination of four flower varieties of *P. grandiflora*: white flowers (single and double-petalled) and pink flowers (single and double-petalled), was studied. Bees' visitations to the four flower varieties at six observation periods of half hour duration from 0930 h to 1230 h were recorded. Pollen production per flower in the four flower varieties was determined. Three different floral patch sizes (small, medium, and large: 20, 40, and 80 flowers respectively) placed at a distance of 1.5 m apart from each other, were presented to the bees.



○--- Single white, ●— Single pink, □— Double white, ■..... Double pink

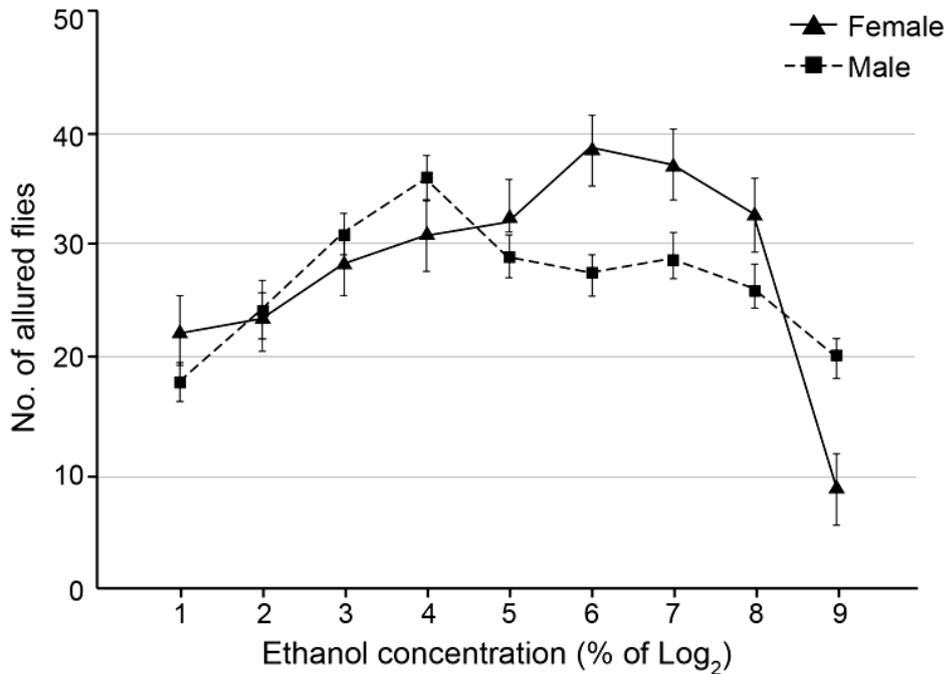


□ Single white, ■ Single pink

Indicate correct conclusion(s) about the honey bees' behaviour with a tick (✓) and incorrect conclusion(s) with a cross (✗). (2 points)

- a. *Apis cerana* preferred the single-petalled *Portulaca grandiflora* flowers regardless of observation period.
- b. Pink flowers were always preferred over white flowers as they had more pollen grains for the bees to harvest.
- c. Flower colour provide an indirect cue to reward size.
- d. Pollinators did not respond to diminishing rewards but floral patch size influenced their foraging patterns significantly.
- e. Larger floral patch size provided stronger advertising signals and the promise of larger rewards.

32. Fruit flies usually find food by following the odour of ethanol produced from fruits. The fruit also serves as the place for male and female flies to mate and reproduce. The graph below shows the relationship between the number of allured flies and the concentration of ethanol.



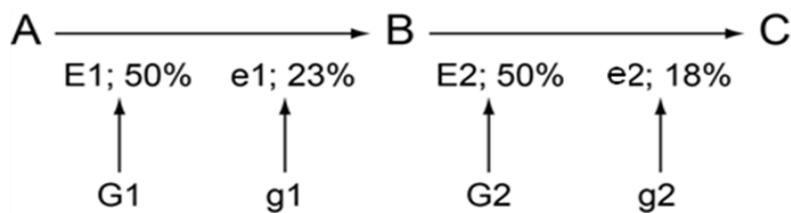
Based on the graph, indicate the correct statement(s) with a tick (✓) and incorrect statement(s) with a cross (✗). (1 point)

- a. The male/female ratio in the number of flies occupying the food source varies depending on the ethanol concentration.
- b. The number of mating animals would be the lowest when ethanol concentration is 9.
- c. The competition between males would be most severe when ethanol concentration is 7.
- d. The number of laid eggs would be the highest when ethanol concentration is around 6 and 7.
- e. The number of attracted flies would be the highest when ethanol concentration is 8.

GENETICS AND EVOLUTION

33. A two-step metabolic pathway in a diploid organism has the following components:

Gene 1 (G1) encodes enzyme E1 that converts substrate A to product B. Its mutant allele g1 produces a defective e1 that has 46% activity of normal E1. Similarly, gene 2 (G2) encodes the enzyme E2 that converts the metabolic intermediate B to the product C, while its mutant allele g2 produces a defective enzyme e2 with 36% activity of normal E2. For both enzymes, each allele contributes 50% towards the protein pool in the cell and both reactions have the same rate in a wild-type cell.



In the F₂ progeny of a cross between G1G1g2g2 and g1g1G2G2 individuals, what fraction is expected to show an elevated level of the metabolic intermediate B? (2 points)

34. In a particular breed of dogs, the hairless condition is produced by the heterozygous genotype. Normal dogs are homozygous recessive. Puppies homozygous for the H allele are usually born dead with abnormalities of the mouth and absence of external ears. If the average litter size at weaning is 6 in matings between hairless dogs, what would be the average expected number of hairless and normal offspring at weaning for matings between hairless dogs and between hairless and normal dogs? (1.8 points)

35. There are two types of red-green colour blindness – deuteranopia and protanopia, governed by two linked loci on the X chromosome. Among 18,121 Norwegian children examined in a study, 9049 were males, of which, 725 were males with colour blindness, 551 had deuteranopia and 174 had protanopia. Of the 40 females with colour blindness, 37 had deuteranopia and 3 had protanopia.

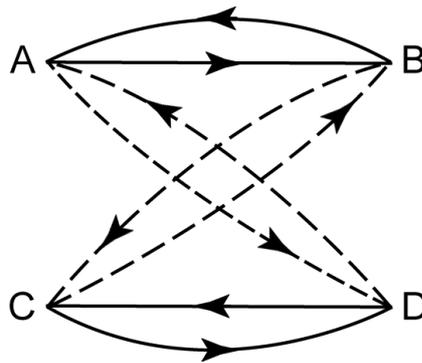
df	χ^2
1	3.841
2	5.991
3	7.815
4	9.488
5	11.070

Table: χ^2 values for $\alpha = 0.05$

Estimate the allele frequencies for deuteranopia (independent of protanopia)-from the data on males. Use these values to test the phenotypic distribution in females for compatibility with the Hardy Weinberg equilibrium (HWE) using the χ^2 test.

Indicate compatibility with HWE with a tick (✓) and incompatibility with a cross (*). (4.0 points)

36. The diagram below presents the patterns of clan membership for a kinship group of Native Americans. The diagram shows the conditions of marriage and the way the clan of the father determines the clan of the children. The broken lines point from the father's clan to the clan of his children and the solid lines point from a man's clan to the clan of a potential wife.



The pattern of clan membership between the four clans A, B, C and D.

A disease X, that is prevalent in this clan community, is a dominant sex linked trait and is carried on the Y chromosome. Answer the following questions relevant to disease transmission between the four clans.

36.1. Maska of clan D has disease X.—After two generations both including sons, indicate the clans that will be affected if only Maska carried the disease, with a tick (✓) and non-affected clans with a cross (✗). (2 points)

36.2. What is the probability of Tala (clan A) and Yonato (clan B) having a son with disease X in clan D if Yonato's father had disease X? (2 points)

37. A number of nutritional mutant strains were isolated from wild-type red bread mold *Neurospora crassa* that responded to the addition of certain supplements in the culture medium by growth (+) or no growth (0). Given in the Table below are the responses for single-gene mutants.

Strain	Supplements added to minimal culture medium				
	Citrulline	Glutamic semialdehyde	Arginine	Ornithine	Glutamic acid
A	+	0	+	0	0
B	+	+	+	+	0
C	+	0	+	+	0
D	0	0	+	0	0

- 37.1. Indicate the sequence (1 – 5) of the five metabolites within the metabolic pathway **in the**

Answer Sheet. (1.5 points)

- 37.2. Indicate the strain that is blocked at each of the four steps in the metabolic pathway **in**

the Answer Sheet. (1.2 points)

38. Given that A^1A^1 = lethal, A^1A^2 = gray, A^2A^2 = black, B^1B^1 = long hair, B^1B^2 = short hair, B^2B^2 = very short hair (fuzzy), and parents that are $A^1A^2B^1B^2$.

- 38.1. What is the fraction of adult offspring that is expected to be gray and fuzzy? (1 point)

- 38.2. In the case when fuzzy is also a lethal trait, what is the fraction of adult progeny expected to be black and short? (1 point)

39. You are given the following number of F_1 flies.

	Male	Female	Total
wild type	80	60	140
mutant	30	30	60

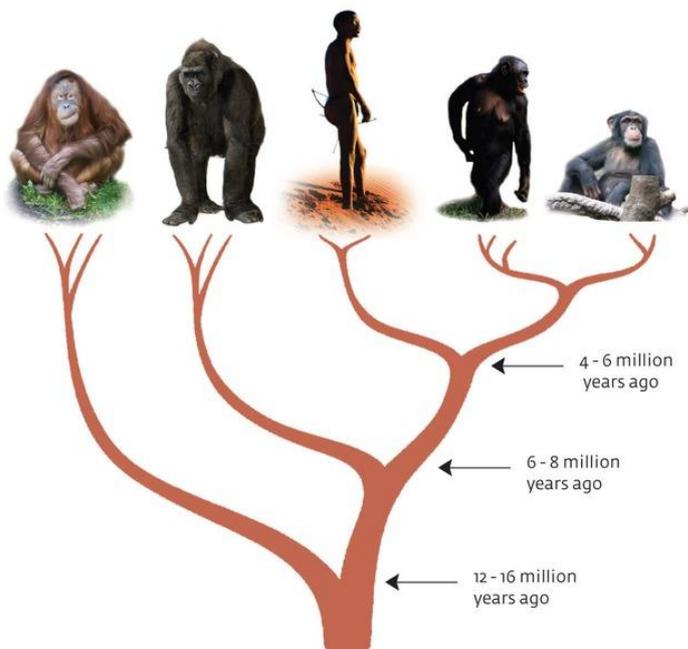
If the mutation was inherited via a simple autosomal recessive mode, what is the most likely parental genotype? Indicate the correct answer(s) with a tick (\checkmark) and incorrect answer(s) with a cross (\times). (1 point)

- a. $w w \times w^+ w^+$
- b. $w^+ w \times w^+ w$
- c. $w^+ w \times w w$
- d. $w^+ w \times w^+ w^+$
- e. $w^+ w^+ \times w^+ w^+$

40. If a paternal chromosome has alleles L, M, and n and the maternal chromosome has l, m, and N. Which of the following chromosomes could possibly be produced as a result of a single crossing over? Indicate the correct answer(s) with a tick (✓) and incorrect answer(s) with a cross (✗). (1 point)

- I. LMN
- II. LMn
- III. LmN
- IV. Lmn
- V. lmn

41. The closest living relative of human (*Homo sapiens*) is widely considered to be the chimpanzee (*Pan troglodytes*) and bonobo (*Pan paniscus*). Together with the orangutans (*Pongo pygmaeus* and *P. abelii*) and gorilla (*Gorilla gorilla* and *G. beringei*) they form the subfamily Homininae. This evolutionary relationship can be presented as shown below.



41.1. The phylogenetic tree demonstrating the evolutionary relationship of the higher primates is constructed using molecular data and is considered to be reliable because:

- a. DNA mutations and polymorphisms can be readily identified and analyzed.
- b. DNA sequences can be converted into protein sequences for comparative analysis.
- c. the availability of large amount of molecular data permits rigorous computational analyses to be conducted.
- d. physically intact and unfragmented genomic DNA can be recovered after millions of years.

Indicate true statement(s) with a tick (✓) and false statement(s) with a cross (✗). (0.8 point)

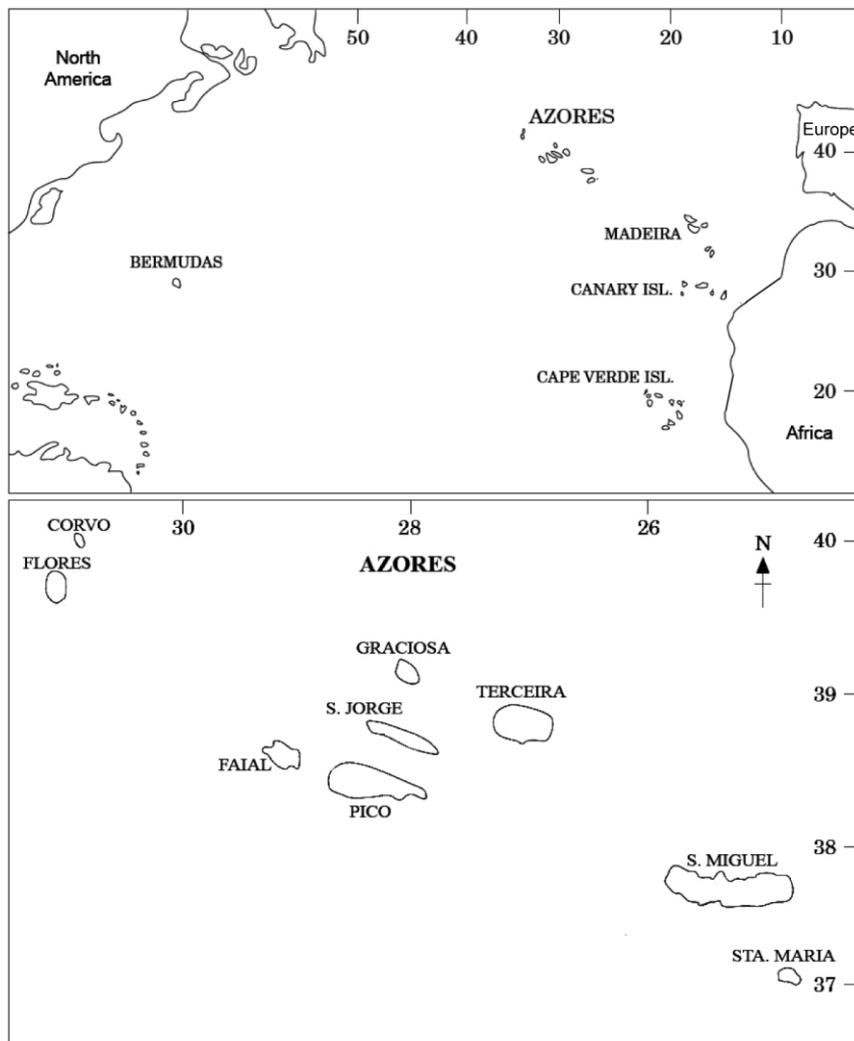
41.2. Most of the oldest fossils belonging to the subfamily Homininae are found in the African continent. This is similarly reflected by the living species, with orang utans being the only species not found in Africa. This observation of fossil distribution supports the:

- a. "Out of Africa" hypothesis whereby the first human beings-evolved in Africa and subsequently migrated to other continents.
- b. "Out of Asia" hypothesis as the oldest living species, the orang utans, are found only in South-East Asia.
- c. "multi-centric origin" hypothesis.

Indicate true statement(s) with a tick (✓) and false statement(s) with a cross (✗). (0.6 point)

ECOLOGY

42. Borges and Brown (1999) studied the arthropod species richness in three islands (Pico, Santa Maria and Terceira), in the Azorean archipelago. The figure below shows the location of the islands with respect to major land masses, Africa and Europe (in the east) and North America (in the west).

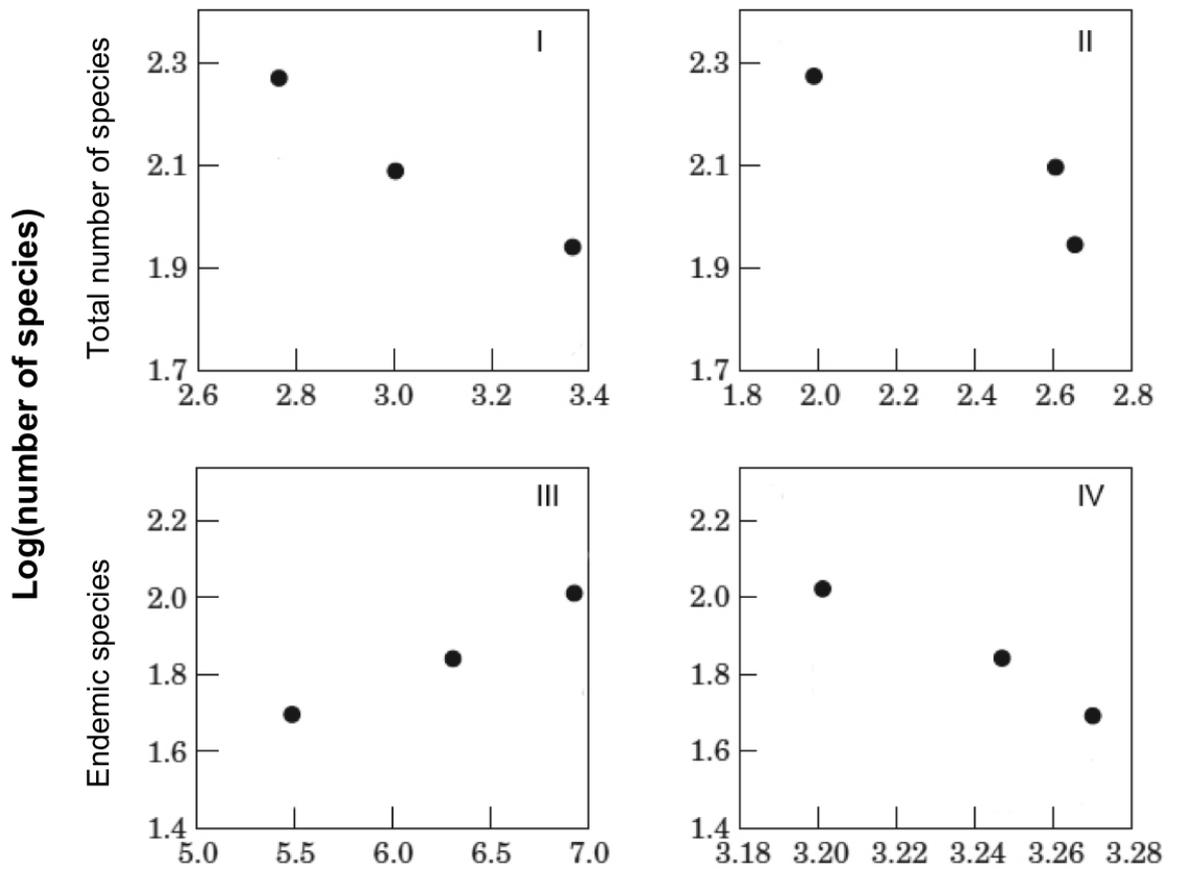


Some other characteristics of the islands are given in the table below.

Island	Altitude (m)	Geological age (Myr)	Distance from mainland (km)
Pico	2351	0.037 – 0.300	1866
Santa Maria	587	8.12	1585
Terceira	1023	0.300 – 2	1770

42.1. Match the following x axes with the correct graphs (I to IV). (2.4 points)

- a. Log_{10} (area in km^2)
- b. Log_{10} (altitude in m)
- c. Log_{10} (distance from mainland in km)
- d. Log_{10} (geological age in years)

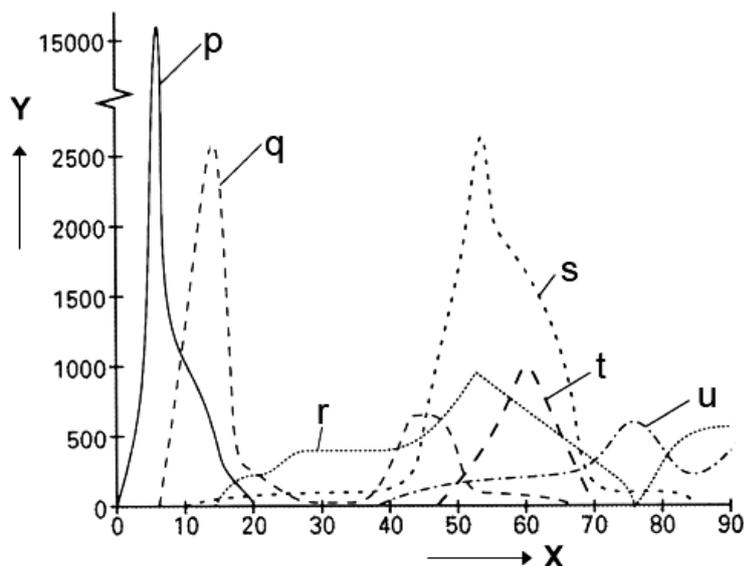


42.2. Estimate from the graphs, the number of endemic species (to the nearest whole number) in the three islands. (1.2 points)

42.3. From the data indicate correct conclusion(s) that can be drawn from the study with a tick (✓) and incorrect conclusion(s) with a cross (✗). (1.5 points)

- a. Diversity was greater on the island with the lowest maximum altitude and decreased with increasing altitude.
- b. Results of this study support the species-area hypothesis.
- c. Isolation alone cannot be used to explain the species richness patterns found in the arthropod assemblage in the three islands.
- d. Species richness patterns in these islands are influenced by both ecological and evolutionary factors.
- e. MacArthur and Wilson's theory of island biogeography is fully supported by the results of this study.

43. Daniel boiled water and hay in a beaker for some time, and left it uncovered for some days. During that period only heterotrophic bacteria were found in the beaker. He then added a few drops of ditch water and covered it loosely. The water from the ditch only contained heterotrophic unicellular organisms (no bacteria or fungi). Daniel regularly determined the size of the populations of the different species (p – u) present in the beaker over a period of time.



X = Time (days); Y = number of individuals per ml at water surface

Looking at the results, some of Daniel's students claimed that in the beaker:

- I. competition is likely to occur
- II. succession is taking place
- III. total biomass is increasing in the period between Day 40 to Day 50

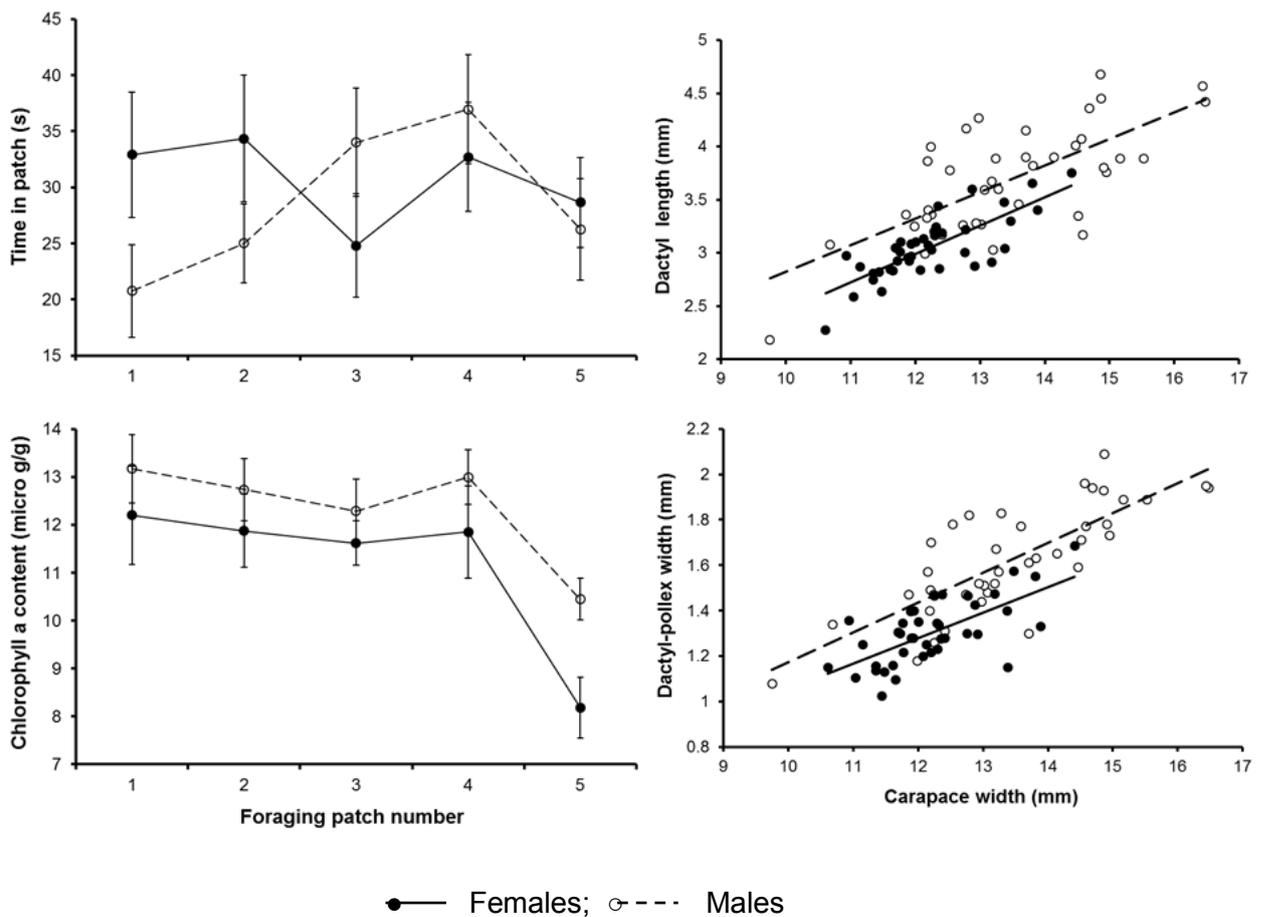
Some other students even went on to predict that:

- IV. the number of dividing bacteria will decrease to zero
- V. the number of the other dividing heterotrophic unicellular organism will decrease to zero
- VI. a climax stage will develop, comprising bacteria and other heterotrophic unicellular organisms, in a stable natural equilibrium

Indicate correct statement(s) with a tick (✓) and incorrect statement(s) with a cross (✗). (1.2 points)

44. Increasing concentration of carbon dioxide (a greenhouse gas) has been linked to global climate change. Carbon dioxide can be removed from the atmosphere and deposited in a reservoir in order to either mitigate or defer global warming and avoid dangerous climate change. The removal process includes carbon dioxide uptake from the atmosphere by all chlorophyllous plants, through photosynthesis. Indicate correct statement(s) concerning the amount of carbon “stored” per unit area in different ecosystems with a tick (✓) and incorrect statement(s) with a cross (✗). (1 point)
- a. net primary productivity (NPP) (or net carbon absorption rate) of coniferous forests > temperate forests > tropical forests
 - b. carbon stocks (the amount of carbon stored) of coniferous forests > temperate forests > tropical forests
 - c. net primary productivity (NPP) of temperate grasslands > savannas (grasslands with scattered trees) > tundra
 - d. net primary productivity (NPP) of secondary forests > climax forests or old growth forests
 - e. as compared to other ecosystems, coral reefs have very high net primary productivity, and their contribution to global production of biomass is large

45. Male fiddler crabs have an enlarged cheliped (the major cheliped) to attract mates and defend territories. However, the major cheliped is useless for foraging; hence males are left with only one feeding appendage – the minor cheliped. Many strategies have been proposed by researchers to explain how male fiddler crabs compensate for this apparent disadvantage. A student conducted a study to investigate some of these strategies. She videotaped the foraging bouts of males and females on the first five patches of sediment upon first emergence at low tide. Sediment samples from these five patches were collected after the crabs have vacated the patch and chlorophyll a content in these samples was determined. Various dimensions of the feeding cheliped in males and females were also compared. The mean number of scoops per second for the two sexes was determined from the videotapes: females, 2.39 ± 0.08 scoops; males, 1.60 ± 0.06 scoops.

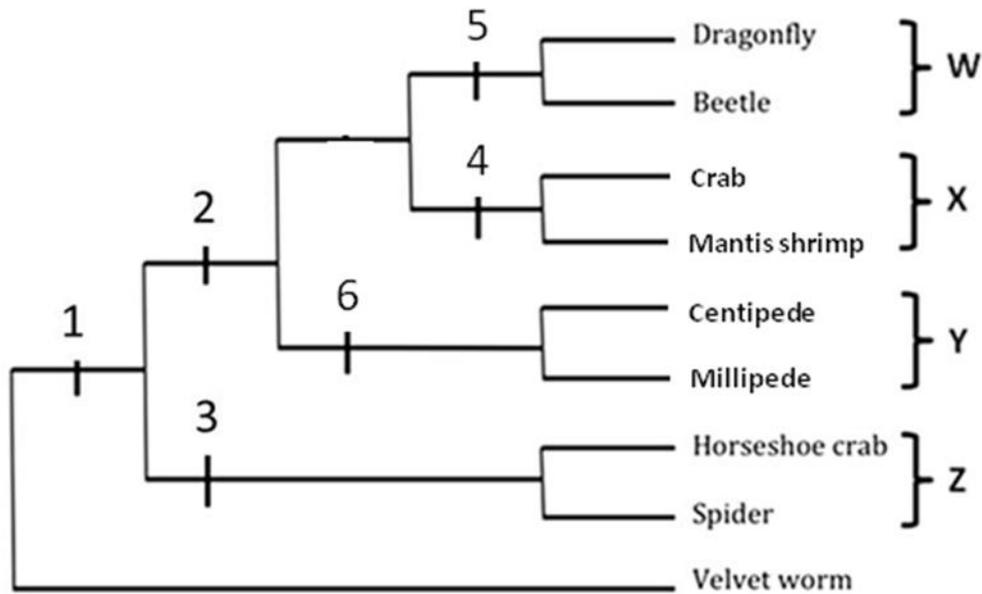


Indicate correct conclusion(s) that can be drawn from the student's study with a tick (✓) and incorrect conclusion(s) with a cross (✗). (2.4 points)

- a. Male fiddler crabs do not compensate for the one-feeding-cheliped-handicap by feeding at a faster rate than females.
- b. There is sexual dimorphism in the minor cheliped.
- c. In general, male fiddler crabs compensate for the one-feeding-cheliped-handicap by staying for a longer period of time in a foraging patch.
- d. Male fiddler crabs generally leave a foraging patch at a higher threshold of chlorophyll a content than females.
- e. Males compensate for the one-feeding-cheliped-handicap by having larger scoops of sediment per lift of the cheliped.
- f. Results of this study do not support the principles of the optimal foraging theory.

BIOSYSTEMATICS

46. Morphological characters (1 – 6) shared by two or more organisms and their recent common ancestor are shown in the cladogram below.



46.1. Which of the morphological characters (1-6) are the synapomorphies for the corresponding taxonomic groups indicated **in the Answer Sheet**. (1.2 points)

46.2. Identify the taxonomic groups (W – Z) in the table provided **in the Answer Sheet**. (1.2 points)

46.3. Based on your knowledge of these organisms and groups, match the morphological characters listed below (I – VI) among the labelled morphological characters from 1 to 6.

(1.2 points)

- I. body organised into head, and elongated (and segmented) trunk; numerous pairs (> 12 pairs) of legs
- II. body organised into head, thorax, and abdomen; three pairs of legs (from thorax)
- III. jointed/segmented appendages
- IV. antennae (one or more pairs); mandibles (chewing mouthparts)
- V. two pairs of antennae; biramous (two branches) appendages
- VI. no antennae; no mandibles

46.4. Classify the groups listed below (I – IV) according to their respective phylogenetic origins

in the Answer Sheet. (1.2 points)

- I. W and X
- II. X and Y
- III. Y and Z
- IV. W, X, Y, and Z

END OF PAPER