| Country: _____ | Student Code: _____ |
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# 23rd INTERNATIONAL BIOLOGY OLYMPIAD

8th – 15th July, 2012

SINGAPORE


## THEORETICAL TEST – PAPER 1

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 |
|---|---|---|---|---|
| × | ✓ | × | × | ✓ |

- 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 89.3.
- 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. The Table below shows the genetic codes of amino acids.

| | U | C | A | G | |
|---|---|---|---|---|---|
| **U** | Phe | Ser | Tyr | Cys | **U** |
| | Phe | Ser | Tyr | Cys | **C** |
| | Leu | Ser | STOP | STOP | **A** |
| | Leu | Ser | STOP | Trp | **G** |
| **C** | Leu | Pro | His | Arg | **U** |
| | Leu | Pro | His | Arg | **C** |
| | Leu | Pro | Gln | Arg | **A** |
| | Leu | Pro | Gln | Arg | **G** |
| **A** | Ile | Thr | Asn | Ser | **U** |
| | Ile | Thr | Asn | Ser | **C** |
| | Ile | Thr | Lys | Arg | **A** |
| | Met | Thr | Lys | Arg | **G** |
| **G** | Val | Ala | Asp | Gly | **U** |
| | Val | Ala | Asp | Gly | **C** |
| | Val | Ala | Glu | Gly | **A** |
| | Val | Ala | Glu | Gly | **G** |

Some viruses (e.g. tobacco mosaic virus (TMV)) have RNA sequences that contain a "leaky" stop codon. In TMV 95% of the time the host ribosome will terminate the synthesis of the polypeptide at this codon but the rest of the time it continues past it.

The following sequences show part of a mRNA from TMV. Indicate the sequence(s) that may result in two polypeptides in the indicated frame with a tick (✓) and those that will not with a cross (✗). (1.8 points)

a. 5′-AUG-UCU-UGU-CUU-UUC-ACC-CGG-GGG-UAG-UAU-UAC-CAU-GAU-GGU-UAA-3′

b. 5′-AUG-ACC-CGG-GGG-UUU-CUU-UUC-UAG-UAU-GAU-CAU-GAA-GGU-UGU-UAA-3′

c. 5′-AUG-CUU-UUC-UCU-UAU-UAG-CAU-GAU-GGU-UGU-ACC-CGG-GGG-CCC-UAA-3′

d. 5′-AUG-CAU-GUU-CUU-UUC-UCU-UAU-UGU-GGU-UGU-ACC-CGG-GGG-UUC-UAA-3′

e. 5′-AUG-CAU-GAU-GGU-UGU-ACC-CGG-GGG-UAG-CUU-UUC-UCU-UAU-UGC-UAA-3′

f. 5′-AUG-UCU-UAU-UGG-CAU-GAU-GGU-UGU-CUU-UUC-ACC-CGG-GGG-AAA-UAA-3′

2. Mitochondria are mainly concerned with the following functions:

   a. thermogenesis

   b. apoptosis

   c. production of ATP

   d. fatty acid metabolism

   Indicate the extensive presence of mitochondria with a tick (✓), intermediate presence (-) and absence of mitochondria with a cross (×). Match the key function(s) of mitochondria (a to d) suited to the respective cells. (1.8 points)

3. Arrange the order of the DNA molecules from lowest to highest in terms of their melting temperature (Tm). (0.9 points)

   a. 5′-AAGTTCTCTGAA-3′

      3′-TTCAAGAGACTT-5′

   b. 5′-AGTCGTCAATGCGG-3′

      3′-TCAGCAGTTACGCC-5′

   c. 5′-GGACCTCTCAGG-3′

      3′-CCTGGAGAGTCC-5′

4. There are various mechanisms by which a cell can commit suicide – a phenomenon known as "apoptosis". One of the mechanisms is triggered by reactive oxygen species. The outer membrane of mitochondria normally expresses a protein Bcl-2 on its surface. Another protein Apaf-1 binds Bcl-2. Reactive oxygen species cause Bcl-2 to release Apaf-1 and a third protein Bax to penetrate the mitochondrial membrane, releasing cytochrome c. The released cytochrome c forms a complex with Apaf-1 and caspase 9. This complex sequentially activates many proteases that digest cellular proteins.

   What will be the fate of a cell exposed to reactive oxygen species in the following conditions?

   I. The cell has expressed a mutant form of Apaf-1 that constitutively (always) bind Bcl-2.

   II. The cell does not express Bcl-2 at all.

   III. The cell overexpresses a form of Bcl-2 that is targeted to cell membrane only.

   IV. A chemical which extends the half life of Bcl-2 is added to the cell.

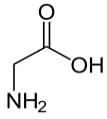
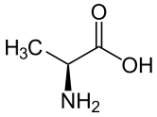
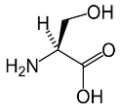
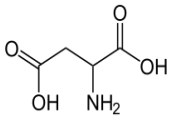
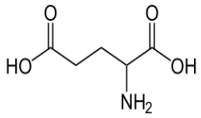
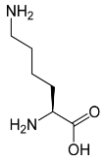
   Match the following fates of the cell with the conditions (I to IV). (2 points)

   a. The cell resists apoptosis.

   b. The cell is forced towards apoptosis.

   c. The fate of the cell cannot be predicted.

5. The Table below shows the chemical structure, $pK_1$, $pK_2$ and $pK_R$ of some amino acids.

| Amino acid | Structural formula | $pK_1$ α-COOH | $pK_2$ α-$NH_2$ | $pK_R$ side chain |
|---|---|---|---|---|
| Glycine (Gly) |  | 2.35 | 9.78 | --- |
| Alanine (Ala) |  | 2.35 | 9.87 | --- |
| Serine (Ser) |  | 2.19 | 9.21 | --- |
| Aspartic acid (Asp) |  | 1.99 | 9.9 | 3.9 |
| Glutamic acid (Glu) |  | 2.1 | 9.47 | 4.07 |
| Lysine (Lys) |  | 2.16 | 9.06 | 10.54 |

5.1. Determine the predominant form (ionic or neutral) for heptapeptides, A to C, at pH 1, pH 7 and pH 12. Calculate their corresponding net charges (with an integer approximation). (3.6 points)

5.2. What is the best pH for the electrophoretic separation of these three peptides from each other?

Indicate the best pH with a tick (✓) and the other pH values with a cross (✗). (0.6 points)

6. Which of the following sequence(s) of cell-cycle phases is/are characteristic of eukaryotes [G: gap; S: synthesis; M: mitosis]? Indicate correct sequence(s) with a tick (✓) and incorrect ones with a cross (✗). (0.5 points)

   a. $G_1$ - S - $G_2$ - $G_0$ - M

   b. $G_0$ - $G_1$ - S - $G_2$ - M

   c. $G_1$ - $G_0$ - $G_2$ - S - M

   d. $G_1$ - $G_0$ - $G_1$ - $G_2$ - S - M

   e. $G_1$ - $G_0$ - $G_1$ - S - $G_2$ - M

7. About the $G_2$ phase

   7.1. Which of the statement(s) describe(s) a cell in the $G_2$ phase? Indicate correct statement(s) with a tick (✓) and incorrect ones with a cross (✗). (0.4 points)

      a. The homologous chromosomes are lined up on the equator.

      b. The homologous chromosomes have been pulled to their respective poles by the spindle apparatus.

      c. The homologous chromosomes have not been replicated yet.

      d. The homologous chromosomes are now in the haploid or n condition.

   7.2. How many chromatin threads are there in a human somatic cell in the $G_2$ phase? (0.5 points)

8. The morphology of three species of bacteria (A to C) are shown below:

A (coccus) B (flagellated bacillus) C (capsulated filament)

8.1. Bacteria in nature prefer to attach to surfaces and exist in a form known as “biofilms”. During the attachment stage, before reaching the surface for attachment, bacteria will encounter a zone of repulsive force as they come very close to the surface. Which bacteria are likely to have an advantage to overcome this repulsive zone? Indicate the correct answer(s) with a tick (✓) and incorrect answer(s) with a cross (✗). (0.6 points)

a. Bacterium A

b. Bacterium B

c. Bacterium C

8.2. After overcoming the repulsive zone and reaching the surface, the strength of attachment on the surface of the three bacteria is likely to be different. Arrange the correct order of attachment strength of the three bacteria in **the Answer Sheet**. (0.6 points)

8.3. A stagnant pool of water was originally rich in organic content, but the nutrient concentration soon became diluted with rainwater. All three bacteria were affected and would attempt to survive the best way they could under this condition. Indicate true statement(s) with a tick (✓) and incorrect statement(s) with a cross (✗). (0.6 points)

a. Bacterium A allows the fastest relative diffusion of nutrients into the interior of its cell.

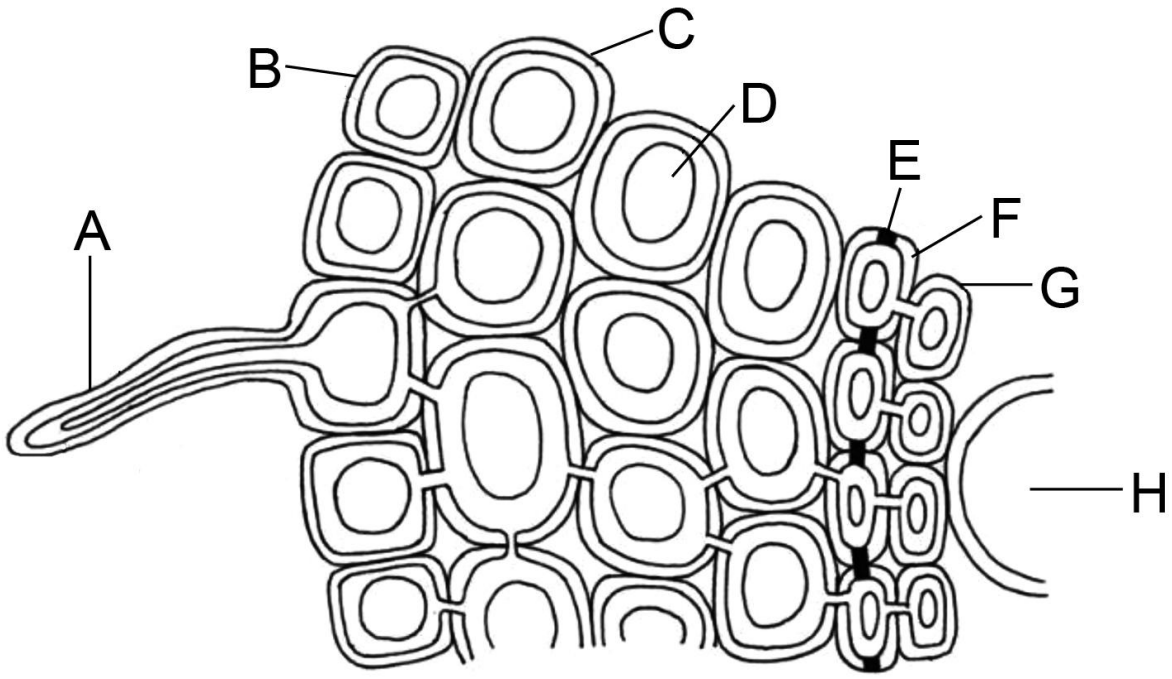
b. Bacterium B can extend its flagellum to reach nutrients above the water level.

c. Bacterium C has a capsule which can actively absorb more nutrients.

9. A laboratory technician stained unknown bacterial cells with different dyes before observing them. The dyes (stains) used are known to target (i) lipopolysaccharide, (ii) nuclear envelope, (iii) DNA, (iv) cytoplasm and (v) ribosomes. Which dyes are likely to stain positive no matter what type of bacteria there may be in the sample? Indicate with a tick (✓) if they will be stained and with a cross (✗) if they will not be stained. (1 point)

## PLANT ANATOMY AND PHYSIOLOGY

10. Study the transverse section of a root in the figure below.




10.1. Match the codes (1 – 18) given in the table below with the labeled parts (A to H) in the above figure. (1.6 points)

| No. | Part | No. | Part |
|---|---|---|---|
| 1 | Hypodermis | 10 | Sclerenchyma cell |
| 2 | Epithelial cell | 11 | Casparian strip |
| 3 | Xylem parenchyma | 12 | Central vacuole |
| 4 | Epidermal cell | 13 | Phloem parenchyma |
| 5 | Xylem fiber | 14 | Pericycle |
| 6 | Root hair | 15 | Companion cell |
| 7 | Exodermal cells | 16 | Phloem fiber |
| 8 | Xylem vessel | 17 | Endodermal cell |
| 9 | Cortical parenchyma cell | 18 | Collenchyma cell |

10.2. The following are three pathways of ion and water absorption:

I. a symplastic pathway

II. an apoplastic pathway

III. a transmembrane pathway

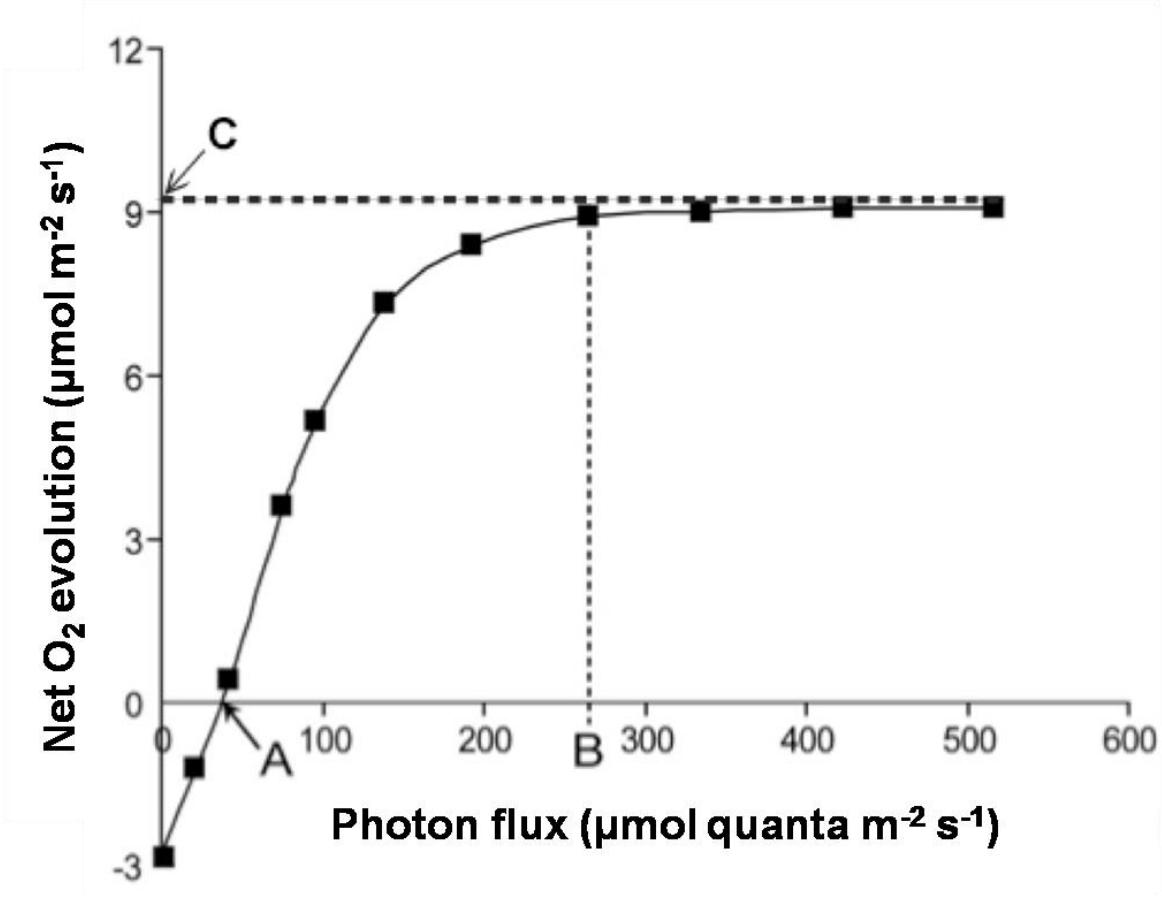
Draw continuous lines and label (with I, II and III) the three different pathways from the outside to H in the figure provided **in the Answer Sheet**. (3 points)

11. Match plant structures (1 – 10) with the corresponding function (A – J). (3 points)

| **Plant cell / Tissue structure** | | **Function(s) / Feature(s)** | |
|---|---|---|---|
| 1 | Thylakoid membranes | A | An intercellular communication network |
| 2 | Vascular cambium | B | Storage of water, digestive enzymes and other inorganic and organic substances |
| 3 | Central vacuole | C | Production of new plant tissues/organs |
| 4 | Plasmodesmata | D | Modified parenchyma cell without nucleus |
| 5 | Apical meristem | E | Small opening in the surface of an ovule, through which the pollen tube penetrates. |
| 6 | Periderm | F | Mechanical support |
| 7 | Sieve tube | G | Presence of electron transport proteins |
| 8 | Trichome | H | Production of secondary vascular tissues |
| 9 | Secondary cell wall | I | Secondary protective tissue |
| 10 | Micropyle | J | Protection and absorption |

12. Study the graph below and determine which of the statements (a to h) are correct.

    Indicate correct answer(s) with a tick (✓) and incorrect ones with a cross (✗). (1.4 points)




a. It is a photosynthetic $O_2$ response curve.

b. Point A is light saturation point.

c. Point B is light compensation point.

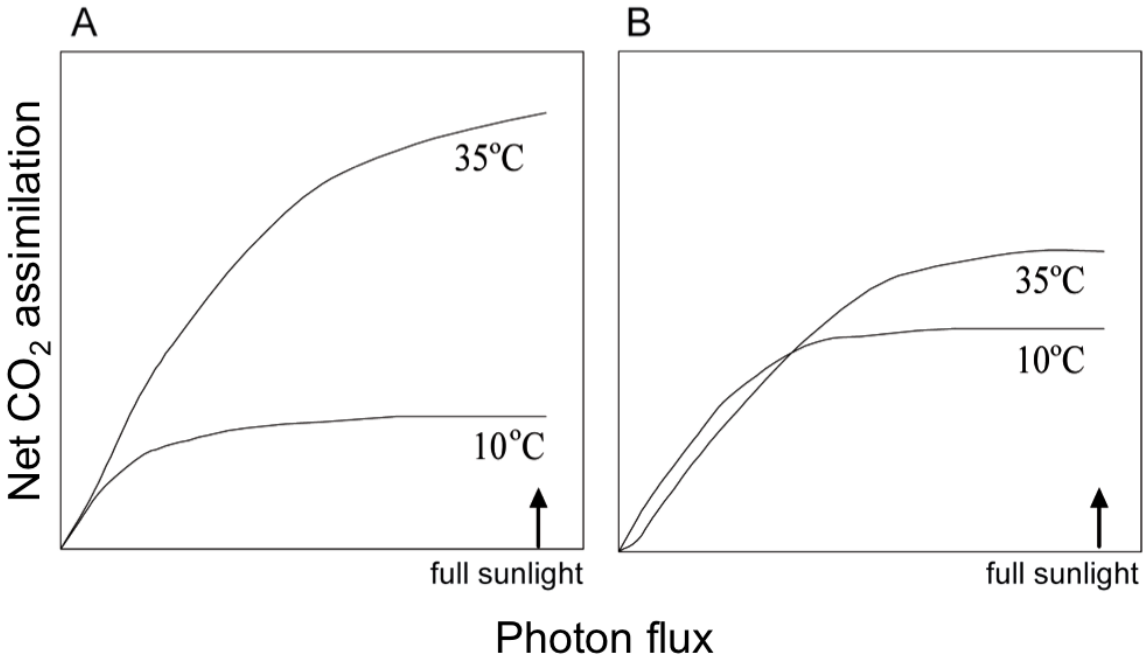
d. C is the maximal photosynthetic rate.

e. Plants stop growth when they grow under the irradiance greater than the value shown at point B.

f. Respiration rate is greater than photosynthetic rate when plants are grown under the light below the value shown at point A.

g. Plants grow (accumulate biomass) when their growth light environments are higher than the photon flux shown at point A.

13. Study the light response curves for leaf photosynthesis of $C_4$ and $C_3$ plants shown below. Indicate correct statement(s) with a tick (✓) and incorrect statement(s) with a cross (×). (1.2 points)




a. Figure A demonstrates the characteristics of $C_4$ plants.

b. $C_3$ plants have a competitive advantage over $C_4$ plants at high temperature and under full sunlight because of a reduction in photorespiration.

c. $C_3$ plants have a competitive advantage over $C_4$ plants at low temperature and under low light because of the higher quantum yield.

14. Some statements about photosynthesis are given below. Indicate true statement(s) with a tick (✓) and false statement(s) with a cross (✗). (1.0 points)

    a. Photophosphorylation involves ATP formation during the light reaction of photosynthesis.

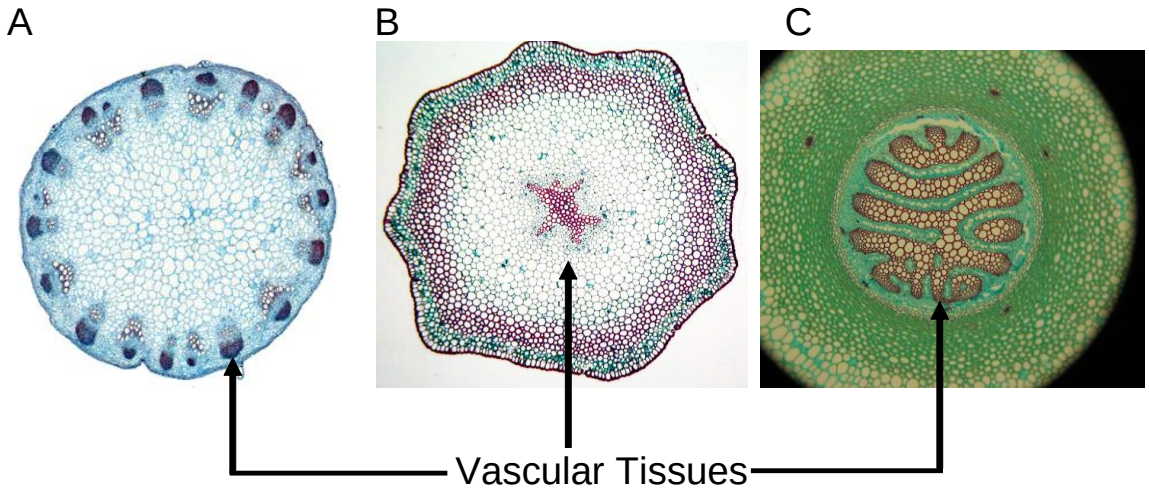
    b. The essential initial role of light in initiating the light reaction of photosynthesis is to produce free oxygen.

    c. In a plant cell, the ATP synthase complexes are only located in the thylakoid membrane.

    d. Photosystem II is required for cyclic photophosphorylation.

    e. It is currently believed that the specific enzymes necessary for the fixation of $CO_2$ into sugar are located in the chloroplast stroma.

15. Arrange the following plants A to C in evolutionary order starting with the most primitive specimen to the most modern. (1.5 points)



16. Match the description or effect (A – J) with their corresponding terms (1 – 10). (1.8 points)

| Term | | Description / effect | |
|---|---|---|---|
| 1 | Ethylene | A | Physiological reaction of organisms to the length of day or night |
| 2 | Photoperiodism | B | Inhibition of the growth of lateral buds |
| 3 | Apical dominance | C | Stem elongation in intact plants |
| 4 | Thigmotropism | D | Prolonged exposure to cold temperatures promotes flowering |
| 5 | Phyllotaxy | E | Leaf and fruit abscission |
| 6 | Cytokinin | F | Bending of growing stems toward light sources |
| 7 | Gibberellin | G | The arrangement of leaves on a stem |
| 8 | Statolith | H | The response of plants to touch |
| 9 | Vernalization | I | Delayed senescence |
| | | J | Gravitropism |

## ANIMAL ANATOMY AND PHYSIOLOGY

17. ~~Referring to the events (I to VIII) below, fill in the correct sequence of events during cardiac excitation-contraction coupling. (1.5 points)~~ **[DELETED]**

~~I. action potential triggers opening of $Ca^{2+}$ channels in the endoplasmic reticulum~~

~~II. release of intracellular $Ca^{2+}$ store~~

~~III. action potential triggers opening of L-type $Ca^{2+}$ channels~~

~~IV. $Ca^{2+}$ influx from the extracellular space~~

~~V. cytosolic $Ca^{2+}$ binds to troponin~~

~~VI. cytosolic $Ca^{2+}$ binds to tropomyosin~~

~~VII. crossbridge forms as myosin heads bind to actin~~

~~VIII. crossbridge forms as actin heads bind to tropomyosin~~

18. Given below are data on the breathing rate, heart rate and body temperature of four different mammals, A to D.

| Animals | Breathing rate (inhalations/min) | Heart rate (beats/min) | Body temperature (°C) |
|---|---|---|---|
| A | 160 | 500 | 36.5 |
| B | 15 | 40 | 37.2 |
| C | 28 | 190 | 38.2 |
| D | 8 | 28 | 35.9 |

18.1. Rank Animals A to D in descending order for surface area per unit volume of the body. (0.8 points)

18.2. Rank Animals A to D in descending order for total volume of blood in the body. (0.8 points)

19. Evaluate the following two statements regarding the respiratory processes of amphibians, reptiles, birds and mammals. Indicate true statement(s) with a tick (✓) and false statement(s) with a cross (✗). (1.6 point)

    I. Negative pressure used to force air into lungs

    II. Lungs are completely ventilated during each breathing cycle

20. Gas exchange in animal taxa involves various respiratory organs (a – d), as well as, the circulatory system (open and closed). For each animal, indicate open circulatory system(s) with a tick (✓) and closed circulatory system(s) with a cross (✗). Match the appropriate organs (a – d) with the animals (adult). (2.6 points)

    a. lungs

    b. gills

    c. skin

    d. trachea

21. Urine production is the result of continuous filtration of plasma through the kidneys. Indicate true statement(s) about the mammalian kidney with a tick (✓) and false statement(s) with a cross (✗). (2 points)

    a. The kidneys have a direct effect on blood pressure.
    b. The kidneys help regulate total blood volume in circulation.
    c. The loops of Henle remove water, ions and nutrients from the blood.
    d. Those able to excrete the most hyperosmotic urine, such as the kangaroo rats living in the desert, have relatively short loops of Henle.
    e. The kidneys partner the lungs in controlling the pH in plasma.
    f. The kidneys help maintain blood pH by excreting hydrogen ions and reabsorbing bicarbonate ions as needed.
    g. The kidneys dispose of volatile acids produced in metabolism.
    h. Ammonia ($NH_3$) is produced in proximal tubule cells during acidosis.
    i. The glomerular filtration rate is affected by blood pressure.
    j. The kidneys produce ADH (antidiuretic hormone).

22. The amount of saliva secreted by a mammal is related to how much chewing is required on feeding. Match the following animals (a – e) to the quantity of saliva secreted as given in the table **in the Answer Sheet**. (0.8 points)

    a. wolf
    b. horse
    c. cattle
    d. human

23. Allergy is a hypersensitive human immune system reaction which is a result of repeated antigen exposure. In comparison, although pseudoallergy is identical to allergy in clinical terms, there is no immunological stage in its development.

    The underlying pathological processes are listed below as observations:

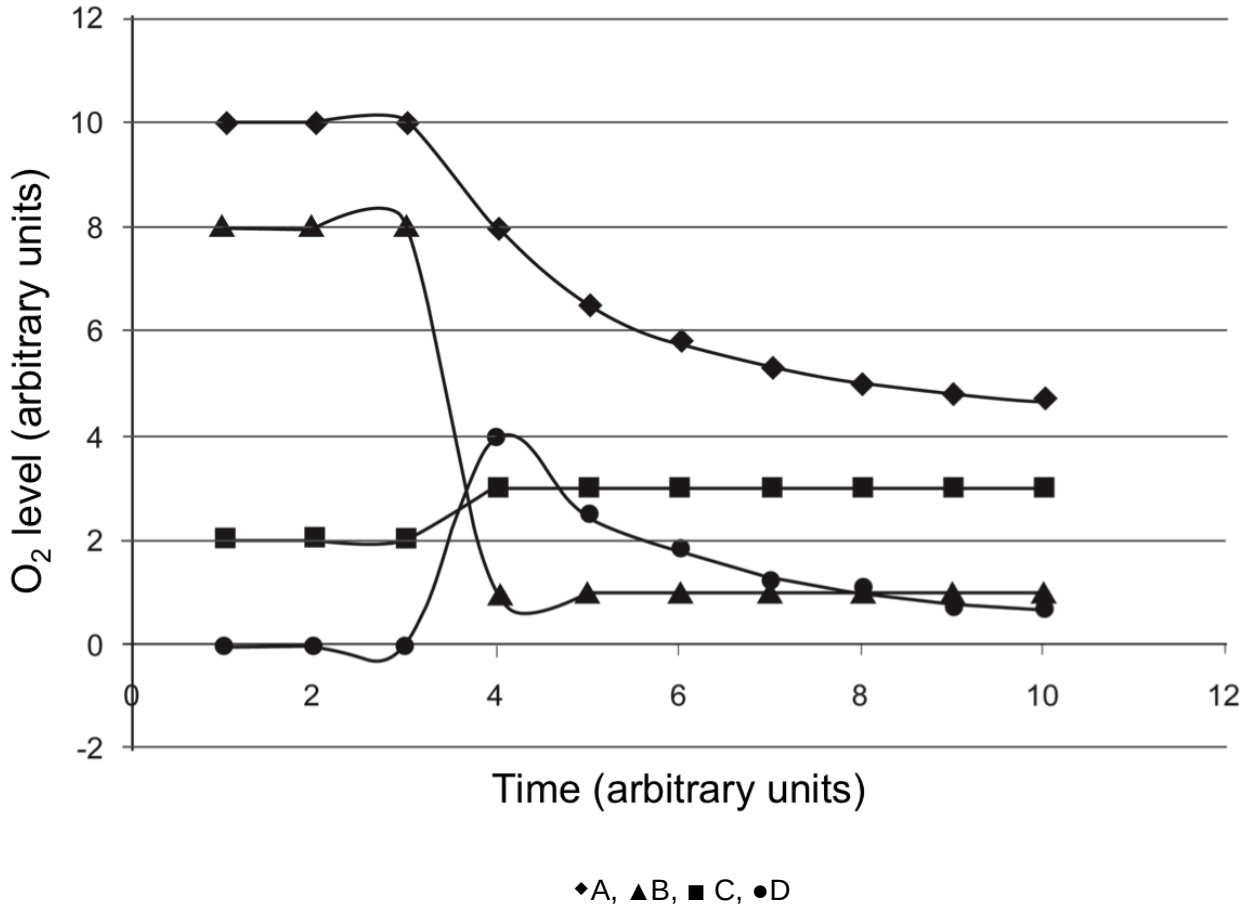
    a. General level of IgE class antibodies in the serum is raised.
    b. Specific IgE class antibodies in the serum is detected.
    c. Histamine – the main mediator of inflammation is released.
    d. A minimal amount of the antigen is needed to demonstrate the reaction.

Indicate for allergy, as well as pseudoallergy, the observation(s) that apply with a tick (✓) and the observation(s) that do not with a cross (×) **in the Answer Sheet**.(0.8 points)

24. The age of animal fossils can be determined by measuring the content of carbon isotope $^{14}C$ in the bones. How is $^{14}C$ accumulated in the bones? Indicate correct statement(s) with a tick (✓) and incorrect statement(s) with a cross (×). (0.6 points)

    a. through consumption and assimilation of organic compounds in the bones
    b. through converting $CO_2$ into organic compounds in the bones
    c. through accumulation of residual $CO_2$ during respiration deposited in the bones

25. European (freshwater) eel usually obtains oxygen by gills but can spend long periods of time out of water using dermal respiration. The graph below shows the level of blood saturation by oxygen and oxygen supply through different organs when the eel was removed from the water (in arbitrary units):




Match the following statements (I to IV) to the corresponding lines (A – D) shown above. (1.2 points)

I. Total blood saturation by oxygen

II. Oxygen supply through gills

III. Oxygen supply through skin

IV. Oxygen supply from air bladder

26. Anatomical characteristics of animals are adapted for their different modes of feeding (a – d).

    a. carnivores

    b. omnivores

    c. non-ruminant herbivores

    d. ruminant herbivores

    26.1. Match the different modes of feeding (a – d) with the corresponding dental features (I – IV). (1.2 points)

    I. no upper incisors, have dental pad, molars allow only lateral movements

    II. canine teeth highly developed and used for tearing

    III. grinding teeth patterns on posterior teeth (molars)

    IV. incisors for nipping, molars slightly angled, jaws move circularly (vertical and lateral)

    26.2. The gastrointestinal (GI) tract surface area to the body surface area ratio differs between herbivores, omnivores and carnivores. Match the different modes of feeding (a – d) with the corresponding GI tract surface/body surface area ratio as listed in the table **in the Answer Sheet**. (1.2 points)

27. Match the adaptations of the digestive systems (a – c) with the corresponding anatomical descriptions. (0.9 points).

    Anatomical descriptions:

    I. simple stomach, limited utilization of foliage-based diets

    II. simple stomach incapable of utilization of foliage-based diets

    III. highly developed sacculated stomach capable of extensive and effective utilization of foliage-based diets

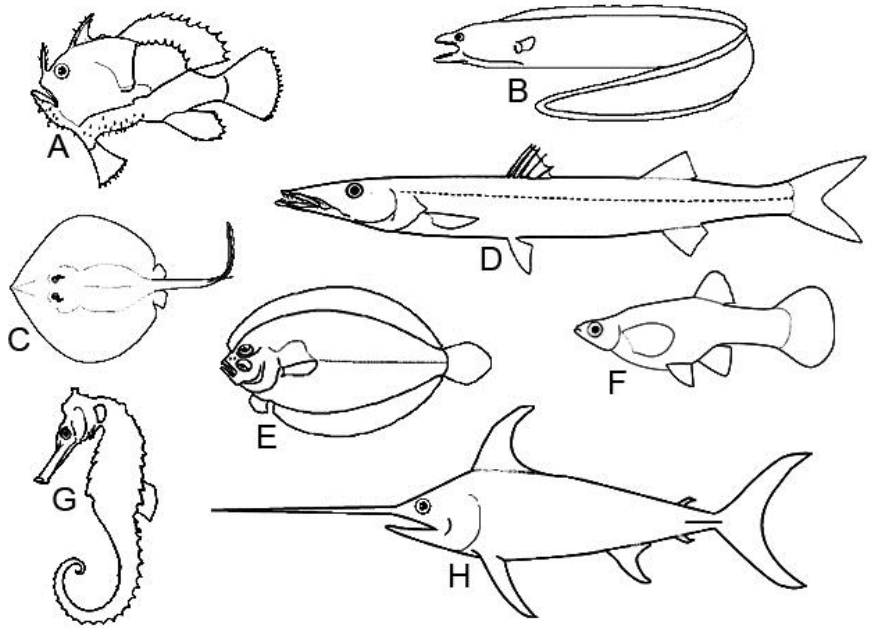
    Digestive adaptations:

    a. extensive fermentation after primary sites of digestion and absorption

    b. extensive fermentation before primary sites of digestion and absorption

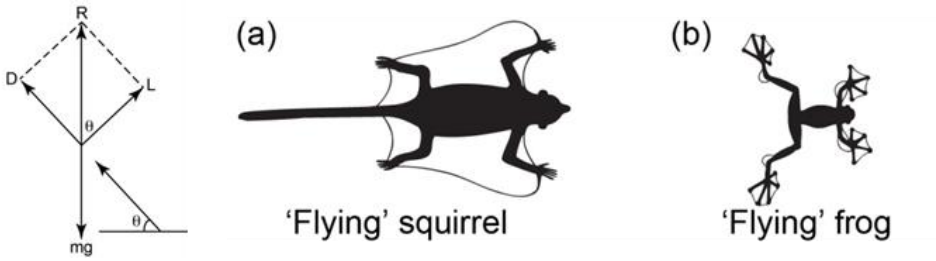
    c. unable to digest some of the substances in grains, fruits and vegetables

28. Fishes are specially adapted for aquatic life in different parts (e.g., surface, middle, bottom) of the water column and various special habitats (e.g., sea grass beds, rock crevices). Their swimming speeds are also partly dependent on their body morphology. Match the fishes (A – H, not drawn to scale) with their respective habitats and indicate the two fastest swimmers and the two slowest swimmers. (2.4 points)



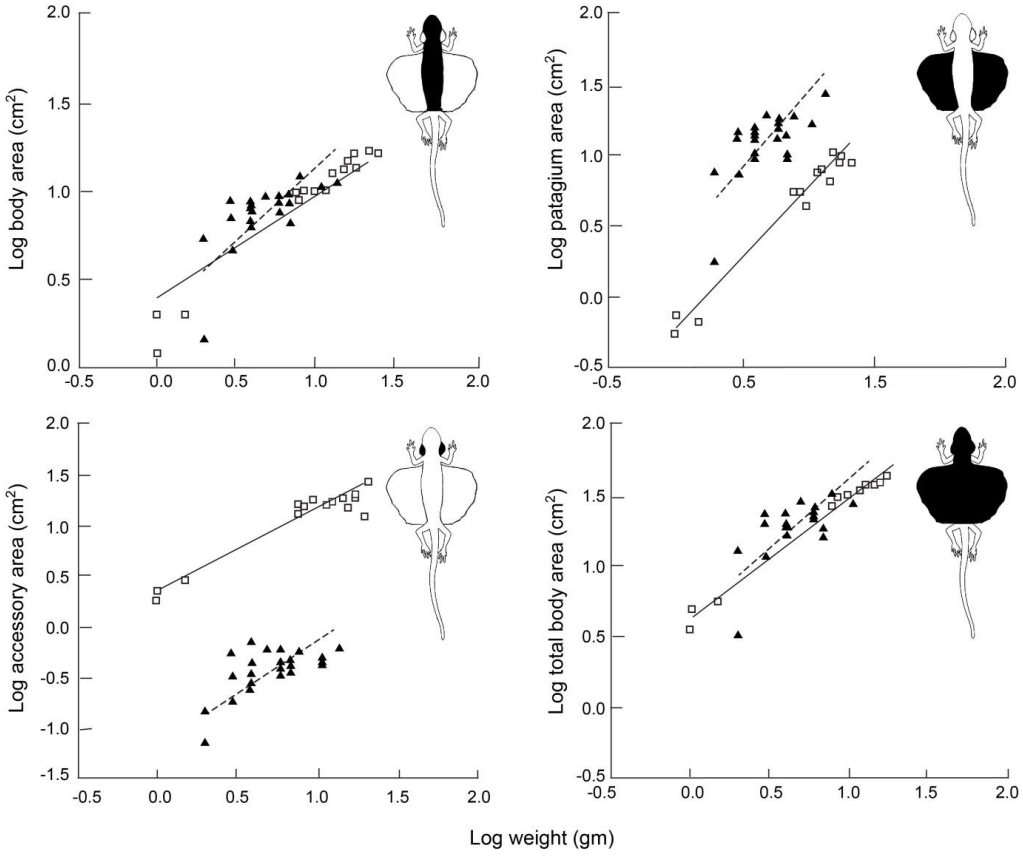
29. In all classes of vertebrates, there are at least a few species that may occasionally take to the air (e.g., 'flying' fish, frog, lizard, and squirrel). They are not capable of true flight but make use of non-flapping locomotion such as gliding and parachuting to slow their descent.

29.1. Animals that glide minimize drag (D) and use lift (L) to produce a more favourable lift-to-drag ratio (L/D ratio). In contrast, animals that parachute maximize D as they often have no significant surface area to produce enough L. When an animal has a steady glide, several forces act upon it (see figure below). Resistance (R) of the outstretched body against the airstream produces L. Drag (D) in the direction opposite to travel is also present, and weight (mg) acts as well. The descending path makes an angle ($\theta$) with the ground.




Match the correct animal, (a or b), with the expected values of L/D and $\theta$ in the table **in the Answer Sheet**. (1 point)

29.2. In 'flying' lizards, the patagium is a fold of skin connecting the forelimbs and hind limbs. Russell and Dijkstra (2001) compared the patagia and accessory aerodynamic surfaces between two species of lizards, *Draco volans* ('flying' dragon) and *Ptychozoon kuhli* ('flying' gecko).




▲------ *Draco volans*; □—— *Ptychozoon kuhli*

Indicate correct conclusion(s) that can be drawn from the study about the morphological adaptations of the lizards for aerial locomotion with a tick (✓), and incorrect conclusion(s) with a cross (✗). (2 points)

a. Although the mean weight of *D. volans* is smaller than that of *P. kuhli*, their body area per unit mass is very similar.

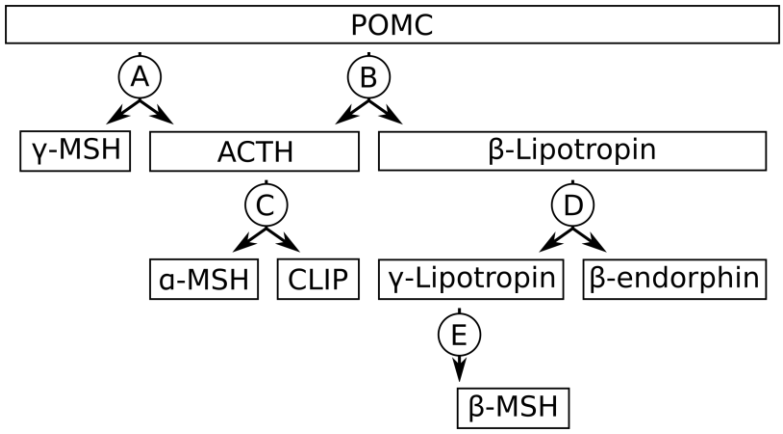
b. Comparison of the patagial area to mass indicates that the patagia of *P. kuhli* are larger than those of *D. volans* of equivalent mass.

c. The accessory structures contribute more significantly to total available aerodynamic area in *D. volans* than they do in *P. kuhli*.

d. The total body area of the two taxa is very similar.

e. The proportional area that is contributed by the patagium is much larger in *D. volans* than in *P. kuhli*, which compensates by the addition of extensive accessory flaps and folds.

30. In the hypophysis, several regulatory peptides are built from the propeptide, Pro-opiomelanocortin (POMC). POMC is cleaved proteolytically (A – E) into various products. Every polypeptide below is represented with N- terminal on the left and C- terminal on the right. Note that each enzyme digests only “matured” precursor peptide.

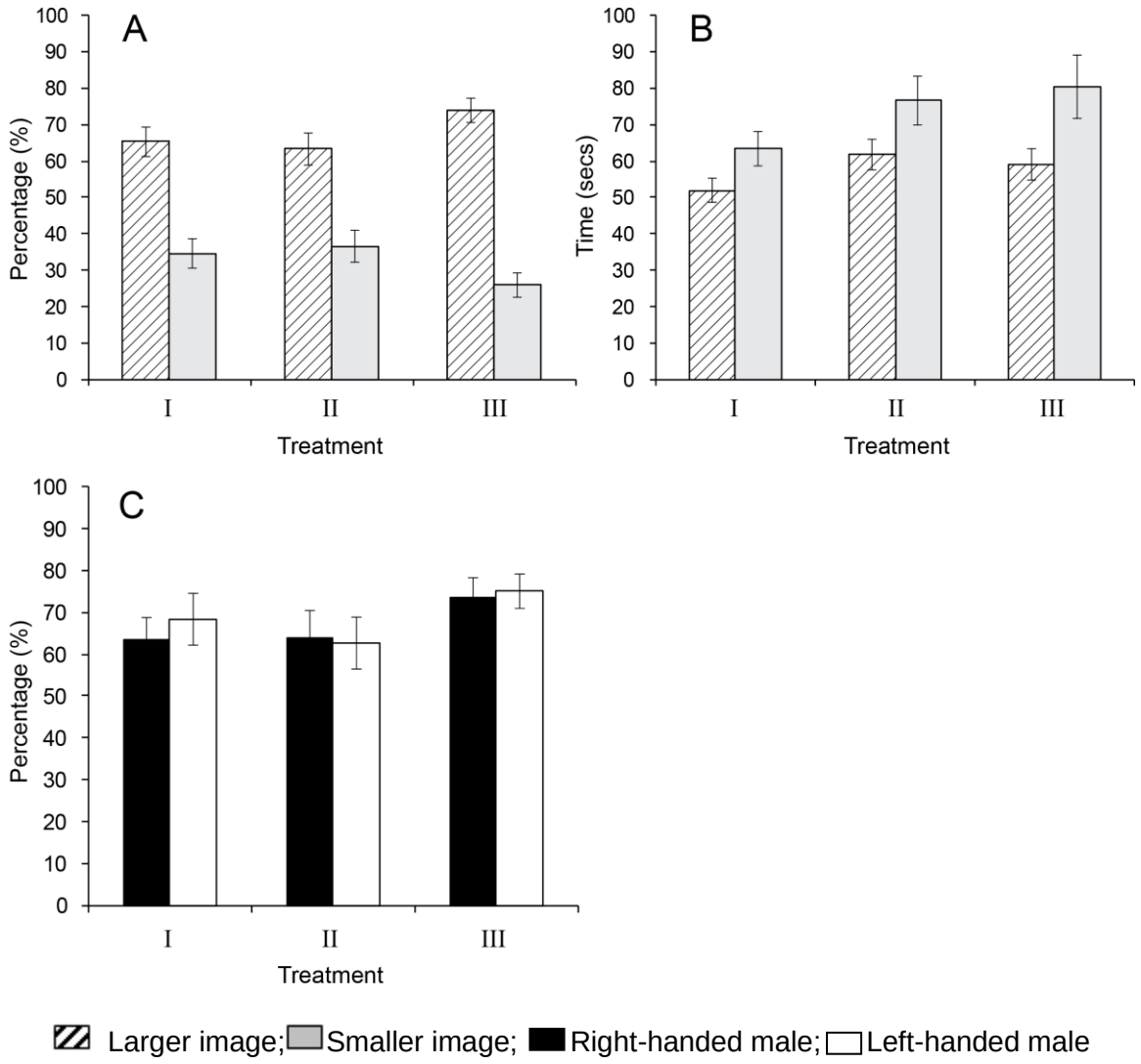



30.1. Write down the minimum number of enzymes needed by a cell to produce β -MSH from POMC. (1 point)

30.2. Write down the minimum number of enzymes needed by a cell to produce α-MSH from POMC. (1 point)

## ETHOLOGY

31. Male fiddler crabs use their enlarged claws chelipeds (major chelipeds) for signalling (e.g., fighting for burrows, waving at females, etc.). A student studied male-female interactions by using mirrors to reflect two different-sized images of the same waving male crab to females. Mirror combinations used in the experiment were: 10x : 3x (Treatment I), 3x : 1x (Treatment II) and 10x : 1x (Treatment III). Ten waving males were presented to 20 females in three trials for each treatment. She recorded the percentage of females (Graph A) and time taken by each female to approach each reflection (Graph B) for each treatment as well as whether the male was right or left-handed (Graph C).



Indicate correct conclusion(s) that can be drawn about the interactions between male and female crabs with a tick (✓), incorrect conclusion(s) with a cross (×) and the statement(s) that cannot be concluded with a dash (–). (1.5 points)

a. Female fiddler crabs generally prefer larger males.

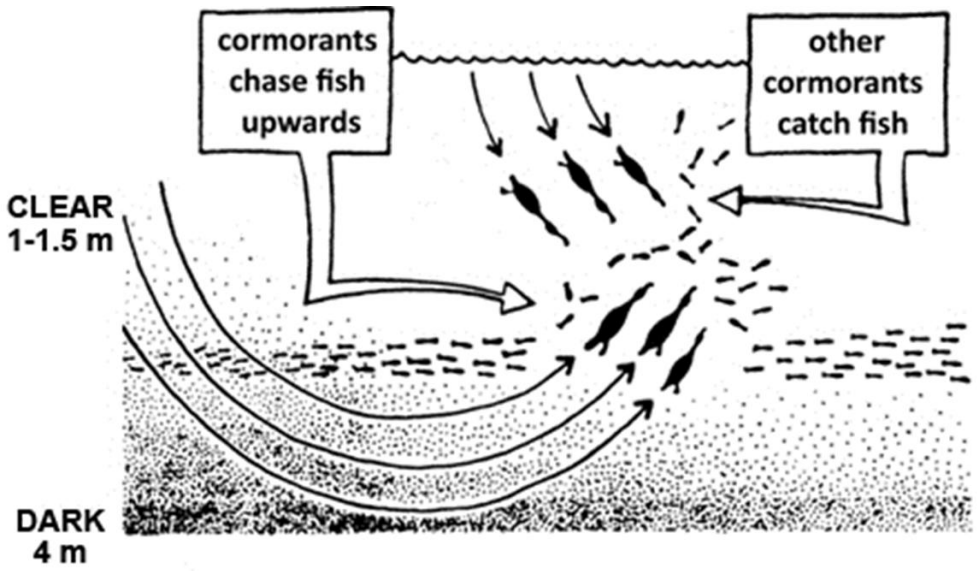
b. In mate-choice selection, male handedness is an important criterion.

c. Males that wave faster generally attracted more females.

d. The mean time taken for females to make a choice differed between Treatments II and III.

e. An obvious difference in cheliped size of males may be necessary before females become more decisive.

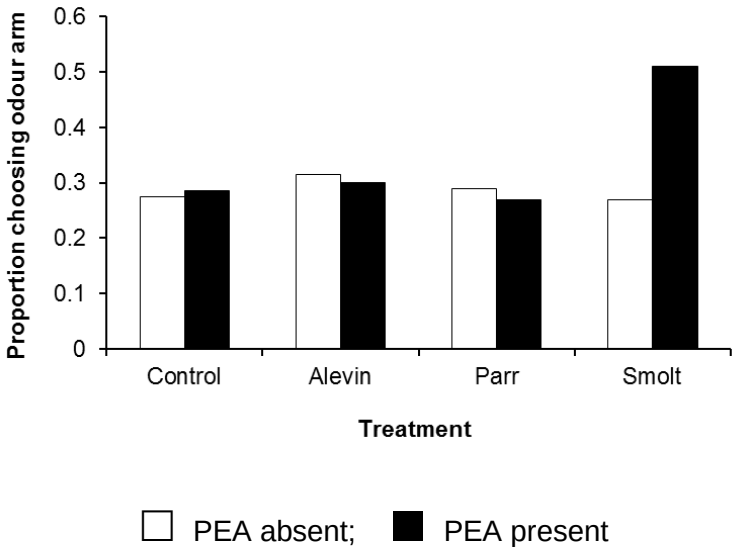
32. Cormorants (*Phalacrocorax carbo)* feed on fish. They dive in the water and chase fish by sight, so water clarity is important. Normally cormorants fish individually, but if the water is murky they may develop a cooperative hunting method in a group. (1.2 points).




Indicate the process(es) that play(s) a role in developing the collaborative hunting strategy of the cormorants with a tick (✓) and use a cross (✗) for inappropriate process(es).

a. competition
b. conditioning
c. habituation
d. social learning
e. imprinting
f. trial and error

33. The figure below from Dittman et al. (1999) shows the behavioural response of mature hatchery-reared Coho salmon, *Oncorhynchus kisutch* to an artificial odorant, β-phenylethyl alcohol (PEA) placed in one arm of a two-arm arena. These salmon were exposed to PEA at different specific developmental stages: alevin (Stage I), parr (Stage II) and smolt (Stage III) in the hatchery before maturity and experimentation. Control fish had never been exposed to PEA.




Indicate correct conclusion(s) with a tick (✓), incorrect conclusion(s) with a cross (×) and the statement(s) that cannot be concluded with a dash (–). (1.2 points)

a. Salmon that had previous exposure to PEA had equal preference for both arms of the arena.
b. Age of salmon is the most important criterion for navigation to natal stream.
c. Chemical cues play a secondary role in salmon homing behaviour.
d. There is a critical period for olfactory imprinting in the Coho salmon.

## GENETICS AND EVOLUTION

34. Bateson and Punnett (1908) studied the flower colour and pollen grain shape in the sweet pea (*Lathyrus odoratus*, which is related to the garden pea, *Pisum sativum*, which Mendel studied). They crossed a true-breeding purple-flowered plant that had long pollen grains with a true-breeding red-flowered plant that had round pollen grains, and tabulated the following results for the $F_2$ progeny:

| Phenotype | Observed |
|---|---|
| Purple flowers, long pollen grains | 296 |
| Purple flowers, round pollen grains | 19 |
| Red flowers, long pollen grains | 27 |
| Red flowers, round pollen grains | 85 |
| Total number of progenies | 427 |

34.1. If the genetic traits are assorted independently, what phenotype ratio would you expect to see? Fill in the expected values for the respective phenotype and test for independent assortment by calculating the $\chi^2$ value. (4 points)

| df | $\chi^2$ |
|---|---|
| 1 | 3.841 |
| 2 | 5.991 |
| 3 | 7.815 |
| 4 | 9.488 |
| 5 | 11.070 |

Table: $\chi^2$ values for $\alpha$ (*p* value) = 0.05

34.2. Indicate the likely explanation with a tick (✓) and inappropriate explanations with a cross (×) for the above observation. (0.8 points)

35. The DNA sequence of the Atlantic salmon (*Salmo salar*) genome, which contains 28 pairs of autosomal chromosomes and a pair of sex chromosomes (XY), has been recently completed. DNA microinjection technique was used to successfully transfer a growth hormone transgene construct into the zygotic stage of salmon fish embryos. Subsequently, 4 transgenic individuals ($F_0$ founders), 2 males and 2 females, were obtained. The growth hormone transgene is under the regulation of a liver-specific enhancer and all 4 transgenic founders have high plasma growth hormone levels leading to accelerated growth. It was confirmed that the transgene is inserted as a single copy within their genomes. Stable lines of transgenic salmon with accelerated growth will be established through crossing. For the establishment of the $F_1$ generation, both the male and female transgenic founders ($F_0$) are outcrossed to the respective gender of wild-type (non-transgenic) salmon

35.1. For the establishment of the $F_2$ generation you have been asked to carry out a sibling-pair cross in order to recover homozygous transgenic individuals carrying the growth hormone transgene. What would be the expected genotype ratio expressed as a %? (1.5 points)

35.2. When you check the ratio of males versus females of the $F_2$ generation you found that there are always more females (70%) than males (30%) regardless of whether the growth hormone transgene is present as null, heterozygous or homozygous within the individuals of the $F_2$ generation. Indicate the appropriate reason(s) with a tick (✓) and the inappropriate one(s) with a cross (✗) from the list below. (0.8 points)

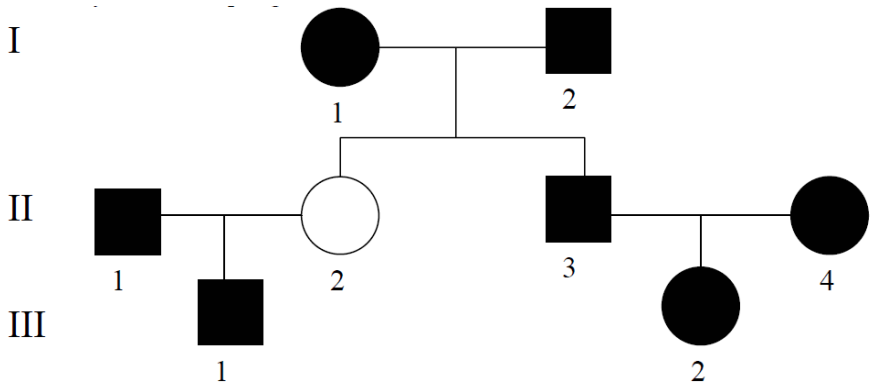
a. Epigenetic silencing in some male individuals has shut down the growth hormone transgene.
b. Integration of the growth hormone transgene is no longer stable.
c. Besides the XY sex chromosomes, environmental factors might have a secondary role in sex determination.
d. The growth hormone transgene has translocated onto the sex chromosomes leading to sex reversal of some males.

36. Chicken with short wings and legs are called “creepers”. When creepers are mated with normal birds they produce creepers and normal chickens with equal frequency. When creepers are mated with creepers they produce two creepers to one normal. Crossing between normal birds produce only normal progeny.

    36.1. What is the simplest genetic basis for creepers and normal chicken? Indicate the correct answer(s) with a tick (✓) and incorrect answer(s) with a cross (×). (0.6 points)

    36.2. Indicate the correct phenotype of chickens carrying two creeper alleles with a tick (✓) and incorrect phenotypes with a cross (×). (0.5 points)

37. The black hair of guinea pigs is produced by a dominant gene B and white by its recessive allele b. Assume that II1 and II4 do not carry the recessive allele.




    37.1. What is the probability of II3 being heterozygous? (1 point)

    37.2. What is the probability that one particular offspring of III1 x III2 will have white hair? (1 point)

38. Some allele combinations can result in a particular mental disorder in humans. The Table shows the enzyme activities of different genotypes (reported as percentage of the normal activity).

| Allele 2 | Allele 1 | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | R231X | P292L | R407W | IVS-12 | E290K | R158Q | R271Q | Y424C |
| R231X | <1 | | | | | | | |
| P292L | <1 | <1 | | | | | | |
| R407W | <1 | <1 | <1 | | | | | |
| IVS-12 | <1 | <1 | <1 | <1 | | | | |
| E290K | | | | ~2 | <3 | | | |
| R158Q | | | | | ~6.5 | 10 | | |
| R271Q | | | | | **X** | ~20 | 30 | |
| Y424C | | | | | | **Y** | 40 | 50 |

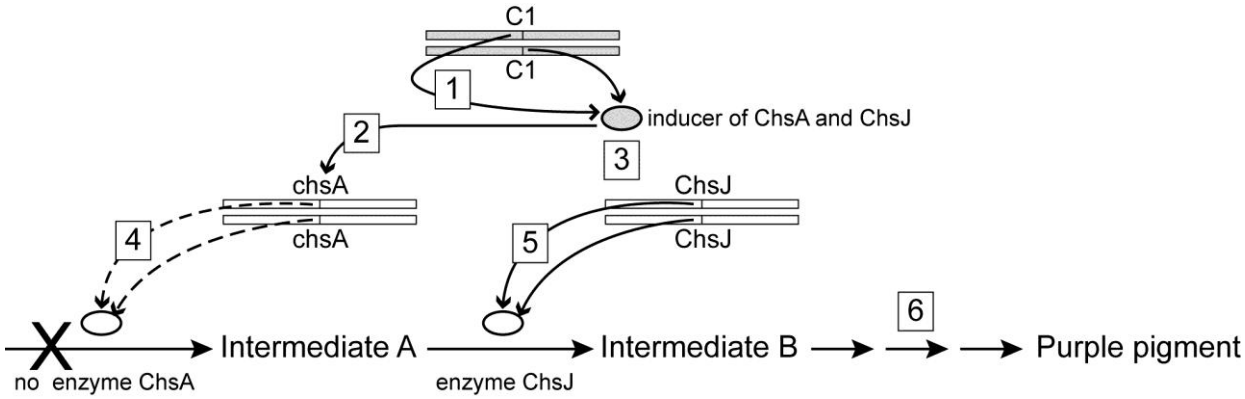
All individuals homozygous or heterozygous for any combination of the first 5 alleles listed above exhibit the classical symptoms of the disease. Individuals heterozygous between Y424C and any of the first four alleles however have mild symptoms. R158Q/R158Q homozygous show classical symptoms of the disease, while R271Q/R271Q homozygous and R271Q/Y424C heterozygous have mild symptoms.

38.1. What is the enzyme activity in individuals for genotype combinations marked by X (R271Q/E290K) and Y (Y424C/ R158Q)? (2 points)

38.2. What is the critical range defining those with classical symptoms from those with mild symptoms? (1 point)

39. In a particular crop plant, several genes govern the production of anthocyanin. In the absence of anthocyanin, the seedling leaves show only green chlorophyll pigmentation. In the presence of anthocyanin, the seedlings have a purple cast on top of the green coloration. A gene locus called *Colourless 1* (*C1*) appears to function as a transacting inducer locus for at least two other loci (*ChsA* and *ChsJ*) that encode two enzymes in the pathway for anthocyanin synthesis (see figure below). The pathway for anthocyanin is blocked in homozygous recessive genotypes as shown for *chsA* in the figure. Assume the following conditions exist: (i) independent assortment applies to all three loci; and (ii) homozygosity for the recessive alleles at any of the three loci causes green seedlings.

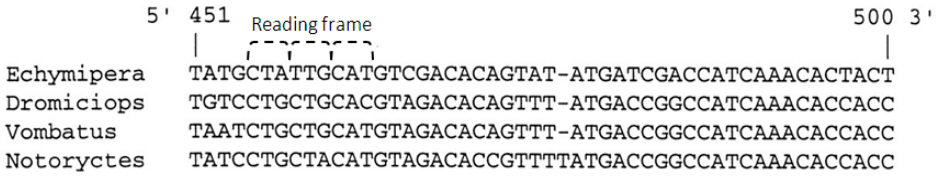
Indicate the expected phenotypic progeny ratios for the two crosses listed in the table **in the Answer Sheet** with a tick (✓) and inappropriate ones with a cross (×). (2.0 points)



40. The marsupial moles (order *Notoryctemorphia*) inhabit the sandy desert regions of South Australia, Western Australia and the Northern territory. They tunnel through the sand, filling in the tunnel behind them and giving the appearance of "swimming" through the sand. The eyes of the marsupial mole are completely covered by skin, measure about 1 mm in diameter and lack a lens or pupil. The optic nerve is greatly reduced. Indicate the correct statement(s) (a – c) with a tick (✓) and incorrect statement(s) with a cross (×). (0.6 points)

    a. The lack of a lens is homologous to the lack of ommatidia in cave flies.
    b. The greatly reduced optic nerve is a vestigial (rudimentary) structure.
    c. The eyes of the marsupial mole are analogous to the eyes of kangaroos.

41. Interphotoreceptor retinoid binding protein (IRBP) is a single-copy gene, the product of which plays a role in the regeneration of rhodopsin in the visual cycle in mammals. This gene was sequenced in several marsupials and the resulting sequences were aligned for comparison. A portion of the sequence of the coding strand of IRBP is shown below. Note that this is not the beginning of the gene and that the correct reading frame has been indicated.




41.1. Starting with the codon involving the frameshift mutation, write down three consecutive amino acids coded for by this gene for *Vombatus* and *Notoryctes.* Use the genetic code table provided in **Question 1**. (1.8 points)

41.2. Indicate true statement(s) with a tick (✓), false statement(s) with a cross (×) and inconclusive statement(s) that cannot be concluded with a dash (-). (0.9 point)

Compared with that of *Vombatus*, the protein product of the IRBP gene in *Notoryctes* will:

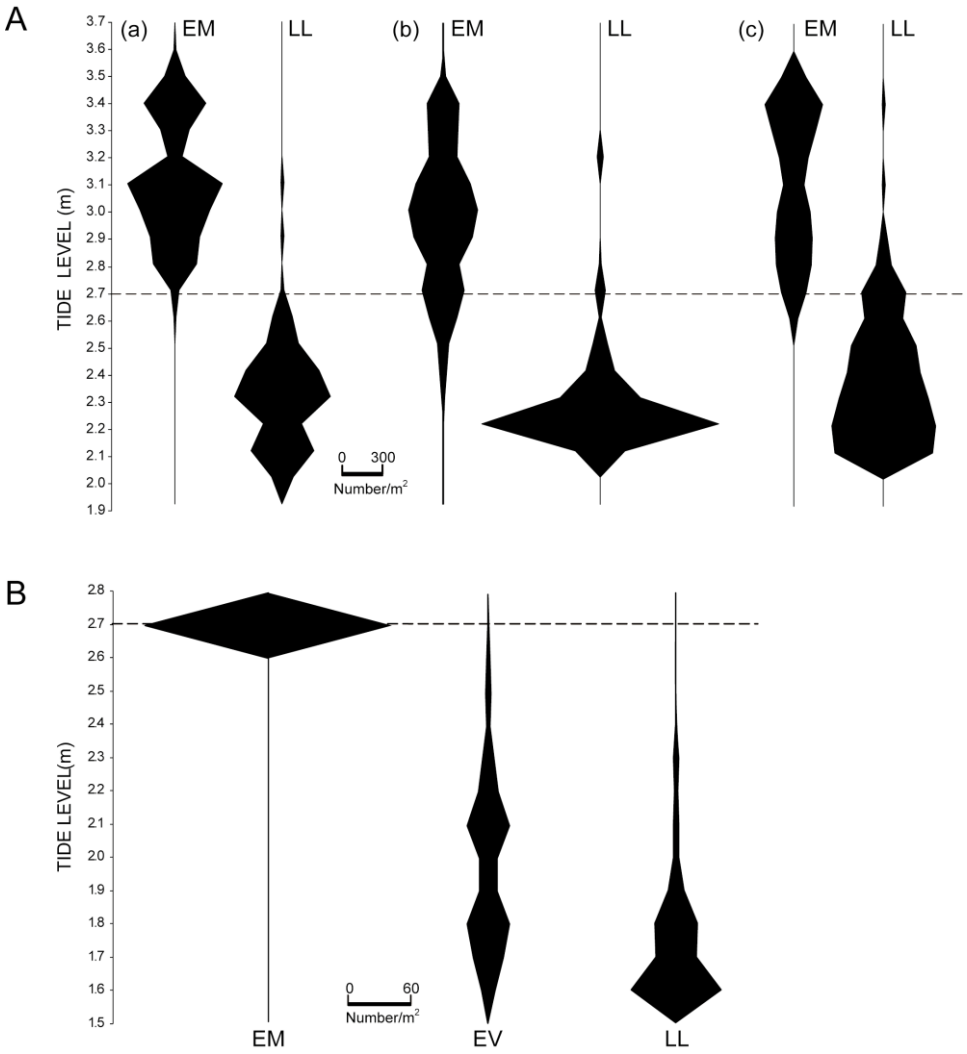
a. contain multiple amino acid substitutions.

b. not begin to be translated as it lacks a START codon.

c. be truncated as it contains a STOP codon at an earlier point.

## ECOLOGY

42. The zonation patterns of littorinid snails on the rocky shores in Singapore were studied at a vertical cliff and a sloping rock. Two taxa of littorinids were found on the vertical cliff (see A) and an additional third species was found on the sloping rock (see B). The snail distribution was recorded in July, September and December 2002 when the mean temperatures of the rock surfaces were 42 °C, 34 °C and 27 °C respectively.




Kite diagram showing the distributions of littorinid species on (A) a vertical cliff: (a) July, (b) September, (c) December 2002; (B) a sloping rock.

EM: *Echinolittorina malaccana*; EV: *E. vidua*; LL: *Littoraria* sp.;- - - ·Mean High Water Spring (MHWS) tide level.

42.1. Indicate correct conclusion(s) about the distribution patterns of the littorinids with a tick (✓), incorrect conclusion(s) with a cross (✗) and inconclusive statement(s) that cannot be concluded with a dash (–). (2 points)

a. Sampling period has no influence on distribution pattern of the two littorinid taxa at the vertical cliff.

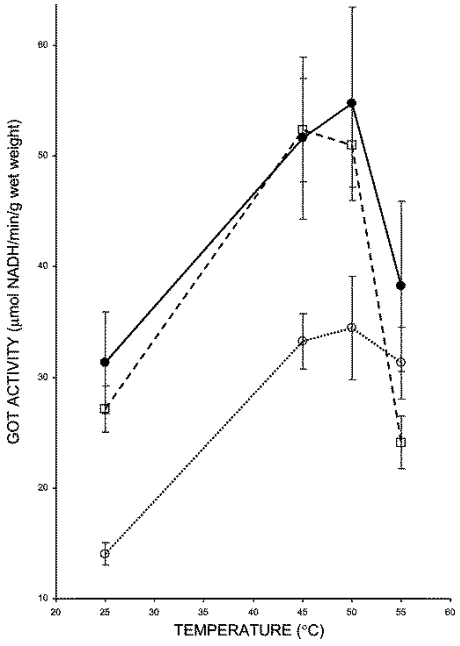
b. *Echinolittorina vidua* and *Littoraria* sp. have similar zones of distribution.

c. The upper limits of the *Echinolittorina malaccana* zone at the vertical cliff were constant regardless of sampling period.

d. The preferred zone of occupation of *Echinolittorina malaccana* is smaller than that of *Littoraria* sp. at the sloping rock.

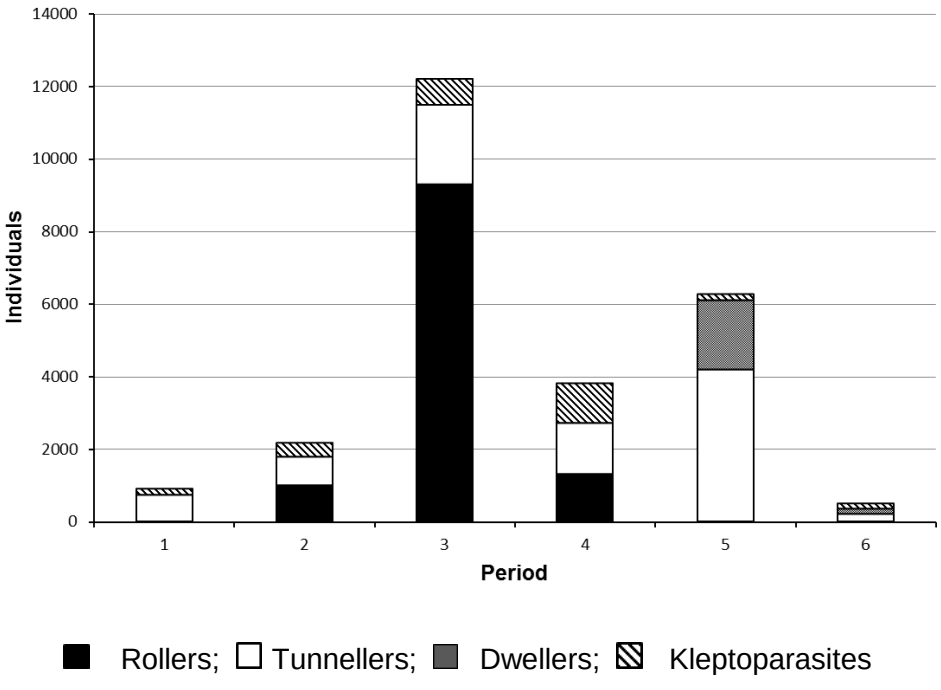
e. *Echinolittorina vidua* is less heat-tolerant than its sympatric species, *E. malaccana*.

42.2. Snails were collected from the field and extracts of six tissue samples of each of the three littorinid taxa were incubated separately at different temperatures. Glutamate oxaloacetate transaminase (GOT) activity was determined and the results of the enzyme assays are presented in the graph below. Indicate the correct taxon (EM, EV or LL) that corresponds to the graph shown in the table **in the Answer Sheet**. (1 point)



43. The ecology of a group of dung beetles was studied in West Africa by Krell-Westerwalbesloh et al. (2004). The beetle community was divided into four categories: (i) rollers, (ii) tunnellers, (iii) dwellers, and (iv) obligatory kleptoparasites. The rollers rapidly form balls from the faeces (in < 1 hour), roll them away from the food source, and deposit them in or on the soil to ensure exclusive use of the dung. The tunnellers make nests directly under the food source and transport dung into the nest where they form dung balls (≈ a few hours). Dwellers feed and reproduce directly in the dung pat. Kleptoparasites use faeces portions monopolised by other groups, e.g., by penetrating dung balls made by the rollers or the dung mass in the subterranean nests of the tunnellers. The abundance (see Table) and flight activity (see Figure) of these beetles (pooled data of 15 samples) at six different periods of the day were recorded.

| Period | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0200-0600 h | | 0600-1000 h | | 1000-1400 h | | 1400-1800 h | | 1800-2200 h | | 2200-0200 h | |
| | N | % | N | % | N | % | N | % | N | % | N | % |
| Dwellers | 51 | 6.46 | 31 | 1.45 | 4 | 0.03 | 78 | 2.09 | 1795 | 27.91 | 172 | 48.45 |
| Obligatory kleptoparasites | 51 | 6.46 | 536 | 25.01 | 1351 | 10.87 | 1230 | 33.00 | 253 | 3.93 | 24 | 6.76 |
| Rollers | 34 | 4.30 | 997 | 46.52 | 8559 | 68.87 | 1243 | 33.35 | 22 | 0.34 | 45 | 12.68 |
| Tunnellers | 654 | 82.78 | 579 | 27.02 | 2514 | 20.23 | 1176 | 31.55 | 4362 | 67.82 | 114 | 32.11 |



Indicate correct conclusion(s) that can be drawn from the study with a tick (✓), incorrect conclusion(s) with a cross (✗) and inconclusive statement(s) that cannot concluded with a dash (–). (1.8 points)

a. There is intense competition in the dung beetle community.

b. Rollers dominate the community of dung beetles.

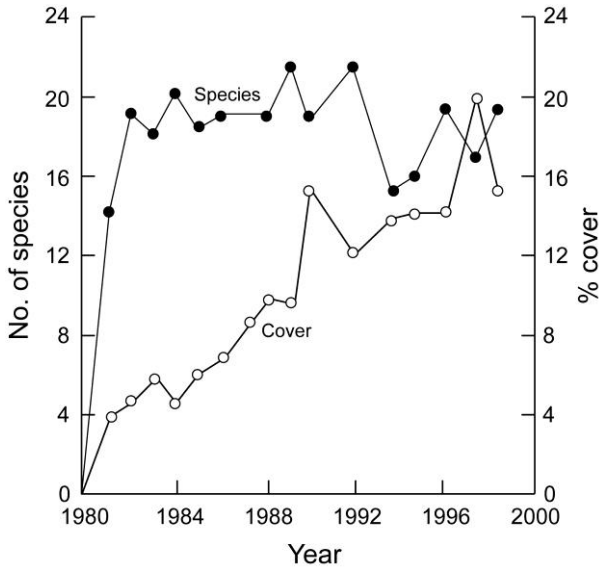
c. The four groups of dung beetles cannot co-exist as they all exploit the same resource in similar ways.

d. One or more of the groups will eventually be out-competed and eliminated in the community.

e. The results of this study support the principle of competitive exclusion and provide evidence for resource partitioning.

f. The ‘realized niche’ of each group is similar to their respective ‘fundamental niche’.

44. Mount St Helens in southwest Washington state (USA) erupted catastrophically on May 18, 1980. The eruption produced a landscape with low nutrient availability, intense drought and frequent surface movements. Permanent plots were established at several sites above the treeline around the crater to monitor recovery after the eruption. The figure below shows the number of species and percentage cover at one of the sites from 1981 to 1998.




Indicate the correct conclusion(s) that can be drawn from the figure above with a tick (✓) and incorrect conclusion(s) with a cross (✗). (1.2 points)

a. The eruption killed all of the vegetation above the treeline.

b. Secondary succession occurred rapidly after the eruption.

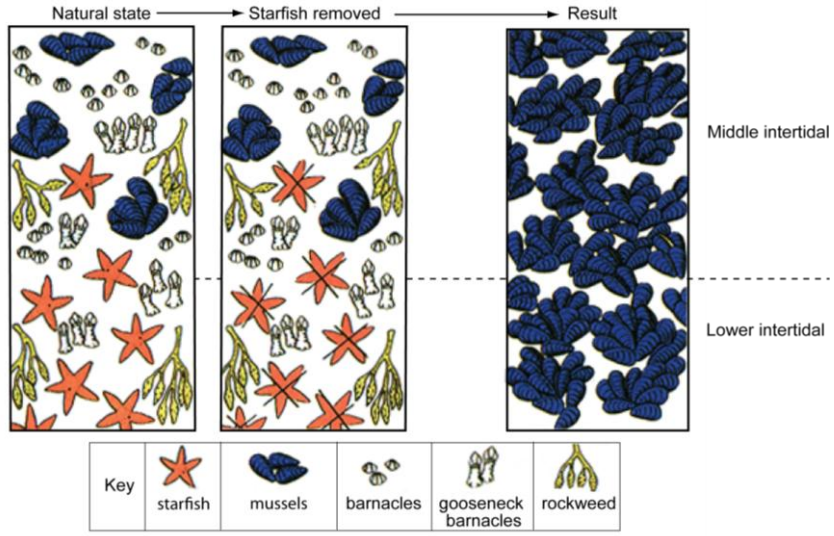
c. Neither space nor light are limiting resources for plants in this environment.

d. Only a few additional species invaded after 1982.

e. Total plant cover in this area has increased relatively slowly due to harsh conditions on the volcanic deposits.

f. A stable plant community of 20 species has been reached at the study site indicating the climax stage in the succession process.

45. The schematic figure below shows a simulation of a marine community done with the objective to study the relationships between its populations.




Starfish – Asteroidea; Mussels – Lamellibranchia; Barnacles – Cirripedia;

Gooseneck barnacles – Cirripedia; Rockweed – Phaeophyta.

Based on the above figure, indicate correct statement(s) with a tick (✓) and incorrect statement(s) with a cross (✗). (1.8 points)

a. The community, in its natural state, includes four species of the Kingdom Animalia.

b. All the animals of this community have three germ layers and are deuterostomates.

c. Phyla of animals represented here are Echinodermata, Mollusca and Arthropoda.

d. In their natural environment, starfish is a keystone species

e. In their natural environment, mussel density is larger in the middle intertidal zone than in the lower intertidal zone because starfish live in the lower intertidal zone.

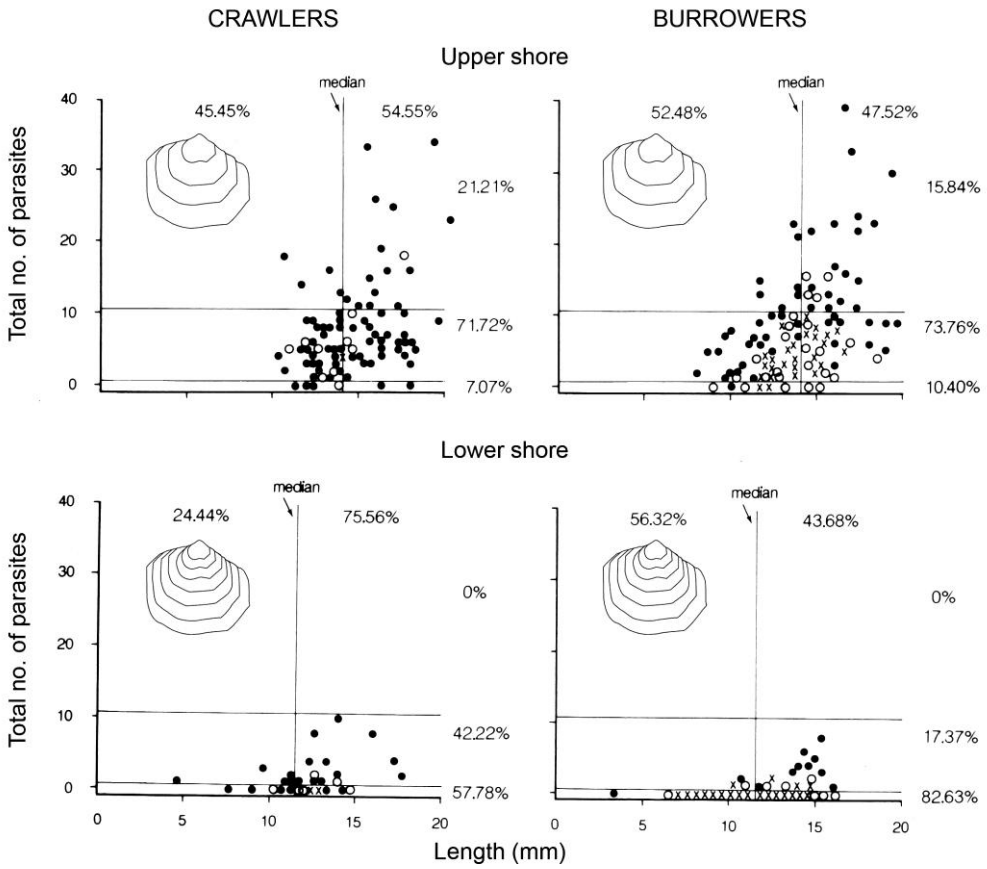
f. At the end of the study, the community collapses and only one population increases its ecological niche.

g. The competitive exclusion of the other populations by the mussels was demonstrated.

h. Mussels occupy the fundamental niche including both the middle intertidal zone and lower intertidal zone.

i. Natural conditions include biotic interactions like inter-specific competition and predation.

46. Growth rate of most intertidal organisms generally declines in an upshore direction. Lim and Green (1991) studied a population of the Baltic clam, *Macoma balthica* (a common bivalve), from two levels of the shore at Hudson Bay, Canada. Annual shell growth rings are distinct in the two sub-populations (see figure below) and the clams from the two zones do not differ genetically. The Baltic clam normally buries itself and is generally hidden from predators. It is the intermediate host to trematodes; the daughter sporocysts of the parasites are found mainly in the gonads of the clam, causing partial or total disappearance of the gonads. Shorebirds, the definitive host of these trematodes, are present in large numbers at the upper shore during ebb tide. The clams in Hudson Bay have been observed to make conspicuous tracks on the sand flats at ebb tide. The number of metacercariae (the next stage in the parasite's life cycle) encysted on the inner shell surface of crawling and burrowing clams from the two shore regions were counted.




Symbols represent number of clams: ○, 1; ●, 2; x, ≥ 3. The vertical line divides clams that were smaller and larger than their median length at their respective tidal level.

Indicate valid conclusion(s) about the behaviour and biology of the Baltic clam with a tick (✓) and invalid conclusion(s) with a cross (✗). (2.8 points)

a. The growth rate of *Macoma balthica* in Hudson Bay conforms to the general rule observed for most intertidal organisms that lower intertidal organisms grow faster than those at the upper shore.
b. A relatively higher proportion of clams was parasitized higher up the shore.
c. Crawling behaviour of the clams could enhance the completion of the parasite's life cycle.
d. Clams that are buried in the sand generally have more metacercaria cysts regardless of shore level.
e. Increased exposure of the clams at the upper shore to shorebirds, the final host of the trematodes, could probably account for the difference in parasite load between the two sub-populations.
f. High parasite load promotes increased somatic growth as reproductive output is reduced due to host castration by the trematodes.
g. Environmental factors probably played a greater role in determining clam growth rate of the sub-populations than heredity.

## BIOSYSTEMATICS

47. Match the following characteristic features with the correct organisms. (1.2 points)

Features:

I. book lung, claws formerly made of three parts, but now reduced to only two, gizzard

II. reduced ribs, undergoes a metamorphosis during ontogenesis

III. hind extremities covered with scales, respiration organ using ventillating air bags, movable upper jaw (maxilla) and lower jaw (mandibula)

IV. thin, tube-like excretion organs ending between mid- and hind-gut, body made of three parts (tagmata), a pair of antennae

V. specialized epithelic muscle cells, nettle cells, radial symmetric body

VI. uses ampullae of Lorenzini to sense electric fields and temperature differences, cartilage skeleton, spiraculum

Organisms:

a. white shark (*Carcharodon carcharias*)

b. house fly (*Musca domestica*)

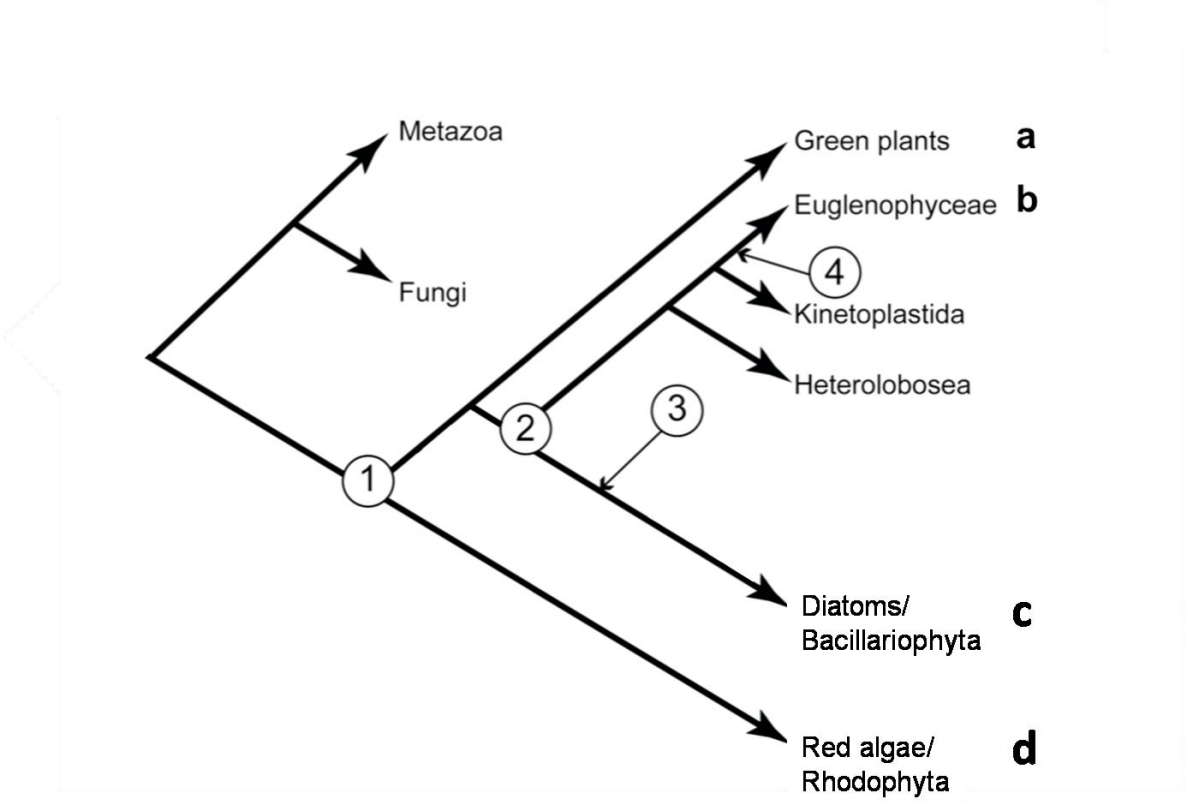
c. bird, common redstart (*Phoenicurus phoenicurus*)

d. brain corals (Faviidae)

e. european garden spider (*Araneus diadematus*)

f. common frog (*Rana temporaria*)

48. One of the known hypothesis of the origin and evolution of plastids is shown in the Figure below.




The processes that facilitated evolution are represented by the numbers (1 to 4) in the diagram above: (1) for primary endosymbiosis, (2) for loss of primary plastids, (3) and (4) for secondary endosymbiosis. These processes resulted in the presence or absence of certain plastids in various taxa.

Match the taxa (a – d) with the corresponding type of plastids **in the Answer Sheet**. (1.2 points)

49. Cladistic systematic researchers apply comparisons among groups in order to differentiate derivative characters and shared primitive characters. In doing this, they use an external group, closely related with the one they are studying.

Condition: The external group is less related to any member of the studied group than the members of the last one are between themselves.

Supposition: The primitive characters that precede the divergence of both groups are homologies.

Taking into account these theoretical concepts, some researchers studied a group and the information they obtained is presented in the following table.

| | Animals represented by double digit codes | | | | | |
|---|---|---|---|---|---|---|
| Characters | A1 | A2 | A3 | A4 | A5 | A6 |
| a. Hair | 0 | 0 | 0 | 0 | 1 | 0 |
| b. Amniotic egg with extra embryonic membranes | 0 | 1 | 0 | 0 | 1 | 0 |
| c. Four legs for locomotion | 0 | 1 | 0 | 0 | 1 | 1 |
| d. Jointed jaws | 0 | 1 | 1 | 0 | 1 | 1 |
| e. Vertebral spine | 0 | 1 | 1 | 1 | 1 | 1 |
| f. Notocord | 1 | 1 | 1 | 1 | 1 | 1 |

Note: 0: absence of character; 1: presence of character

49.1. After analyzing the information above, identify the external group. (0.2 points)

49.2. Identify the characters (a – f) that are shared between the external and internal groups. (0.2 points)

49.3. Identify the primitive character present in all members of the internal group alone. (0.2 points)

49.4. Identify the last point of divergence of the cladogram given **in the Answer Sheet** using the most appropriate character. (0.2 points)

49.5. Fill in the cladogram which best represents the relationships between A1 to A6 using the information analyzed **in the Answer Sheet**. (1.8 points)

**END OF PAPER**