INTERNATIONAL BIOLOGY OLYMPIAD e. V. IBO

27th International Biology Olympiad

July 17-23, 2016
Hanoi, Vietnam

Theoretical Test

PART B

Total points: 50
Duration: 3 hours

DEAR PARTICIPANTS,

Please write your **student code** in the given box.
Write down your answers using a pen in the **Answer Sheet**. Only answers given in the **Answer Sheet will be evaluated**.

Part B consists of 50 questions:

- Q51-Q60: Cell Biology
- Q61-Q68: Plant Anatomy and Physiology
- Q69-Q80: Animal Anatomy and Physiology
- Q81-Q83: Ethology
- Q84-Q93: Genetics and Evolution
- Q94-Q98: Ecology
- Q99-Q100: Biosystematics

For each True/False multiple choice question, indicate in the **Answer Sheet** if each of the four statements is True or False. **Mark "√" for True and False statements** in the **Answer Sheet**. If you need to change an answer, you should strikethrough the wrong answer and write in the new one.

Scoring for one question:

- If all four answers are correct, you will receive 1 point.
- If only three answers are correct, you will receive 0.6 point.
- If only two answers are correct, you will receive 0.2 point.
- If only one answer is correct, you will not receive any points (0).

You can use the ruler and the calculator provided.
Stop answering and put down your pen immediately when the bell rings at the end of the exam. Enclose the **Answer Sheet** and **Question Paper** in the provided envelope.

Good luck!!!

CELL BIOLOGY

Q.51

A scientist prepared 3 essential components for high-throughput screens of protein kinase inhibitors. First, individual protein kinase genes are fused to the major capsid (head) gene of T7 phage. When expressed in bacteria, the fusion proteins are assembled into the phage capsid, with the kinases displayed on the outer surface. Second, an analog of ATP, which can bind to the ATP-binding pocket of the kinases, is attached to magnetic beads. Third, a bank of test compounds is prepared.

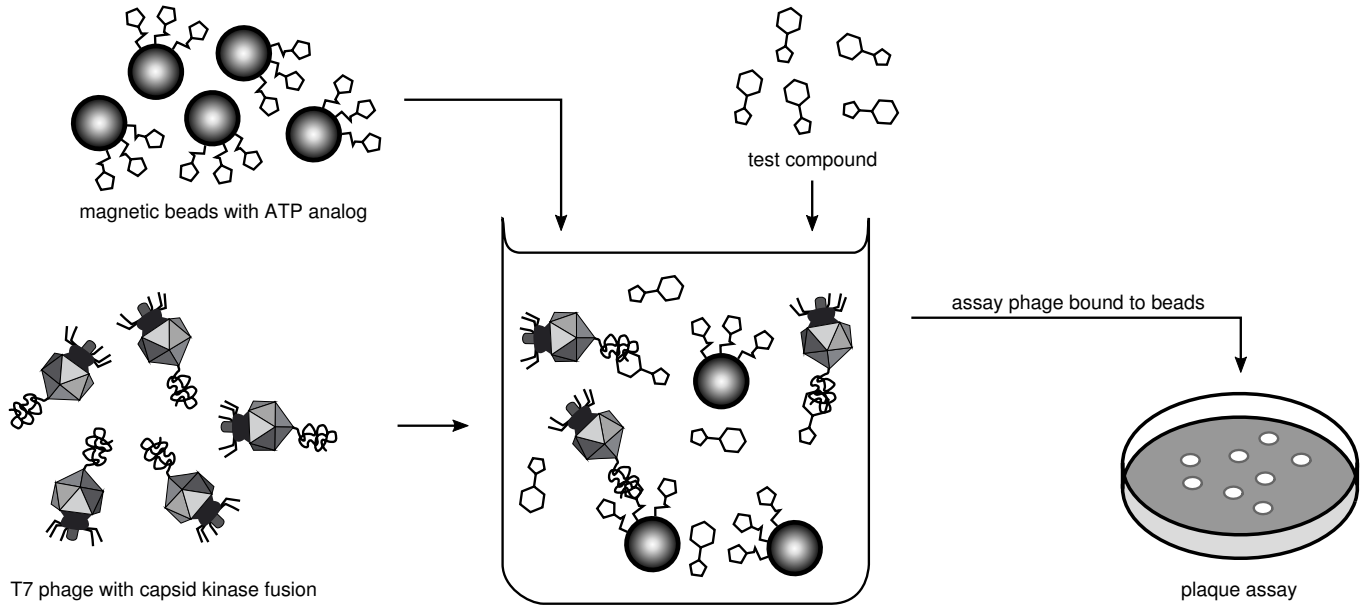


Figure Q.51 Screening potential inhibitors of protein kinases

To measure the ability of a test compound to bind a kinase, phage displaying a specific kinase is mixed with the magnetic beads in several wells of a 96-well plate. Then the test compound is added to individual wells over a range of different concentrations. The mixtures are incubated with gentle shaking for 1 hour at 25°C, the beads are pulled to the bottom with a strong magnet, and all the free (unbound) components are washed away. Finally, the remaining, attached phage are dissociated from the beads using an excess of the same ATP analog that is attached to the beads, and counted by measuring the number of plaques they form on a bacterial lawn on a Petri dish (**Fig.Q.51**).

Indicate in the **Answer Sheet** if each of the following statements is True or False.

A. When the binding process reaches equilibrium, all potential inhibitor molecules will be bound to the kinase.

B. Test compounds that show high inhibition in this assay must bind the ATP-binding cleft of the kinase.

C. Small differences in evolutionary conserved ATP binding sites on kinases allow targeting specific kinases.

D. A strongly binding test compound will yield a low count in the plaque assay.

Q.52

You identified a gene in fission yeast, homologous to a telomerase subunit from a protozoan. You then make a targeted deletion of one copy of the gene in a diploid strain of the yeast and then induce sporulation to produce haploid organisms. All four spores germinate perfectly, and you are able to grow colonies on nutrient agar plates. Every 3 days, you re-streak colonies onto fresh plates. After four such serial transfers, the descendants of two of the original four spores grow poorly, if at all. You take cells from the 3-, 6-, and 9-day master plates, prepare DNA from them, and cleave the samples at a chromosomal site about 35 nucleotides away from the start of the telomere repeats. You separate the fragments by gel electrophoresis, and hybridize them to a radioactive telomere-specific probe (dark bands) (**Fig.Q.52**). Assume that generation time is 6 hours.

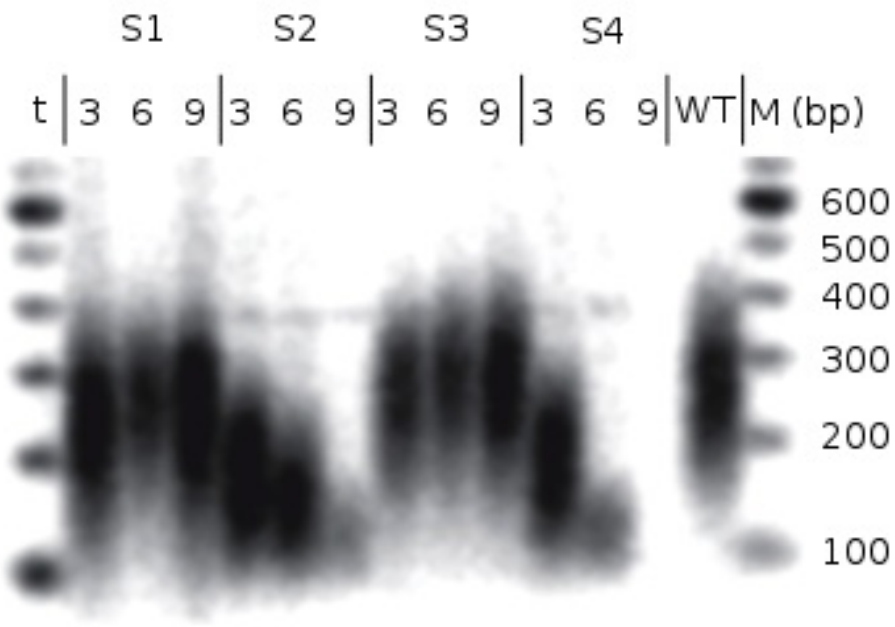


Figure Q.52 Analysis of telomeres from descendants of four fission-yeast spores (S1-S4) at different days (t). WT is the normal diploid yeast

Indicate in the **Answer Sheet** if each of the following statements is True or False

A. The average length of telomeres in fission yeast is 300 nucleotides.

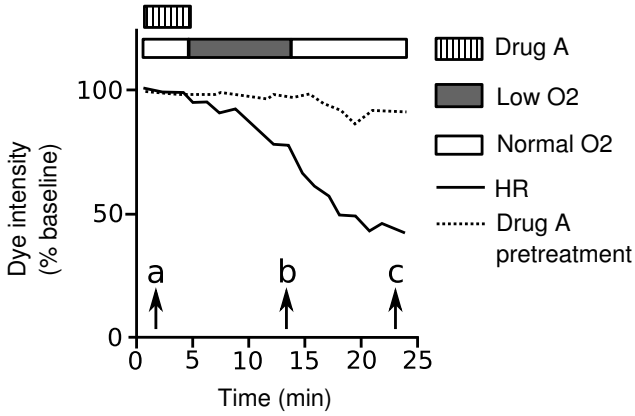
B. Spores 2 and 4 appear to lack telomerase.

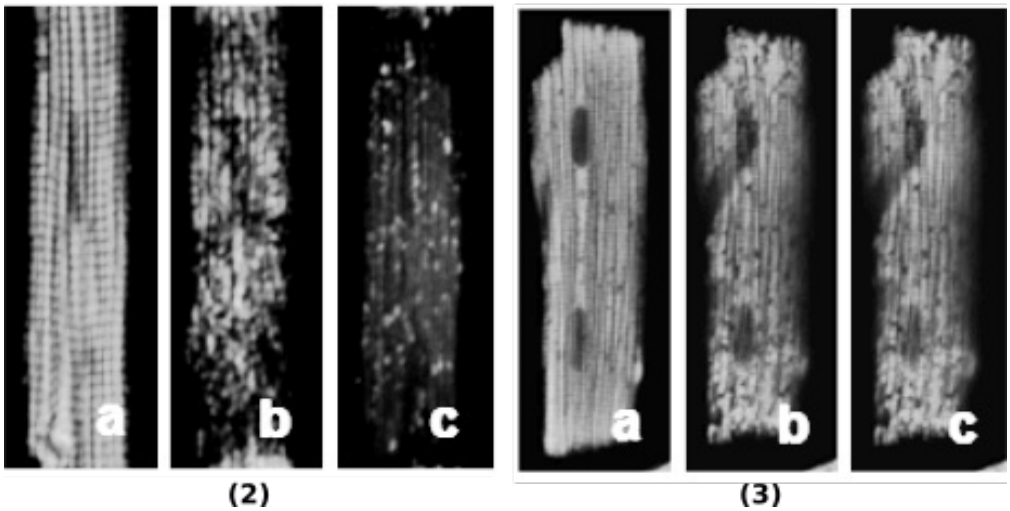
C. Fission yeast telomeres lose less than 20 nucleotides per replication.

D. The fission yeasts that lose their telomeres will have normal cell size.

Q.53

Reoxygenation after a period of lack of oxygen causes cardiomyocyte damage. One of the most important indices evaluating myocardial functions is mitochondrial membrane potential, which is labelled by a cell permeant dye (positively-charged, grey color in the figure below and red color in the attached figure) readily accumulating in active mitochondria due to their relative negative charge.
The figure below illustrates hypoxia/reoxygenation (HR)-treated single myocyte model (1) with or without pre-hypoxic treatment of drug A. Myocyte images were captured at time points (a, b, c).





Indicate in the **Answer Sheet** if each of the following statements is True or False.

A. As seen in **Fig.Q.53.(2)a**, cardiomyocytes are a type of striated muscle cells.

B. Hypoxia leads to a drop in pH in the matrix.

C. Drug A pretreatment is good for cell because it prevents the collapse of mitochondrial membrane potential in HR.

D. Captured images in drug A pretreatment group are presented in (2) and captured images in HR treatment without pretreatment of drug A are presented in (3).

Q.54

Antifreeze glycoproteins (AFGPs) possess the ability to inhibit the formation of ice and are therefore essential to the survival of many marine teleost fishes that routinely encounter sub-zero temperatures. A typical AFGP consists of repeating tripeptide units, the alanyl-threonyl-alanyl (Ala-Thr-Ala)$_n$ unit connected to a disaccharide through a glycosidic bond at the second hydroxyl group of the threonine residue. To identify chemical groups which affect antifreeze activities of this glycoprotein, scientists synthesized numerous AFGP analogues by modifying both the structure of the sugar moieties and the peptide by replacing three groups R_1, R_2, R_3 as shown in **Fig.Q.54** with different chemical groups and recorded the antifreeze activity.

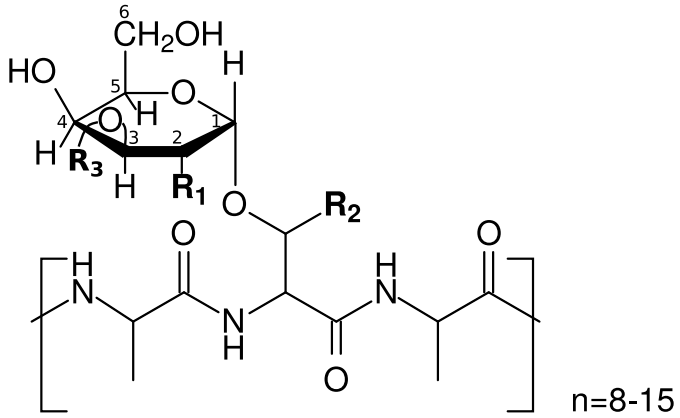


Figure Q.54 The structure of a typical AFGP

The results of the study are shown in the following table.

R_1	R_2	R_3	Antifreeze activity
HO	CH_3	Galactosyl	No
N-Acetyl	CH_3	Galactosyl	Yes
N-Acetyl	H	Galactosyl	No
N-Acetyl	CH_3	H	Yes
O-Acetyl	CH_3	H	No
N-Acetyl	CH_3	Galactosyl-Galactosyl	No

Indicate in the **Answer Sheet** if each of the following statements is True or False.

A. A disaccharide bound to the threonine residue is required for antifreeze activity.

B. A mutant that has threonine residues replaced with serine residues reduces antifeeze activities.

C. *N*-acetyl group at the C-2 position is required for antifreeze activity.

D. Different numbers of repetitive motifs in AFGP genes amongst closely related species might have been caused by DNA polymerase inaccuracy.

Q.55

F1 subunit (a peripheral membrane protein) of the ATP synthase catalyses ATP synthesis using proton motive force responsible for the rotation of F_0 subunit (integral membrane protein complex) in one direction. F_1 is composed of three alpha and three beta subunits arranged in alternating manner around a central shaft, the gamma subunit.
To study the rotation, Masasuke Yoshida and his team attached a fluorescently labelled actin filament to gamma and watched its movement.

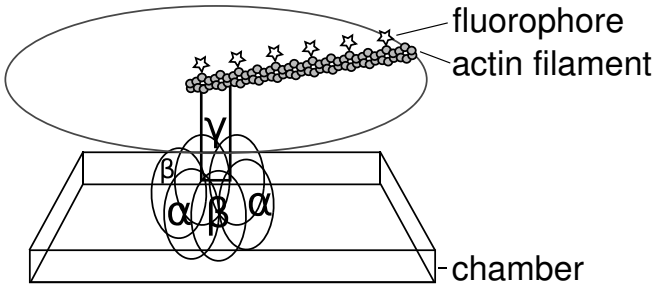


Figure Q.55A Attachment of labelled actin filament to ATP synthase.

Rotating actin filaments were observed by an inverted fluorescence microscope after addition of 2 mM ATP into a chamber containing actin-tagged F_1 complex immobilized on the bottom side as a mirror image formed on a camera. The time interval between images was 220 ms. A series of 12 images were taken and is shown in **Fig. Q.55.**

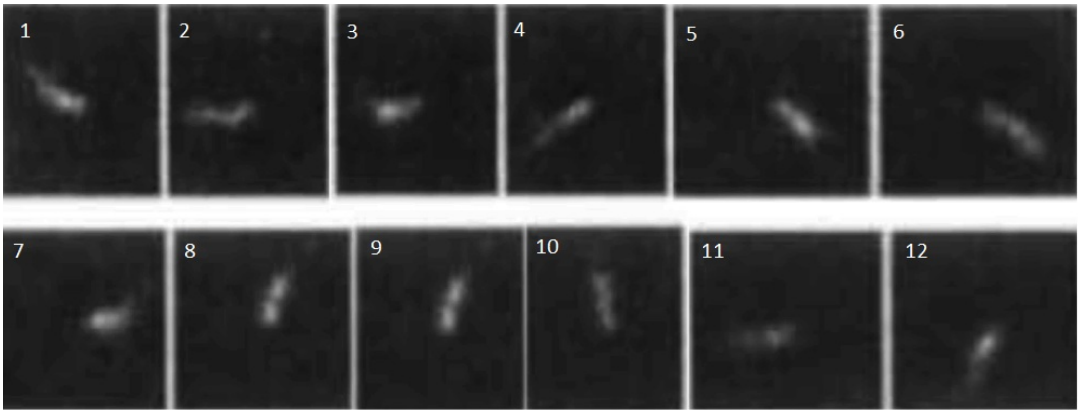


Figure Q.55B Sequential images of a rotating actin filament attached to the subunit in the F1 complex. The numbers indicate the shot images.

Indicate in the **Answer Sheet** if each of the following statements is True or False.

A. Hydrolysis of ATP by F_1 leads to the conformational change of a and b subunits.

B. From the set of figures, the filament rotated anticlockwise (looking from the cytosolic side).

C. Rotary rate is below 0.3 rounds per second.

D. Rotating the actin filament in the opposite direction is coupled with ATP synthesis.

Q.56

Lactic fermented vegetables are traditional food in many Asian cuisines. Microorganisms commonly found in the fermentation broth are lactic acid bacteria, yeast and filamentous fungi.

Fig.Q.56 below shows the flowchart of viable cell counts (log CFU/mL) of three different microbial groups and the pH value during the lactic fermentation course of cabbage. Oxygen dissolved in fermentation broth decreased with time and was completely consumed after the 22nd day.

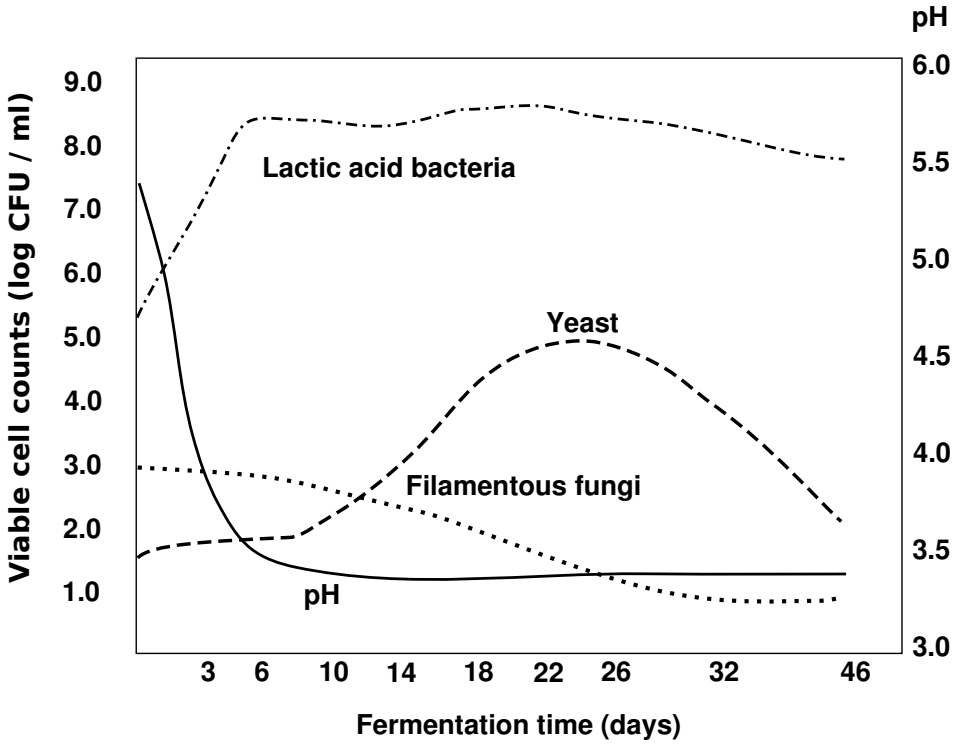


Figure Q.56 Changes in microflora during lactic acid fermentation of cabbage.

Indicate in the **Answer Sheet** if each of the following statements is True or False.

A. The drop in pH value from day 1 to day 3 was caused by only organic acids produced exclusively by lactic acid bacteria.

B. Lactic acid produced by lactic acid bacteria favours the growth of yeast cells from day 10 till day 26.

C. Yeast cells shifted from fermentation to aerobic respiration after day 22.

D. Some filamentous fungi showed tolerance to low pH.

Q.57

Microorganisms that live at high salt concentration (above 2M of NaCl) are exposed to media with low water activity, and must have mechanisms to avoid water loss by osmosis. Analyses of intracellular ionic concentration of Halobacteriales living in salt lakes show that these microorganisms maintain extremely high salt (KCl) concentration inside their cells. The presence of high intracellular salt concentration requires special adaptations of the proteins and other macromolecules of the cells.

Indicate in the **Answer Sheet** if each of the following statements is True or False

A. Most intracellular proteins of Halobacteriales contain a large excess of charged amino acids on their outer surface.

B. Halobacteriales spend a lot of ATPs to maintain osmotic pressure.

C. Most intracellular enzymes of Halobacteriales lose their catalytic activity when suspended in solutions containing less than 1 M NaCl.

D. In Halobacteriales, amino acids can be imported through Na^+/amino acids antiporters.

Q.58

Influenza A genome consists of 8 separate single stranded RNA molecules, which encode a total of 11 viral proteins. Influenza A viruses are categorized by their two surface antigens, the hemagglutinin (H), of which there are 18 different subtypes (H1-18); and neuraminidase (N), of which there are 11 different subtypes (N1-11) (**Fig.Q.58A**). The influenza A virus life cycle is presented in **Fig. Q.58B**.

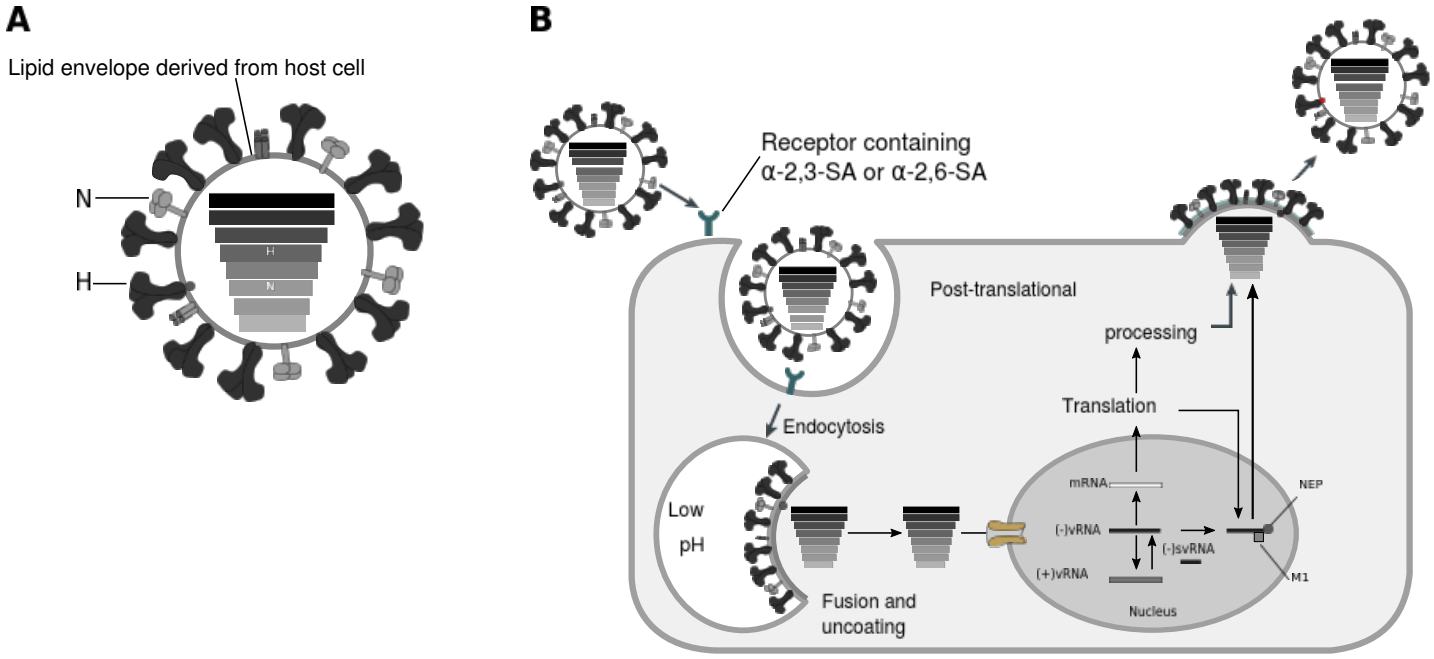


Figure Q.58 Influenza A virus: (A) virus structure and (B) virus life cycle.

Indicate in the **Answer Sheet** if each of the following statements is True or False.

A. Influenza A viruses exhibit rapid evolutionary dynamics because the genome is segmented.

B. In theory, there are 88 types of influenza A viruses.

C. Influenza A viruses exhibit high mutation rates because the genome is single strand RNA.

D. Influenza A virion can infect the cells only if RNA-dependent RNA polymerase is present.

Q.59

Phosphorylation is a major post-translational modification widely used in the regulation of many cellular processes. A method to determine the phosphorylation status of proteins is to run an electrophoresis in a modified gel with a chemical group containing metal ions (M) that can reversibly bind phosphates and thus affects migration of phosphorylated proteins.

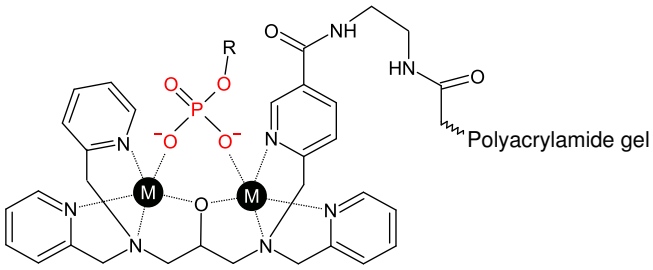


Figure Q.59.A Phospho-tag polyacrylamide gel

This technique was used to study the phosphorylation of protein p35. Three mutant forms of this protein were generated: a serine to alanine substitution in position 8 (S8A); a threonine to alanine substitution in position 138 (T138A) and both amino acid substitutions (2A). Note that serine and threonine can be phosphorylated while alanine cannot. Then two yeast strains with normal (wt) or inactive cyclin-dependent kinase 5 (Cdk5) (kn) were transformed with either the wild type version of p35 gene (wt) or one of the three mutant forms. Cell lysate of the eight resulting strains was loaded on a Phospho-tag gel. The proteins from the gel were transferred by western-blot to a membrane that was treated with anti-p35 antibodies. The result is shown below.

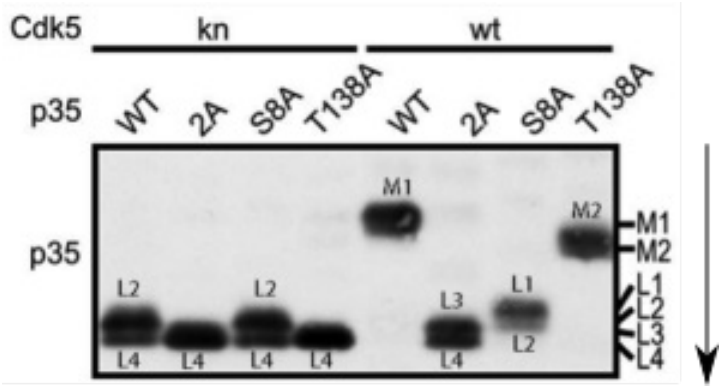


Figure Q.59.B Immunoblotting with anti-p35. The arrow indicates the direction of migration p35 bands are named M1, M2, L1, L2, L3, and L4. L4 band corresponds to the completely non-phosphorylated form of p35

Indicate in the **Answer Sheet** if each of following statements is True or False

A. Protein p35 has only two phosphorylation sites: serine 8 and threonine 138.

B. Protein p35 can be phosphorylated by a protein kinase different from Cdk5.

C. In strain Cdk5-wt p35-S8A only a few p35 molecules are phosphorylated at T138.

D. Phosphate groups attached to S8 are more accessible to phosphate binding groups of the Phospho-tag gel than phosphate groups attached to T138.

Q.60

Polarity, charge and molecular weight of molecules can affect their rate of passive diffusion through membranes. Amino acids and drugs like aspirin differ in both efficiency and location of absorption. In the figure below the chemical structure the pKa values of aspirin and arginine are represented.

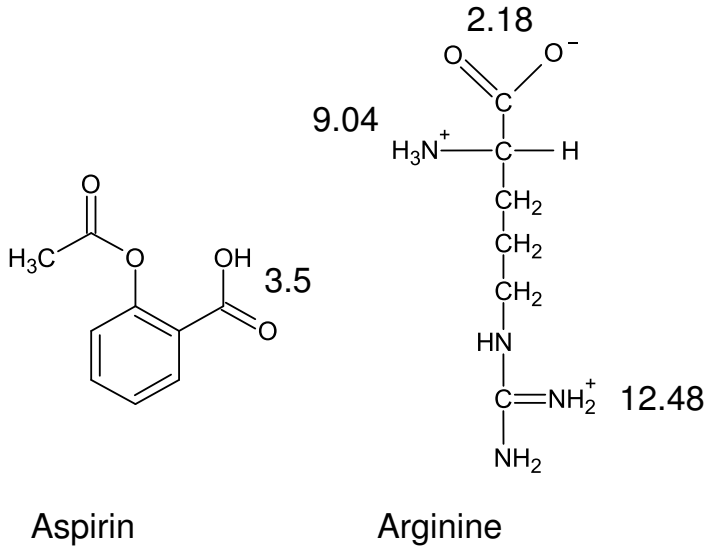


Figure Q.60

Indicate in the **Answer Sheet** if each of following statements is True or False.

A. Aspirin diffuses through membranes mainly in the stomach because more aspirin molecules are in deprotonated form at pH of about 1.6 in the stomach.

B. Based on molecular weight, one would expect Aspirin to diffuse more easily through membrane than Arginine

C. Optimal pH range for Arginine absorption by passive diffusion is between 2.18 and 9.04.

D. Omeprazole, a proton pump inhibitor, blocks the entry of Aspirin into the blood in the initial few minutes after oral administration.

PLANT ANATOMY AND PHYSIOLOGY

Q.61

To study the effects of cadmium (Cd) on root development, two experiments on maize seedlings with 6-cm-long root were conducted. First, seedlings were grown either in media supplemented with 5 µM Cd (Cd5) or without Cd (Cd0). Second, seedlings were grown either in two layers of agar without Cd (Cd0-Cd0) or unilaterally to 100 µM Cd (Cd0–Cd100). Four days later, root growth was recorded (**Figure Q.61-1**) and cross-sections of roots were stained to visualize suberin lamellae in endodermis (**Figure Q.61-2**, sections correspond to cut sites from **Figure Q.61-1**).

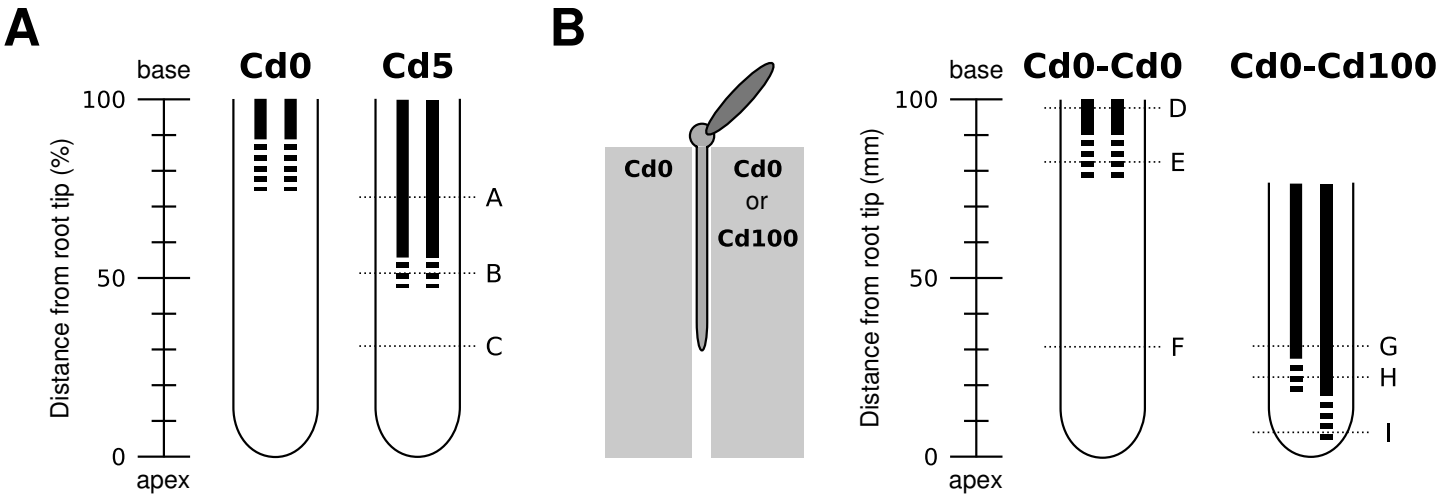


Figure Q.61-1. Distance from root apex to root base as obtained from experiments 1 (A) and 2 (B). The regions of mature endodermis in the roots are shown as solid and dashed lines.

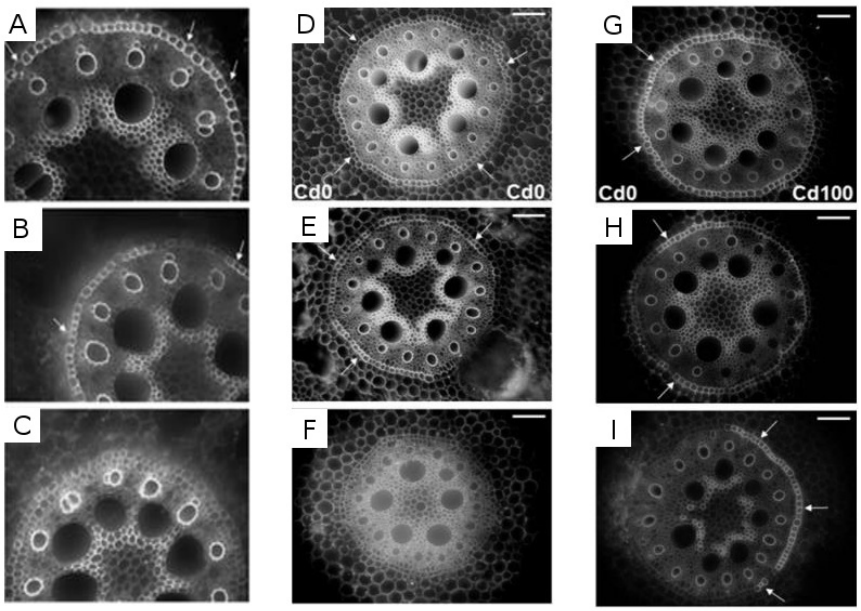


Figure Q.61-2. Cross sections at position marked in Figure Q.61-1. White arrows indicate suberin lamellae in the endodermis.

Indicate in the **Answer sheet** if each of the following statements is True or False.

A. The treatment of Cd resulted in the reduction of elongation zone of the root, leading to decreased root length.

B. Endodermal cells with suberin lamellae were already present at a distance of approximately 0.5 cm from the root apex in tissues adjacent to agar containing Cd100, however, suberinized cells were found much further from the apex on the other side.

C. In roots exposed unilaterally to Cd (Cd0–Cd100), the development of the endodermis was accelerated and asymmetrical.

D. In high Cd containing media, suberin lamellae in endodermal cells were not present in older parts of the root likely due to the restriction of Cd in younger part.

Q.62

To understand the effect of desiccation on herbaceous plants and their responses, scientists conducted a study on three *Ranunculus* species in their natural habitats, including *R. bulbosus* in dry meadow, *R. lanuginosus* in humid meadow, and *R. acris* in both habitats. They measured leaf water potential and hydraulic conductance of these species in response to dehydration (Fig.Q62). Xylem staining experiment on *R. acris* in dry habitat was used to estimate loss of conductivity due to embolism. An estimated 50% loss of xylem hydraulic conductivity occurred at -2MPa or less owing to embolism. Previously, leaf hydraulic vulnerability studies found 50% reduction in leaf hydraulic conductance between – 1 and – 1.8 MPa in pernnial grasses and at – 1.8 MPa in woody plant species.

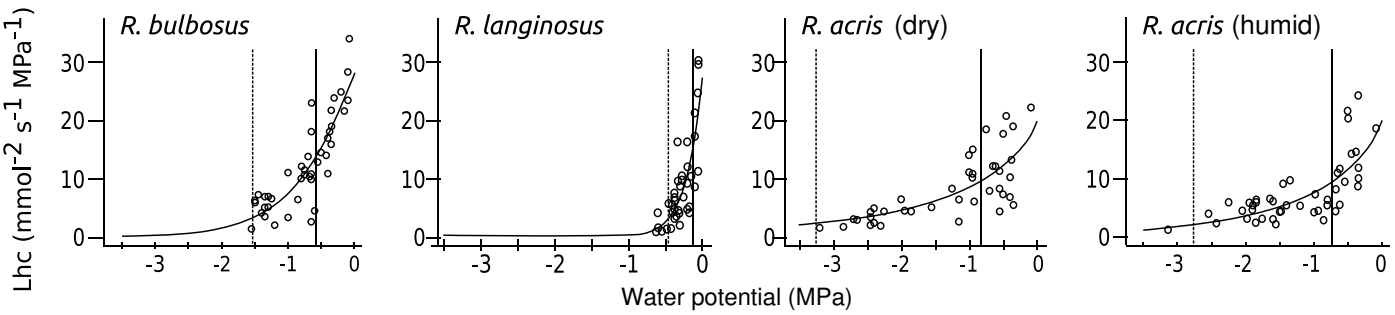


Figure Q.62 Leaf hydaulic conductance (Lhc) of *Ranunculus* species/populations in response to dehydration. Solid and dashed vertical lines indicate, respectively, fitted 50% and 88% leaf hydraulic conductance losses.

Indicate in the **Answer sheet** if each of the following statements is True or False.

A. All species were very vulnerable to water stress. In species with narrow ecological amplitude, the drought-exposed *R. bulbosus* was less vulnerable to desiccation than the humid habitat *R. lanuginosus*.

B. Herbaceous species would be more vulnerable to water stress than woody species and perennial grasses, but also would show interspecific and intraspecific adjustments in hydraulic vulnerability based on the water availability of their respective habitats.

C. The leaf hydraulics method employs hydraulic conductance including both xylary and extraxylary pathways.

D. The effect of drought in these plant species is found to be a loss of leaf hydraulic conductance at moderate water potential based on extraxylary pathways rather than embolism formation.

Q.63

A protein can be integrated into a membrane through a polypeptide sequence or via a lipid anchor. The attachment of eukaryotic proteins to the outer leaflet of the plasma membrane occurs only via Glycosylphosphatidylinositol (GPI) anchors. The biosynthesis of GPI glycolipid is a multistep process relies on many proteins, including GPI transamidase. In *Arabidopsis* plants, *AtGPI8* gene encodes the enzyme GPI transamidase. To study the role of this gene in plant development, scientists constructed a mutant (*atgpi8-1*) plant line. They observed phenotypes of both wild type (WT) and mutant plants.

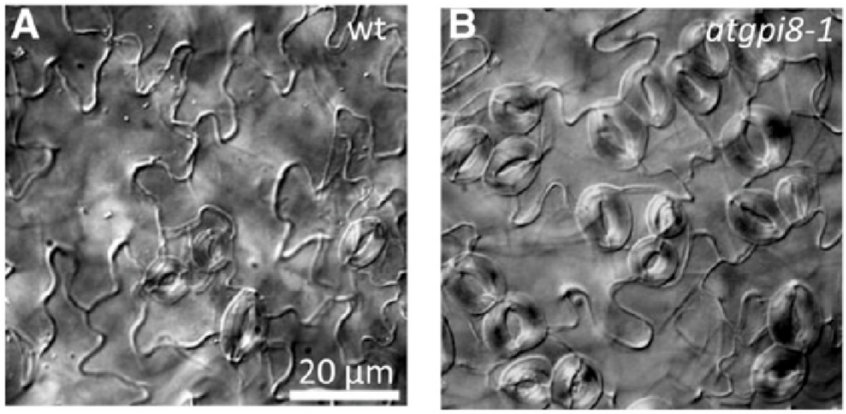


Figure Q.63.1 *Cotyledonous epidermis of wild type (A) and atgpi8-1 (B) plants.*

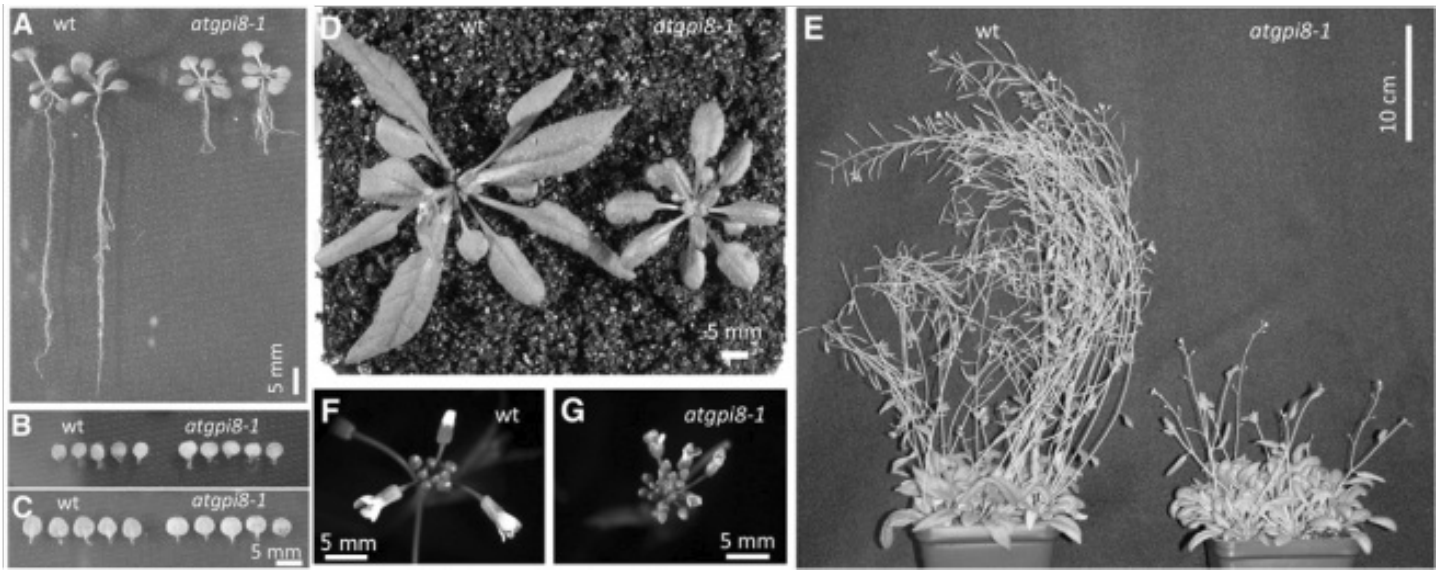


Figure Q.63.2 Growth phenotypes of wild type and *atgpi8-1* plants. (A) Seedlings, (B) cotyledons and (C) first two leaves of seedlings. (D) 30-day-old and (E) 60-day-old plants. F- G: Inflorescences.

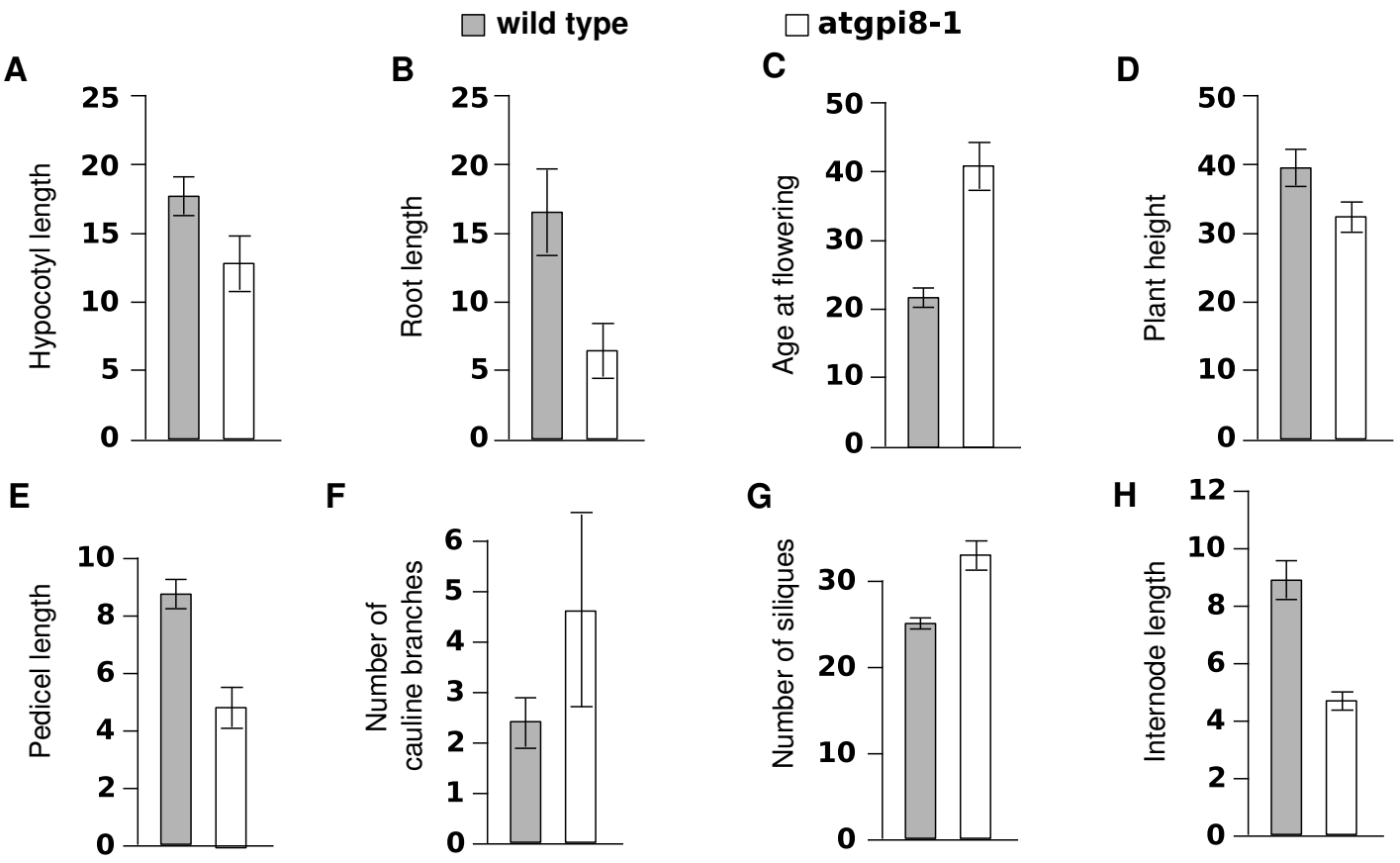


Figure Q.63.3 *Morphometric analysis of wildtype (gray bars) and atgpi8-1 (white bars) seedlings and mature plants. All differences are statistically significant.*
Measurements for D-H were carried out at full maturation at 60 days for wildtype and 90 days for mutants.

Indicate in the **Answer sheet** if each of the following statements is True or False.

A. The early post germination growth of cotyledons and first two leaves are not affected by the mutation. However, root growth, hypocotyl elongation and stomata differentiation are strongly affected by the mutation.

B. The data suggest that GPI anchoring promotes the growth of leaves in vegetative plants; however, it inhibits axillary shoot formation.

C. The *atgpi8-1* mutation leads to reduced internode and pedicel elongation. However, the height of *atgpi8-1* plants is only moderately reduced likely because the number of internodes is increased.

D. The results indicate that *AtGPI8* gene promotes early transition to flowering, but inhibits fruit production.

Q.64

Photosynthesis of submerged aquatic plants is severely impeded by many environment factors. In seawater and freshwater, light density and its spectrum is changed with depth in the water column and thus influence photosynthesis. Other factors affecting photosynthesis include level of carbon dioxide (CO_2) and oxygen (O_2).

Swamp Raspwort (*Meionectes brownie*) is a wetland plant species but can grow as a submerged aquatic plant in freshwater. An experiment was conducted to study the photosynthesis of the aquatic vegetation. Diurnal fluctuations in surface irradiance, partial pressure of O_2, CO_2 concentration and pH of the water in Swamp Raspwort-rich ponds are shown in **Figure Q.64**.

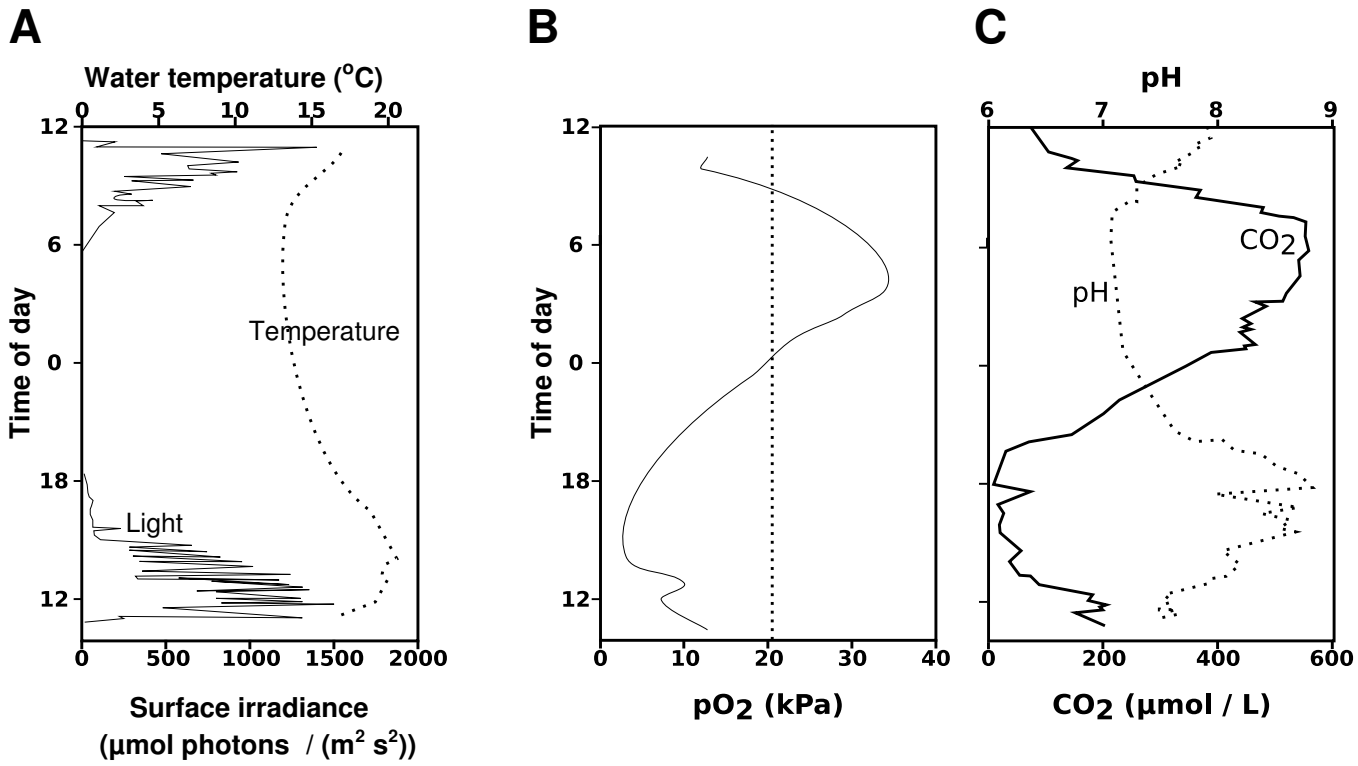


Figure Q.64

Indicate in the **Answer sheet** if each of the following statements is True or False.

A. In the underwater of ponds, light limitation appears early in the morning and co-limitation of both light and CO_2 takes place early in the afternoon.

B. The decrease in level of O_2 in water column during the night is caused by the Swamp Raspwort respiration.

C. In water column of ponds, CO_2 molecules are directly produced by respiration of Swamp Raspwort and by conversion from HCO^-_3 at pH neutral results in increasing CO_2 level.

D. As indicated in the figure, temperature variation in ponds rich Swamp Raspwort is from 13 to 20°C. The alteration in temperature is mainly maintained by high density of this plant species.

Q.65

Nitrogen assimilation plays an important role in plant metabolism as well as in plant cell development. Plant cells can acquire inorganic nitrogen in the form of ammonium (NH_4^+) and nitrate (NO_3^-). When entering the plant cells through membrane-bound nitrate transporter (NRT), NO_3^- can be reduced to NO_2^- by nitrate reductase (NR) and subsequently to NH_4^+ and amino acids (AA). In addition, NO_2^- can be converted into nitric oxide (NO), then forming S-nitrosoglutathione (GSNO) by reaction with glutathione (GSH), and finally into oxidized glutathione (GSSG) and NH_4^+ under catalysis of S-nitrosoglutathione reductase 1 (GSNOR1)

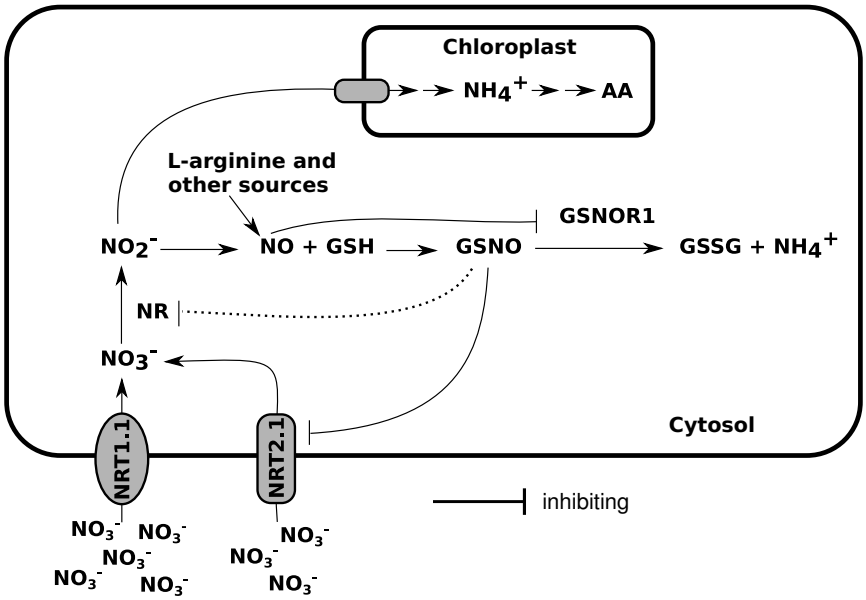


Figure Q.65 A schematic model for the control of nitrogen assimilation in plants through NO signalling

Indicate in the **Answer sheet** if each of the following statements is True or False.

A. In the nitrogen metabolism process of the plant cells, NO is one of the products but plays a role signaling regulation of NH_4^+ formation and NO_3^- assimilation.

B. NH^{4+} level in chloroplasts of plant cells is controlled by activity of GSNO.

C. Reduction of NO^{2-} ions mainly occur in cytosol

D. NO feedback regulates flux through nitrate assimilation pathway and controls its bioavailability by modulating its own metabolism.

Q.66

A study on the effects of lead (Pb), a toxic heavy metal, on growth and photosynthesis of two microalgae, *Chlorella* and *Scenedesmus* was conducted. The figure on the left below shows the growth of these strains responded differently to lead concentration after 4 day treatment. From growth rate (*Ke*), generation time (G) of each strain at each concentration of lead can be calculated as equation: G= (ln2)/*Ke.* The right hand **Figure Q.66** is result of the effect of lead on photosynthesis of these strains, indicated by Fv/Fm, a sensitive parameter that decreases when photosynthesis is impaired. The concentration of lead that gives half-maximal response, the IC_{50}, can be estimated based on response versus lead concentration plots.

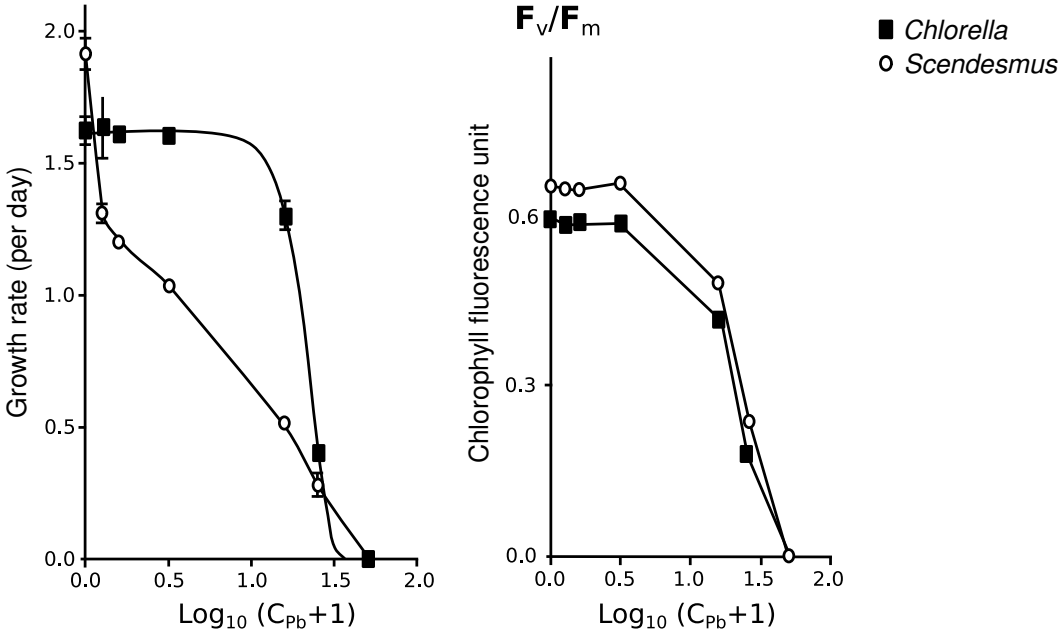


Figure Q.66

Indicate in the **Answer sheet** if each of the following statements is True or False.

A. Estimated IC_{50} of growth for the *Scenedesmus* was higher than that for the *Chlorella.*

B. Photosynthetic impairment by Pb was likely responsible for the growth decrease in the *Chlorella* but this was not the scenario in the *Scenedesmus*

C. The estimated IC_{50} for effects on F_V/F_m was higher than that for growth in *Scenedesmus*

D. At lead concentration that $Log_{10}([Pb]+1)$ is 0.5, the *Scenedesmus* reproduced faster than the *Chlorella* did.

Q.67

Scientists constructed gibberellic acid (GA)-deficient and GA-insensitive transgenic lines of poplar plants. They measured concentration of phytohormones, including GA1 and GA4 and IAA, in the leaves and roots of transgenic and wildtype plants (**Table Q.67**). They also measured the growth of plants in greenhouse and *in vitro* conditions (**Figure Q.67**).

Table Q.67 *Phytohormone concentrations (ng/g dry weight) in leaves and roots of the wild type and the two transgenic types*

Organ	Plant types	GA1	GA4	IAA
Leaf	Wild-type	58.1 ± 15.4	6.64 ± 3.18	22.5 ± 3.1
Leaf	GA-deficient	19.9 ± 9.4**	5.53 ± 2.33*	21.1 ± 5.9
Leaf	GA-insensitive	139.6 ± 21.9**	12.2 ± 3.6**	19.6 ± 3.7
Root	Wild-type	77.1 ± 29.3	2.24 ± 0.74	61.4 ± 4.1
Root	GA-deficient	48.8 ± 9.6**	1.15 ± 0.62**	72.9 ± 5.2*
Root	GA-insensitive	97.7 ± 31.5**	3.93 ± 0.68**	69.1 ± 9.7*

* and ** indicate significant differences compared to wild-type at 0.05 and 0.01 levels by Student T-test.

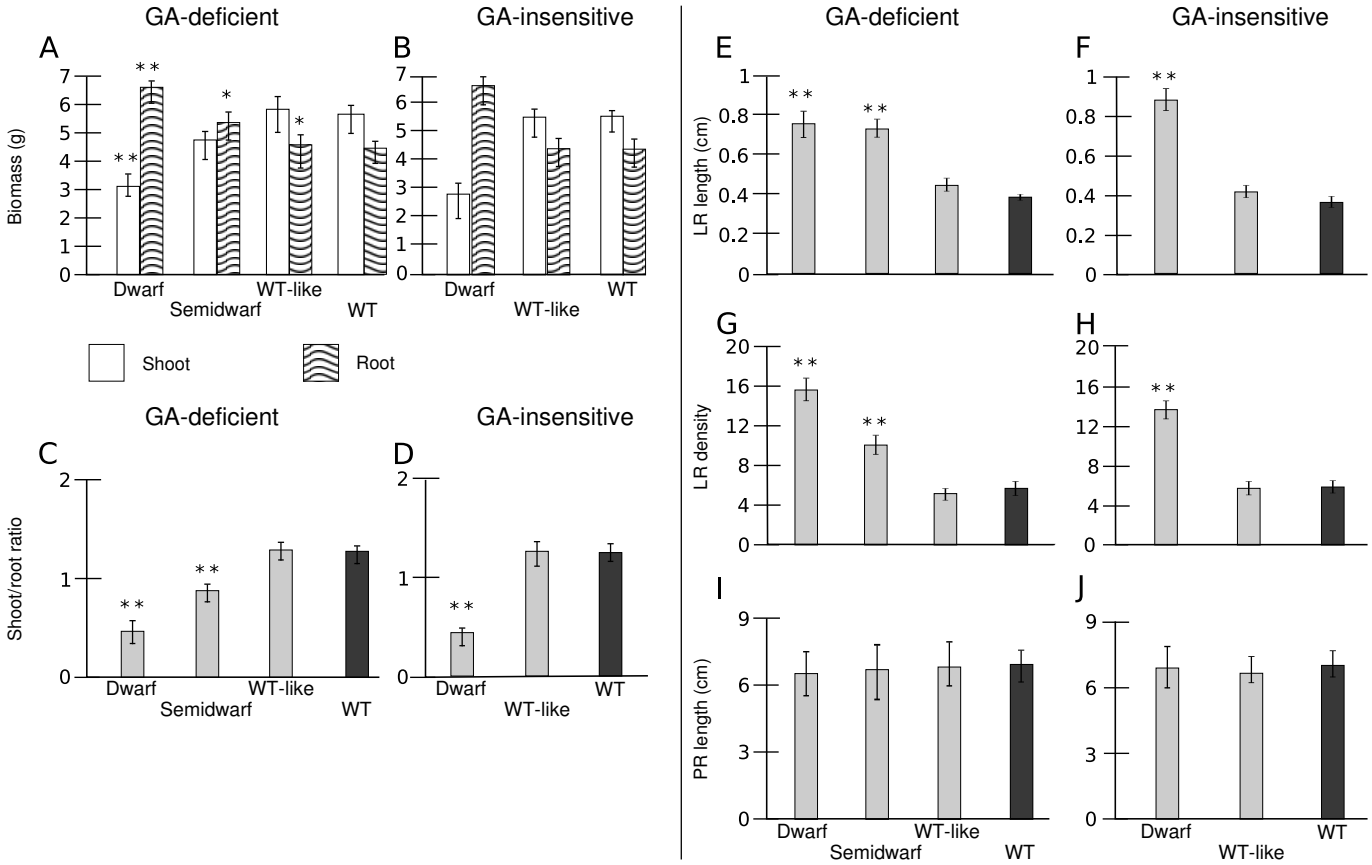


Fig.Q.67 A-D: Root and shoot biomass under greenhouse conditions. Top panel shows the fresh biomass of shoots and roots in GA-deficient (A) and GA-insensitive (B) transgenics. Bottom is the shoot/root ratio in GA-deficient (C) and GA-insensitive (D) transgenics. * and ** indicate significant differences.

E-J: Root development in GA-deficient and GA-insensitive transgenic lines grown in vitro. LR - Lateral root; PR - Primary root. * and ** indicate significant differences compared to wild-type plants (WT).

Indicate in the **Answer sheet** if each of the following statements is True or False.

A. Greenhouse-grown dwarf plants of both transgenic types display a significant reduction in aerial biomass and an increase in belowground biomass, leading to a significant reduction in the shoot-to-root ratio relative to the wild-type control.

B. The most severely dwarfed plants have more, as well as longer, lateral roots than the wild-type control.

C. The degree of dwarfism in both GA-insensitive and GA-deficient lines is positively correlated with the extent of primary and lateral root formation and elongation.

D. In poplar plants, gibberellins negatively affect lateral root formation, and there may be an interaction between gibberellins and auxin that regulates lateral root formation.

Q.68

Scientists grew cucumber plants in different nutrient conditions to obtain either super ovary or normal ovary types. They labelled flowers when they emerged and observed the development of flowers. Based on the color and shape, corolla development was divided into four consecutive stages: green bud (G), green-yellow bud (GY), yellow bud (Y), and flowering (F). They also measured plant growth regulator concentrations in different flower developmental stages.

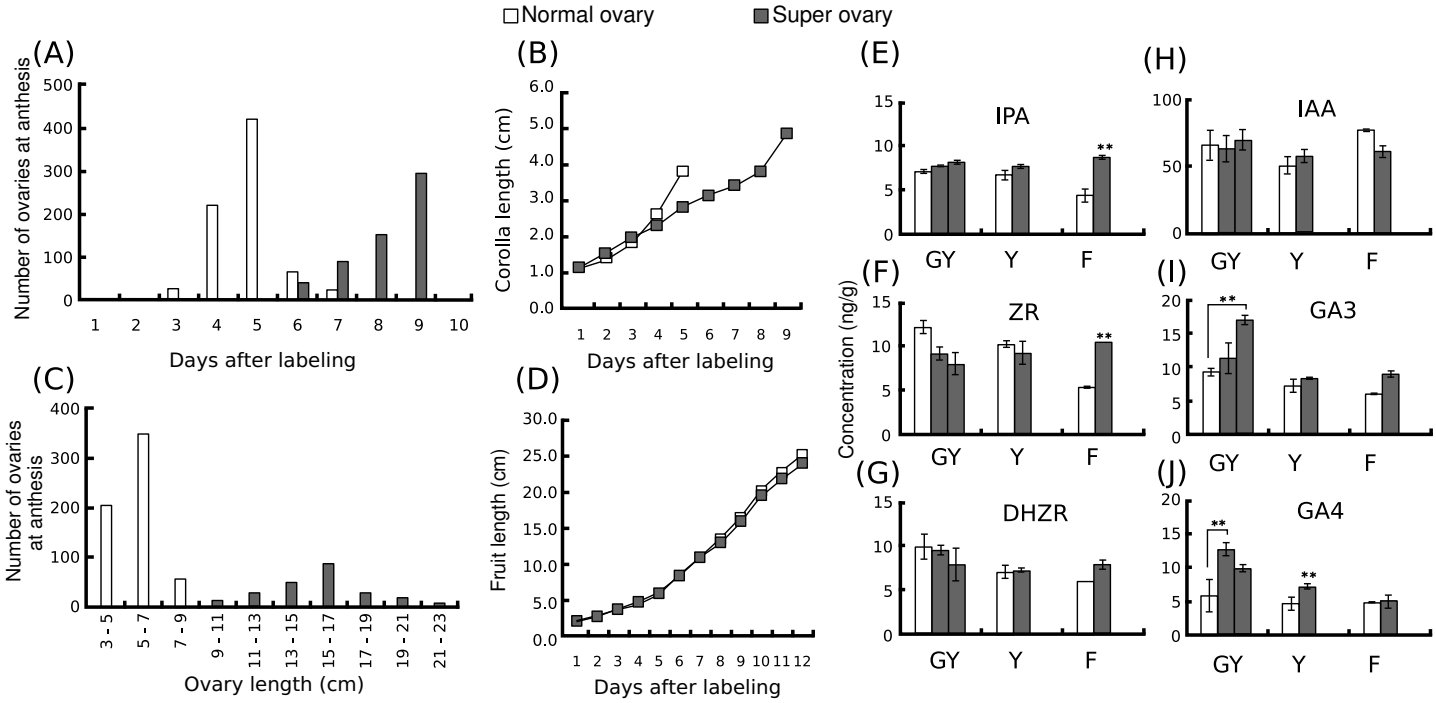


Fig.Q.68 A-D: Morphological characterization of the normal ovary and super ovary types. E-J: Concentration of cytokinins (IPA, ZR, DHZR), gibberellins (GA3, GA4) and auxin (IAA) in different flower developmental stages. In super ovary type, two sub-stages were included. ** indicates statistically significant differences within one developmental stage.

Indicate in the **Answer sheet** if each of the following statements is True or False.

A. The corolla progression between stages was much delayed in the super ovary

B. The ovary at anthesis was on average much longer in the super ovary than the normal ovary, while at the same time courses after labelling, fruit length was not different between two types.

C. Gibberellins were increased in the super ovary during the early stages of corolla development, which corresponds to the enlarged corolla size.

D. Cytokinins appear to be the primary regulator for the time of flower opening in cucumber, whereas auxin is probably involved in the size control of corolla and fruit.

ANIMAL ANATOMY AND PHYSIOLOGY

Q.69

Figure Q.69 shows the regulation of HCl secretion in the parietal cell of the stomach.

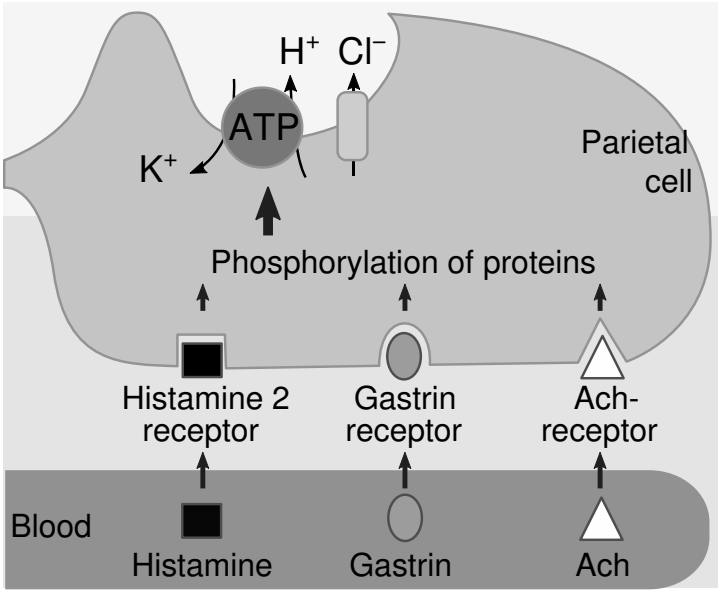


Figure Q.69

Drugs 1, 2, 3, and 4 inhibit gastric acid secretion differently *in vivo* via one of the four pathways: inactivating the H^+/K^+ATPase, blocking the Histamine 2 receptor, blocking Gastrin receptor, and blocking Acetylcholine (Ach) receptor.
A set of experiments were conducted to determine in which pathway these drugs inhibit gastric acid secretion. Parietal cells were isolated and cultured in different media. Each medium contained one of the four drugs. Each drug-containing medium was added with one of three compounds (Histamine, Gastrin, Ach). The HCl secretion of parietal cells in the cultures was determined. The following table shows the results of the experiments.

(–: No HCl secretion; +: HCl secretion; ?: not shown).

	No drug	Drug 1	Drug 2	Drug 3	Drug 4
No addition	–	–	–	–	–
Histamine added	?	?	?	?	–
Gastrin added	?	?	?	+	?
Ach added	+	–	?	?	–

Indicate in the Answer sheet if each of the following statements is True or False.

A. HCl was secreted by the parietal cells cultured in the medium containing Drug 1 and Histamine.

B. Drug 2 blocked Gastrin receptors.

C. Drug 3 blocked Histamine 2 receptors.

D. The parietal cells cultured in the medium containing Drug 4 and Ach had lower levels of intracellular K^+ than the cells cultured in the medium containing only Ach.

Q.70

The glycoprotein 4-1BB is a receptor that is highly expressed on the surface of active T-cells. The 4-1BB ligand (4-1BBL) is a molecule that binds to and activates 4-1BB. It is found strongly expressed on antigen-presenting cells. Bidirectional signals of 4-1BB and 4-1BBL interaction increase the activity of white blood cells and increase the production and secretion of cytokines, such as MCP-1 which promotes the infiltration of leukocytes (**Figure Q.70**). Currently, many studies have shown a relationship between the signaling pathways via 4-1BB/4-1BBL interaction and several human diseases, including those related to metabolism.

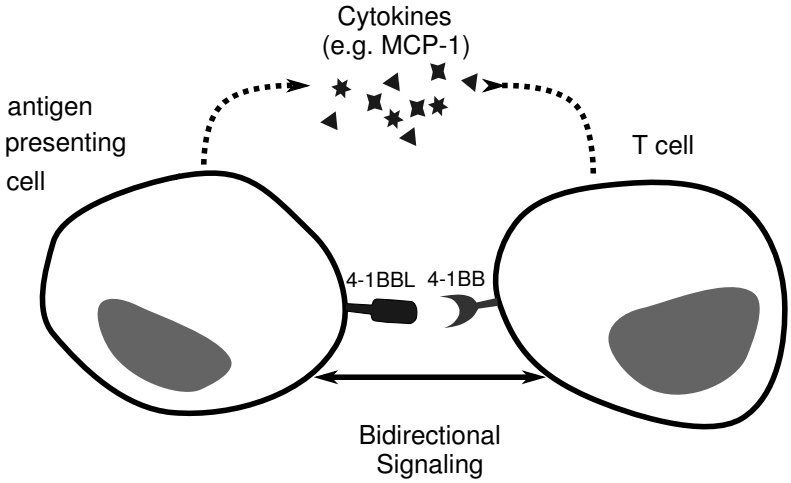


Figure Q.70

Indicate in the Answer sheet if each of the following statements is True or False.

A. Inhibition of 4-1BB expression diminishes the development of atherosclerosis.

B. Activation of 4-1BB limits the effect of autoimmune diseases on the body.

C. All three kinds of cells, macrophages, dendritic cells and natural killer cells strongly express 4-1BBL.

D. Blocking the 4-1BB and 4-1BBL interaction increases graft tolerance.

Q.71

The action potential of cardiac muscle cells differs from that of other cells such as skeletal muscle cells and neurons. **Figure Q.71** displays the different phases of action potential in cardiac muscle cells.

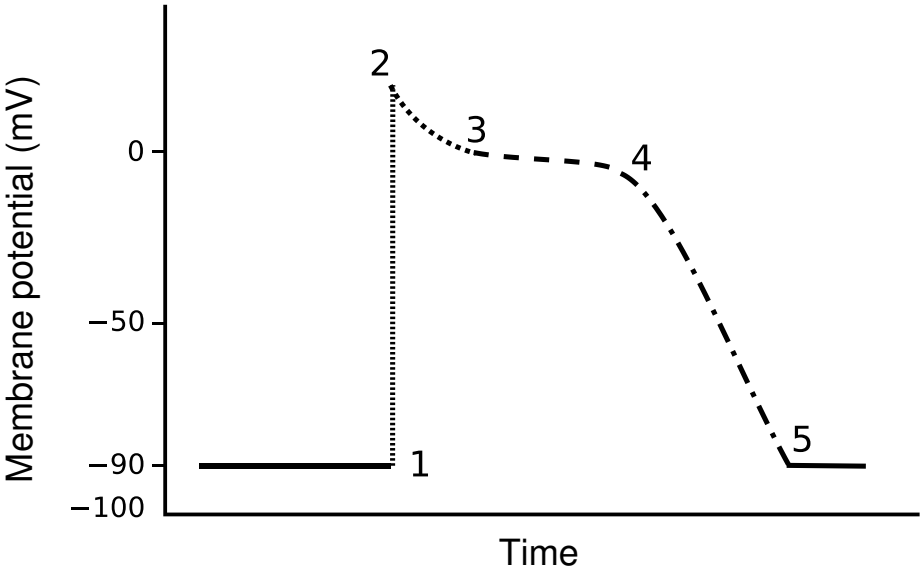


Figure Q.71

Indicate in the Answer sheet if each of the following statements is True or False.

A. A substance that inhibits the reuptake of Ca^{2+} into the sarcoplasmic reticulum increases the time interval from 3 to 4.

B. The concentration of K^{+} in the sarcoplasm at position 2 is higher than that at position 3.

C. Injection of adrenaline decreases the time interval from 1 to 5.

D. The height of action potential (from 1 to 2) is decreased when the sarcoplasmic level of Na^{+} is higher than the normal level.

Q.72

Parathyroid hormone (PTH) plays an important role in the regulation of plasma calcium and phosphate levels. Figure Q.72 shows the changes in levels of PTH, Ca^{2+}, and phosphate (Pi) in plasma of mice injected with a specific inhibitor of PTH secretion.

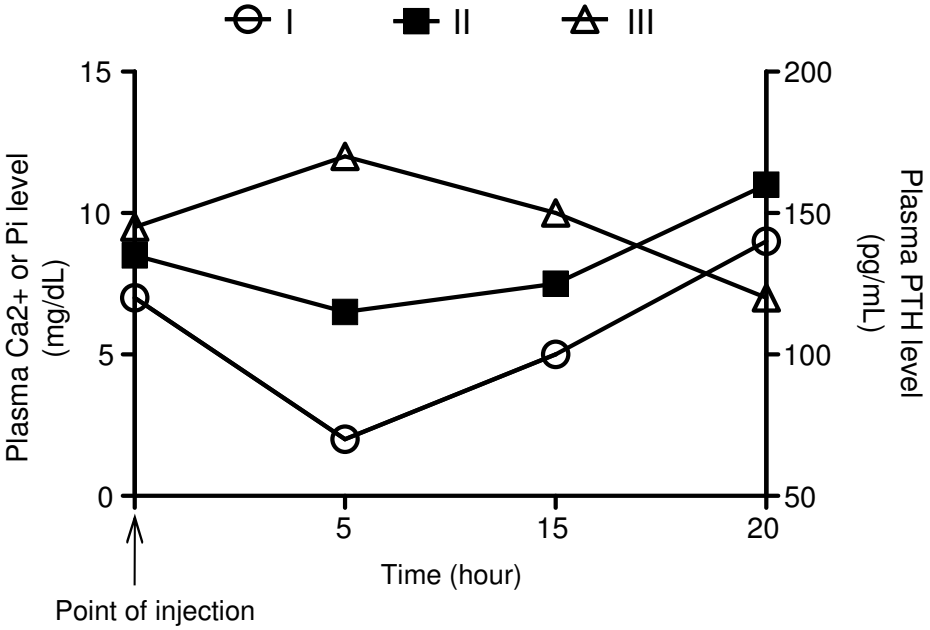


Figure Q.72

Indicate in the Answer sheet if each of the following statements is True or False.

A. If Line I shows the level of PTH, then Line II and Line III would likely be showing the levels of Pi and Ca^{2+}, respectively.

B. PTH knock-out mice would have higher Pi levels in their urine compared with the wild type mice on the same diet.

C. Eating a calcium-rich diet decreases the plasma level of vitamin D (active form) in healthy people.

D. People with calcium-sensing receptor suppression have higher levels of plasma Ca^{2+} compared with healthy people on the same diet.

Q.73

The following table describes the rate of blood flow to different parts of the body including brain, skin, intestines, and cardiac muscle at rest and during strenuous exercise.

Part of the body	Rate of blood flow/cm3/min	
	At rest	During exercise
I	250	1200
II	500	500
III	500	1000
IV	2500	90

Indicate in the Answer sheet if each of the following statements is True or False.

A. At rest, ATP of the cells of part I comes mainly from oxidation of fatty acid.

B. The activity of insulin receptors in the cells of part II is increased during exercise, enhancing glucose uptake.

C. The increase in blood flow to part III during exercise helps to regulate the body temperature.

D. Epinephrine decreases blood flow to part IV via β-receptor.

Q.74

A man had lost approximately 700 mL of blood in a severe injury of a major artery in a motorcycle accident. At the time of accident, his blood pressure was 90/50 mmHg. Several physiological changes should be expected in response to hemorrhage.

Indicate in the Answer sheet if each of the following statements is True or False.

A. Oxygen affinity of hemoglobin in peripheral tissues was increased.

B. Total peripheral resistance was increased.

C. Hyperpolarization occurred in the cells of the sinoatrial node.

D. Vasoconstriction occurred in the brain and in the coronary arteries.

Q.75

In a simple way, respiratory disorders can be classified as obstructive or restrictive disorders. Obstructive disorders are characterized by a reduction in the airflow rate in the respiratory tracts. Restrictive disorders are characterized by a reduction of lung volume.

Figure Q.75 shows the shapes of the flow-volume loops measured during forced inspiration and forced expiration in healthy people with normal respiratory function and in four patients suffering from four common types of respiratory disorders.

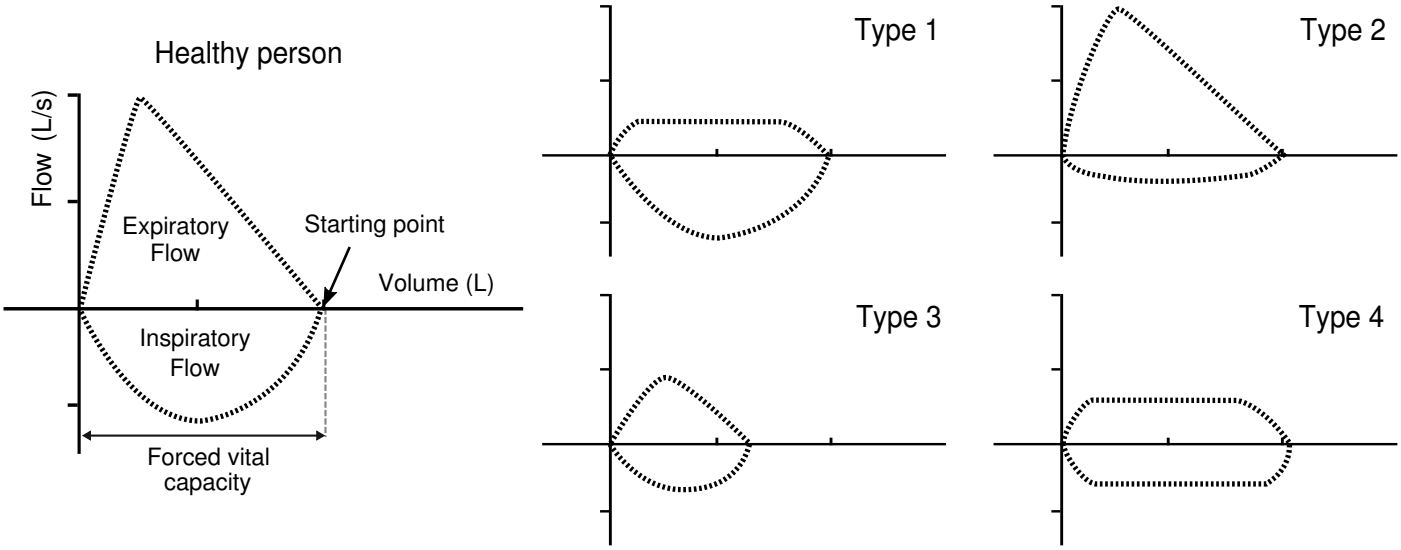


Figure Q.75

Indicate in the Answer sheet if each of the following statements is True or False.

A. The blood pH of a patient with Type 1 is higher than that of healthy people.

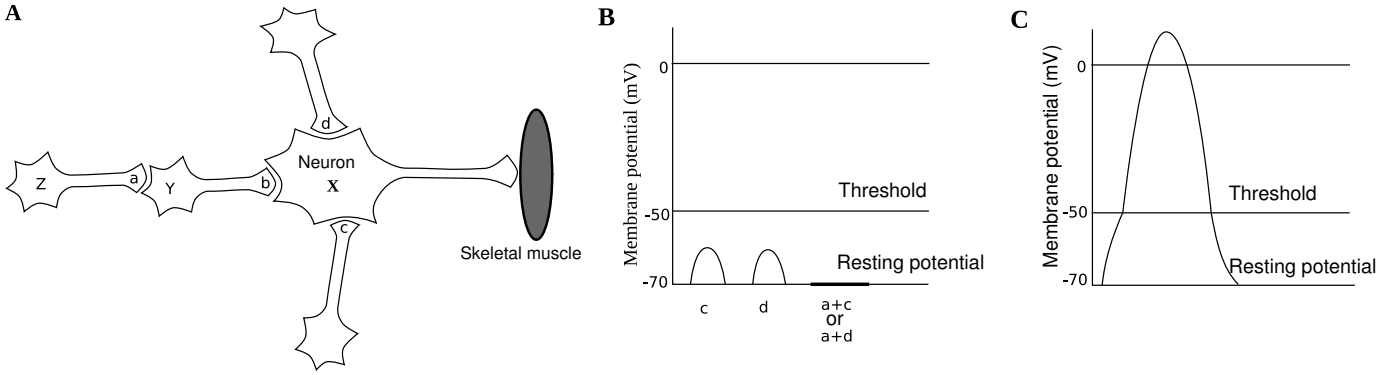
B. The time of the forced inhalation of patient with Type 2 is shorter than that of healthy people.

C. A patient with Type 3 displays a higher breathing rate than healthy people.

D. Residual volume in a patient with Type 4 is higher than that of healthy people.

Q.76

Figure Q.76A shows neuron X receives signals directly from three separate nerve terminals *b*, *c* and *d*. Neuron Y receives signals from nerve terminal *a*.
Figure Q.76B shows the various postsynaptic potentials recorded in neuron X after receiving input signals directly from terminals *b*, *c*, and *d* and indirectly from terminal *a*.
Figure Q.76C shows the action potential recorded in neuron Y after receiving input signals from the presynaptic terminal *a*.



Figures Q.76A, B, and C

Indicate in the Answer sheet if each of the following statements is True or False.

A. Action potentials could be generated in neuron X if nerve terminal *c* is stimulated rapidly.

B. When three nerve terminals *a*, *c* and *d* are stimulated simultaneously, the postsynaptic potentials recorded in neuron X are smaller than those when the nerve terminals *c* and *d* are stimulated simultaneously.

C. Nerve terminal *a* releases inhibitory neurotransmitter and nerve terminal *b* releases excitatory neurotransmitter.

D. In the mammalian body, there are many neurons like neurons Z, Y, X. Neurons Z, Y, X are sensory neurons, Renshaw cells (inhibitory neurons) and motor neurons, respectively. If a substance (e.g., Strychnine) injected in the body blocks glycine receptors, diaphragm contracts fully and remains contracted.

Q.77

A set of experiments on the regulation of hormone secretion and effects of various drugs on the activities of endocrine glands were conducted on rats. Rats were divided to different groups and each group was injected with a hormone or a drug. Some physiological parameters were collected and analysed.

Indicate in the Answer sheet if each of the following statements is True or False.

A. The group of rats injected with the drug that reduces the sensitivity of hypothalamus to cortisol resulted in higher plasma levels of both glucose and insulin than those in the group of rats injected with the drug that reduces the sensitivity of adrenocorticotropic hormone (ACTH) receptors.

B. The group of rats injected with the drug that increases the sensitivity of hypothalamus to thyroxine resulted in higher metabolic rate and body temperature than those in the group of rats injected with the drug that increases the sensitivity of target cells to thyrotropin-releasing hormone (TRH).

C. The group of rats injected with propylthiouracil (which blocks thyroid hormone synthesis) resulted in smaller thyroid gland and body weight than those in the group of rats injected with placebo.

D. The group of rats injected with thyroid stimulating hormone (TSH) had smaller pituitary gland and bigger adrenal glands compared with the group of rats injected with corticotrophin-releasing hormone (CRH).

Q.78

Some researchers studied the changes in the level of saliva cortisol and 2-AG (2-arachidonoylglycerol) concentration in blood in two groups of people with motion sickness and without motion sickness (no sickness) during parabolic flight maneuvers (PFs). During PFs, the saliva cortisol levels and 2-AG blood concentrations were measured from samples taken in-flight before start of the parabolic maneuvers (T0), after 10 parabolas (T1), 20 parabolas (T2), and 30 parabolas (T3), termination of PFs (T4) and 24 h later (T5). The results are shown in **Figure Q.78**.

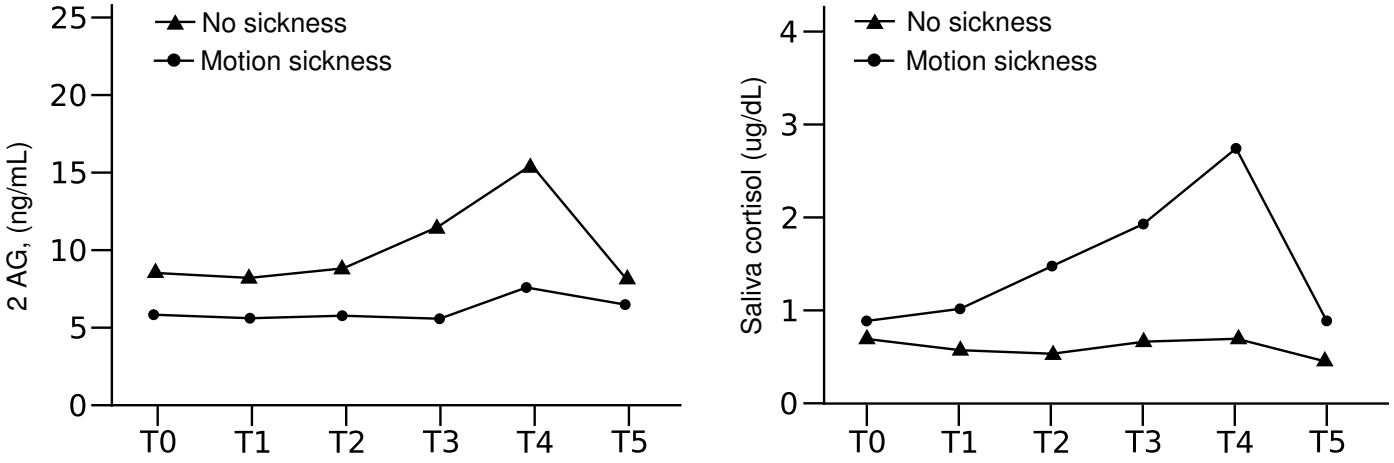


Figure Q.78

Indicate in the Answer sheet if each of the following statements is True or False.

A. A 2-AG inhibitor can be used to reduce motion sickness.

B. In motion sickness group, the blood glucose level at T4 was higher than at T1.

C. At T2, the blood ACTH (adrenocorticotropic hormone) level in the no sickness group was higher than that in the motion sickness group.

D. In motion sickness group, the blood CRH (corticotropin-releasing hormone) level at T5 was lower than that at T2.

Q.79

When a person born and brought-up at sea level and then moves to a village at an altitude of 3000 metres above sea level by helicopter, some adaptations of their body occur to compensate for the decreased oxygen pressure at high altitude.

Indicate in the Answer sheet if each of the following statements is True or False.

A. The moment the person arrives at the high altitude, oxyhemoglobin dissociation curve shifts to the left (indicating greater affinity of hemoglobin for oxygen).

B. After several days living at the high altitude, the person's blood viscosity is decreased, enabling his blood to deliver more oxygen to his tissues.

C. After several weeks living at the high altitude, the person's lung cells of this person produce more nitric oxide (NO).

D. Many people who ascend rapidly to high altitude experience some degree of acute mountain sickness (e.g., headache, malaise, and nausea). Which may be treated with a drug that causes bicarbonate to be excreted in the urine.

Q.80

Figure Q.80 demonstrates the relationship between oxygen concentration and oxygen partial pressure (Po_2) in blood of two species of vertebrates (species *a* and *b*). Each sample was subjected to two levels of carbon dioxide pressure (Pco_2): curve I represents the values measured at normal Pco_2 and curve II represents the values measured at elevated Pco_2. The blood having passed through the lungs of the two species normally has a Po_2 of 100 mm Hg and the deoxygenated blood leaving the tissues has a Po_2 of 40 mm Hg.

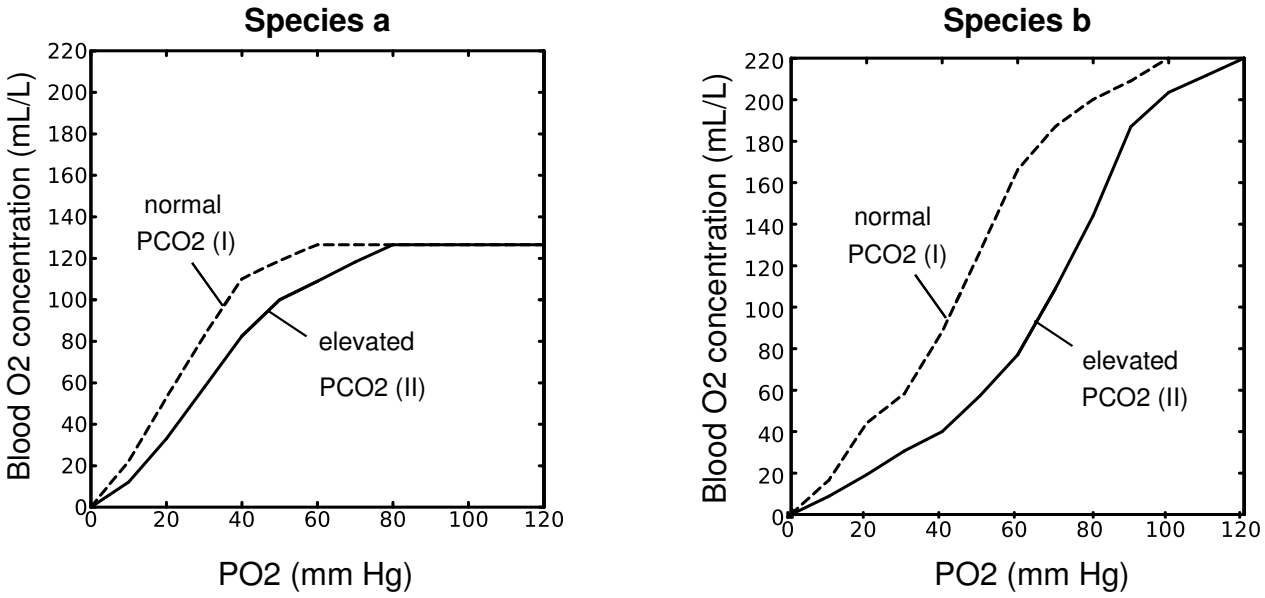


Figure Q.80

Indicate in the Answer sheet if each of the following statements is True or False.

A. While comparing curve I of species *a* with curve I of species *b*, you can predict that the O_2 concentration of the blood in the lungs of species *a* will be higher than that of species *b*.

B. If you expose deoxygenated blood of the two species at the same level of Pco_2 to increasing Po_2, the first blood to become saturated with O_2 would be that of species *a*.

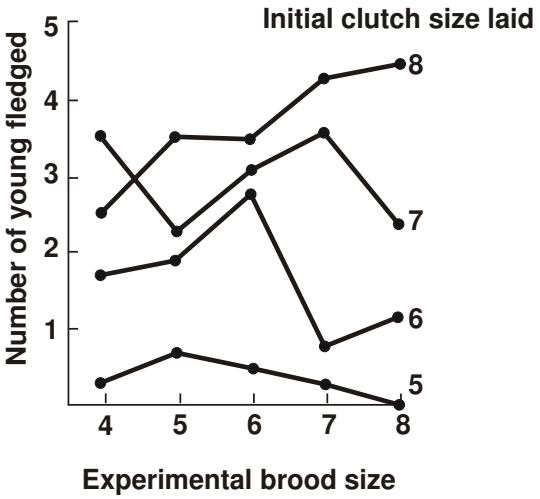
C. In species *b*, if curves I and II represent the Pco_2 of oxygenated and deoxygenated blood, respectively, there will be less than 160 mL of O_2 released from a litre of blood as it passes through the tissues.

D. In species *a*, an increase in Pco_2 in the blood reduces the affinity of hemoglobin for oxygen but has no effect on the maximum oxygen-carrying capacity in the blood.

ETHOLOGY

Q.81

In an experimental study on magpies *Pica pica*, conducted in Sweden, Goran Högstedt manipulated the original clutch size (shown on the right of the graph) of experimental birds to generate a number of different clutch sizes for each category of bird, as shown in the X-axis. The number of young fledged successfully by the birds under these different conditions is indicated by the Y-axis. Food abundance and quality of territory are thought to be associated with clutch size. Predation is lower in large clutches.



Analyse the following statements, with reference to the data provided and indicate in the answer sheet if each of the statements is true or false.

A. The birds, in general, did better with experimentally manipulated, larger broods.

B. The reproductive rate of birds is closest to that which maximises individual breeding success.

C. Birds in high quality territory tend to have larger clutches.

D. Experimentally-manipulated clutches experience higher starvation.

Q.82

The behaviour of two similar-sized species of fiddler crabs (*Uca latimanus* and *U. musica*) that intermingle in the same habitat was studied. Males build hoods over their burrows for mate attraction. Mate searching is a dangerous activity for fiddler crab females, so these females may be forced to make suboptimal choices for their own safety, especially in areas where their conspecifics are in lower densities. The figures **Fig.Q.82** below show the approaches made by females of the two species to male crabs as well as to burrows (with and without hoods) of conspecific males.

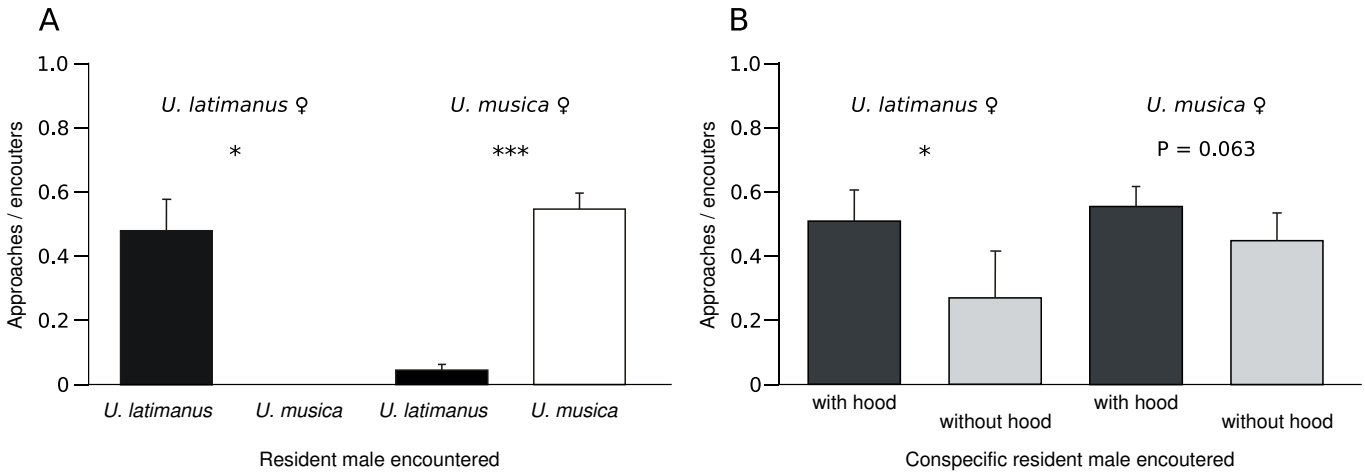


Fig. Q.82: (A) Mean (±SE) proportion of resident *Uca latimanus* and *U. musica* males approached by wandering *U. latimanus* females and *U. musica* females. * $p < 0.05$; *** $p < 0.0001$.
(B) Mean (±SE) proportion of resident conspecific males with and without hoods approached by wandering *U. latimanus* females and *U. musica* females. * $p < 0.05$.

Indicate in the answer sheet if each of the following statements is true or false.

A. Females of both species approached a greater proportion of the conspecific males than the heterospecific males they encountered.

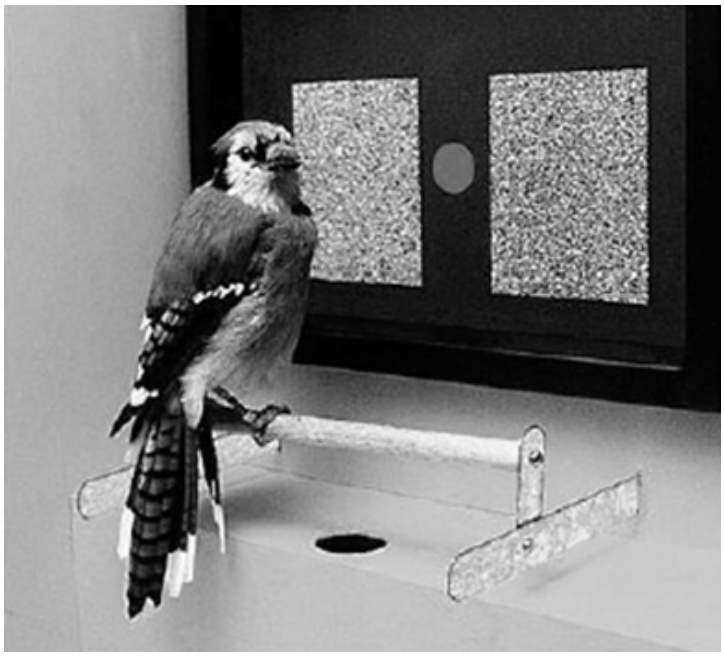
B. Attraction of *U. musica* females to hoods is not as strong as that of *U. latimanus* females.

C. A male fiddler crab's willingness to court all females, regardless of species, is made used of by females of both species for shelter-seeking and avoidance of predators.

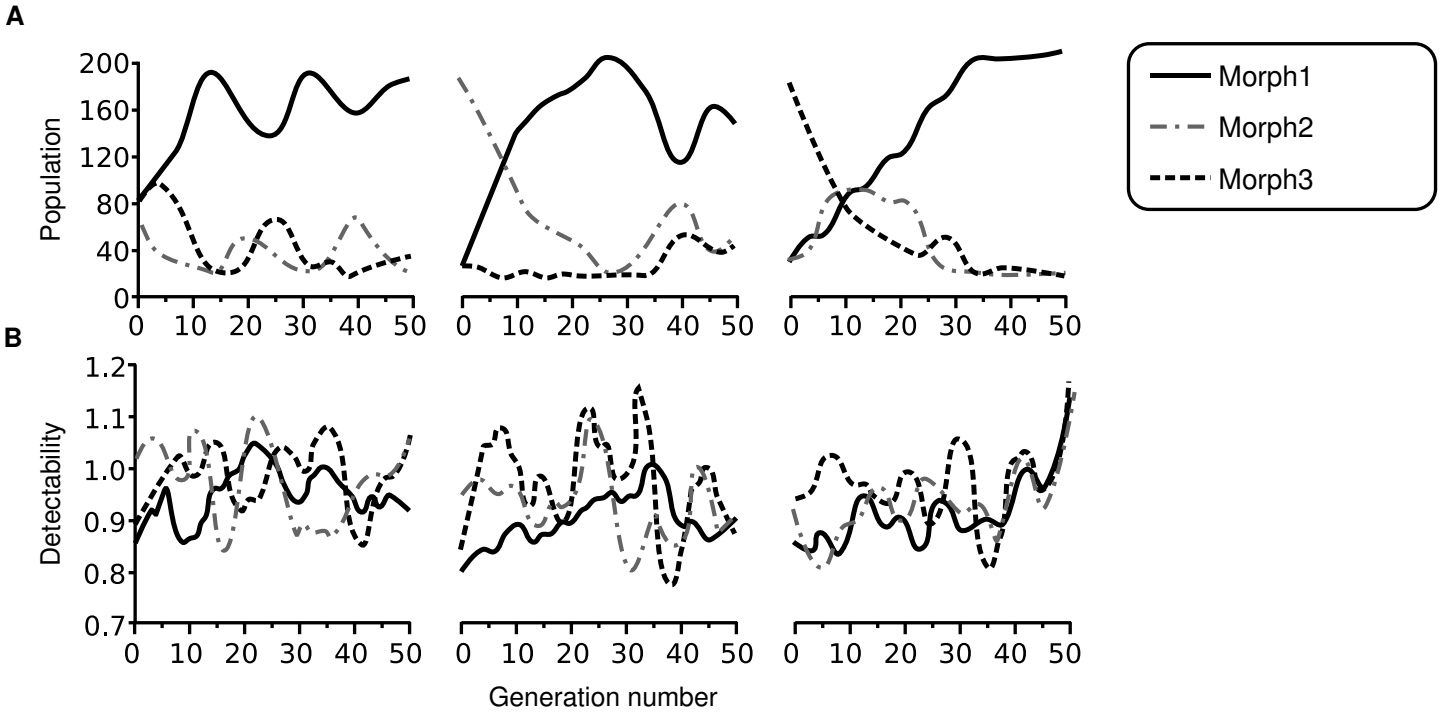
D. An overlap in habitat use between these two similar-sized fiddler crabs has no impact on both signalers and receivers.

Q.83

Three morphs of a polymorphic species of *Catocala* moths differ only in the patterns on the forewings. Six experienced blue jays (*Cyanocitta cristata)* searched for prey on a computer screen in a series of trials.



Each trial involved a screen showing the presence or absence of a moth from three distinct morphs of a moth population. If the bird found the moth, it was rewarded with food. Each bird had 36 prey and 84 no-prey trials and lasted for 50 days. Three replicates were carried out, with the second having a larger population of morph 2 and third replicate starting off with a larger relative abundance of morph 3.



A, Population numbers of the three morphs. **B**, Prey detectability

Indicate in the answer sheet if each of the following statements is true or false.

A. Morph 1 was the most cryptic morph.

B. Relative numbers that escaped detection determine the abundance of each prey type.

C. Preferential feeding behavior of the blue-jays of the most prevalent morph maximizes their foraging success.

D. Polymorphisms are maintained in the population through frequency-dependent selection by predators.

GENETICS AND EVOLUTION

Q.84

An organism has four genes, A, B, C and D with two alleles each. An individual heterozygous for these genes was bred with one that is homozygous recessive. The cross produced 3288 offspring with phenotypes shown in the table below:

Phenotypes	Number of individuals
ABCD	675
ABCd	83
ABcD	1
ABcd	74
AbCD	73
AbCd	1
AbcD	84
Abcd	670
aBCD	655
aBCd	86
aBcD	1
aBcd	73
abCD	71
abCd	1
abcD	87
abcd	653

Indicate in the answer sheet if each of the following statements is true or false.

A. The four loci are genetically linked.

B. The distance between gene B and gene D is 9 cM.

C. The distance between gene D and gene C is 10.5 cM.

D. Interference happened with a value less than 0.25. Interference = 1-(observed frequency of double crossover/expected frequency of double crossover).

Q.85

A plant is normally red-flowered. Plant breeders obtained three genetically different pure mutated lines of white-flowered plants (designated as a, b and c). They performed crosses and observed progeny phenotypes as follows:

Cross	Parent	Progeny
1	line a x line b	F_1 all white
2	line a x line c	F_1 all red
3	line b x line c	F_1 all white
4	red F_1 from cross 2 x line a	1/4 red : 3/4 white
5	red F_1 from cross 2 x line b	1/8 red : 7/8 white
6	red F_1 from cross 2 x line c	1/2 red : 1/2 white

Indicate in the answer sheet if each of the following statements is true or false.

A. Line (a) has only one homozygous mutated gene.

B. Line (b) shares two homozygous mutated genes with line c.

C. Line (c) shares one homozygous mutated gene with line a.

D. Line (b) has three homozygous mutated genes.

Q.86

Indicate in the answer sheet if each of the following statements is true or false.

A. A completely recessive allele is lethal when homozygous. If the dominant allele mutates to the recessive allele at a rate of 10^{-6}, then the frequency of the lethal allele when the population reaches mutation-selection equilibrium is 0.001.

B. If the frequency of a completely recessive lethal allele is 0.2 and it remains unchanged from generation to generation due to the superior fitness of heterozygotes, then the intensity of selection against the dominant homozygotes should be 0.025.

C. Selection for recessive alleles is less effective than selection against recessive alleles.

D. In a large, randomly mating population, the frequency of an autosomal recessive lethal allele is 0.2. The frequency of this allele in the next generation will be 0.07 if the lethality takes place before reproduction.

Q.87

Indicate in the answer sheet if each of the following statements about cancers is true or false.

A. A particular type of colon cancer can be caused by recessive alleles even though its inheritable pattern appears similar to that of a dominant trait.

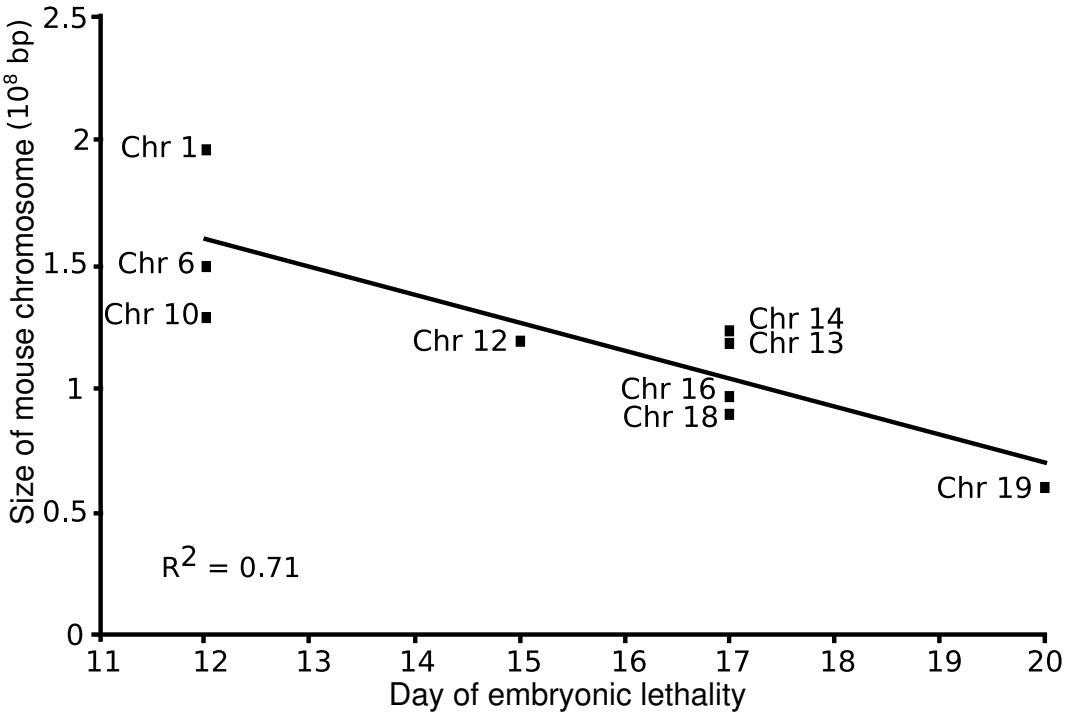
B. In one patient, normal cells have only one mutated *p53* allele but cancer cells have two identical mutated *p53* alleles. Then it can be concluded that the second mutated *p53* allele is formed by gene conversion.

C. Some cancers have been effectively treated with drugs that cause demethylation. Then it can be concluded that genes causing those cancers are more likely to be oncogenes.

D. Chromosome inversions can produce novel oncogenes.

Q.88

Mouse embryos that were trisomic for each of the 20 different chromosomes were monitored during embryonic development. Their survival time was plotted against the size of trisomic chromosome in **Fig.Q.88**.



Based on this information, indicate in the answer sheet if each of the following statements is true or false.

A. Chromosome 19 likely encodes fewer transcripts than other chromosomes shown in the graph.

B. The total amount of genetic material of the additional chromosome solely determines the severity of the defects associated with the chromosome imbalance.

C. Assuming that genes on chromosome 1 and 10 have similar contribution to embryo development, gene density on chromosome 1 is probably lower than that on chromosome 10.

D. Genes on chromosomes 12 are probably more important for embryo development than those on chromosome 13.

Q.89

mRNAs in the cytoplasm of eukaryote cells frequently form closed loops by circularization. Indicate in the answer sheet if each of the following statements concerning closed loops is true or false.

A. Circularization is due to a phosphodiester bond between the 5’end and the 3’end of mRNA.

B. Circularization increases stability of mRNAs.

C. Circularization enhances translocation speed of the ribosomes.

D. Controlling circularization is a mechanism of post-transcriptional regulation.

Q.90

Pedigrees 1-4 show the inheritance of four different **rare** disorders. It is known that the disease in pedigree 4 is X-linked recessive.

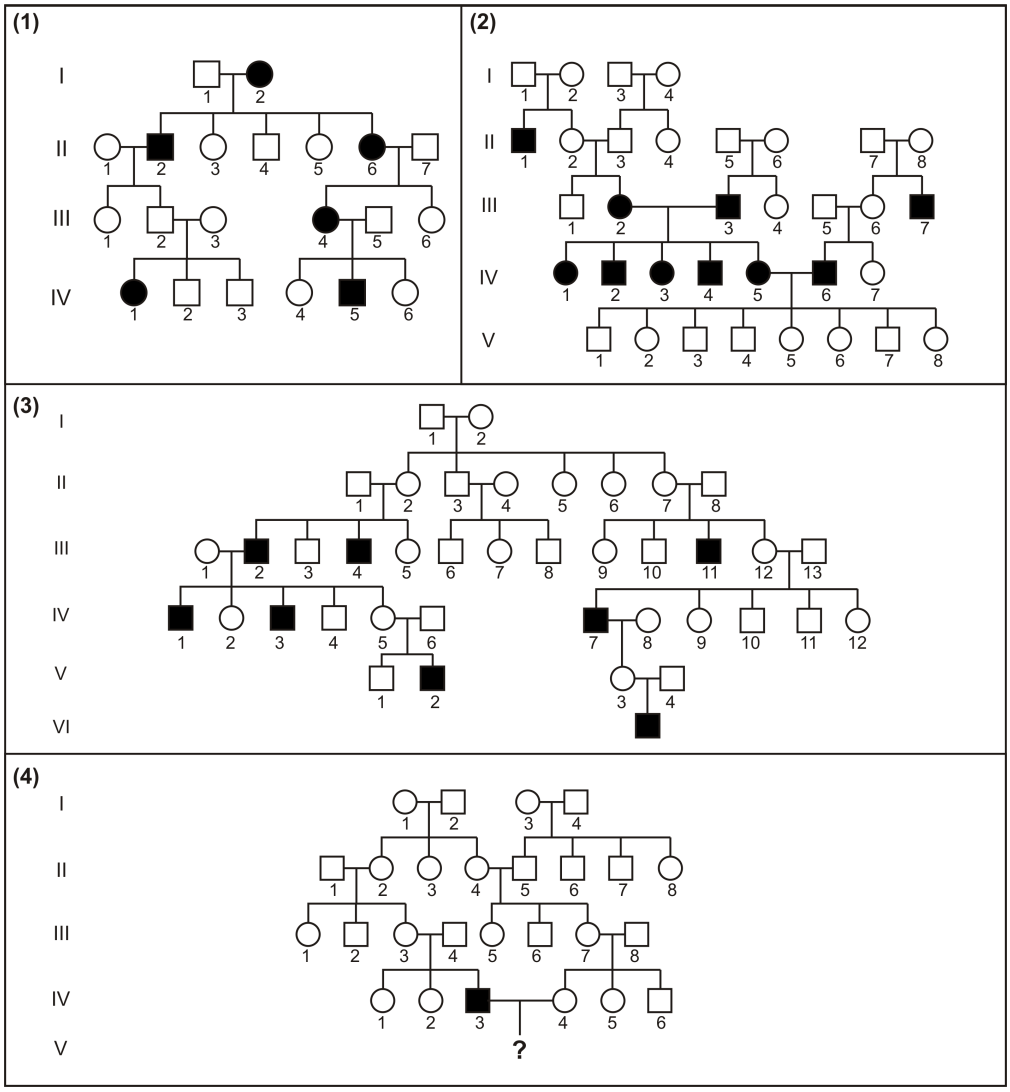


Figure Q.90

Studying the pedigrees and indicate in the answer sheet if each of the following statements is true or false.

A. The disorder in pedigree 1 is most likely caused by a recessive allele.

B. Person III_2 and III_7 in pedigree 2 have the same genotype.

C. Pedigree 3 shows the inheritance of the disorder can be caused by a recessive allele on X-chromosome.

D. If the affected man and his unaffected wife in pedigree 4 have a son then the probability of this son be affected is 0.125.

Q.91

Polymorphic DNA sequences are widely used for molecular identification. Short tandem repeat (STR) is composed of multiple repeats of 2-8 nucleotides flanked by two conserved sequences. Each STR locus normally has more than two alleles. Single nucleotide polymorphism (SNP) is a variation at a single position in a DNA sequence among individuals. Each SNP usually has only two alleles. Seven individuals were genotyped for two autosomal and two mitochondrial (mtDNA) SNPs, two autosomal and two Y-linked (NRY) STRs (**Table Q.91**).

	Autosomes				NRY		mtDNA	
Individuals	SNP1	SNP2	STR1	STR2	STR1	STR2	SNP1	SNP2
Ind_1	A/A	A/A	13/15	18/20	13	12	C	A
Ind_2	A/C	A/G	12/14	18/21	13	15	T	A
Ind_3	C/C	A/G	14/15	18/21	13	15	C	G
Ind_4	A/C	G/G	13/15	19/19	11	14	T	G
Ind_5	C/C	A/G	14/15	18/19	-	-	C	G
Ind_6	A/C	G/G	14/14	18/19	-	-	T	G
Ind_7	C/C	G/G	14/16	19/21	-	-	C	A

Table Q.91

Indicate in the answer sheet if each of the following statements is true or false.

A. If the same number of SNPs or STRs are used, SNPs are better than STRs for distinguishing individuals.

B. Ind_6 is more likely a child of Ind_2 and Ind_5 than Ind_3 is.

C. Ind_4 is possibly a brother of Ind_6.

D. It is possible that Ind_7 is a granddaughter of Ind_1 and Ind_6.

Q.92

A wildtype female *Drosophila* was mated with a wildtype male that had been X-ray irradiated. One of the F1 females was mated with a male that had recessive phenotype (caused by recessive allele a). Progenies of the second mating were unusual in two aspects. Firstly, there were twice as many females as males. Secondly, while all the males were wild type, ½ of the females were wild type, and the other ½ exhibited the recessive phenotype a.

Indicate in the answer sheet if each of the following statements is true or false.

A. X-rays converted a dominant allele (A) on the chromosome X, coding for wild type, to a recessive allele (a).

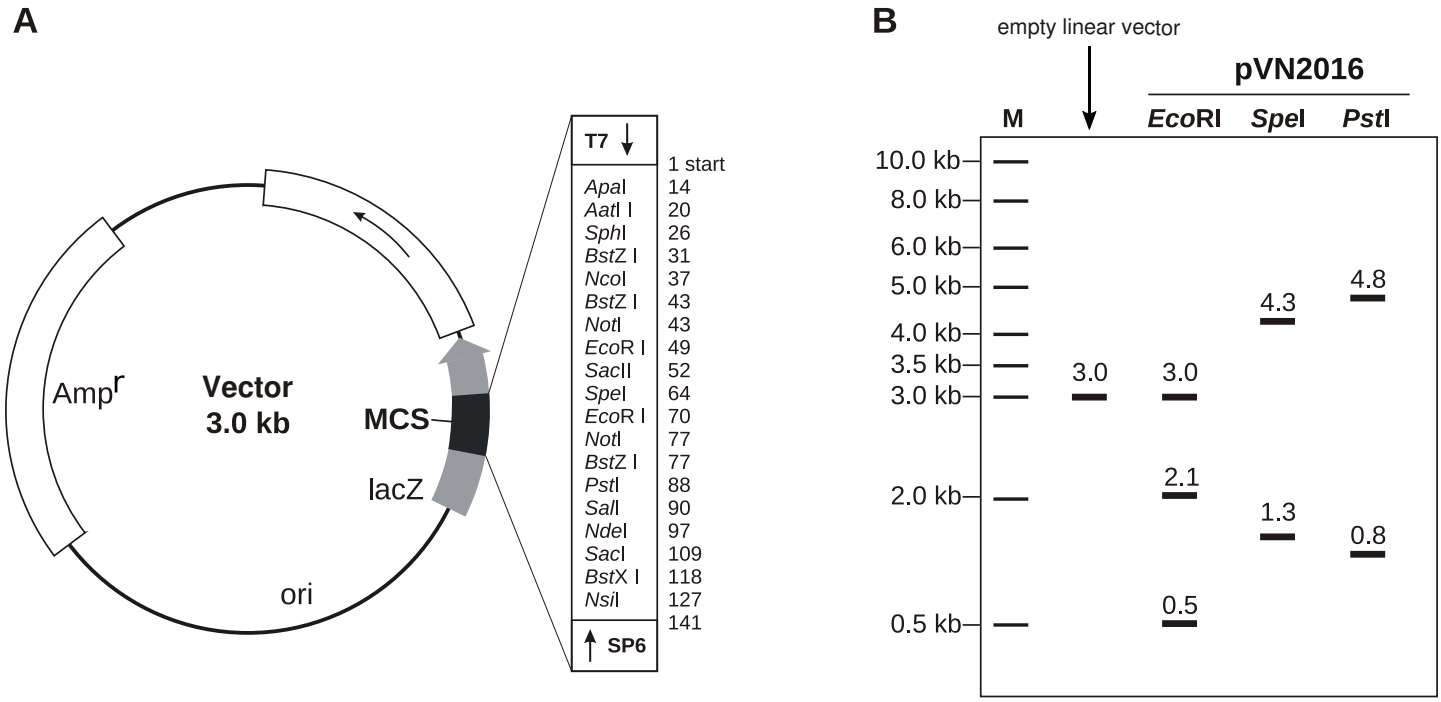
B. X-rays produced a chromosomal translocation.

C. A loop might be seen on one pair of chromosomes during prophase of meiosis 1 in the mated F_1 female.

D. If a female from the second mating exhibiting recessive phenotype (a) was crossed to a wild type male then her progenies compose of females and males at the ratio of 2 females to 1 male.

Q.93

Mr. Trung cloned a coding sequence (CDS) of a gene into a vector and named the resulted plasmid as pVN2016. The CDS was inserted at the *Sac*II recognition site which is located in the multi cloning site (MCS) region within the *lacZ* gene of the vector (**Fig.Q.93A**). The inserted CDS has a *Pst*I restriction site located 0.8 kb upstream of its stop codon. To identify the size and direction of the inserted CDS, Mr. Trung digested this plasmid with different restriction enzymes, and the results of the digestions are shown in **Fig.Q.93B**.



(A) A schematic map of the vector, numbers indicate positions of restriction enzyme recognition sites located in the vector
(B) A schematic electrophoresis of digestive products using different restriction enzymes, M: 1 kb DNA ladder.

Based on above data, indicate in the answer sheet if each of the following statements is true or false.

A. The CDS is 2.6 kb in length and has an *Eco*RI recognition site at about 0.5 kb from one of its ends.

B. *Spe*I can be used to determine the orientation of the CDS.

C. The CDS is oriented in the same direction as *lacZ*.

D. If plasmid pVN2016 is digested by both enzymes *Spe*I and *Eco*RI in Tango buffer (*Eco*RI and *Spe*I cut at 100% and 20% efficiency, respectively), five fragments of 0.5, 0.8, 1.3, 2.1 and 3.0 kb could be detected by gel electrophoresis assuming that fragments smaller than 50 bp are not visible.

ECOLOGY

Q.94

Scientists constructed models for four threatened tree species in sub-tropical forests in Vietnam, and used these models to estimate tree ages (**figure Q.94**). Tree age is measured by ring count and trunk diameter at breast height (DBH). Rates of growth were categorised using changes in DBH from 10 to 1000, with 1000 at the finest-grain measure of change.

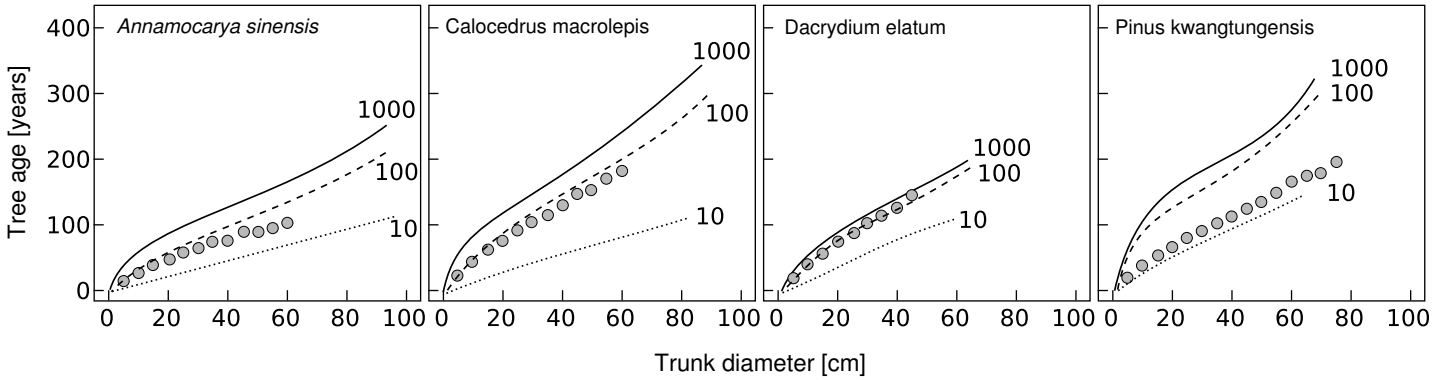


Figure Q.94. Estimated (lines) and observed (circles) ages for DBH categories of four tree species.

Indicate in the **Answer sheet** if each of the following statements is True or False.

A. Using the smallest category gives the most accurate information of tree age of *P. kwangtungenesis*.

B. Age estimates increase particularly strongly from 100 to 10-category model in *D. elatum*.

C. Model with just 10 DBH categories underestimate the observed ages for three species.

D. For *D.elatum,* measuring DBH using either 100 or 1000 will give an accurate estimate of tree age, whereas to estimate the age of *C. macrolepis,* only 100 gives a reliable estimate.

Q.95

To understand the effects of several factors on plants (*Agrimonia rostellata* and *Trillium erectum*) in forest ecosystems, students transplanted seedlings into experimental sites and observed the proportion of surviving seedlings growing with native or non-native vegetation, with or without slugs, and with low or high earthworm density. The results are shown in the figure below.

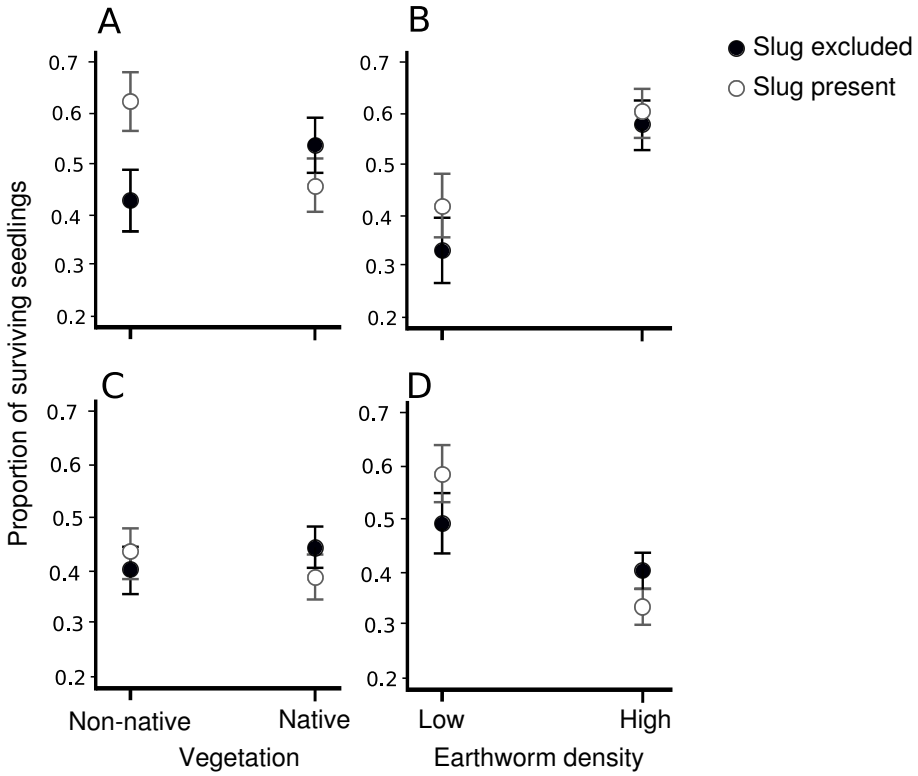


Figure Q.95 Proportion of surviving seedlings. *Agrimonia rostellata* (A, B) and *Trillium erectum* (C, D)

Indicate in the **Answer sheet** if each of the following statements is True or False.

A. Slug exclusion has a positive effect on the survival of *Agrimonia rostellata* and *Trillium erectum* in high earthworm density.

B. Slug effects are dependent on other stressors, especially on interactions with non-native plants and earthworms.

C. Earthworms have positive effects on *Agrimonia rostellata* and *Trillium erectum*.

D. Non-native plants and slugs synergistically decrease seedling survival through increased competition and consumption.

Q.96

Students cultured plants, including four grass species (*A. capillaris, A. odoratum, F. rubra*, and *H. lanatus*) and four herbs (*C. jacea, L. vulgare, P. lanceolata,* and *R. acetosa*) without legumes, in different blocks with treatments of monoculture and mixtures of two, four or all eight species. They then measured different parameters as functions of plant species richness, as shown in the figure below. Values are shown in $\log_2$ scale.

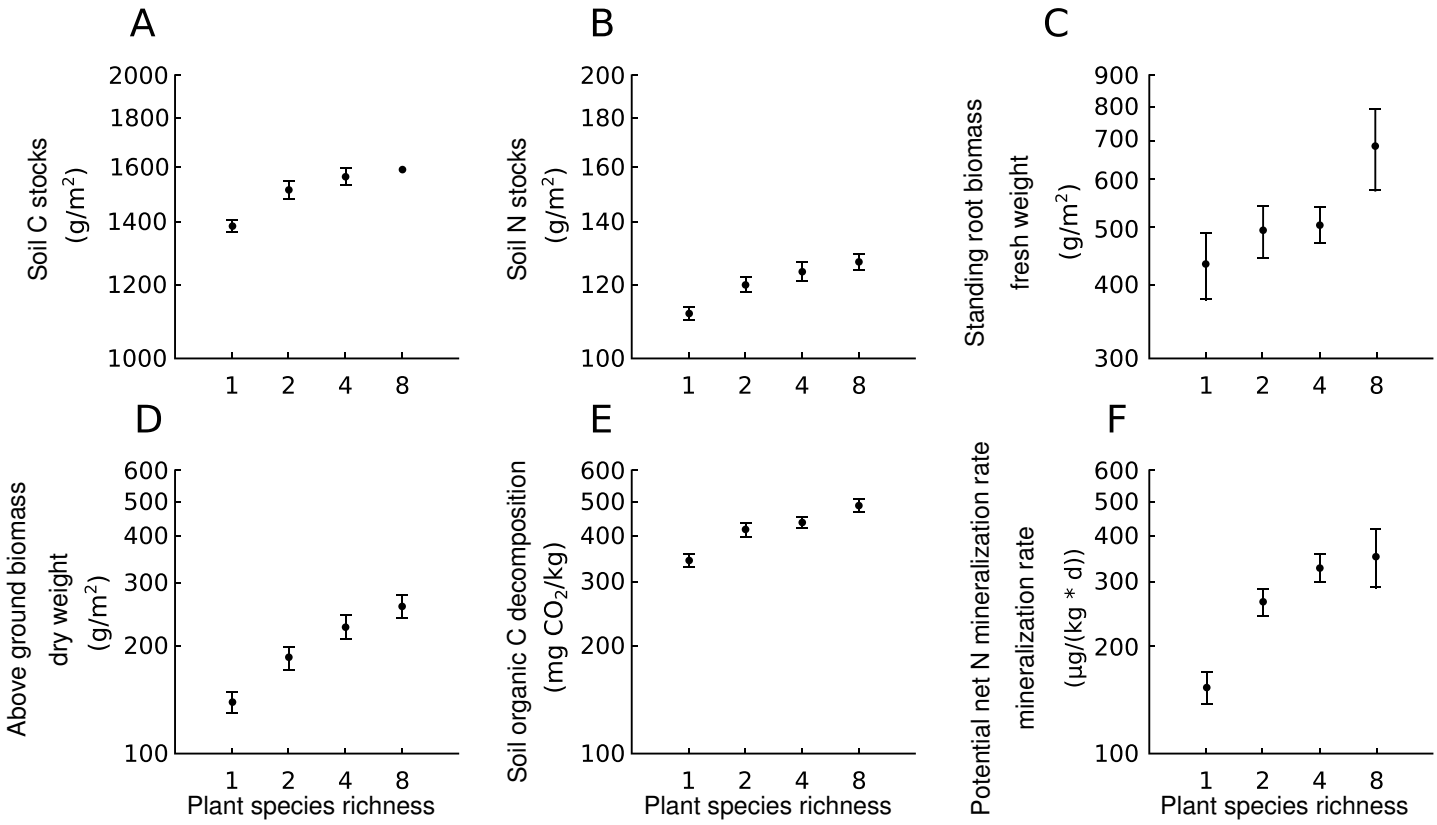


Figure Q.96

Indicate in the **Answer sheet** if each of the following statements is True or False.

A. Above ground biomass increases but root biomass decreases with the increase of species richness.

B. Plant species richness promotes soil C stocks mainly through enhanced plant productivity, despite accelerated soil organic C decomposition.

C. Greater soil N stocks at higher species richness is mainly attributed to increased N retention, rather than N input, with enhanced plant productivity.

D. More diverse ecosystems can increase the potential for C sequestration in terrestrial ecosystems.

Q.97

A rocky shore contains many shallow rock pools dominated by macroalgae and grazing gastropods, comprising primarily *Patella ulyssiponensis* (P), *Littorina littorea* (L) and *Gibbula umbilicalis* (G). The experiment is designed to test the interaction between grazer species and the additive interaction with nutrient enrichment. Pools contained either none, one, two or all three of grazer species at realistic densities (*Patella*, *Littorina* and *Gibbula*). Another complete set of all the manipulation grazer treatments was also established concurrently where nutrient concentrations were enhanced to compare the simultaneous effects of grazer treatments at ambient and enriched nutrient conditions. Gross ecosystem productivity (GEP), number of algal taxa, and the biomass (dry weight) of all algal species were measured.

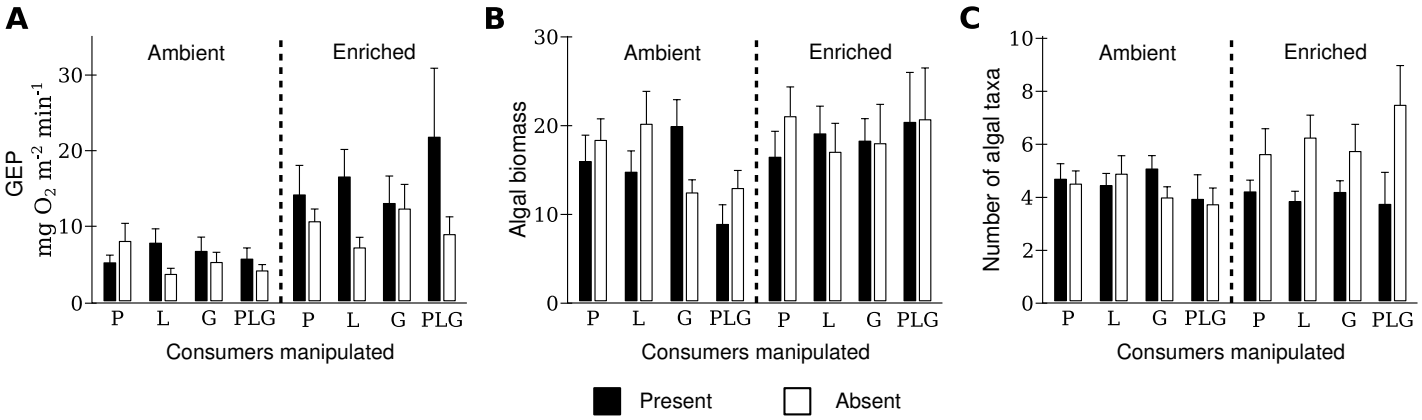


Figure Q.97

Indicate in the **Answer sheet** if each of the following statements is True or False.

A. Gross ecosystem productivity is enhanced by nutrient enrichment and is greater in pools where *Littorina* is present.

B. The effects of grazer species loss on accumulated algal biomass are regulated by nutrient conditions, grazer identity and grazer diversity.

C. The effects of loss of grazer species on ecosystem functioning depend upon both the diversity and identity of the species present.

D. The presence of all grazers results in lower algal diversity and biomass in both nutrient conditions.

Q.98

Gall aphids (*Pemphigus betae*) live in poplar plants. Adult females produce galls on poplar leaves. Some fraction of these galls will emerge and survive to adulthood. Female aphids complete their life cycle after laying eggs in the leaves. All the progeny of a single female aphid are contained in one gall. A student recorded observation on several aphid populations, shown in the table below. All environmental parameters are assumed constant.

Population	Number of aborted galls	Number of successful galls	Female/Male ratio in adult stage
1	35	70	1/1
2	25	75	1/2
3	21	63	Not given
4	16	32	1/1

An equation representing number of female aphids in t^{th} generation is established as below:

$$N_t = [f \times r \times (1\text{-}m)]^t \times N_o$$

Whereas:
N_t – number of adult female aphids in the t^{th} generation
N_o – number of adult female aphids in the initial generation
m – fraction mortality of the young aphids
f – number of progeny per female aphid
r – ratio of female aphids to total adult aphids.
Theoretically f, m and r are constant.

Indicate in the **Answer sheet** if each of the following statements is True or False.

A. Population 1 has a constant number of adult females across generations when each female produces 4 progeny.

B. When every female in population 2 produces 3 progeny, this population will have a constant number of adult females across generations.

C. When population 3 has a constant number of adult females across generations and each female aphid produces 4 progeny, the female/male ratio of the population in adult stage is 1/2.

D. Given that each female in population 4 produces 6 aphids and taking the offspring of population 4 to be in the first generation, the number of adult females in the third generation will be 384.

BIOSYSTEMATICS

Q.99

Information about the relationships among organisms is a useful source of data for scientists investigating a wide variety of biological questions. Indicate in the answer sheet if each of the following statements about using the phylogenetic trees is true or false.

A. Phylogenetic trees can be used to determine how many times a particular trait independently evolved.

B. Phylogenetic trees can suggest whether a particular trait is the ancestral one.

C. Phylogenetic trees can be used to determine the timing of evolutionary lineage splits.

D. Phylogenetic trees can be used to determine the virus’s origins in human populations.

Q.100

The analysis of DNA and protein sequences nowadays is widely used in constructing phylogenetic trees. Indicate if in the answer sheet each of the following statements is true or false.

A. The number of differences in a nucleotide sequence of two species increases with time that has passed since the species split from a common ancestor.

B. If the same protein of two related species are different at only one amino acid, then multiple substitutions might have occurred since the two species split.

C. rRNA sequence analysis is useful for phylogenetic relationship among species within a genus.

D. Pseudogenes can be used for constructing phylogenetic trees.

END OF THEORY PART B