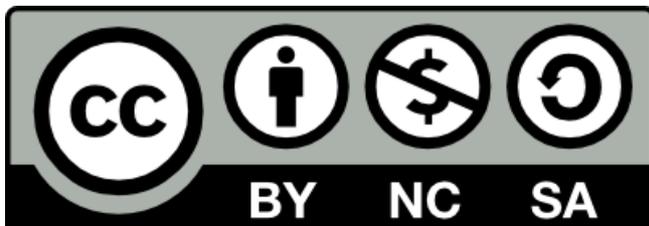




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# 25th INTERNATIONAL BIOLOGY OLYMPIAD

5 – 13 July, 2014

INDONESIA



## THEORETICAL TEST PART B QUESTION PAPER

Total points: **48**

Duration: 180 minutes

|                    |       |
|--------------------|-------|
| <b>COUNTRY:</b>    | ..... |
| <b>STUDENT ID:</b> | ..... |

**INSTRUCTIONS:**

1. Fill in your STUDENT ID and your country in the Answer Sheet.
2. Each question contains four statements which you must indicate as True or False.
  - If you answer correctly to all four statements, you will receive 1 point.
  - If you answer correctly to only three statements, you will receive 0.6 point.
  - If you answer correctly to only two statements, you will receive 0.2 point.
  - If there is only one statement with the correct answer, you will not receive any points (0).
  - There is no minus system.
3. Tick (√) the correct answer in your Answer Sheet using a pen (in ink). If you need to change an answer, you should strikethrough the wrong answer and write in the new one (see the example below). In the table, T=True, F=False.

| No. | Statement | T            | F            |
|-----|-----------|--------------|--------------|
| 1.  | A         |              | √            |
|     | B         | <del>√</del> | √            |
|     | C         | √            |              |
|     | D         | √            | <del>√</del> |

4. You may use a calculator in your exam.
5. GOOD LUCK.

**CELL AND MOLECULAR BIOLOGY**

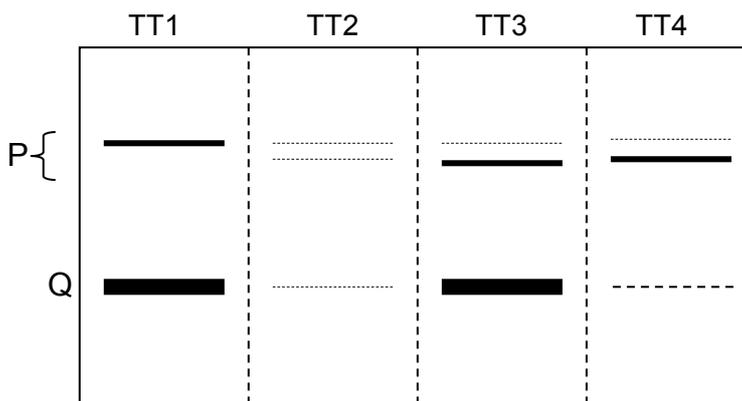
1. In order to study translation and translocation of proteins P and Q (both monomeric), *in vitro* experiments were carried out by Guenther Blobel and colleagues that eventually led to the Noble Prize in medicine. The following cell-free preparations were first obtained:

- Preparation I(A): Isolation of functional ribosomes to which protein P synthesizing mRNA was still attached.
- Preparation I(B): Isolation of functional ribosomes to which protein Q synthesizing mRNA was still attached.
- Preparation II: Isolation of microsomes [ER fraction] free from mRNA and ribosomes.
- Preparation III: Isolation of ribosomal subunits containing translation initiation factors.

The reaction mixtures were prepared in test tubes 1-4 as shown in the table below and the proteins synthesized were analyzed by SDS polyacrylamide gel electrophoresis followed by autoradiography.

| Test Tube [TT] No.   | 1 | 2 | 3 | 4 |
|--|---|---|---|---|
| Preparation I (A)  | + | + | + | + |
| Preparation I (B)  | + | + | + | + |
| Preparation II   | - | - | + | + |
| Preparation III  | + | + | + | + |
| Radiolabelled amino acids and other factors required for translation | + | + | + | + |
| Protease   | - | + | - | + |

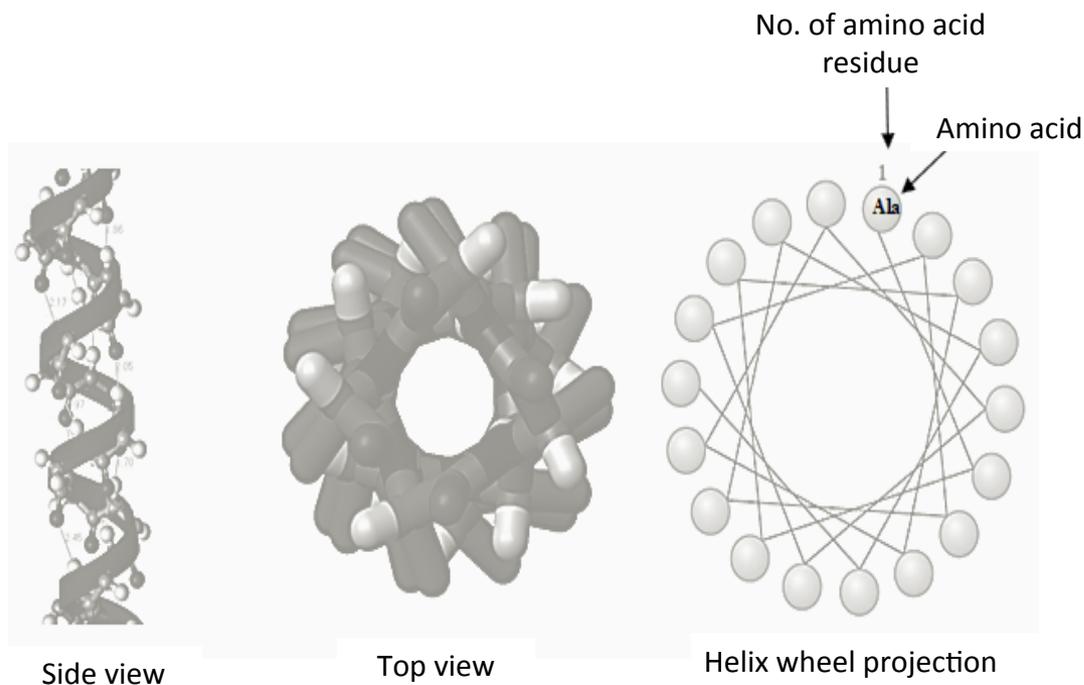
Results of autoradiography analysis are shown below.



**Indicate whether the following statements are true or false.**

- A. Protein Q is post-translationally modified.
- B. Protein P has a signal peptide sequence.
- C. Protein Q is most likely to be cytoplasmic protein.
- D. Protein P could be a secreted protein.

2. A helix-wheel projection is a model of amino acid sequences of the alpha helix domain of a protein. The model can be used to show the distribution of amino acid residues along with its hydrophobicity throughout the helix. Reading the model is like looking at the helix vertically from the top so the helix will appear as a circle. The side group of each amino acid residue will face outwards as shown in **Figure 2.1**:



**Figure 2.1.** side view, top view, and helix-wheel projection of an alpha-helix protein

A full circle of a helix consists of 3.6 amino acid residues. The following sequences show one alpha helix domain consisting of 18 amino acids from three different proteins (A-C). Information about the hydrophobicity of all 20 common amino acids is shown in **Figure 2.2**.

Protein A : MLQSMVSLQLVSSIIQ

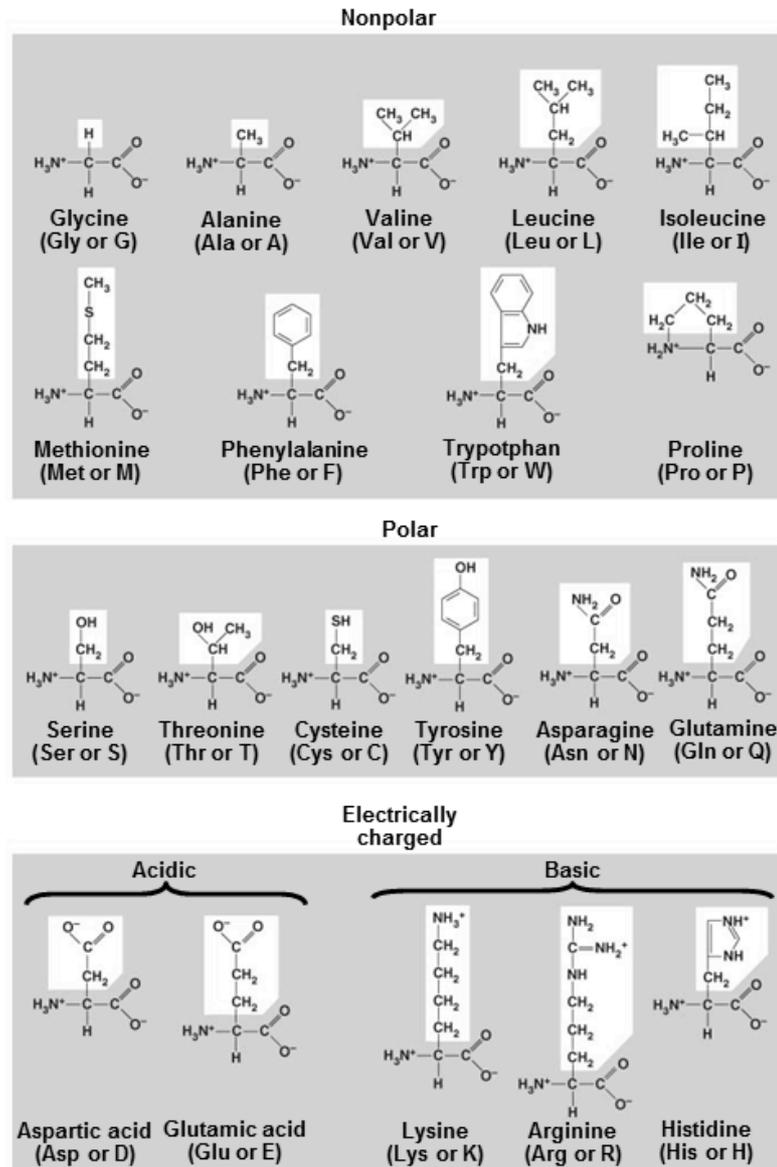
Protein B : TGAAAYAVVLFIMAYYMS

Protein C : KSSRKTPKKATARKSQRT

**You will be provided with an extra sheet of paper with empty helix wheel projections for fragments of proteins A, B, C**

**Indicate whether the following statements are true or false.** An alpha helix:

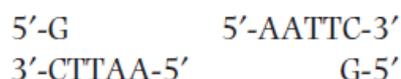
- similar to the one in protein A can be found in the transmembrane region of water-channel proteins i.e. aquaporins.
- similar to the one in protein C can be found in the outer surface of cytosolic proteins.
- similar to the one in protein C is amphipathic.
- similar to the one in protein B might be found in the transmembrane domain of a receptor.



**Figure 2.2.** Structure of 20 common amino acids

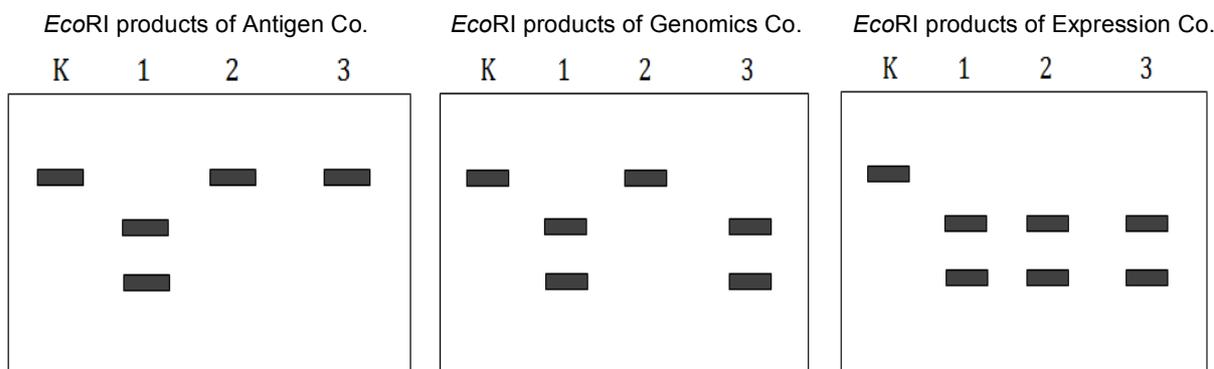
3. A researcher was asked to evaluate the purity of three *EcoRI* restriction enzymes from three different companies (Antigen Co., Genomics Co., and Expression Co.). Some contaminant enzymes which were thought to be present in the *EcoRI* tubes were exonuclease and phosphatase. Exonuclease cuts the overhang base (single strand) from the restriction product of *EcoRI* while phosphatase removes the free phosphate group on the 5' end of a DNA strand. The evaluation was performed in three steps:

- Step I: Plasmid X which contains two *EcoRI* restriction sites was incubated with *EcoRI* from each of the three companies, resulting in 5'-P-overhang.



- Step II: Plasmid X from step I was ligated again using DNA ligase.
- Step III: The ligated plasmid X was once again cut by *EcoRI* from the respective company.

The researcher ensured that he performed the reactions so well that there was no partial digestion. The resulting fragments from each step were then analyzed by gel electrophoresis shown below.



■ = DNA band

K = Control, plasmid X without cutting by *EcoRI*

1 = DNA fragment from results of Step I

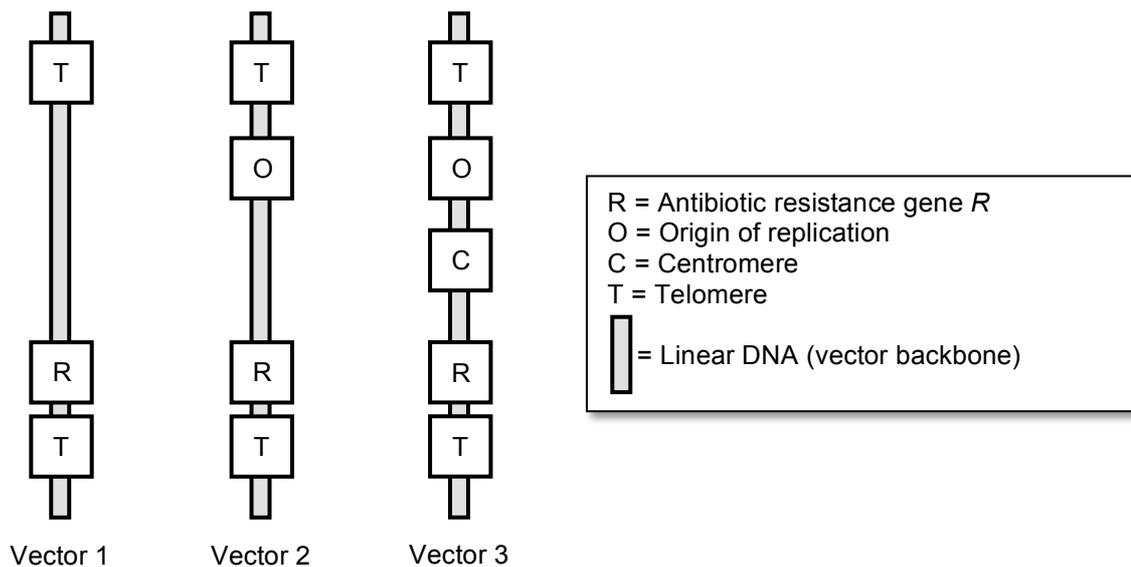
2 = DNA fragment from results of Step II

3 = DNA fragment from results of Step III

**Indicate whether the following statements are true or false.**

- EcoRI* from Expression Co. contains exonuclease as contaminant.
- DNA ligase only joins overhanging DNA ends.
- EcoRI* from Antigen Co. contains phosphatase as contaminant.
- EcoRI* from Genomics Co. is free from exonuclease and phosphatase as contaminant.

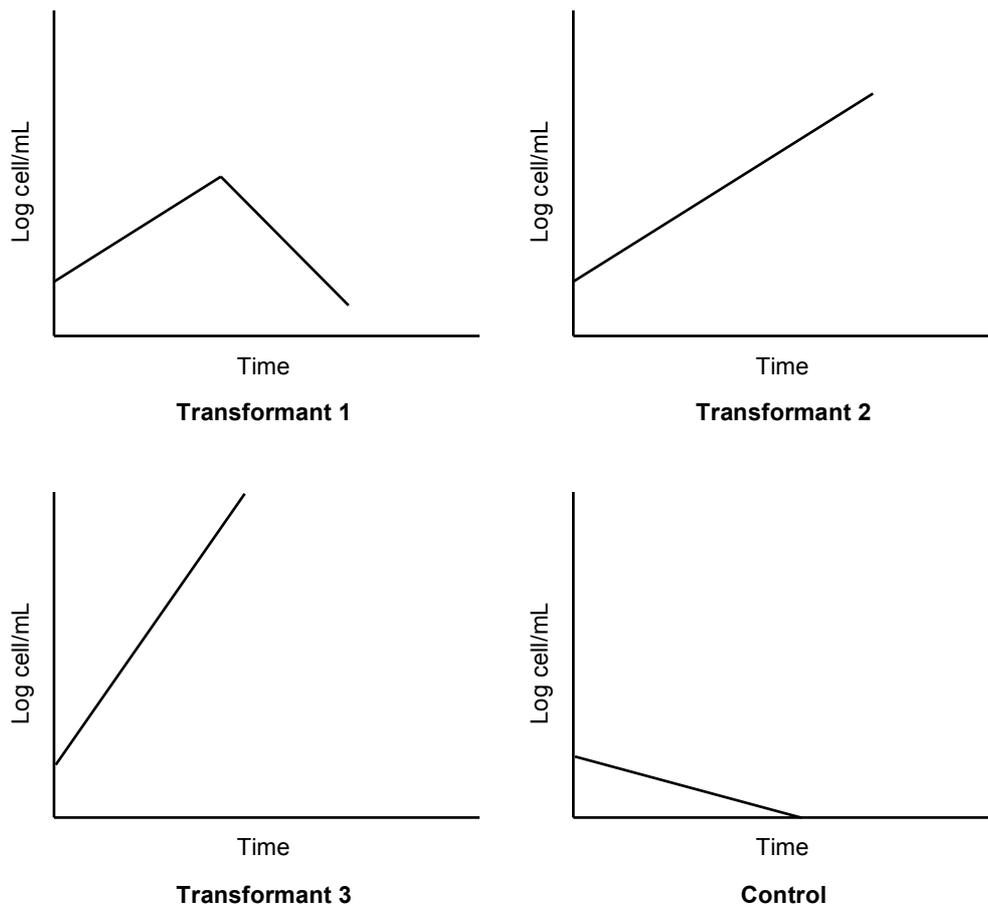
4. The diagram below shows three DNA vectors containing an antibiotic resistance gene, *R*.



You then transformed each of the vectors into a yeast culture in three following steps:

- Step I: Three batches of competent yeast cells were made.
- Step II: Each batch was mixed with one of the vectors and transformed
- Step III: Transformed yeast cells were then grown in selective liquid culture containing the antibiotics and the cell concentration (cell/mL) was measured. As a control, untransformed yeast culture was used. The initial cell concentration for each transformed culture and the control was set at the same value.

Growth of the yeast cultures is shown on the graphs below. All axis are on the same scale for each graph. Transformant 1, 2, and 3 were transformed by Vector 1, 2, and 3, respectively.



**Indicate whether the following statements are true or false.**

- A. In Transformant 2, the vector was not evenly distributed during cell division. Only the daughter cells containing Vector 2 were able to survive and grow.
- B. In Transformant 3, daughter cells containing more copy of Vector 3 than the parent cells can be found.
- C. The inheritance of Vector 1 into each daughter cells of Transformant 1 only happened at the initial stage of cell growth in the liquid culture.
- D. The presence of centromeres and telomeres in Vector 3 helps the vector to be completely inherited from the parent cells by the daughter cells.

5. Five intracellular molecules A, B, C, D, and E are normally synthesized at a constant rate of 1000 molecules/second but with different lifetimes or survival rates inside the cell. The lifetimes of molecule A = 300 s, B = 200 s, C = 100 s, D = 50 s, and E = 10 s. The presence of signal X increases the synthesis rate of all five molecules by ten times without changing their lifetime.

**Indicate whether the following statements are true or false.**

- A. E has the highest intracellular concentration at the steady-state
- B. The number of molecule B at the steady-state is 200,000.
- C. One second after signaling by X, molecule A will have the largest increase in concentration.
- D. One second after signaling by X, the amount of E is less than twice as much as the steady state.

6. Graft rejection often occurs following organ transplantation. The donor organ is damaged by the recipient's immune response which rejects the foreign antigen present on the organ. However, there is almost no case of graft rejection during transfusion of blood with the same blood type.

**Indicate whether the following statements are true or false.**

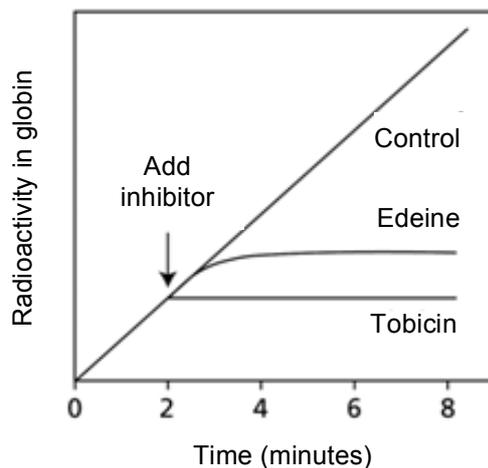
- A. Red blood cells can be recognized by recipient's Natural Killer (NK) cells but are not killed due to presence of inhibitory molecule at the surface.
- B. Most proteins present on the surface of red blood cells are similar between different individuals.
- C. Red blood cells do not contain MHC I proteins.
- D. During whole blood transfusion, only the cellular component is transferred but not the plasma component.

7. *Helicobacter pylori* is a Gram-negative pathogenic bacterium which causes gastritis, stomach and duodenal ulcers. Its ability to colonize hostile environments within the stomach cavity is due to production of several virulence factors. At the initiation stage of infection, *H. pylori* secretes urease which acts as pH buffer to survive in the acidic environment. Urease also helps modify the mucus layer of the stomach by reducing its viscosity hence and facilitates bacterial penetration into the stomach epithelial cells. Another virulence factor produced by *H. pylori* is type-IV secretion system. This structure injects the bacterial toxin into the host epithelial cells.

**Indicate if each of the following statements is true or false.**

- A. *H. pylori* is an acid tolerant, not an acidophilic bacteria.
- B. Concentrations of the CO<sub>2</sub> and ammonia in the stomach correlate with the abundance of *H. Pylori*
- C. Before injecting the toxin *H. Pylory* is able to specifically recognize the epithelial cells
- D. Type IV secretion system of *H. pylori* is homologous with cilia in *Paramecium*.

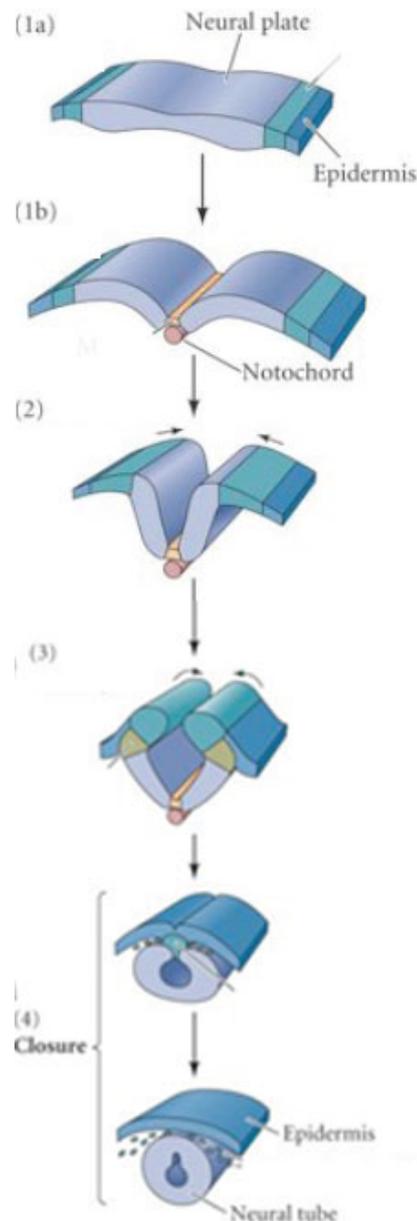
8. Prof. Tobi successfully isolated two new antibiotic candidates, **tobicin** and **edeine** from two different bacterial cultures and studied the effects on protein synthesis by detecting the presence of radioactive amino acid residues in globin using reticulocyte lysate (cell-free translation system), globin mRNA, and radioactive amino acids. The figure below suggests that these two antibiotics work by inhibiting protein synthesis. The arrow indicates the addition of inhibitor at a concentration of 10 microM. No inhibitor was added for the control.



**Indicate if each of the following conclusions is true or false based on the result of the experiment**

- A. Tobicin inhibits the elongation of translation.
- B. Edeine is a competitive inhibitor with lower affinity to ribosome than tobricin.
- C. Edeine and tobricin are broad-spectrum antibiotics which inhibit growth of either Gram-positive or Gram-negative bacteria.
- D. Edeine inhibits the initiation of translation.

9. Formation of the neural tube involves a sharp ventral bend as shown in the diagram below. This bend is associated with formation of wedge-shaped cells of the “floorplate”.

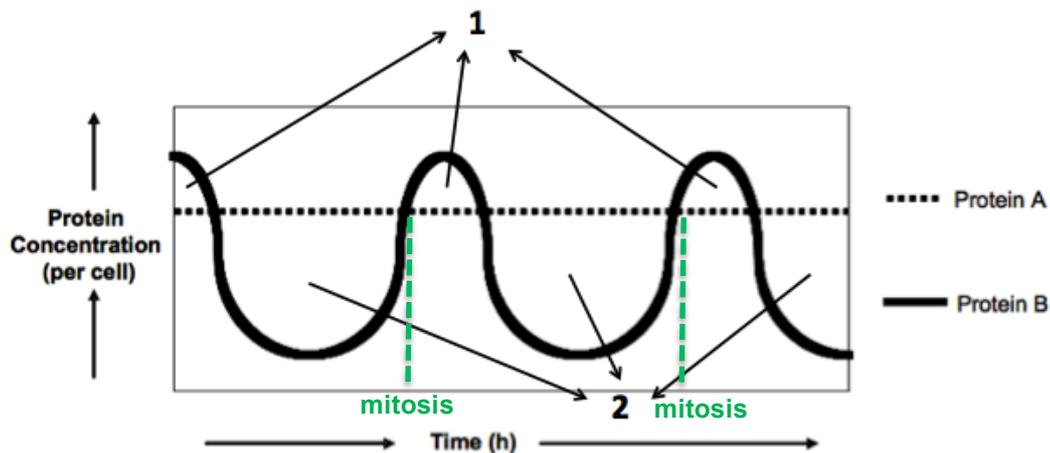


As shown in the diagram above, the floorplate lies above a structure called the notochord.

**Indicate if each of the following statements is true or false.**

- A. If the notochord is removed, invagination of the neural ectoderm will still occur.
- B. Microtubule orientation would be expected to change in the floorplate cells as they become wedge-shaped.
- C. Adding blebbistatin, a chemical which inhibits myosin function, to the developing floorplate, wedge cell formation would continue.
- D. Administration of EDTA disrupts neural tube formation. (EDTA chelates calcium ions).

10. Two temperature-sensitive yeast strains are unable to proceed through the cell cycle at non-permissive temperature. Mutations in both mutants are located in different genes. Analysis shows that a mutation in one strain inhibits the expression of Protein A, while mutation in another strain inhibits the expression of Protein B. Observing the abundance of each proteins in wild-type cells, the following result are seen.



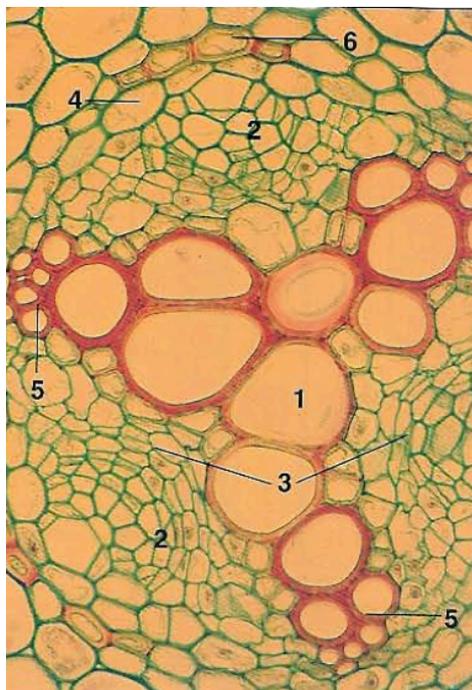
In the wild-type cells, Protein A is a kinase which phosphorylates other proteins. Protein A is only active when Protein B concentration exceeds the concentration of Protein A.

**Indicate if each of the following statements is true or false.**

- The activity of protein A is not regulated by regulation of protein concentration but likely by post transcriptional modification such as phosphorylation
- Yeast cells with mutated Protein B will be arrested at G2-M boundary under non-permissive temperature.
- If a mutant expressed Protein B in high level constitutively, cells are likely to become smaller each generation.
- In human cells, the complex between A and B could be inactivated by tumour suppressor proteins

**PLANT ANATOMY AND PHYSIOLOGY**

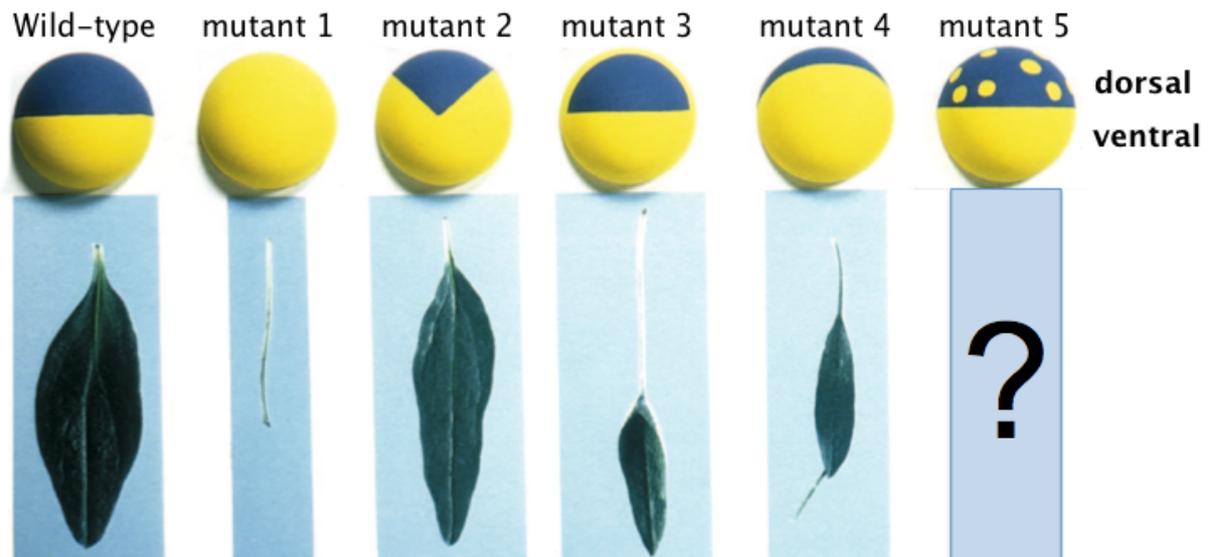
11. The figure shows a representative cross section of an angiosperm plant.



**Indicate if each of the following statements is true or false.**

- A. This structure most likely represents a dicotyledon plant.
- B. Cells of number 5 have thickened walls made of lignin.
- C. Number 2 will differentiate into a lateral root.
- D. Based on physiological age, tissue number 5 is older than tissue number 1.

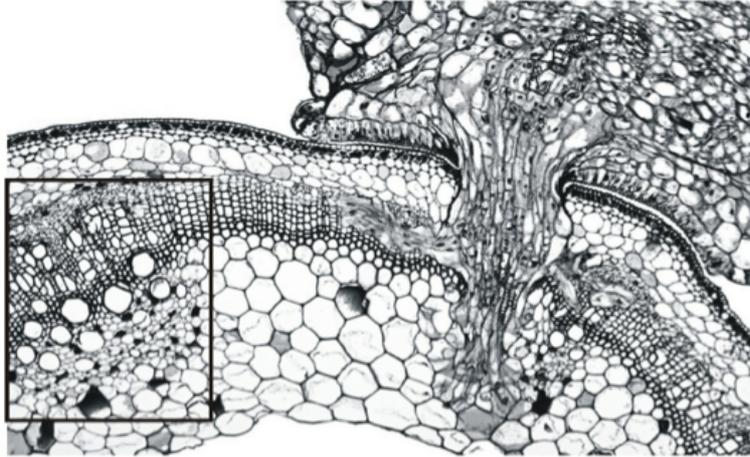
12. Mutation at the *phantastica* (*phan*) locus has been identified and characterized in *Antirrhinum majus*. Each *phan* mutant produces a variety of leaf phenotypes. The figure shows a model developed to study the effect of *phan* mutation and the action of dorsalizing function (DF) in leaf development. Early leaf primordia are depicted as yellow hemispheres viewed from a distal position. Dorsal areas of the primordia experiencing DF expression are coloured blue. Different leaf morphologies are shown below the patterns of expression of *phan* mutants.



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

- These variations show polarity of leaf development.
- The dorsal area of leaf primordia determines the development of laminae.
- The ventralized leaf primordia will result in *phan* mutants lacking laminae.
- If patches of ventral cells are attached on dorsal area shown in mutant 5, it will result in *phan* mutants lacking laminae.

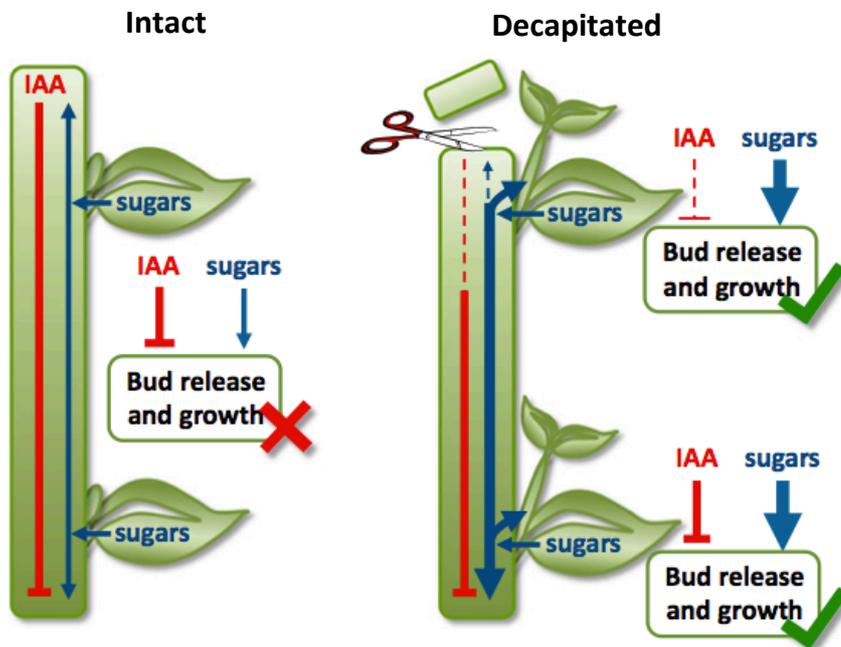
13. The figure shows a cross section of parasitic plant haustoria penetrating the vascular bundle of the host plant. The intact vascular bundle is shown in the inserted diagram.



**Indicate if each of the following statements is true or false.**

- A. This parasitic plant is probably photosynthetic, because its haustoria penetrate the host's phloem only.
- B. The haustorium of this parasite is a modified leaf.
- C. The interaction of the host and parasite is likely to be obligate.
- D. The host plant is a dicot.

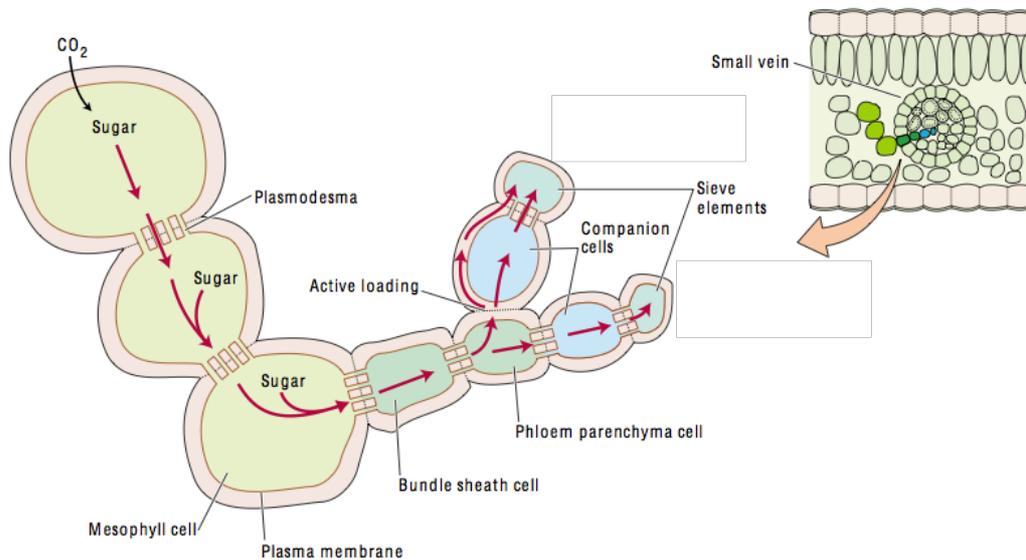
14. The diagram shows a model of apical dominance in intact and decapitated plants. Next to each plant is a model description of bud release and growth as it relates to the regulation by the IAA (auxin) and sugars. At each axillary bud, the width of solid lines indicates high levels of abundance and dashed lines indicate low.



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

- Auxin is the only hormone involved in axillary bud growth induction.
- Decapitation will cause sugar accumulation in axillary buds.
- Axillary buds on a decapitated stem will serve as a new auxin source.
- From this model, apical dominance is maintained in intact plants predominantly by the limitation of axillary bud's access to sugar.

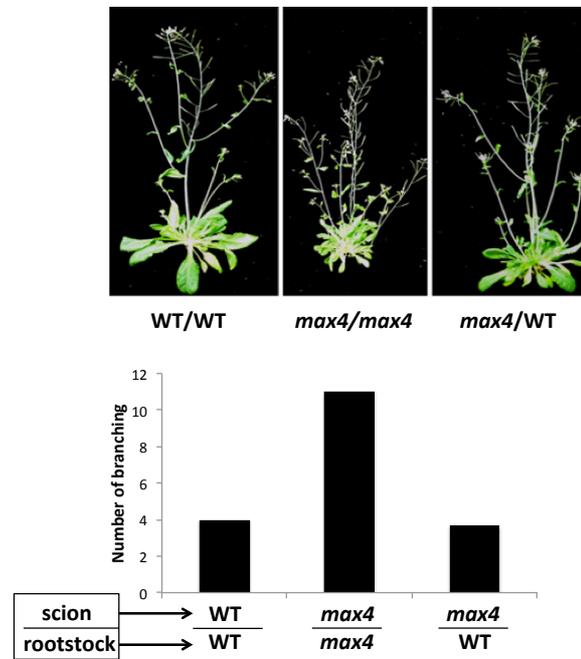
15. The diagram shows how sugar translocation occur in leaf phloem.



**Indicate if each of the following statements is true or false.**

- A. Similar to water transport through xylem, photosynthate is also translocated through dead cells, but with different mechanism
- B. Photosynthate is transported symplastically and apoplastically to the sieve elements and companion cells.
- C. Symplastic sugar translocation requires ATP.
- D. In leaves, sugars become more concentrated in the sieve elements and companion cells than in the mesophyll cells.

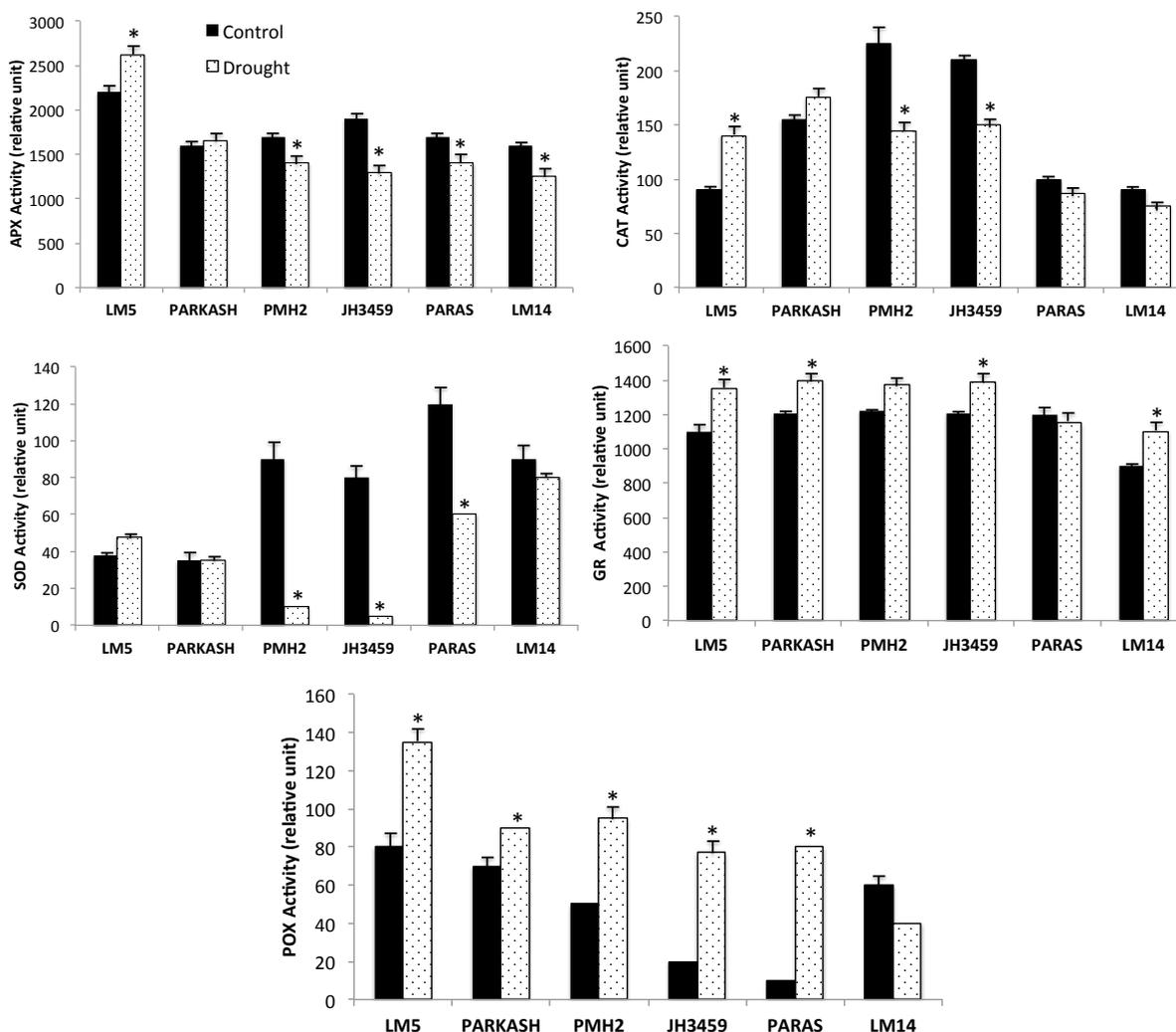
16. In addition to auxin and cytokinin involvement in branching, the *MAX4* gene is known to control the production of the signal molecule strigolactone and its derivatives which inhibit branching. To investigate its influence on branching, graft of *max4* mutants and wild type plant were made as shown in the figure below:



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

- In this experiment, number of branchings is determined by the substance produced in roots.
- Mutant *max4* does not produce strigolactone and resulted in higher numbers of branching.
- Grafting WT scion with *max4* rootstock will produce less branching compare to WT/WT graft.
- The higher ratio of cytokinin to auxin will inhibit axillary branching compare to WT/WT graft.

17. Two leaf-stage maize seedlings with genotypes LM5, PARKASH, PMH2, JH3459, PARAS, and LM14 are exposed to drought condition for 72 hours. Figures show activity of several enzymes involved in the defense against leaf oxidative stress: i.e. ascorbate peroxidase (APX), catalase (CAT), superoxide dismutase (SOD), peroxidase (POX), and glutathione reductase (GR). Vertical bars show standard deviation for the mean of three replicates. The asterisk indicates a significant difference between control and drought treatment within each genotype using t-test.



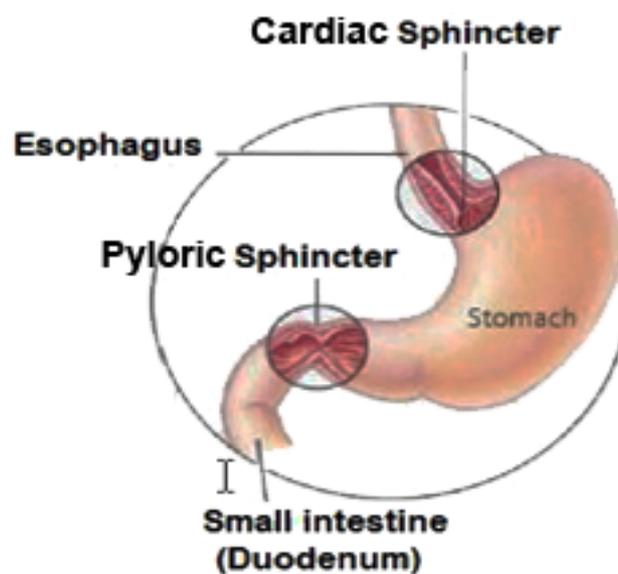
Indicate if each of the following statements is true or false.

- A. All genotypes responded similarly to drought stress.
- B. Drought stress does significantly change the activity of GR in all genotypes.
- C. Peroxidase is an important enzyme to alleviate drought stress.
- D. Based on the activity of the five enzymes, LM5 and PARKASH are most likely to be the top two drought tolerant genotypes.

**ANIMAL ANATOMY AND PHYSIOLOGY**

18. Stomach emptying is determined by the strength of antral peristaltic contractions and the resistance offered by the pyloric sphincter. The time taken to empty half the stomach contents was measured in one patient and compared with normal data.

| Individual | Time taken for stomach to empty half its contents (min) |       |
|------------|---|-------|
|            | Liquid  | Solid |
| Normal     | <20   | <120  |
| Patient    | 18  | 150   |



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

- A. The patient has a higher risk of malnutrition as compared to healthy individual.
- B. The patient is likely to experience an increase in acid reflux.
- C. An increase in pyloric sphincter resistance will accelerate the emptying of solids from the stomach.
- D. If the patients vomits, the vomited material does contain bile.

19. Olympians, at least in sports, can run faster, leap higher and lift more than ‘normal’ humans. Such elite athletes earn their titles with an astonishing amount of hard work and support (like you in IBO), but many also have some unearned advantages: the right genes.

There is growing evidence that world-class athletes carry a minimum set of particular ‘performance-enhancing’ genes. For instance, almost every male Olympic sprinter and power athlete ever tested carried the wt 577R allele variant of the gene *ACTN3* (alpha-Actinin 3).

Actin filaments are stabilized by actin binding proteins including actinins of which there are two main types, type 2 and type 3. *ACTN3* is expressed only in fast twitch fibers, *ACTN2* is expressed in all skeletal muscle fibers and is essential for their function.

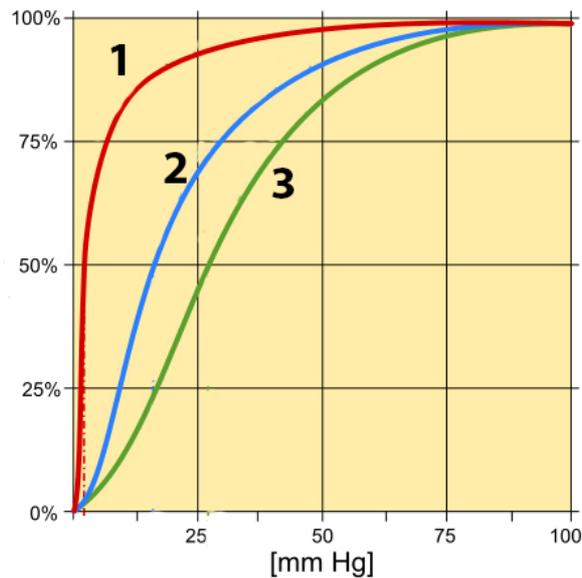
In general population, there are people of:

- XX - TYPE: homozygous for inactive *R577X*, associated with a natural predisposition to endurance events.
- RR – TYPE: homozygous for wt *R577*, associated with a natural predisposition for sprint-power events.
- RX - TYPE: heterozygous are equally but not optimally suited for both endurance and sprint-power events.

**Indicate if each of the following statements is true or false.**

- A. These alleles are expected to be at very similar frequencies in all human populations
- B. Selection will prevent a loss of function mutation in the gene *ACTN2* to reach high frequencies
- C. Similar the *R577X* variant is found in large cats (especially in cheetahs)
- D. Football forwards, must be able to accelerate quickly yet need to be able to run throughout the entire match, are most likely to be of the RX-TYPE than XX - TYPE

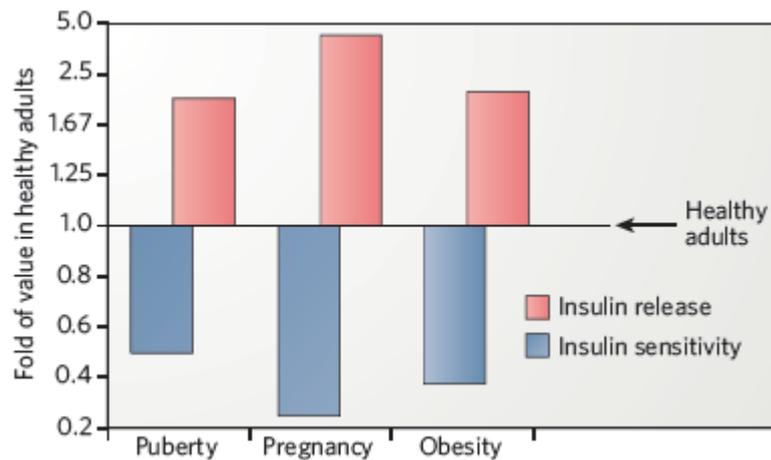
20. The graph shows three dissociation curves of oxygen binding proteins.



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

- A. Curve 1 corresponds to the protein which is present in very high amounts in skeleton muscles of whales.
- B. Curve 2 could be found at acidosis in individual, normally displaying curve 3.
- C. Curve 2 could be found at a lower temperature in individual normally displaying curve 3.
- D. Curve 2 belongs to fetal if curve 3 belong to maternal hemoglobin

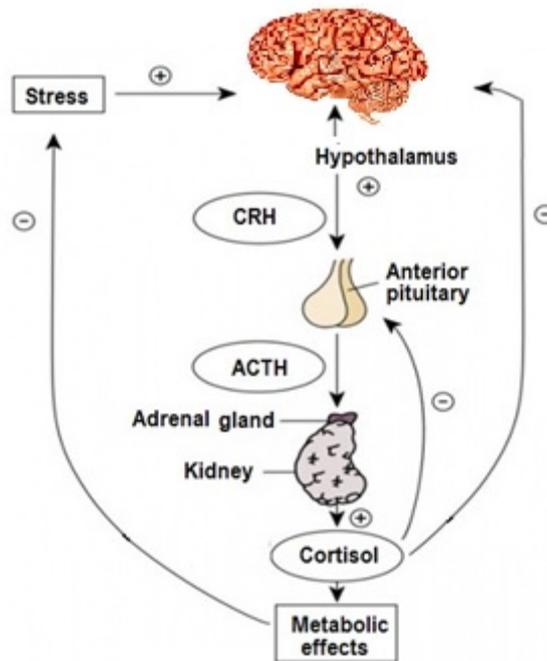
21. Obesity is associated with several conditions, such as type 2 diabetes. Both obesity and type 2 diabetes are associated with insulin resistance as depicted in the figure below. Insulin sensitivity also modulates  $\beta$ -cell function and is almost always decreased in obesity.



**Indicate if each of the following statements is true or false.**

- A. Obese individuals have similar insulin release and greater insulin sensitivity as compared to those at puberty.
- B. The data shown on the graph support the idea that insulin release could be correlated to insulin sensitivity in all individuals.
- C. Elevated blood glucose levels due to decreased insulin sensitivity usually causes the increased insulin release in obese individuals
- D. A trained athlete with type 1 diabetes would display lower release & higher sensitivity to those healthy adults

22. The diagram outlines the feedback mechanisms regulating secretion of stress hormones in the human body.



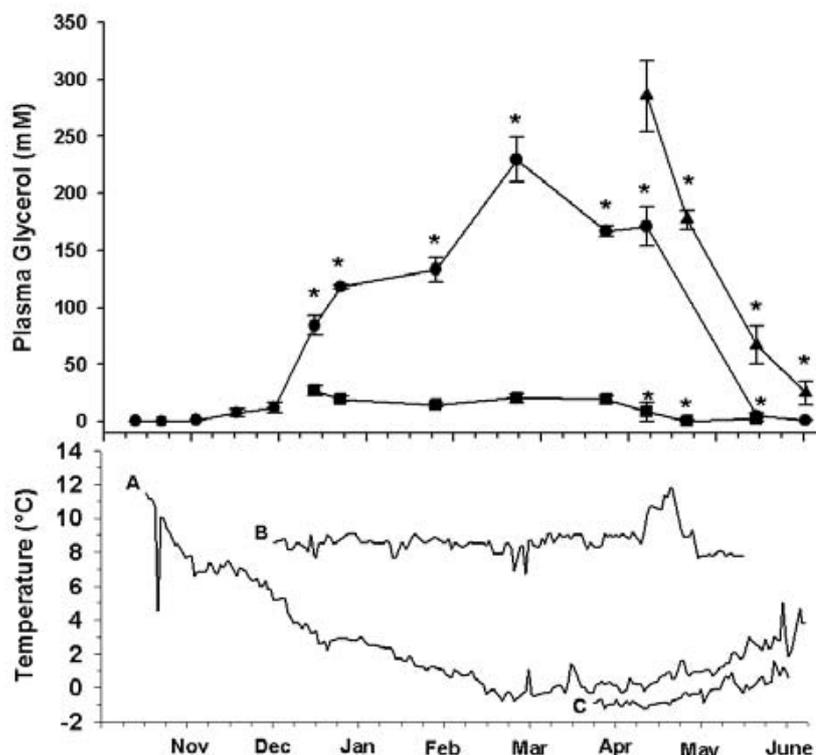
Levels of hormones involved in stress responses can be abnormal in a large number of clinical states

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

|    | CRH    | ACTH   | Cortisol | Cause   |
|----|--------|--------|----------|---|
| A. | High   | High   | High     | Long term stress                                  |
| B. | High   | High   | Low      | Chronic adrenal insufficiency (Addisons' disease) |
| C. | Low    | Low    | High     | Adrenal hyperfunction (Chusing's disease)         |
| D. | Normal | Normal | High     | During long-term treatment with cortisol          |

23. As an adaptation to extremely low temperatures in fast flowing water, Rainbow smelt (*Osmerus mordax*) produces glycerol in its blood plasma, liver, muscle and other tissues that avoids freezing at sub-zero temperatures. Maintenance of glycerol levels requires active feeding on insect larvae and active glycerol-3-phosphate dehydrogenase (GPDH).

Glycerol can be synthesized from dihydroxyacetone phosphate (DHAP) formed either from the amino acid alanine or from glucose in an incomplete glycolysis. The figure below shows the correlation between plasma glycerol content and temperatures



Seasonal pattern of plasma glycerol concentrations (mM) (●: in natural temperature;■: in artificially increased temperature;▲: in artificially decreased temperature) and temperature profile (A=natural, B= increased, C= decreased) for smelt held in a long-term acclimation study from October 2000 to June 2001. Symbols represent mean ± SEM (n=5), \* indicates significance from initial sampling point within a treatment.

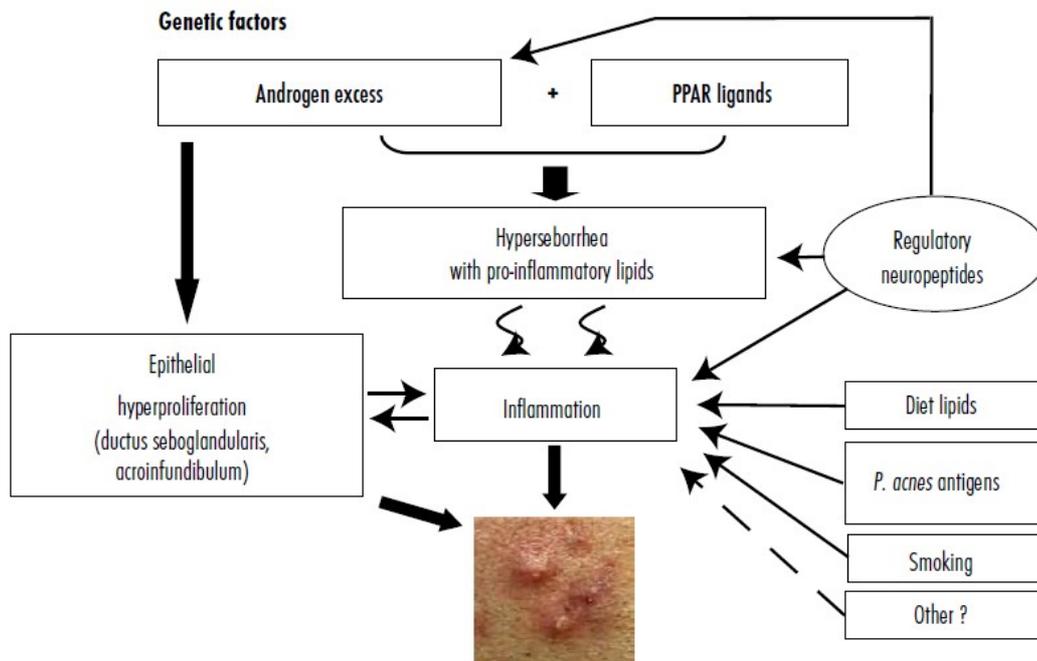
Effect of glycerol on freezing point of water used in engine coolers.  
(Molecular weight of glycerol is 102 g/mol.)

| Concentration of glycerol (%) | Freezing point of water/glycerol solution (°C) |
|-------------------------------|--|
| 0.0                           | 0.0  |
| 5.0                           | - 0.6  |
| 10.0                          | - 1.6  |
| 11.5                          | - 2.0  |

**Indicate if each of the following statements is true or false.**

- A. Fast mobilization of glycerol is primarily dependent on protein in food and protein deposits in muscle tissue rather than dietary glucose and mobilization of glycogen stores in the body.
- B. Since glycerol is poisonous ( $LD_{50}$  dose in guinea-pig is 7.5g/kg body weight), it is not advisable to eat rainbow smelt caught wintertime from water of subfreezing temperatures .
- C. The level of plasma glycerol alone is sufficient for surviving the temperatures the fish is exposed to in experiment C.
- D. When the rainbow smelt fish was kept at increased temperature B ( $10^{\circ}\text{C}$ ), the plasma glycerol level, will probably not permit the fish to survive if instantly moved to temperatures prevailing during winter time.

24. Acne can be formed by several factors, such as genetic factors, androgen, nutrition, bad habit (smoking), or infection of the hair follicle by the strictly anaerobic propionibacteria as shown in this figure below.



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

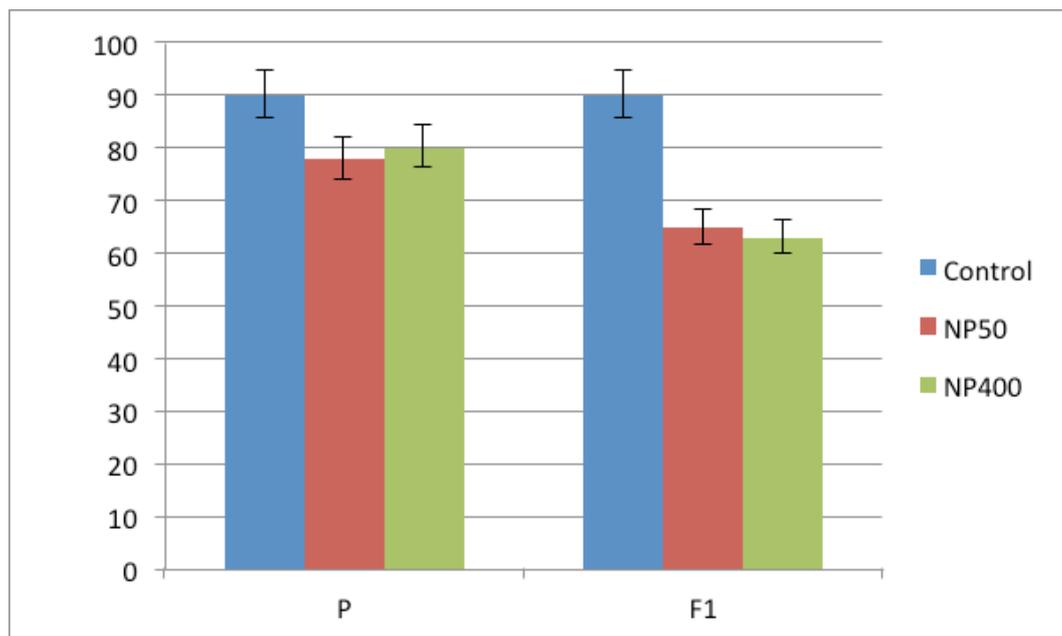
- A. Acne may be aggravated in males with an extra Y-chromosome (XYY males).
- B. Some peroxides are efficient to reduce acne when applying to the skin
- C. Inhibition of prostaglandins secretion will aggravate acne.
- D. The substrates used by bacteria in acne formation are actually compounds essential for epidermis lubrication.

25. A 15-year-old boy was diagnosed as a case of Duchenne muscular dystrophy (DMD) and presented with progressive proximal weakness of the lower limbs starting at 4 years old followed by involvement of the upper limbs. In DMD, there is a mutation in dystrophin gene leading to the absence of the corresponding protein. Dystrophin is a molecular ‘shock absorber’ in the sarcolemma and has a major structural role in muscle as it links the internal cytoskeleton to the extracellular matrix.

**Indicate if each of the following statements is true or false.**

- A. Increased levels of creatine kinase and other muscle-specific proteins in the blood plasma are used to diagnose the DMD
- B. ATP cannot bind to myosin heads in the muscle of DMD.
- C. Motor neurons can initiate contraction in muscle fiber of DMD.
- D. The maximal contractile force of skeletal muscles is significantly reduced in DMD.

26. Para-Nonylphenol (4-nonylphenol / NP) is used in the preparation of lubricating oil additives, plasticizers and surface active agents. It has also been found in polyvinyl chloride (PVC) used in the food processing and packaging industries. In an experiment to observe the effect of para-Nonylphenol on parental and 1<sup>st</sup> generation male mice, adult mice (P-generation) were treated with NP for four weeks. For the F1 generation, the treatment was administered during pregnancy, lactation and pubertal period up to adulthood. The results show that para-Nonylphenol was able to influence membrane integrity of sperm acrosome (see figure below) and that the litter of F1 and F2 generations are therefore smaller.

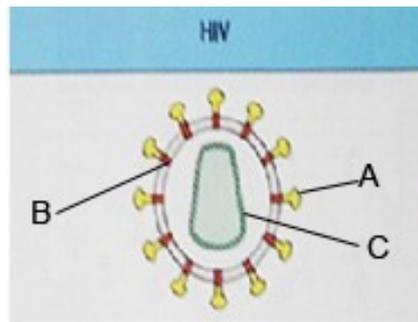


Percentage of spermatozoa with labelled acrosome as sign of their sperm membrane integrity of control mice, mice treated with para-nonylphenol 50 mg/g body weight (NP50) and 500 mg/g body weight (NP500), measured in parental (P) and 1<sup>st</sup> generation (F1)

**Indicate if each of the following statements is true or false.**

- The effect of NP has begun since meiosis occurred in spermatogenesis.
- If a defective sperm fertilizes an egg, the zygote will develop abnormally.
- Defects in sperm are more severe in F1 generation due to longer NP exposure
- If NP has the same effect on humans as on mice, it will potentially impair male fertility

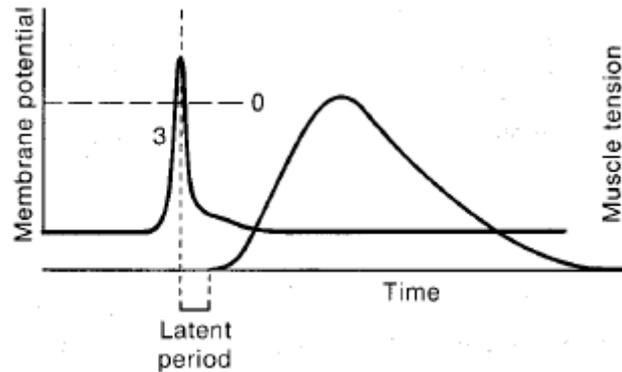
27. The HIV-1 lifecycle is a complex multistage process involving interactions between HIV-1 proteins and host macromolecules. The early phase of the lifecycle consists of infection of host cell and integration of viral genome, and the late phase of the lifecycle consists of regulated expression of the viral gene products followed by production of viral particles. The HIV proteome consist of 20 different molecules, only subset of them is targeted by the immune system. Immunogenic molecules are shown in the picture.



**Indicate if each of the following statements is true or false.**

- A. A-specific antibodies could efficiently interfere with infectivity of the particular viral strain.
- B. The gene for protein A is undergoing rapid evolution (much more quickly than happens for C) resulting in escape variants to which preformed antibodies do not bind.
- C. Peptide fragments derived from protein C could activate cytotoxic response of CD8 positive T-lymphocytes.
- D. Due to lack (or highly diminished number) of helper T-cells, the humoral response is crippled and unable to clear the HIV infection.

28. The following figure shows a relationship between membrane potential and skeletal muscle tension. The latent period is gap between action potential and muscle contraction.

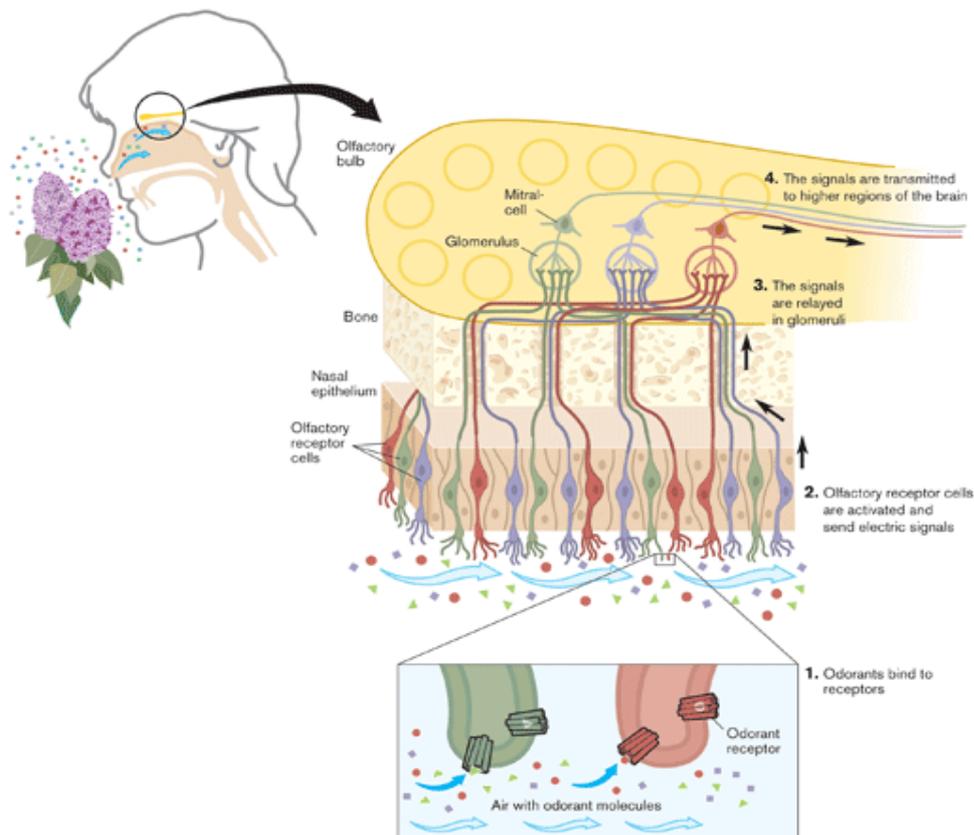


**Indicate if each of the following statements is true or false.**

- A. Both ascending and descending parts of the membrane potential curve reflect ion gradient-driven processes.
- B. Both ascending and descending parts of the tension curve reflect ATP-dependent processes.
- C. The peak of the tension curve reflects minimum number of actin-myosin cross-bridges formed.
- D. A decrease in temperature will decrease the duration of the latent period

29. **(DELETED)** Axel and Buck (The Nobel Prize in Physiology or Medicine 2004) discovered and characterized a large gene family, containing more than 1,000 different genes (about three per cent of the whole human genome) encoding equivalent number of olfactory receptors.

### Odorant Receptors and the Organization of the Olfactory System



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

- A. ~~Olfactory receptors belongs to a family of seven times membrane spanning molecules associated with trimeric G-proteins.~~
- B. ~~Each glomerulus in the olfactory bulb receives synaptic inputs from the primary olfactory receptor neurons of one type expressing particular odorant receptor scattered among about the thousand different types of olfactory receptor neurons localized in the olfactory epithelium.~~
- C. ~~Olfactory receptor neurons are able to regenerate and are replaced in about every two months.~~
- D. ~~Odorant receptors are localized on cilia of olfactory receptor cells and are analogous to the cilia.~~

- 30.** The effects of high altitude on humans are considerable. After the human body reaches around 2,100 m (7,000 feet) above sea level, the saturation of oxyhemoglobin begins to plummet. However, the human body has both short-term and long-term adaptations to altitude that allow it to partially compensate for the lack of oxygen.

**Indicate if each of the following statements is true or false.**

- A. Unacclimatized people experiencing high altitudes sense lack of oxygen by the carotid bodies, which causes hyperventilation followed by the respiratory alkalosis. This inhibits the respiratory center from enhancing the respiratory rate as much as would be required.
- B. During full acclimatization, there is a decrease in the plasma volume and increase of the hematocrit number.
- C. At high altitude an unacclimatized person's heart rate increases, stroke volume is slightly decreased and non-essential bodily functions are suppressed. This result in a decline in digestion efficiency.
- D. In the skeletal muscle tissue full acclimatization leads to lower density of capillaries and decreased myoglobin content.

**GENETICS AND EVOLUTION**

31. Three corn phenotypes plant-color booster, liguleless and silkless are all controlled by a single gene located on the same chromosome. In all cases, the wild type allele is dominant. A cross between a plant with wild type characters and a plant showing all three recessive phenotypes resulted in the following progeny

| type | silk      | color     | ligule     | number of progeny |
|------|-----------|-----------|------------|-------------------|
| 1    | wild type | wild type | wild type  | 7                 |
| 2    | wild type | wild type | liguleless | 179               |
| 3    | wild type | booster   | wild type  | 41                |
| 4    | silkless  | wild type | wild type  | 352               |
| 5    | wild type | booster   | liguleless | 398               |
| 6    | silkless  | wild type | liguleless | 49                |
| 7    | silkless  | booster   | wild type  | 158               |
| 8    | silkless  | booster   | liguleless | 10                |
|      |           |           |            | Total=1194        |

**Indicate if each of the following statements is true or false.**

- A. The wild type parent plant carried a chromosome with only dominant alleles.
- B. Recombination frequency between the loci encoding plant-color booster and liguleless was 37.18 %.
- C. The locus controlling silkless is located between the loci controlling the other phenotypes.
- D. The progeny of a back-cross between an all wild type progeny and the wild type parent will result in a similar distribution of phenotypes to that found on the table.

32. Earlier research suggested that the red flower pigment of plant species was the result of a chemical pathway including multiple steps and that all intermediate pigments were white. Three pure-bred lines with white flowers (White 1, 2 and 3) of this species were crossed with each other and the following ratio of colors were obtained among the progeny:

| No of Cross | Cross             | F1      | F2 (F1 x F1)    |
|-------------|-------------------|---------|-----------------|
| 1           | White 1 x White 2 | All Red | 9 Red : 7 White |
| 2           | White 2 x White 3 | All Red | 9 Red : 7 White |
| 3           | White 1 x White 3 | All Red | 9 Red : 7 White |

**Indicate if each of the following statements is true or false.**

- A. These results suggest that flower color is controlled by two genes.
- B. F1 plants were all heterozygous for all genes controlling flower color.
- C. A cross between an F1 individual of cross 1 and a pure White 3 individual will result in only white individuals.
- D. One fourth of all offspring between a cross of F1 individuals from crosses 1 and 3 are expected to be white.

33. Each of five mutant strains of *Escherichia coli* (1 – 5) has a mutation affecting the *lac* operon. Mutant 1 has a mutation in the *lacY* gene and the others have one each of the following mutations:

- A nonsense mutation in *lacZ*; a nonfunctional  $\beta$ -galactosidase is produced.
- A *lacO<sup>C</sup>* mutation; the repressor cannot bind to the operator.
- A promoter mutation; RNA polymerase cannot bind to the promoter.
- A super-repressor mutation; lactose cannot bind and inactivate the repressor

The *lac* operon from each mutant was inserted on a plasmid into a wildtype and the mutant *E. coli* strains and their ability to grow on lactose-containing medium was assayed. + indicates the ability to grow and – indicated that no growth was observed. Growth requires both functional LacZ and LacY.

|                                  |   | Host cell |   |   |   |   | Wildtype |
|----------------------------------|---|-----------|---|---|---|---|----------|
|                                  |   | 1         | 2 | 3 | 4 | 5 |          |
| Inserted<br><i>lac</i><br>operon | 1 | -         | + | + | - | - | +        |
|                                  | 2 |           | + | + | + | + | +        |
|                                  | 3 |           |   | - | - | - | +        |
|                                  | 4 |           |   |   | - | - | -        |
|                                  | 5 |           |   |   |   | - | +        |

Indicate if each of the following statements is true or false based on the type of mutation in mutant 2 - 5

- Mutant 2 has a LacO<sup>C</sup> mutation.
- Mutant 3 has a promoter mutation.
- Mutant 4 has a super-repressor mutation.
- Mutant 5 has a LacZ nonsense mutation

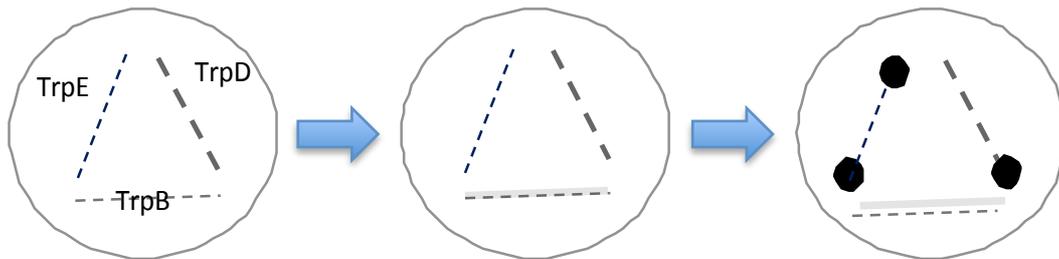
34. Two highly inbred strains of a plant (P1 x P2) were crossed to get F1 plants, which were then selfed, all in the same location. The mean and variance of stem height were evaluated in every generation. Stem height is controlled by many genes modulated by environmental factors.

| Generation   | Stem Height (Mean) | Stem Height (Variance) |
|--------------|--------------------|------------------------|
| P1           | 60.5 cm            | 4.3 cm                 |
| P2           | 85 cm              | 4.2 cm                 |
| F1 (P1 x P2) | <b>Data lost</b>   | 5.1 cm                 |
| F2 (F1 x F1) | <b>Data lost</b>   | 25.4 cm                |

**Indicate if each of the following statements is true or false.**

- A. The mean stem height was approximately similar among F1 and F2 individuals.
- B. The variance in stem height among F1 individuals is determined by both genetic and environmental factors.
- C. In F2, environmental factors have a greater effect on stem height variation than do genetic factors.
- D. F1 individuals are heterozygous for all genes contributing to stem height.

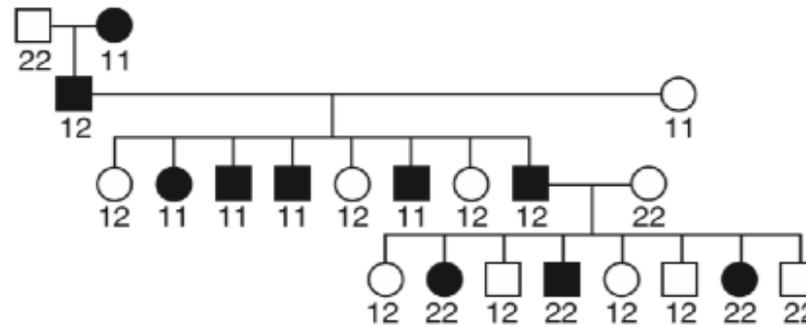
35. Three mutant bacterial strains, TrpB<sup>-</sup>, TrpC<sup>-</sup> and TrpE<sup>-</sup>, each defective in one of the steps in the tryptophan biosynthesis pathway were streaked in a triangle on a petridish, as shown below. The very small concentration of tryptophan in the medium allowed them to grow and form pale streaks until it was depleted. Some regions of the streaks, however, continued to grow slowly and became thicker. The tryptophan pathway involves the successive conversion of chorismate to anthranilate, indole and finally, tryptophan:



**Indicate if each of the following statements is true or false.**

- A. These results suggest that intermediates of the biosynthetic pathway are actively secreted out of the cells.
- B. TrpC<sup>-</sup> has a mutation in the enzyme that catalyzes the conversion of indole to tryptophan.
- C. TrpE<sup>-</sup> has the capability to synthesize tryptophan if the medium contains anthranilate or indole.
- D. Indole will continue to accumulate in the medium where TrpB<sup>-</sup> cells are in the vicinity of TrpC<sup>-</sup> cells.

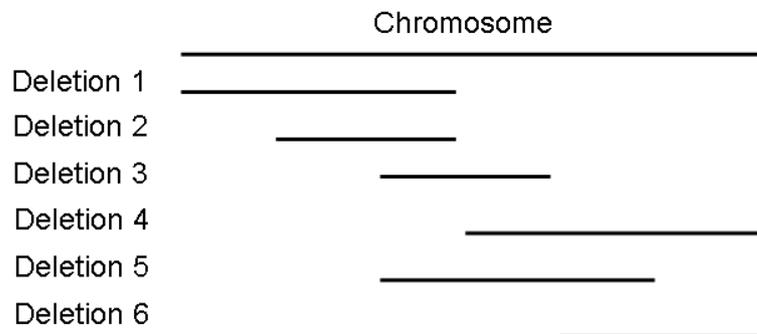
36. The pedigree below shows the inheritance of a rare genetic disease (inherited by autosomal dominant allele) in a family. Locus for this disease is unknown. A genetic consultant is curious whether the inheritance of this disease is linked with a certain genetic marker (microsatellite) located on chromosome 5 in humans. This microsatellite has two main allele variants: allele 1 and allele 2. The pedigree shows the inheritance of the disease (dark means the person has the disease) and the microsatellite marker associated with it in each person (1 or 2)



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

- It is possible that the gene for the disease is also located on chromosome no 5
- If a person has the disease, he/she would always have microsatellite allele 1 variant
- In the 4<sup>th</sup> generation, only one child obtained a recombinant chromosome from his/her father
- From the 3<sup>rd</sup> and 4<sup>th</sup> generation, it could be concluded that the recombination frequency between the gene of the disease and the microsatellite was 3/16

37. The locations of six deletions have been mapped to the *Drosophila* chromosome as shown in the following diagram.



Recessive mutations *a*, *b*, *c*, *d*, *e* and *f* are known to be located in the same regions as the deletions, but the order of the mutations on the chromosome is not known. When flies homozygous for the recessive mutations are crossed with flies homozygous for the deletions, the following results are obtained, where the letter “m” represents a mutant phenotype and a plus sign (+) represents the wild type.

| Deletion | Mutations |          |          |          |          |          |
|----------|-----------|----------|----------|----------|----------|----------|
|          | <i>a</i>  | <i>b</i> | <i>c</i> | <i>d</i> | <i>e</i> | <i>f</i> |
| <b>1</b> | m         | +        | +        | m        | +        | m        |
| <b>2</b> | +         | +        | +        | m        | +        | m        |
| <b>3</b> | +         | m        | +        | m        | +        | +        |
| <b>4</b> | +         | m        | m        | +        | m        | +        |
| <b>5</b> | +         | m        | m        | m        | +        | +        |
| <b>6</b> | +         | +        | m        | +        | m        | +        |

**Indicate if each of the following statements is true or false.**

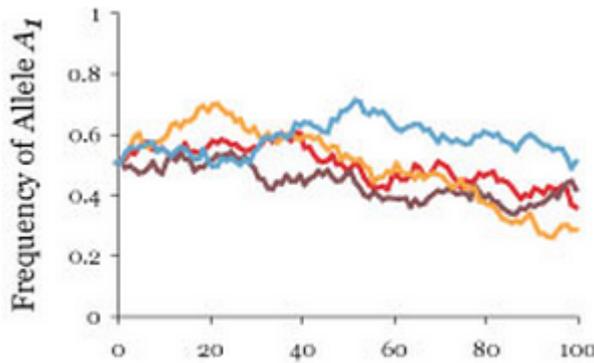
- Mutation *d* is located in the overlapping area between deletion 4 and deletion 6.
- Location of the deletion where mutation *b* is located can be deduced using information of overlapping area between deletions 3, 4 and 5.
- Among the six mutations, mutation *d* is located in the shortest deletion
- The relative order of the six mutations on the chromosome is *a*, *f*, *d*, *b*, *c*, *e*.

**38.** Suppose that the horse's color is determined by one gene which has two alleles  $B$  and  $b$ .  $B$  allele is dominant over  $b$  and expresses brown color, while  $b$  allele is recessive and codes for black color. There were two populations of horses in two separate locations. In population 1, the allele frequency of  $B$  was 0.5, while in population 2 it was 0.2. The size of population 1 was five times larger than population 2. Initially, both populations were in Hardy Weinberg Equilibrium. Then, the two populations joined into one unified population..

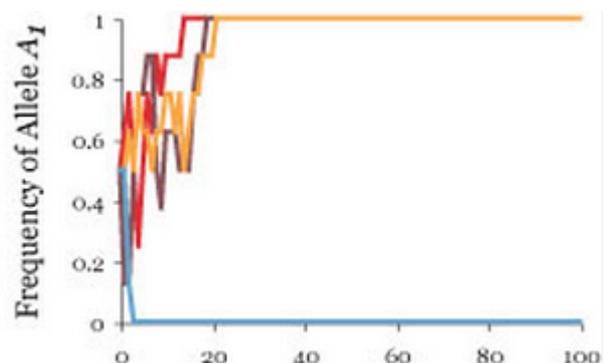
**Indicate if each of the following statements is true or false.**

- A. The above phenomenon is an example of genetic drift
- B. After the populations joined, the allele  $B$  frequency is higher than frequency allele  $b$ .
- C. Two generation after the population joined, 12.6 % of all offsprings between two brown horses are expected to be black.
- D. Among 1000 offspring born in the first generation after the populations joined, 698 are expected to be brown horses.

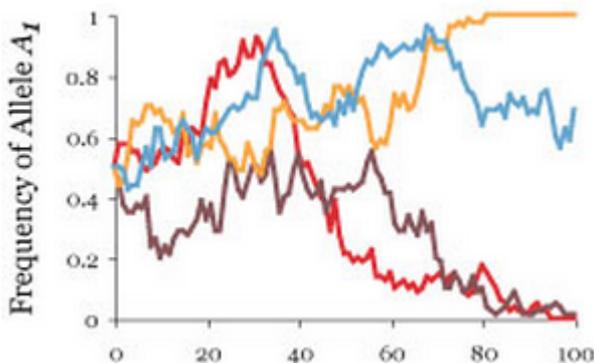
39. Figures (A, B, and C) illustrate the results of a series of computer simulations of changes in allele frequencies in a group of populations due to chance alone (*genetic drift*). The simulations were done in different population sizes. X axis indicates the number of generation, Y axis indicates allele frequency and different colors indicate the repetition of simulations.



Simulation on Population I



Simulation on Population II

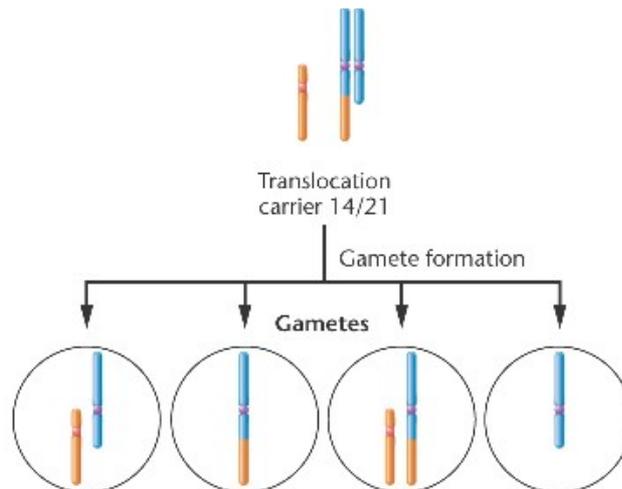


Simulation on Population III

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

- A. Among the three simulations, Simulation III was done on the smallest population size while Simulation I was done on the largest population size.
- B. Time of fixation of an allele at 50% is shorter in Population I than in Population III.
- C. Probability that new mutation will be lost in a population will be higher in Population III than in Population I.
- D. Results, such as those obtained for Population II can also be obtained when a weakly deleterious allele is simulated.

**40. Robertsonian translocation** is a rare form of chromosomal rearrangement that can potentially involve the five acrocentric chromosome pairs, namely 13, 14, 15, 21 and 22, in humans. Other translocations occur too but are inviable. During a Robertsonian translocation, the participating chromosomes break at their centromeres and the long arms fuse to form a single chromosome with a single centromere. The short arms also join to form a reciprocal product, which typically contains nonessential genes and is lost within a few cell divisions. The figure below shows the four possible gametes produced by a carrier of a Robertsonian translocation.



**Indicate if each of the following statements is true or false.**

- A. The fusion of gamete B with a normal gamete results in a translocation carrier with a normal phenotype but 45 chromosomes.
- B. The fusion of gamete C with a normal gamete results in trisomy 21. (Down Syndrome).
- C. The fusion of gamete D with a normal gamete results in a lethal monosomy.
- D. Among the offspring of two translocation carriers, one-fourth is expected to have 44 chromosomes.

**ECOLOGY**

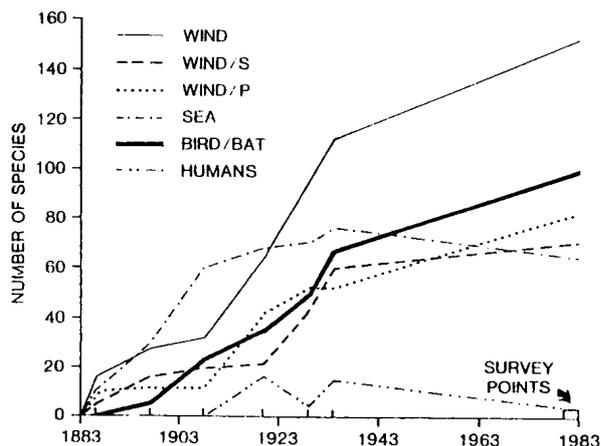
41. The table below is a static life table for an unspecified invertebrate species with a life span of around five months. Certain values in the table are missing, and are denoted by the letters A to J.

| Age class<br>( $x$ ) | Number<br>alive<br>( $n_x$ ) | Number<br>dying<br>( $d_x$ ) | Proportion<br>surviving<br>( $l_x$ ) | Mortality<br>rate<br>( $q_x$ ) |
|----------------------|------------------------------|------------------------------|--------------------------------------|--------------------------------|
| 0-1                  | 2000                         | C                            | 1.000                                | 0.944                          |
| 1-2                  | 112                          | D                            | 0.056                                | G                              |
| 2-3                  | 74                           | 27                           | 0.037                                | H                              |
| 3-4                  | A                            | 43                           | E                                    | I                              |
| 4-5                  | B                            | 3                            | F                                    | J                              |

**Indicate if each of the following statements is true or false.**

- A. The values for A and B are respectively 47 and 4.
- B. The values for G and H are respectively 0.019 and 0.014.
- C. The above life table is based on cohort data.
- D. The organism recorded in the life table is most likely a K-strategist with a Type-I survival curve.

42. Studies spanning a period of more than 100 years have recorded the changes in vegetation on islands around the volcanic area of Krakatau, Indonesia. The following graph shows the number of plant species recorded, since after the volcanic eruption of 1883 up to 1983. The graph differentiates species according to their mode of dispersal, i.e., by wind (S=Spermatophytes, P=Pteridophytes), sea, bird/bat, or humans.



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

- A. Dispersal through mutualistic relationships was most important in determining plant establishment on the Krakatau islands.
- B. In 1943, most plants would likely have small-sized seeds.
- C. Leaching of nutrients is likely to be higher in 1963 than 1923.
- D. Plant community change as illustrated above is an example of primary succession.

43. Vascular plants and macroalgae produce a variety of secondary metabolites that can function as defenses against herbivory. These defense chemicals can either be present and produced at effective levels continuously (constitutive defense) or increase in production when induced by herbivory or artificial clipping (inducible defense). In many vascular plants, response to herbivory may also result in increased resistance to further grazing. An experimental study examined the importance of phlorotannins (polyphenolics) in the chemical defense mechanism of the brown seaweed (macroalgae) *Ascophyllum nodosum*, which is grazed upon by two species of mesoherbivores, i.e., the gastropod *Littorina obtusata* and the isopod *Idotea granulosa*. Part of the study results is presented in the figures below:

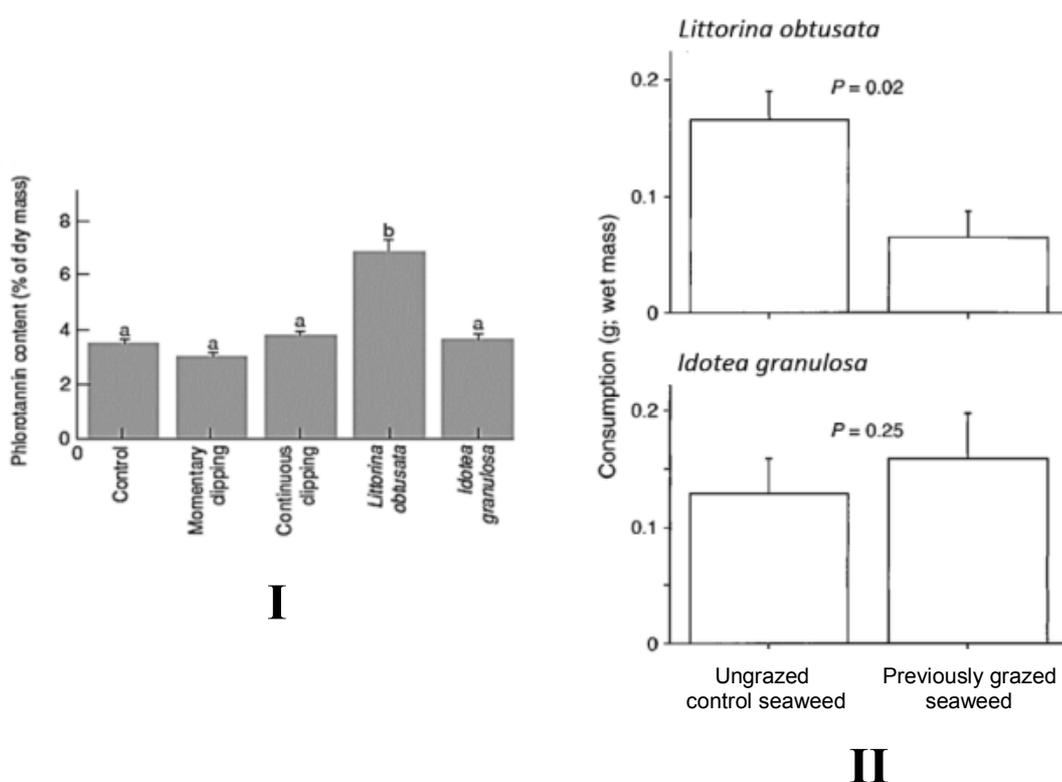


Figure: (I) Phlorotannin content of *A. nodosum* seaweed after exposure to grazing by mesoherbivores and simulated herbivory (clipping with a hole punch). Control treatment received no physical damage (no clipping or herbivory). (II) The amount of *A. nodosum* shoots consumed by mesoherbivores in two-choice feeding preference experiments. Mesoherbivores were offered a choice between seaweed shoots that had been grazed by individuals of the same herbivore species or shoots from control seaweed.

**Indicate if each of the following statements is true or false.**

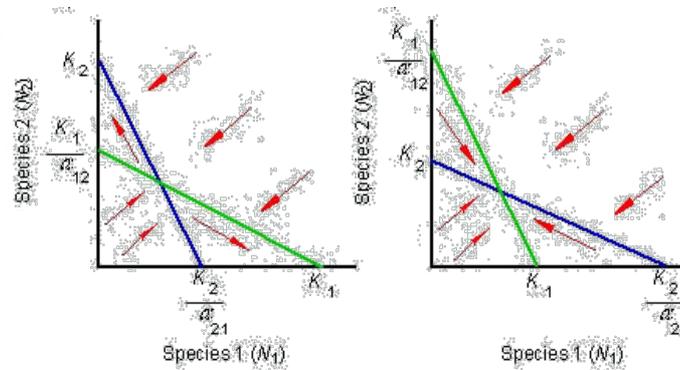
- A. There is a high degree of specificity in the elicitation of chemical responses by *A. nodosum* to physical damage.
- B. Production of phlorotannins by *A. nodosum* is strictly an inducible defense.

- C. *A. nodosum* that had been grazed by *I. granulosa* were less susceptible to further grazing, compared to ungrazed ones, as a result of induced resistance.
- D. The different feeding modes of the two predators are likely to be responsible for the differential chemical response of the algae.

44. Given below are Lotka-Volterra equations which model the competition between populations of Species 1 and Species 2. In the equations,  $N$ =number of individuals,  $K$ =carrying capacity,  $r$ =intrinsic rate of increase, and  $\delta$  ( $\alpha$  in the figure) = competition coefficient.

$$\frac{dN_1}{dt} = r_1 N_1 \frac{(K_1 - N_1 - \delta_{12} N_2)}{K_1}$$

$$\frac{dN_2}{dt} = r_2 N_2 \frac{(K_2 - N_2 - \delta_{21} N_1)}{K_2}$$

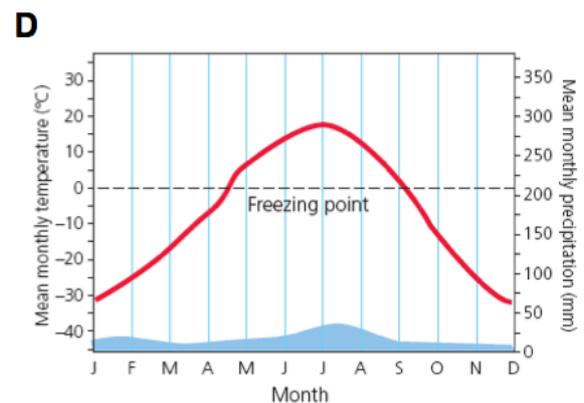
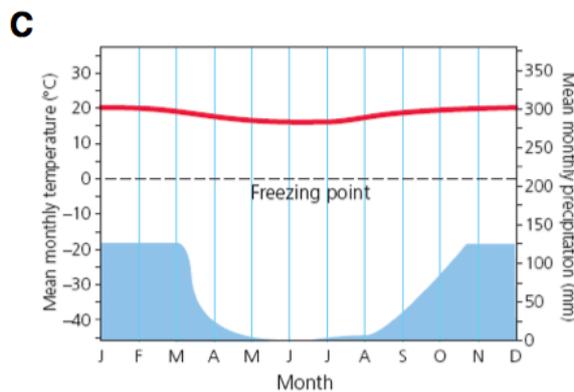
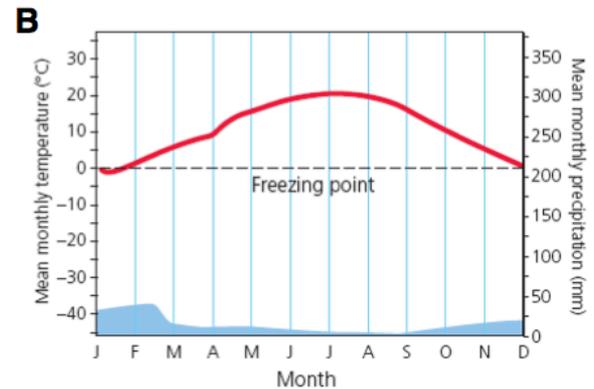
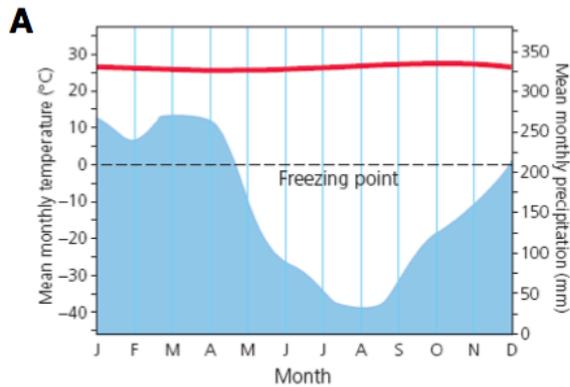


The figure shows two possible positions of the isoclines, i.e., lines which indicate zero population growth for the two populations on a graph that relates  $N_1$  (green) to  $N_2$  (blue). Arrows indicate direction of population change. The location of the isoclines depends on the parameter values, which for species 1 and species 2 are found to be:  $K_1=80$ ,  $K_2=100$ ,  $\delta_{21}0,80$ , and  $\delta_{12}=0,67$ . Based on the graphs, the outcome of the competition between the species can be predicted.

**Indicate if each of the following statements is true or false.**

- This model assumes that carrying capacity is constant.
- The outcome of this competition is co-existence of Species 1 and Species 2.
- The two species will co-exist if intraspecific competition is stronger than interspecific competition.
- The competitive exclusion principle states that all competition will eventually result in the exclusion of one of the competing species.

45. Terrestrial biomes are distinguished primarily by their predominant plants and are associated with particular climates. Climate diagrams are used as a tool to explore the relationship between the distribution of terrestrial vegetation and climatic factors, particularly seasonal variation in temperature and precipitation. Pictured below are climate diagrams for four biomes (A, B, C and D). The bold, red curve denotes mean monthly temperature, while the filled blue area denotes mean monthly precipitation.



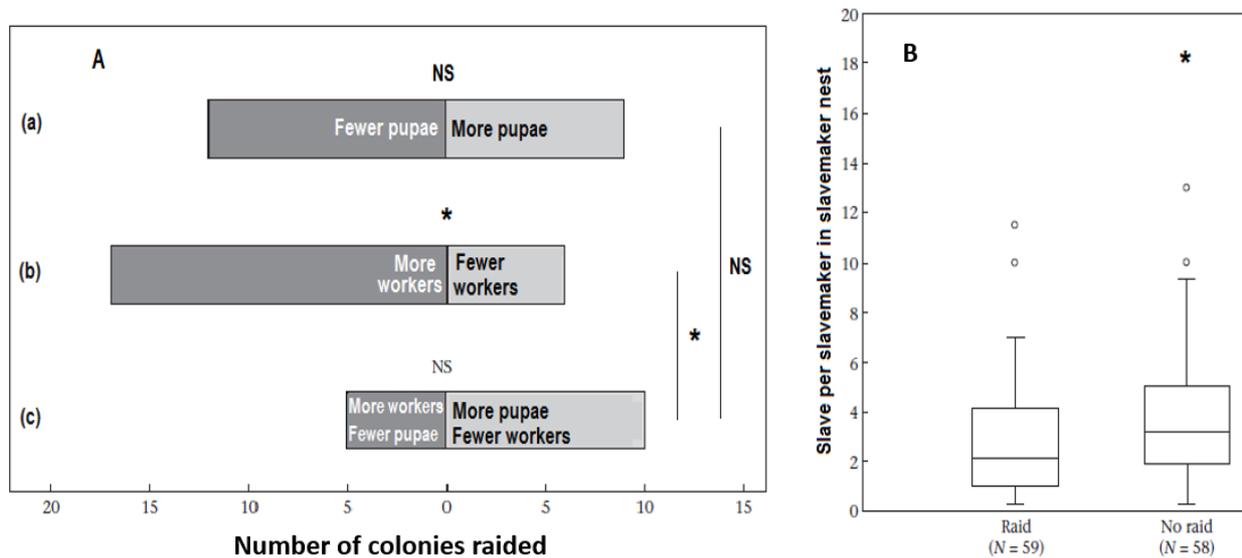
Indicate if each of the following statements is true or false.

- Biome A is found in tropical countries such as Indonesia.
- Permafrost can be found in Biome B.
- Biome C is characterized by the presence of large herbivorous mammals.
- Succulent plants with reduced leaves are among the typical plants found in Biome D.

**ETHOLOGY**

46. *Protomognathes americanus* (slave-making ants) are eusocial parasites that live in highly organized societies and exploit the brood care behavior of *Temnothorax*, a related host species. *P. americanus* attacks *Temnothorax* colonies to replenish their slave workforce, but the *Temnothorax* host workers defend their colonies and kill intruders. Additional new slaves are critical to the slave-makers' life cycle since they ensure the colony's survival. Prior to attack, a single scout evaluates the host colony's susceptibility. If found suitable, the scouts recruit slave-maker workers to attack the colony. A study of preferences of the scout ant to demographic parameters of host colony prior to raid (A) and the decision of raiding in the condition of the slave-making colony (B) is shown in the graphs below.

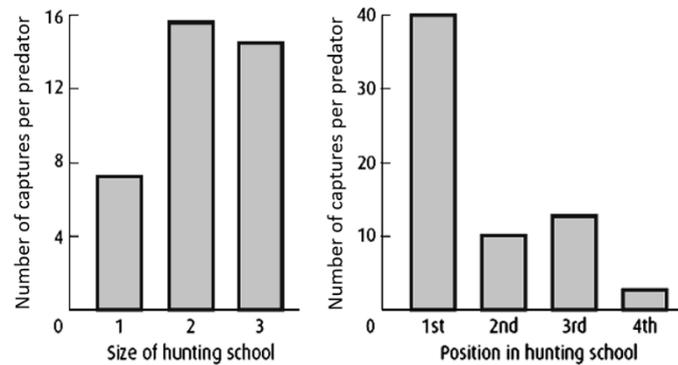
Note: \* indicates statistically significant data, NS: not statistically significant



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

- A. Scouts prefer colonies with more workers since they indicate larger and better quality colonies.
- B. Host workers are caught by raiding workers since the slavemaker colony needs these workers as slaves
- C. Slavemaker colonies send out scouts to find new hosts on a regular basis.
- D. The scouts join the raiding party to guide the attack throughout the raiding process

47. Some animals form temporary groups as they receive certain advantages when they are together. A study (see figure below) examined the success of hunting groups of fish that hunt prey, also found in large schools.

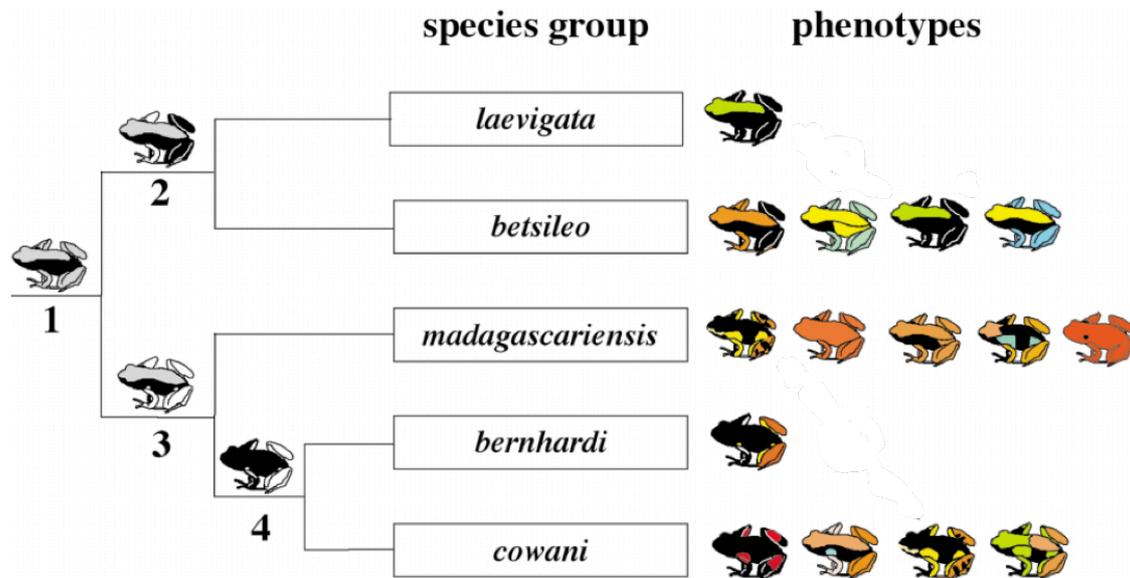


**Indicate if each of the following statements is true or false.**

- A. The total number of captures increases with increasing hunting school size
- B. A stable dominant hierarchy is set up in large hunting schools with more than four fishes
- C. The individuals in the second and third positions in a hunting school should leave and hunt solitarily
- D. Bigger hunting groups increase the energy spent by individuals in hunting

**BIOSYSTEMATICS**

48. A study investigated the evolution of aposematic pattern in the Malagasy poison frogs (*Mantella*) using data from mitochondrial 16S rRNA sequences. The phylogenetic tree is shown below with the dorsal coloration phenotypes of each group. The non-black areas in the ancestral species 1 through 4 indicate colored areas, but of unknown color.



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

- A. The *madagascariensis* species group is a sister taxon to the ancestor of the *bernhardi-cowani* species groups.
- B. This study provides evidence for homoplastic patterns evolution in these frogs.
- C. The aposematic patterns in these frogs may have evolved in response to nocturnal predators.
- D. Mitochondrial 16S rRNA is often more suited to infer deep phylogenetic relationships than non-coding DNA of the same length.

49. **(DELETED)** The phylogenetic tree for Eutheria in the Tree of Life is shown in Figure 1 and that from a more recent study (Sen Song et al. 2012) in Figure 2.

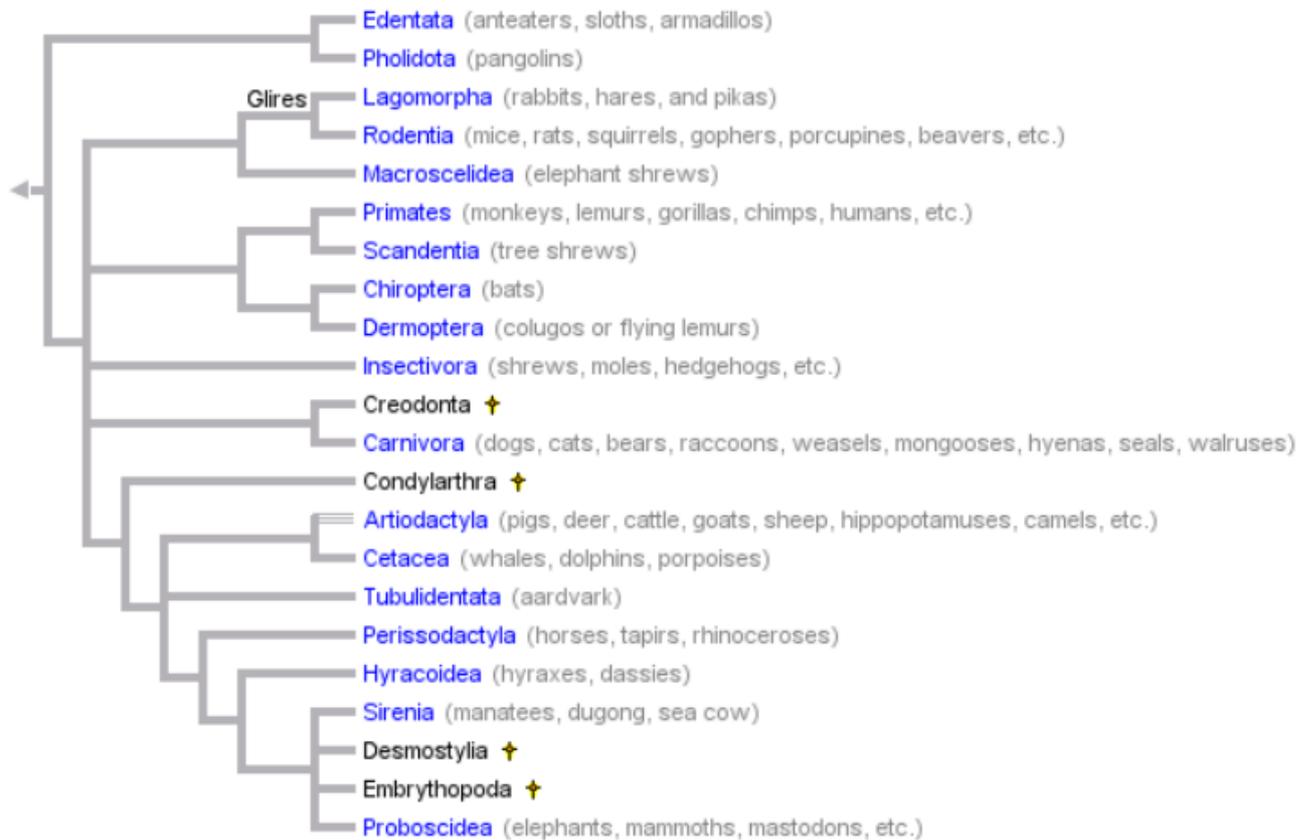


Figure 1

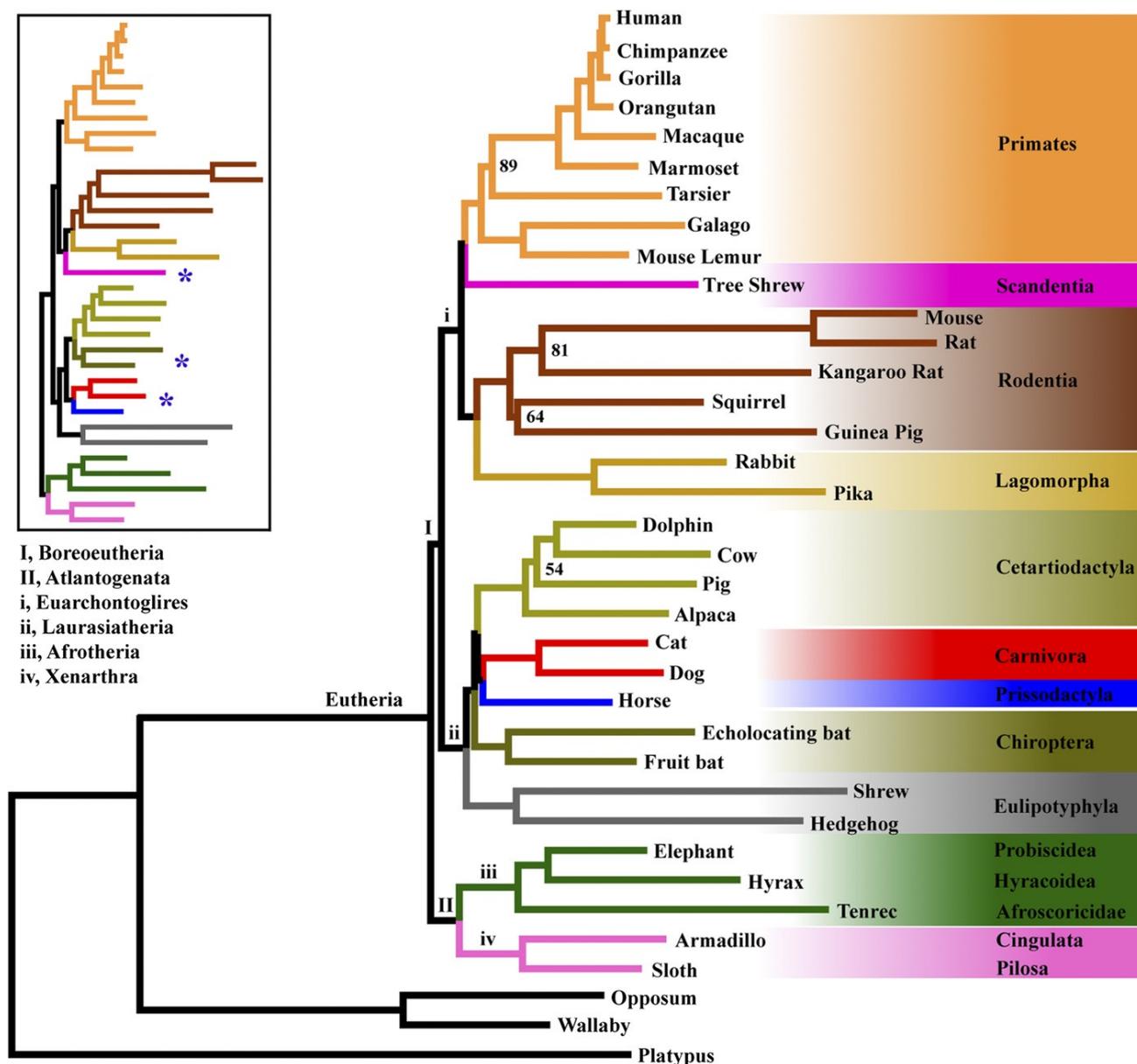
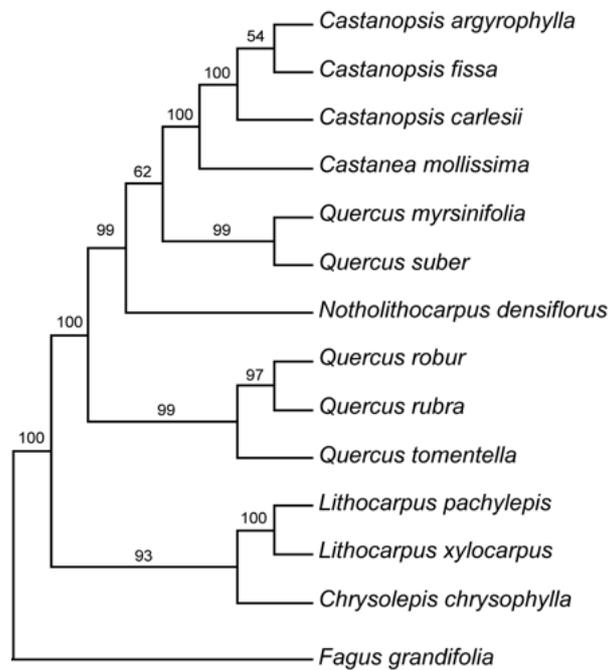


Figure 2

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

- A. The tree depicted in Figure 2 has resolved the polyphyletic groups present in the tree shown in Figure 1.
- B. We now have evidence that the Carnivora emerged from a paraphyletic ungulate clade.
- C. There is still no consensus on whether Primates and Scandentia are sister taxa.
- D. The differences between two phylogenetic trees may be due to gene tree heterogeneity.

50. A phylogeny of the plants family Fagaceae was generated, as shown below, and included *Fagus grandifolia* as the outgroup. The numbers above each branch represent bootstrap support values for the clades..



**Based on this phylogeny, indicate if each of the following statements is true or false.**

- A. *Quercus suber* is more closely related to *Castanopsis fissa* than to *Quercus rubra*.
- B. The genera of some species have to be changed.
- C. The phylogenetic relationships among *Castanopsis* species are poorly resolved.
- D. *Fagus grandifolia* is the ancestral species of all other taxa in this tree.

**END OF TEST**