ENVELOPE COVER SHEET

Student Code: _____

20th INTERNATIONAL BIOLOGY OLYMPIAD

Tsukuba, JAPAN 12th – 19th July, 2009

THEORETICAL TEST: PART A

Time available: 120 minutes

GENERAL INSTRUCTIONS

1. Open the envelope after the start bell rings.
2. A set of questions and an answer sheet are in the envelope.
3. Write your 4-digit student code in every student code box.
4. The questions in Part A have only one correct answer. Mark the correct answer with “X” on the **Answer Sheet** clearly, as shown below.

No.	A	B	C	D	E	F
A0			X			

5. Use pencils and erasers. You can use a scale and a calculator provided.
6. Some of the questions may be marked “DELETED”. DO NOT answer these questions.
7. Stop answering and put down your pencil IMMEDIATELY after the end bell rings.

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THEORETICAL TEST: PART A

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No.	A	B	C	D	E	F
A0			X			

3. Use pencils and erasers. You can use a ruler and a calculator provided.

4. Some of the questions may be marked “DELETED”. DO NOT answer these questions.

5. The maximal points of Part A is 81 (1.5 point each question).

6. Stop answering and put down your pencil IMMEDIATELY after the end bell rings.

GOOD LUCK!!

Cell Biology

A1. Which treatment is most effective in breaking as many hydrogen bonds as possible in an aqueous solution (pH 7.0) of 1 mg/mL DNA and 10 mg/mL protein?

A. Addition of hydrochloric acid to make the pH 1.0.

B. Addition of sodium hydroxide solution to make the pH 13.0.

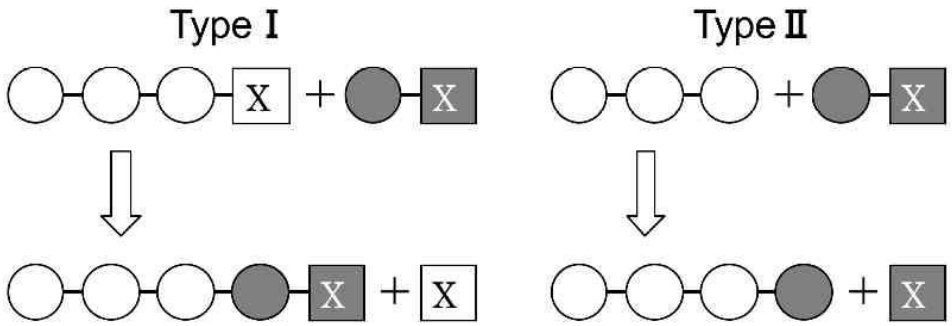
C. Addition of urea to a concentration of 6 mol/L.

D. Addition of sodium dodecyl sulfate (a detergent) to a concentration of 10 mg/mL.

E. Heating the solution to 121°C.

F. Freezing the solution to -80°C.

A2. For the elongation of biopolymer molecules, there are two basic mechanisms, as shown below. In Type I elongation, the activation group (marked with an X) is released from the chain of growth. In Type II elongation, the activation group is released from the unit which is coming into the chain of growth. By which of these mechanisms are DNA (D), RNA (R),and protein (P) biosynthesized?



	Type I	Type II
A	(D)	(R), (P)
B	(P)	(D), (R)
C	none	(D), (R), (P)
D	(R), (P)	(D)
E	(D), (R)	(P)
F	(D), (R), (P)	none

A3. The movement of a ciliated protozoan is controlled by a protein called RacerX. When this protein binds to another protein, Speed, found at the base of the cilia, it stimulates the cilia to beat faster and the protozoan to swim faster. Speed can only bind to RacerX after phosphorylation of a specific threonine residue. How would you expect the mutant protozoan to behave if this threonine residue in Speed is replaced by an alanine residue?

A. Swims fast occasionally.

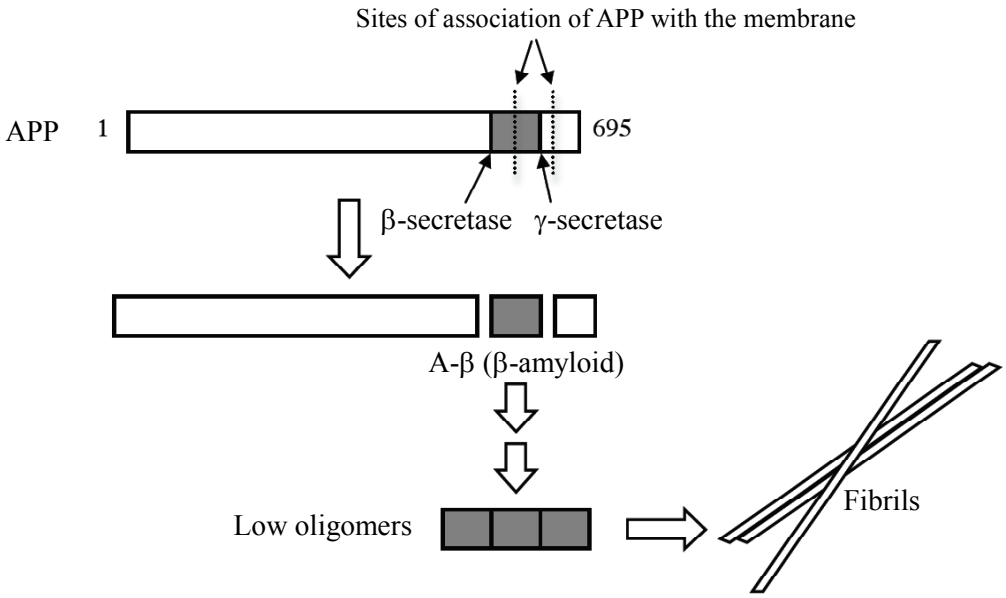
B. Always swims fast.

C. Never swims fast.

D. Switches rapidly back and forth between fast and slow swimming.

E. Cannot move at all.

A4. It is suggested that Alzheimer's disease is manifested by increased accumulation of a small peptide known as β-amyloid (A-β, 40-42 residues). Production of A-β occurs by proteolytic cleavage from a much longer protein APP, a membrane-inserted protein, by two proteases. The figure below shows the hypothesis for the production of the A-β molecule (the gray shaded box), displaying the sequential action of β-secretase to form the N-terminus of A-β and γ-secretase to cleave its substrate within a phospholipid membrane to produce the C-terminus of A-β. The produced A-β monomers then associate to form insoluble oligomers and toxic fibrils.



Which of the following is effective as an anti-Alzheimer therapy based on the above mechanisms?

I. Inhibiting the activity of β-secretase

II. Inhibiting the membrane targeting of γ-secretase

III. Inhibiting the oligomerization of A-β

IV. Enhancing the cellular mechanism of removal and degradation of A-β oligomers

A. Only I, II, IV

B. Only I, II, III

C. Only I, III, IV

D. Only II, III, IV

E. I, II, III, IV

A5. Human acetaldehyde dehydrogenase acts as a tetramer. Two alleles, *N* encoding a normal polypeptide and *M* encoding a mutant polypeptide, are known for the gene of this enzyme. Tetramers containing one or more mutant polypeptides have effectively no enzymatic activity. If the acetaldehyde dehydrogenase activity of the *NN* homozygote cells is 1, what is the activity of the *NM* heterozygote cells, assuming that both alleles are expressed at equal rates?

A. 1/2

B. 1/4

C. 1/8

D. 1/16

E. 1/32

A6. In 1961 Mitchell proposed a highly original explanation for ATP synthesis, which he called the chemiosmotic coupling model. Which of the following is correct?

A. ATP synthesis in mitochondria can be explained by the chemiosomotic model, but in chloroplasts it cannot.
B. ATP synthesis in mitochondria and chloroplasts can be explained by the chemiosomotic model only when the concentration of H^+ ions in the cell is higher than 0.1 mmol/L.
C. The energy source for mitochondria is electrons from nutrients, but for chloroplasts the energy source is electrons from water.
D. In mitochondria H^+ ions are pumped into the matrix, but in chloroplasts they are pumped into the thylakoid lumen.
E. H^+ ions are transferred through ATP synthase both in mitochondria and chloroplasts.

A7. A scientist, studying the process of photosynthesis, illuminates a culture of unicellular green algae for a certain period of time. Then she turns off the light and adds radioactive CO_2 by bubbling it in the culture for 30 minutes. Immediately she measures radioactivity in the cells. What is she likely to observe?

A. No radioactivity in the cells, because light is necessary to produce sugars starting from CO_2 and water.
B. No radioactivity in the cells, because CO_2 is used to produce O_2 during the light-dependent reactions.
C. No radioactivity in the cells, because CO_2 is taken by the plant cells only during illumination.
D. Radioactivity in the cells, because CO_2 is used to produce sugars even in the dark.
E. Radioactivity in the cells, because CO_2 is incorporated into NADPH in the dark.

A8. Which of the following are true for the relative permeabilities of human red blood cells and artificial phospholipid bilayer vesicles (called artificial vesicles hereafter) to glucose and ethanol?

I. Both red blood cells and artificial vesicles are more permeable to glucose than to ethanol.
II. Both red blood cells and artificial vesicles are more permeable to ethanol than to glucose.
III. In both red blood cells and artificial vesicles, the permeability to ethanol is almost the same as that to glucose.
IV. While red blood cells and artificial vesicles show almost the same permeability to glucose, red blood cells have a higher permeability to ethanol than artificial vesicles.
V. While red blood cells and artificial vesicles show almost the same permeability to ethanol, red blood cells have a higher permeability to glucose than artificial vesicles.

A. I, IV
B. I, V
C. II, IV
D. II, V
E. III, IV
F. III, V

A9. A previously unknown organism that lacks nuclear membrane and mitochondria has just been discovered. Which of the following would this organism most likely possess?

A. Lysosome

B. Cilium

C. Endoplasmic reticulum

D. Chloroplast

E. Ribosome

A10. In eukaryotic cells, the oxidative phosphorylation reactions are catalyzed by various enzymes. Which of the following is correct?

A. All of these enzymes are coded in nuclear DNA, synthesized in ribosomes and imported into mitochondria.
B. Some of these enzymes are coded in mitochondrial DNA. Their messenger RNA is exported outside mitochondria and the enzymes are synthesized in ribosomes. The enzymes are then imported back into mitochondria.
C. Some of them are coded in mitochondrial DNA and synthesized in mitochondrial ribosomes.
D. All of them are coded in mitochondrial DNA and synthesized in mitochondrial ribosomes.
E. A copy of mitochondrial DNA is exported outside mitochondria. The synthesized enzymes are imported into mitochondria.

A11. Jellyfish-derived genes encoding fluorescent proteins, such as green fluorescent protein (GFP), are widely used in molecular biological studies particularly for the purpose of tagging and visualizing proteins of interest. PLX is a plant gene encoding an unknown protein. A chimeric gene consisting of the PLX gene and the GFP gene was constructed to produce a PLX-GFP fusion protein under an inducible promoter, and introduced into mesophyll protoplasts by electroporation. The following figures show schematic images of fluorescence micrographs of the same protoplast at various times after the induction of PLX-GFP expression.

Before the induction (dotted line indicates the protoplast outline)

Shortly after the induction

Long after the induction

In consideration of the change in the spatial pattern of the fluorescent signals, speculate which of the following cell structures most likely corresponds to the fluorescent signals in the middle picture.

A. Nucleoli

B. Mitochondria

C. Golgi apparatuses

D. Nuclear pores

E. Chloroplasts

F. Peroxisomes

A12. The recognition sequence for the restriction endonuclease *Ava*I is CYCGRG, where Y is any pyrimidine and R is any purine. What is the expected distance (in bp = base pairs) between the restriction sites of *Ava*I in a long, random DNA sequence?

A. 4096 bp

B. 2048 bp

C. 1024 bp

D. 512 bp

E. 256 bp

F. 64 bp

A13. The arabinose operon of *Escherichia coli* is not expressed in the absence of arabinose. This is attributable to the AraC protein, which binds to the promoter of the arabinose operon and acts as a suppressor to prevent its transcription. Normally the arabinose operon is expressed in the presence of arabinose. In mutants that lack the *AraC* gene, however, the arabinose operon is not expressed even in the presence of arabinose. Based on this information, which of the following can be reasonably inferred with respect to AraC?

A. The transcription of the *AraC* gene is induced by arabinose.
B. The transcription of the *AraC* gene is blocked by arabinose.
C. The AraC protein is converted into an activator in the presence of arabinose.
D. The AraC protein is degraded in the presence of arabinose.

A14. Nucleotide sequence duplications in a gene cause severe effects on its function in some cases while they do not in other cases. Which of the following duplication events would most likely result in the synthesis of a **non-functional** protein?

A. A base pair is duplicated just before the translation initiation site.
B. Three base pairs are duplicated just before the translation initiation site.
C. A base pair is duplicated in the coding region near the translation initiation site.
D. Three base pairs are duplicated in the coding region near the translation initiation site.
E. A base pair is duplicated in the coding region near the stop codon.
F. Three base pairs are duplicated in the coding region near the stop codon.

Plant Anatomy and Physiology

A15. Cell walls of vessels and tracheids of vascular plants contain a phenolic polymer called "lignin", which together with cellulose confers mechanical strength to these water-conducting tissues. If vessels/tracheids are deficient in lignin, they:

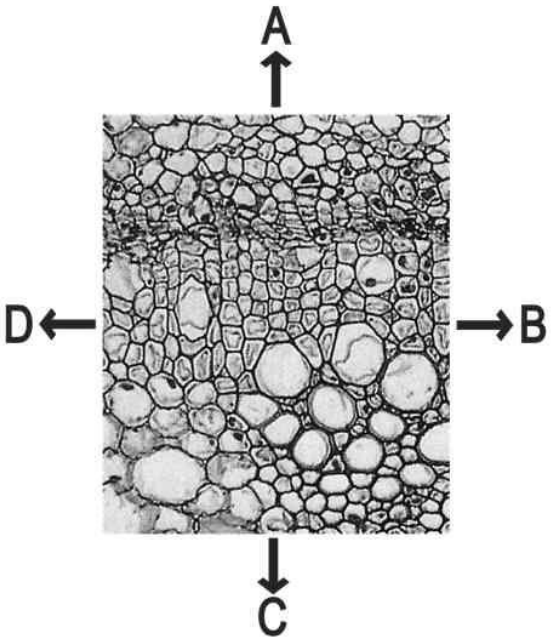
A. burst outward when transpiration is very active.

B. burst outward when transpiration is very inactive.

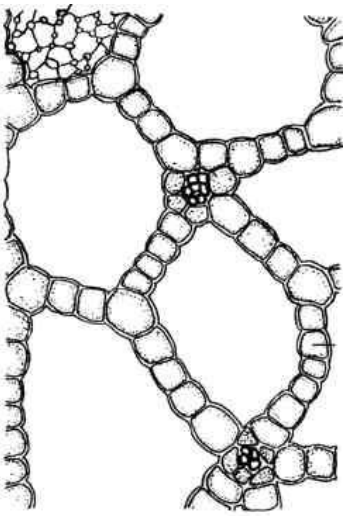
C. collapse inward when transpiration is very active.

D. collapse inward when transpiration is very inactive.

A16. The following micrograph shows a part of the transverse section of the stem of a dicot plant. Which arrow indicates the direction towards the center of the stem?



A17. The plant tissue shown below is likely to be from a:



A. xerophyte

B. mesophyte

C. halophyte

D. hydrophyte

E. epiphyte

A18. To examine the effect of phytohormones P1 and P2 in plant tissue culture, leaf segments were excised from plants grown under the light, placed on medium that contained P1 and/or P2, and cultured in the dark. As a control experiment, leaf segments were cultured without P1 or P2 in the dark.

(a) When only P1 was added to the medium, adventitious roots formed on the explants.

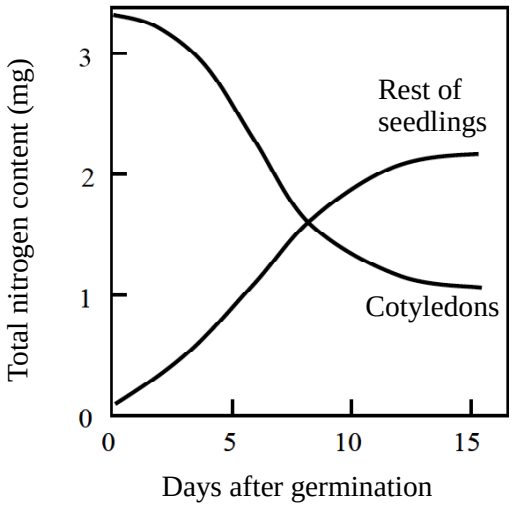
(b) When only P2 was added to the medium, neither organogenesis nor callus formation occurred. The explants retained green color for a longer period than the explants of the control experiment.

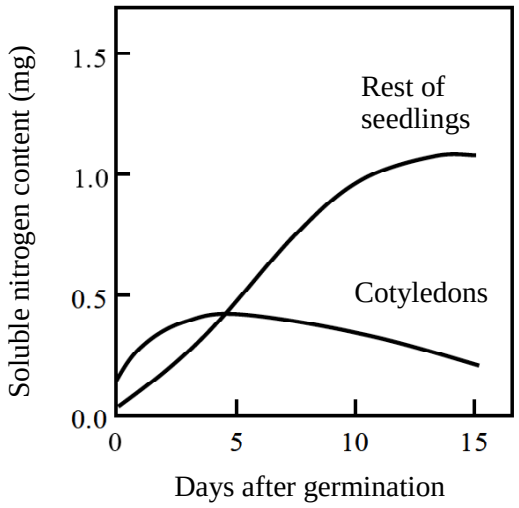
(c) When both P1 and P2 were added to the medium, callus formed on the explants.

Based on this information, P1 and P2 were:

	P1	P2
A	Auxin	Gibberellin
B	Auxin	Cytokinin
C	Gibberellin	Auxin
D	Gibberellin	Cytokinin
E	Cytokinin	Gibberellin
F	Cytokinin	Auxin

A19. Exalbuminous (endospermless) seeds of a certain plant species were immersed in pure water, germinated, and grown in the dark. Total nitrogen content and soluble nitrogen content (nitrogen in low-molecular-weight compounds such as amino acids) were measured for cotyledons and the other parts of the seedlings. The results are shown in the following figures. With respect to the nitrogen metabolism in seedlings of this plant, which of the following statements is the most appropriate explanation?





Proteins in cotyledons were degraded to produce amino acids,

A. which were eventually consumed as nitrogen sources for the growth of cotyledons.

B. which were eventually excreted from seedlings as wastes.

C. which were translocated and provided almost all of the nitrogen sources required for the initial growth of seedlings.

D. which were translocated and provided about half of the nitrogen sources required for the initial growth of seedlings.

A20. Two alleles *G* and *g* are present at a particular locus of a fern species. Spores were collected from a heterozygous sporophyte with *Gg* genotype of the fern species. Gametophytes were grown from the spores and self-fertilized by isolating each sexually matured gametophyte. What is the expected ratio of the *GG* : *Gg* : *gg* genotypes of the sporophytes?

A. 1 : 2 : 1

B. 2 : 1 : 1

C. 3 : 0 : 1

D. 0 : 3 : 1

E. 1 : 0 : 1

F. 0 : 1 : 1

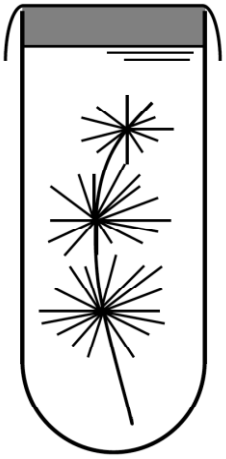
A21. Totally submerged aquatic plants can cause a pH change in the surrounding water when they carry out photosynthesis. What pH change happens and what causes it?

A. The pH falls because carbon dioxide is absorbed.

B. The pH rises because carbon dioxide is absorbed.

C. The pH falls because oxygen is released.

D. The pH rises because oxygen is released.



A22. If the ambient temperature rises by 5°C, photorespiration would:

A. Increase in rice, decrease in maize

B. Increase in maize, decrease in rice

C. Increase in rice, little effects on maize

D. Increase in maize, little effects on rice

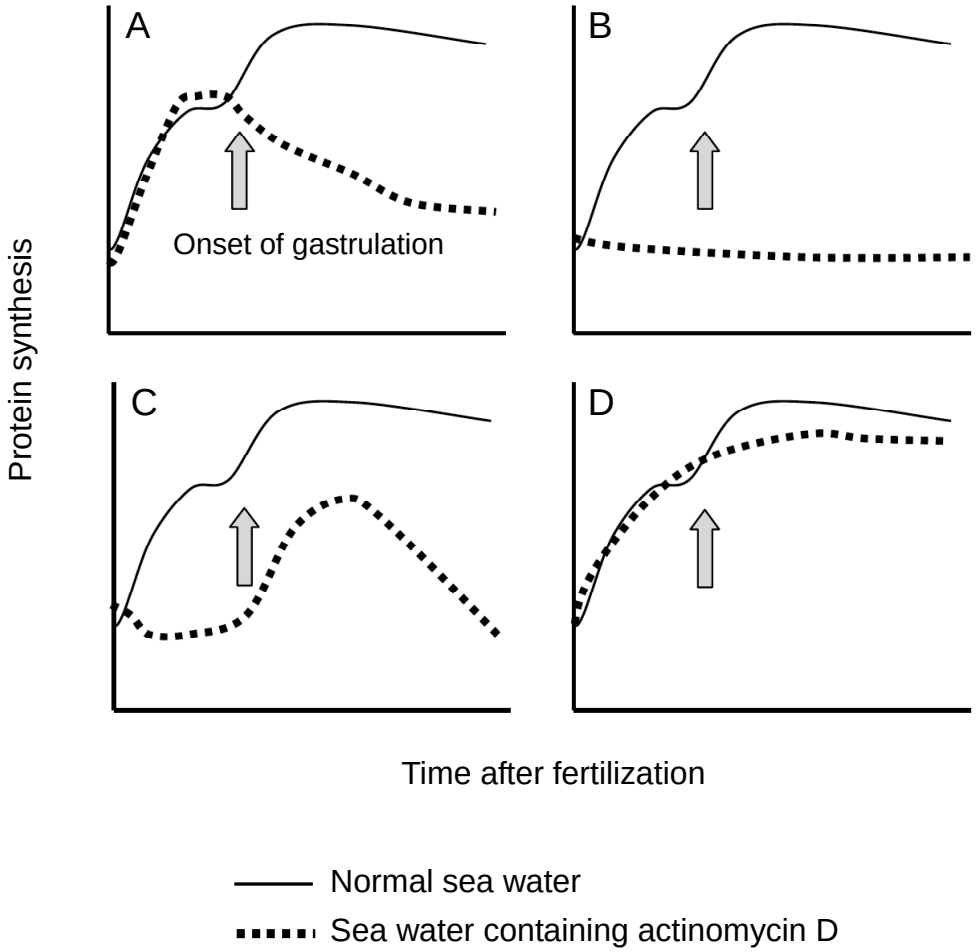
E. Increase in both species

F. Decrease in both species

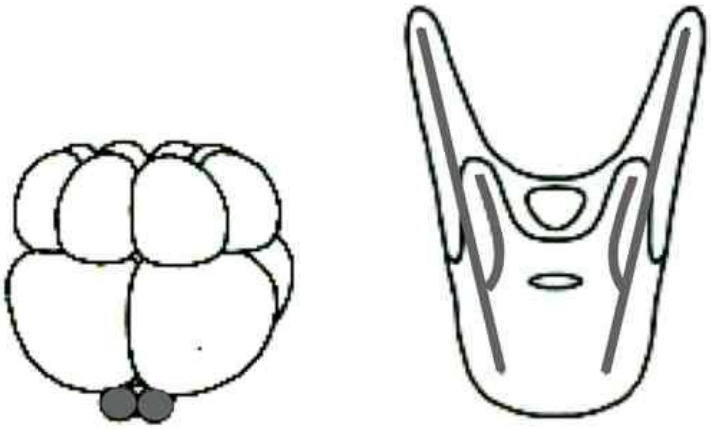
Animal Anatomy and Physiology

A23. When fertilized sea urchin eggs were reared in sea water containing actinomycin D, an inhibitor of transcription, eggs developed normally until the blastula stage, but stopped development after that. This is due to the fact that in embryos the process of transcription does not take place during the cleavage period, and the proteins necessary for the development are translated from mRNA stored in the eggs.

If protein synthesis is measured during this experiment, which of the following graphs would be obtained?



A24. At the 16-cell stage, the sea urchin embryo consists of three types of cells: eight mesomeres, four macromeres and four micromeres, from animal pole to vegetal pole. When four micromeres were labeled by fluorescent dye, all the spicule forming cells in the resulting 2-day-old larva were fluorescent (see figure).



Thus, in normal larvae, spicule forming cells are derived solely from micromeres. However, even if all the micromeres are removed from a 16-cell embryo, spiculogenesis still occurs in 2-day-old larva. From this we can conclude that:

A. all the cells in a 16-cell-stage embryo can form spicules when receiving an appropriate signal from micromeres.
B. all the cells in a 16-cell-stage embryo can form spicules when the micromeres are removed.
C. micromeres or their descendent cells send a spiculogenesis-inhibiting signal to other cells.
D. micromeres or their descendent cells send a spiculogenesis-inducing signal to other cells.

A25. The crab-eating frog is a unique amphibian which has adapted to the marine habitat and lives in mangroves. Different from marine bony fish, these frogs deal with the osmotic problem by:

A. drinking sea water and excreting excess salt.

B. excreting a large amount of excess water as urine.

C. excreting nitrogen waste as ammonia.

D. storing urea in their body fluid.

A26. Which of the following states occurs if the lung alveoli lose their elasticity?

I. Residual volume decreases.

II. pO_2 in the air inhaled has to increase in order to keep the saturation of hemoglobin at the same level.

III. Blood pH increases.

A. Only I

B. Only II

C. Only III

D. I and II

E. I and III

F. II and III

A27. Which of the following statements about skeletal muscle is NOT correct?

A. The length (distance) of a single muscle contraction depends on the concentration of Ca^{2+} ions in the sarcoplasmic reticulum.

B. Muscles with short sarcomeres contract faster than muscles with long sarcomeres.

C. The velocity of muscle contractions is determined by myosin-ATPase activity.

D. Tetanus is the effect of repeated stimulations within a very short interval.

E. Rigor mortis (death rigidity) appears when the concentration of Ca^{2+} in cytoplasm is high but ATP is lacking.

A28. Which of the following would occur if a neuron was experimentally stimulated simultaneously at both ends?

A. The action potentials would pass in the middle and travel to the opposite ends.
B. The action potentials would meet in the middle and then be propagated back to their starting positions.
C. The action potentials would stop as they meet in the middle.
D. The stronger action potential would override the weaker action potential.
E. Summation would occur when the action potentials meet in the middle, resulting in a larger action potential.

A29 What happens when the pancreatic duct of a certain mammal is temporarily ligated for an experiment? Note that carbohydrate and other nutrients in the diet are in proper amounts and ligation of the pancreatic duct is not critical for survival of the animal.

The amount of carbohydrate:

A. increases in feces, decreases in urine.

B. increases in feces, does not change in urine.

C. decreases in feces, increases in urine.

D. decreases in feces, does not change in urine.

E. increases both in feces and urine.

F. decreases both in feces and urine.

A30. Shown is the change of glucose concentration in the blood, measured by taking small blood samples from the fingertip of a person who drank a solution containing 50 g of glucose.

Time after drinking the solution (min)	Glucose conc. in the blood (mmol/L)
0	4.9
15	6.1
30	7.7
45	6.4
60	4.2
90	4.2
120	4.0
150	4.8

Has the glucose concentration at any time during the experiment been equal to or higher than 7.7 mmol/L in the hepatic portal vein and the hepatic vein?

	hepatic portal vein	hepatic vein
A.	no	no
B.	no	yes
C.	yes	no
D.	yes	yes

A31. A substance from the plant *Gymnema sylvestre* blocks the sweet taste of sugar and also blocks absorption of sugar by the small intestine. What can be assumed from these two phenomena?

A. It metabolizes sucrose to glucose and fructose.

B. It polymerizes sugar into oligosaccharides.

C. It binds with sugar receptors and transporters.

D. It binds with certain neurotransmitter receptors and transporters.

E. It binds with insulin receptors.

A32. When a species of poisonous fish was fertilized *in vitro* and cultured in an indoor plastic tank filled with artificial seawater, they were never poisonous. Young fish grown in this tank were next divided into two groups and placed in separate pens in a bay where they were exposed to real seawater. One pen had a horizontal net that prevented the fish from reaching the sea bottom, while the other pen had no horizontal net. Subsequently, no poison was detected from the fish cultured in the pen with the net, but poison was found in fish from the other pen.

What do you conclude from this experiment? To be toxic:

I. some component not in artificial seawater but in natural seawater is necessary.
II. it is necessary that they grow up to adults.
III. it is necessary that they can reach the sea bottom.

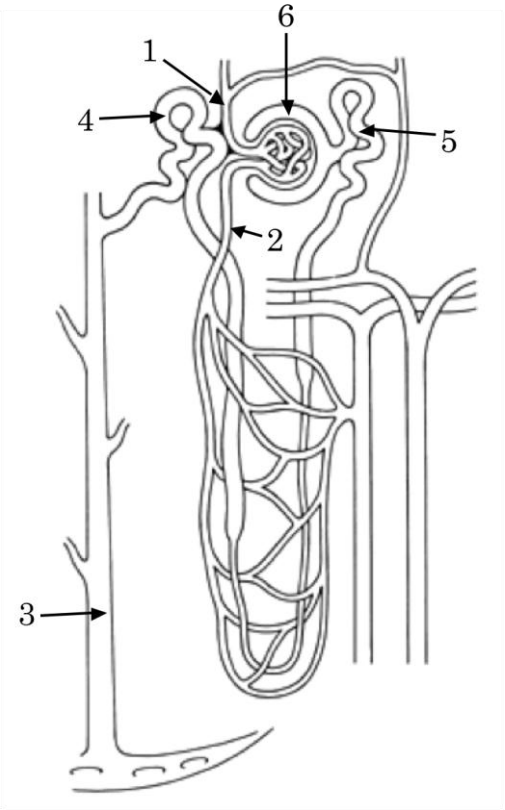
A. Only I
B. Only II
C. Only III
D. Both I and II
E. Both I and III
F. Both II and III

A33. What can be most likely inferred from the following statements (1 to 4) about a disease of patient X?

1. Patient X has a disease that makes her very sensitive to infection by bacteria and viruses.
2. The IgG gene of this patient is normal.
3. This disease is caused by the abnormality of gene “x” which does not work at all.
4. When T cells of a normal person and B cells of patient X are mixed and cultured in the presence of reagents that activate these cells, IgG is secreted into the culture medium. However, when B cells of a normal person and T cells of patient X are combined, IgG is not secreted.

A. Gene “x” needs to be expressed in B cells for the production of IgG.
B. T cells of patient X are normal.
C. IgG is produced by T cells.
D. Gene products of gene “x” are necessary for T cells to induce B cells to produce IgG.
E. The genome of B cells does not contain gene “x”, while that of T cells does.

A34. The diagram shows a simplified kidney tubule and associated blood vessels, and the table shows the presence or absence of substances (X, Y, Z) in each part (1–6) of the diagram.



	X	Y	Z
1	Present	Present	Present
2	Present	Present	Present
3	Absent	Present	Absent
4	Absent	Present	Absent
5	Present	Present	Absent
6	Present	Present	Absent

Identify the substances X to Z.

	X	Y	Z
A	Urea	Glucose	Proteins
B	Urea	Proteins	Glucose
C	Glucose	Urea	Proteins
D	Glucose	Proteins	Urea
E	Proteins	Glucose	Urea
F	Proteins	Urea	Glucose

Ethology

A35. The vampire bat of Costa Rica is often not able to acquire blood from a mammal on a given night. Wilkinson (1984) trapped bats which were not allowed to feed for a night and found that they were given regurgitated blood by certain cave-mates. Based on this knowledge, which of the following observations are indispensable to confirm the occurrence of reciprocal altruism in this species?

Data showing that:

I. blood is exchanged only between kin.

II. blood is exchanged between non-kin.

III. weak bats are frequently given blood even if they cannot give it to others.

IV. bats who are given blood donate it to those who have given it to them before.

Combinations:

A. Only I

B. Only IV

C. I, III

D. I, IV

E. II, III

F. II, IV

A36. In a certain bird species, territory-holding males are sexually mature, have red chest feathers and aggressively drive out intruders. Several models, shown below, were built to test territory defense in this species. What is the most likely sequence of attack on these models in decreasing order of aggression?

I. A model of a normal juvenile bird with brown chest feathers

II. A model of a normal adult bird with red chest feathers

III. A model of an adult bird with brown chest feathers

IV. A model of a juvenile bird with red chest feathers

Sequences

A. I $\rightarrow$ III$\rightarrow$ IV $\rightarrow$ II

B. I $\rightarrow$ IV $\rightarrow$ III $\rightarrow$ II

C. II $\rightarrow$ III $\rightarrow$ IV $\rightarrow$ I

D. II $\rightarrow$ IV $\rightarrow$ III $\rightarrow$I

Genetics and Evolution

A37. A man with a genetic disease marries a phenotypically normal woman. They have four girls and four boys; all of the girls have the same disease as their father, but none of the boys does. What is the most likely explanation?

The disease is caused by:

A. an autosomal dominant allele.

B. an autosomal recessive allele.

C. an X-linked dominant allele.

D. an X-linked recessive allele.

E. a Y-linked allele.

A38. There is a degenerative disease which develops in people between 35 and 45 years old. It is caused by a dominant allele. A couple has two children, who are both younger than 20 years old. One parent has the disease (heterozygote), but the other parent, who is 50 years old, does not. What is the probability that the **both** children will develop this disease when they become older?

A. 1/16

B. 3/16

C. 1/4

D. 9/16

E. 3/4

A39. There are n+1 alleles at a particular locus on an autosome. The frequency of one allele is 1/2 and the frequencies of the other alleles are all 1/(2n). Under the assumption of Hardy-Weinberg equilibrium, what is the total frequency of heterozygotes?

A. (n – 1)/(2n)

B. (2n – 1)/(3n)

C. (3n – 1)/(4n)

D. (4n – 1)/(5n)

E. (5n – 1)/(6n)

A40. At a locus for an enzyme which is inherited independently of sex, the frequencies of genotypes in a population were as follows.

	FF	*FS*	*SS*
Female	30	60	10
Male	20	40	40

Predict the frequency of the *FS* genotype in the next generation, assuming that they will mate randomly.

A. 0.46

B. 0.48

C. 0.50

D. 0.52

E. 0.54

A41. How does the occurrence of self-fertilization relative to cross-fertilization affect the fixation of an advantageous and recessive allele that newly appeared in a population by mutation?

A. The allele will be fixed most quickly when the relative occurrence of self-fertilization is highest.
B. The allele will be fixed most quickly when the relative occurrence of self-fertilization is lowest.
C. The allele will be fixed most quickly when the relative occurrence of self-fertilization is moderate.
D. The relative occurrence of self-fertilization does not affect the fixation of the allele.
E. The relative occurrence of self-fertilization affects the fixation of the allele only when the population is very small.

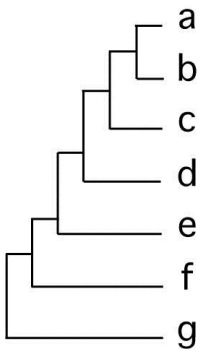
A42. The following table shows the number of estimated nucleotide substitutions that have occurred in a gene among seven species.

The number of estimated nucleotide substitutions between each pair of species

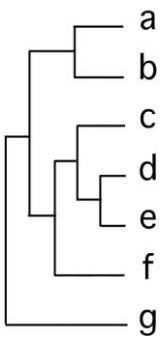
	b	c	d	e	f	g
a	39	72	128	126	159	269
b		81	130	128	158	268
c			129	127	157	267
d				56	154	271
e					151	268
f						273

Which is the most appropriate tree that shows the phylogenetic relationship among these seven species?

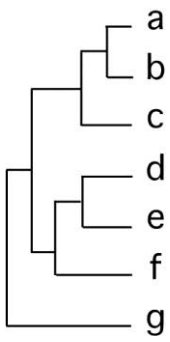
A.



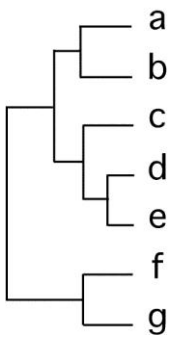
B.



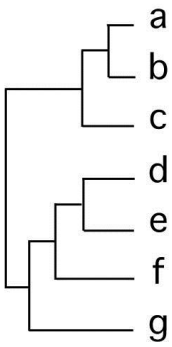
C.



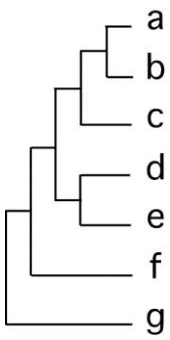
D.



E.



F.



A43. Suppose that at a neutrally evolving genomic region of a species the mutation rate from the base pair GC to AT is three-times the mutation rate from AT to GC. What is the expected GC content at equilibrium?

A. 1/2

B. 1/3

C. 1/4

D. 1/5

E. 1/6

A44. A species of insect was found to have developed resistance to a commonly used insecticide. Which of the following is the most likely explanation?

A. Stabilizing selection caused development of resistance in the insect population.
B. The original gene pool included genes that conferred resistance to the insecticide.
C. The insecticide stimulated development of resistance in certain individuals and this was inherited.
D. The insecticide caused a mutation that was favorable to resistance and this was inherited.

A45. Darwin's finches are a prime example of adaptive radiation. Which of the following best describes this adaptive radiation correctly?

A. The genetic variability that can be found among individuals of the same species.
B. The evolutionary process by which different forms, adapted to different niches, arose from a common ancestor.
C. A sudden diversification of a group of organisms from closely related species.
D. The evolutionary process that allows for the changes that occur within the same lineage.
E. The evolutionary process of adaptation of species through a kind of polymorphism.

A46. Multigene families are groups of two or more identical or very similar genes. Which of the following statements about multigene families is correct?

A. Globin gene families do not have pseudogenes, because globins are essential for oxygen transport.

B. Ribosomal RNA gene families in multicellular eukaryotes have many identical genes, because many ribosomes are required for active protein synthesis.

C. Compared with multicellular eukaryotes, prokaryotes have many multigene families, because prokaryotes have to reproduce very quickly.

D. The number of genes in a multigene family always increases by unequal crossing over.

Ecology

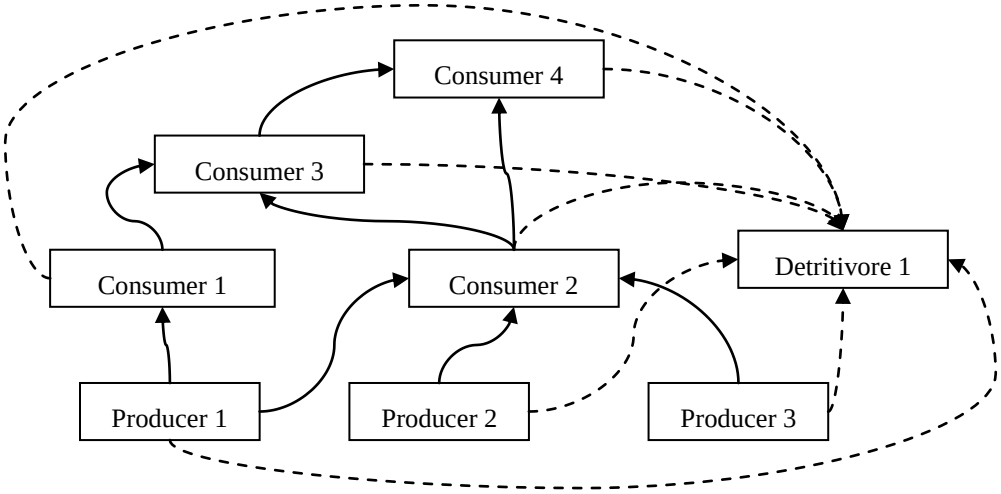
A47. The following table shows the net primary productivity and biomass without soil organic matter in five ecosystems.

Ecosystem	Net primary productivity ($g/m^2/year$)	Biomass (kg/m^2)
Tropical rainforest	2200	45
I	2000	15
II	1200	30
III	900	4
Boreal forest	800	20

Choose from A to F in the table below the most appropriate combination of ecosystems for I, II and III above.

	I	II	III
A	African dry savanna	Tropical swamp & marsh	Temperate deciduous forest
B	African dry savanna	Temperate deciduous forest	Tropical swamp & marsh
C	Temperate deciduous forest	African dry savanna	Tropical swamp & marsh
D	Temperate deciduous forest	Tropical swamp & marsh	African dry savanna
E	Tropical swamp & marsh	African dry savanna	Temperate deciduous forest
F	Tropical swamp & marsh	Temperate deciduous forest	African dry savanna

A48. The diagram below represents the relationships between organisms in a remote pond ecosystem.



From this information, which of the following is the most likely to be correct?

A. DDT present in the ecosystem would accumulate to the highest concentrations in the tissues of Detritivore 1.
B. The introduction of Consumer 4 individuals from an external population would lead to a temporary increase in numbers of Producer 2.
C. Disease in the Producer 1 population would lead to an increase in the Producer 3 population.
D. Extermination of Consumer 3 would cause a sustained increase in the population of Consumer 2.
E. Consumer 1 is more adaptable with regard to its food source than Consumer 3.

A49. The table below shows the results of measurements of production in two ecosystems in the temperate zone: a rainforest and a field with an annual crop. All results are stated in MJ/m^2 / year (1 MJ = 10^6J).

	[I] Rainforest	[II] Field with an annual crop
Gross Primary Production (GPP)	188	102
Respiration (autotrophs)	134	38
Respiration (heterotrophs)	54	3

Of these two ecosystems, which has a higher ratio of respiration by heterotrophic organisms to net primary production (NPP)? What is the reason? Choose the correct option from A to F.

A. [I] < [II] : The rainforest has larger GPP and more consumers than the crop field.

B. [I] < [II] : The rainforest has larger NPP and more consumers than the crop field.

C. [I] < [II] : The rainforest has larger NPP and less consumers than the crop field.

D. [II] < [I] : The rainforest has smaller GPP and more consumers than the crop field.

E. [II] < [I] : The rainforest has smaller NPP and more consumers than the crop field.

F. [II] < [I] : The rainforest has smaller NPP and less consumers than the crop field.

A50. What does the energy input into most food webs typically depend on? Choose the most likely factor from the following.

A. Grazing rate of the primary consumers

B. Material cycling efficiency rate of the whole ecosystem

C. Efficiency rate of producers converting solar radiation energy into chemical energy

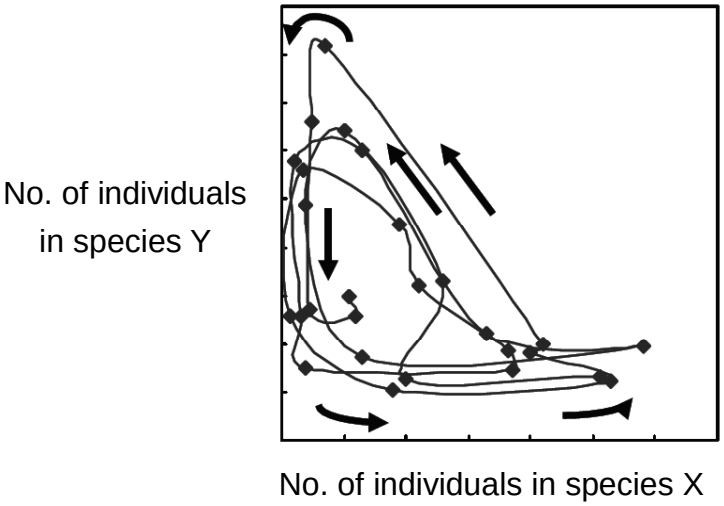
D. Action of nitrogen-fixing bacteria

E. Heat-energy costs due to respiration within each trophic level

A51. Which factor most promotes the stability of population dynamics in a developed terrestrial ecosystem?

A. Food webs that have many trophic levels each of which consists of few species only
B. A few species of producers with very high production rates
C. Rapid nutrient recycling by active decomposers
D. Food webs that have very few trophic levels and limited niche overlaps
E. A few eminent and competitively-dominant species

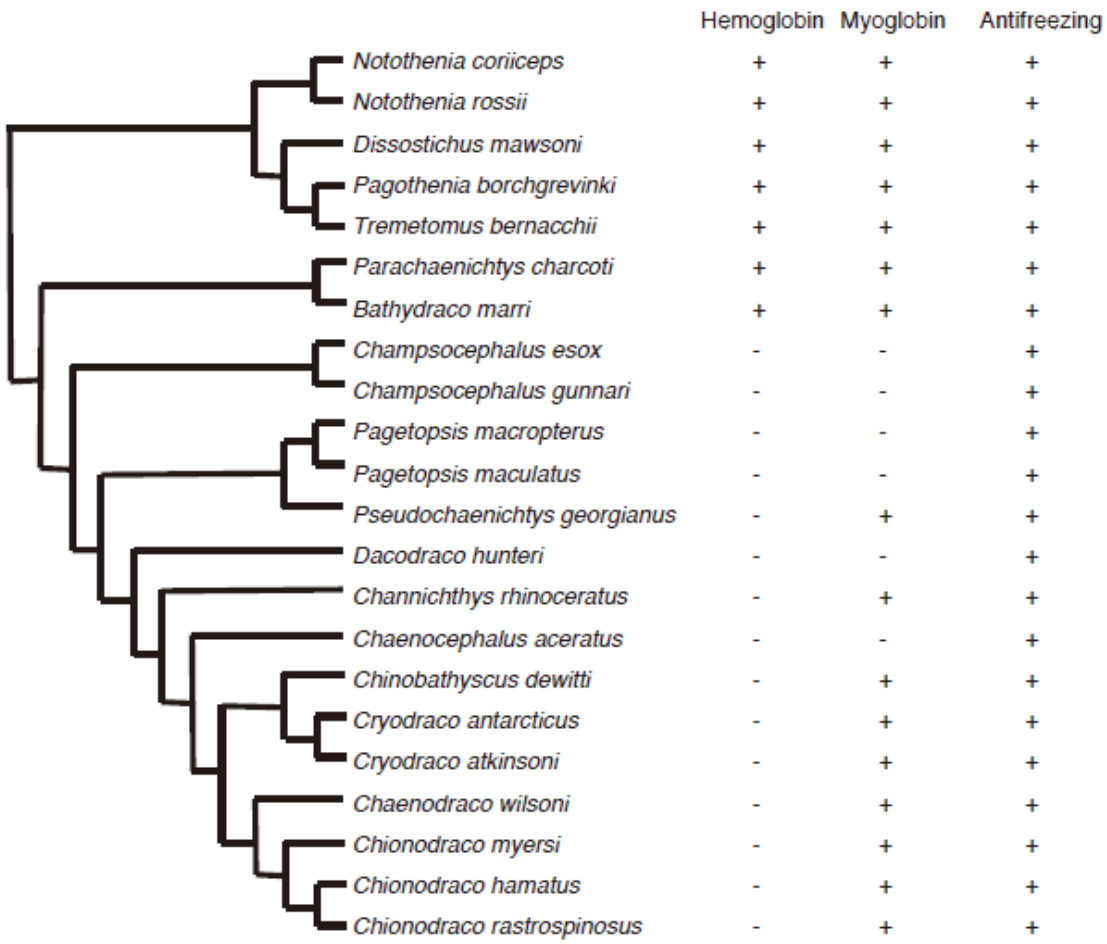
A52. Animal species X and Y have a temporal negative correlation of population abundances, in which arrows indicate the anti-clock-wise (counter-clock-wise) orbit of population dynamics. Choose the most likely combination of explanation and its reasoning.



	Relationship between species X and Y	Reasoning
A.	interspecific competition between X and Y	Y decreases at high density of X Y increases at low density of X
B.	interspecific competition between X and Y	Y increases at intermediate density of X X decreases at intermediate density of Y
C.	predator (X) and prey (Y)	Y decreases when X increases from low density Y increases when X decreases from high density
D.	prey (X) and predator (Y)	

Biosystematics

A53. The following phylogenetic tree shows the relationships among Antarctic icefish and their relatives. Icefish refer to all the species in the tree that have lost hemoglobin and thus possess clear blood. Some icefish species also lost myoglobin which is usually found in muscle cells. In these species, myoglobin lost its function due to distinct mutations. In addition, icefish and relatives possess an anti-freezing glycoprotein to arrest the growth of ice crystals in their tissues. To the right of the tree, whether or not each species possess hemoglobin, myoglobin and the anti-freezing glycoprotein is shown. What conclusion can you draw from the tree?



	Hemoglobin	Myoglobin	Antifreezing
Notothenia coriiceps	+	+	+
Notothenia rossii	+	+	+
Dissostichus mawsoni	+	+	+
Pagothenia borchgrevinki	+	+	+
Trematomus bernacchii	+	+	+
Parachaenichtys charcoti	+	+	+
Bathydraco marri	+	+	+
Champsocephalus esox	-	-	+
Champsocephalus gunnari	-	-	+
Pagetopsis macropterus	-	-	+
Pagetopsis maculatus	-	-	+
Pseudochaenichtys georgianus	-	+	+
Dacodraco hunteri	-	-	+
Channichthys rhinoceratus	-	+	+
Chaenocephalus aceratus	-	-	+
Chinobathyscus dewitti	-	+	+
Cryodraco antarcticus	-	+	+
Cryodraco atkinsoni	-	+	+
Chaenodraco wilsoni	-	+	+
Chionodraco myersi	-	+	+
Chionodraco hamatus	-	+	+
Chionodraco rastrospinosus	-	+	+

A. Anti-freezing glycoprotein has originated in the icefish clade relatively recently.

B. Myoglobin was lost multiple times in the icefish clade.

C. The anti-freezing glycoprotein was necessary before the icefish could lose hemoglobin.

D. The loss of hemoglobin appears to be a more recent trait than the loss of myoglobin.

E. Because myoglobin can substitute for the functions of hemoglobin, icefish could lose hemoglobin.

A54. A list of the shared derived characters for some metazoan phyla is shown below.

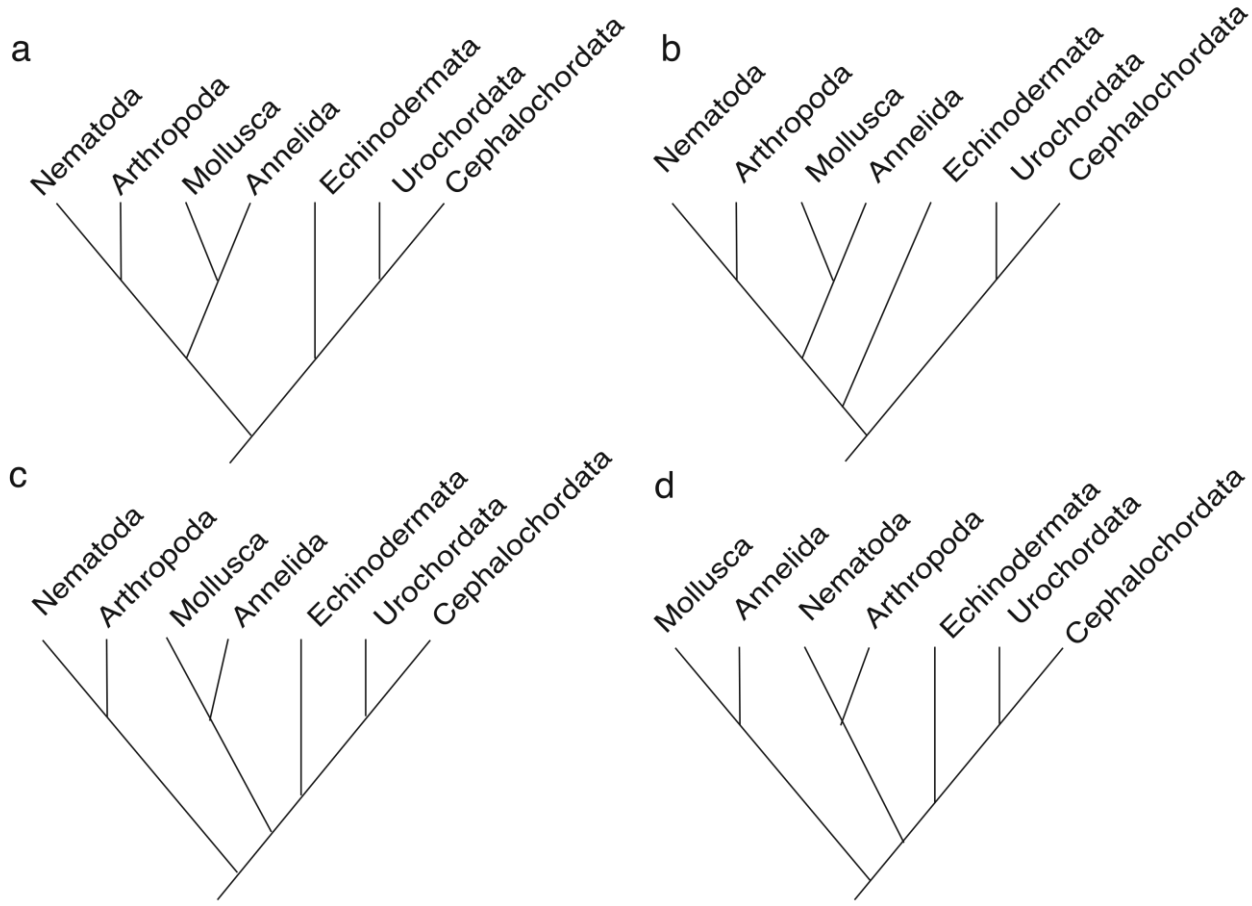
Identify **all** the phylogenetic tree(s) which are consistent with the statements below.

I. Presence of trochophore larva is a shared derived character of the Mollusca and the Annelida.

II. Molting is a shared derived character of the Arthropoda and the Nematoda.

III. Presence of a notochord is a shared derived character of the Urochordata and Cephalochordata.

IV. Developmental fate of blastopore to form the anus is a shared derived character of the Urochordata, Cephalochordata and Echinodermata.



A. a

B. a, c

C. a, d

D. b, c

E. a, b, d

F. a, c, d.

* * * * * END OF PART A * * * * *