ENVELOPE COVER SHEET

Student Code: _____

20th INTERNATIONAL BIOLOGY OLYMPIAD

Tsukuba, JAPAN 12th – 19th July, 2009

THEORETICAL TEST: PART B

Time available: 150 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 B may have more than one correct answer. Fill your all answers in the **Answer Sheet** for Part B. The marks, numbers, or characters to answer questions in Part B vary depending on questions. The ways to answer are indicated along with the questions.
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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3. Use pencils and erasers. You can use a scale and a calculator provided.
4. Some of the questions may be marked “DELETED”. DO NOT answer these questions.
5. The maximal points of Part B is 108 (points are indicated in each question).
6. Stop answering and put down your pencil IMMEDIATELY after the end bell rings.

GOOD LUCK!!

Cell Biology

B1. (3 point) On a dry matter basis, is the average proportion of the following elements significantly higher in herbaceous vascular plants or in mammals? For each element mark ‘X’ in the appropriate box.

A. Nitrogen

B. Oxygen

C. Calcium

D. Potassium

E. Sodium

F. Phosphorus

B2. (2.5 points) Match each of the following properties of water with a benefit to organisms by putting a letter (A to E) in the appropriate box.

Property

I. Low light absorption in the visible region

II. High heat capacity

III. High heat released during fusion

IV. High heat of vaporization

V. Polarity of molecules

Benefit to organisms

A. Biological membranes composed of lipid molecules are thermodynamically stable.

B. Terrestrial plants and animals can cool themselves with minimum loss of water content.

C. Temperature changes in plants and animals are minimized under fluctuating environmental conditions.

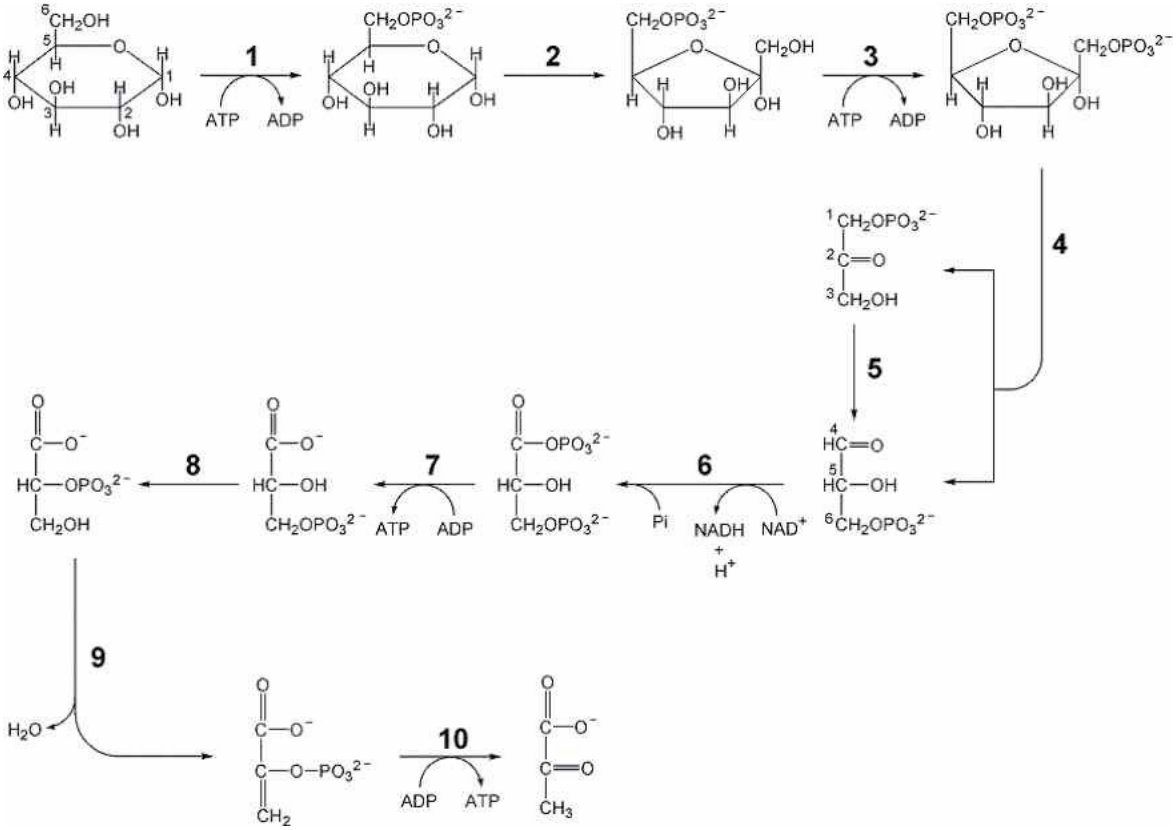
D. Plants can efficiently utilize solar radiation for photosynthesis.

E. Plants and animals are protected against freezing at low temperatures.

B3. (3 points) A coding region of a gene consists of 735 base pairs without stop codon. Calculate the molecular mass of the protein from this gene. The average molecular mass of the free amino acid in this protein is assumed to be 122. Five disulfide bonds are present in the protein. Show your calculations.

B4. (3.5 points) Glycolysis is essential for all organisms.

(1) The figure below shows the reactions of glycolysis. The numbers in the figure indicate enzymes which catalyze the reactions. Categorize each enzyme into the “enzyme type” listed below and put each reaction number in an appropriate box. Note that some enzyme types may be missing.



Enzyme type:

A. Oxidoreductase

B. Transferase

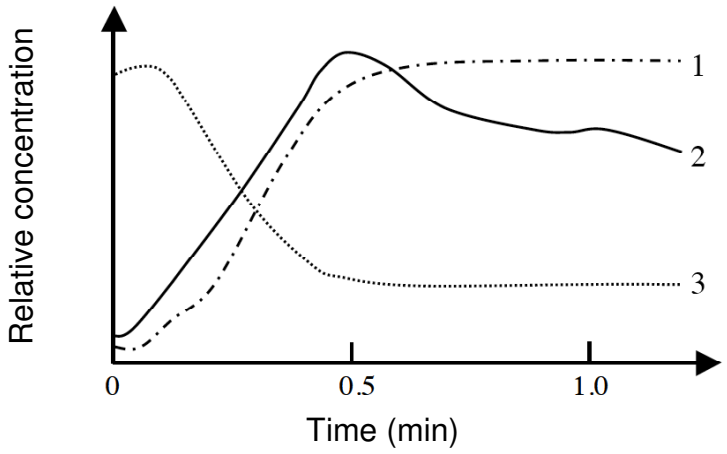
C. Hydrolase

D. Lyase

E. Isomerase

F. Ligase

(2) A cell culture of muscle cells was incubated in oxygenated medium that was then quickly made anoxic. The concentrations of three compounds which are important in glucose metabolism were measured immediately after oxygen removal (marked as time 0) and shown in the graph below:



Match each curve of the graph (1, 2, and 3) with the metabolite whose concentration change it depicts:

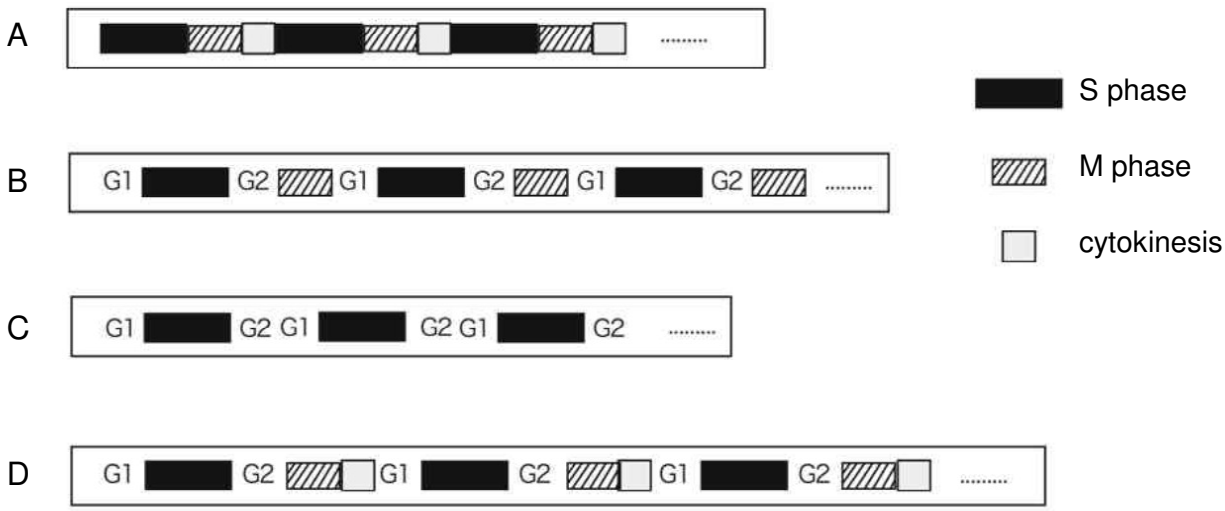
Metabolites:

A. Glucose-6-phosphate

B. Lactate

C. Fructose-1,6-bisphosphate

B5. (2 points) Different patterns of cell cycling (A to D) are shown below. Correctly match them with the given cell types they represent.



Cell types

I. Human epithelial cell

II. Sea urchin embryonic cells up to 128-cell stage

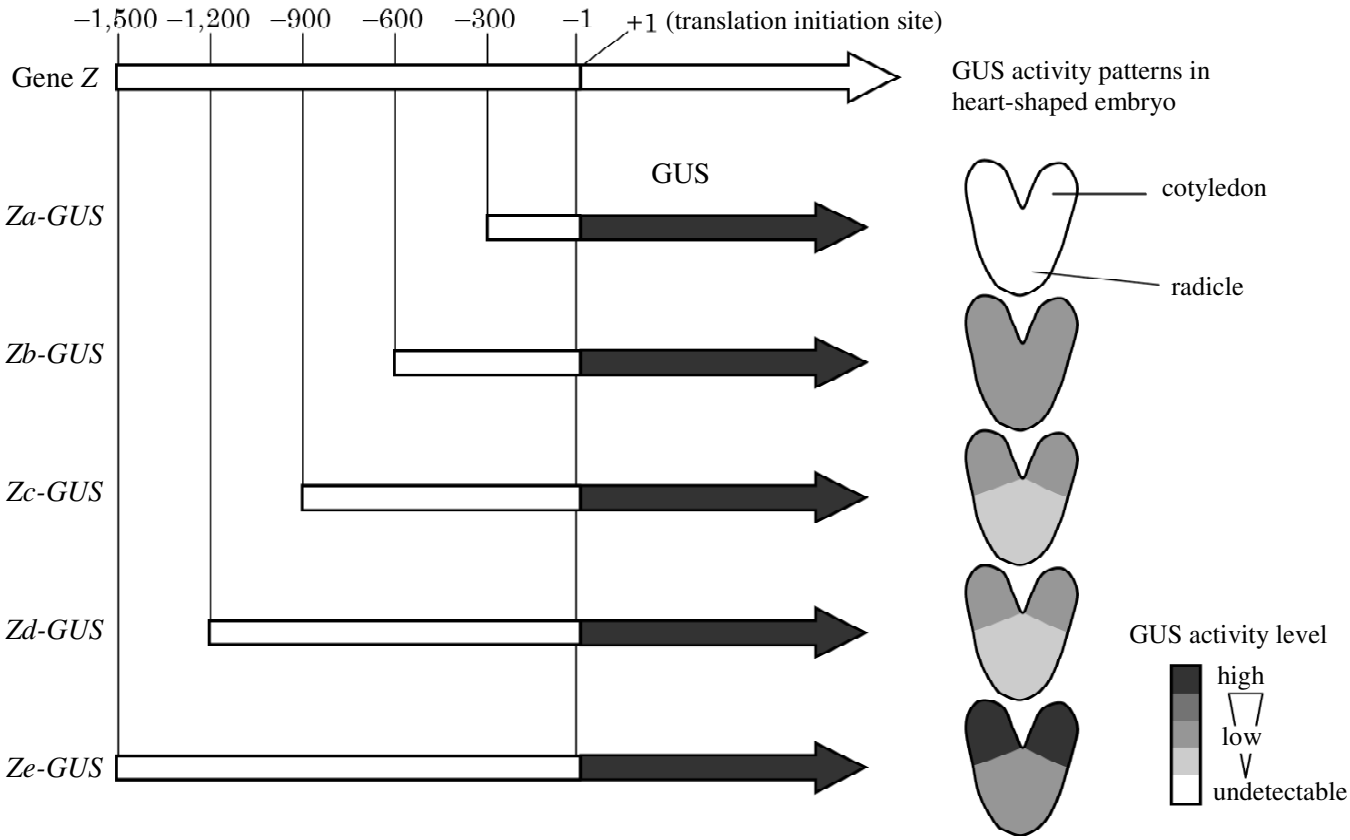
III. Drosophila salivary gland cell

IV. Plasmodium of slime mold

B6. (3 points) A cell suspension of a microorganism was fed with [^{3}H]-labeled uridine and incubated. Cell components were fractionated from these cells and radioactivity in the mRNA fraction was measured, which revealed that 2.5 picomoles of uridine were incorporated into mRNA in 1 x 10^6 cells. Assuming that the base composition of mRNA is random and that the average length of mRNA is 3,000 bases, calculate how many molecules of mRNA were synthesized in each individual cell during incubation.

(Avogadro's number: 6 x 10^{23})

B7. (4 points) From the model plant *Arabidopsis*, 0.3, 0.6, 0.9, 1.2, and 1.5-kbp genomic fragments upstream of the translation start site of gene *Z* were isolated and designated *Za*, *Zb*, *Zc*, *Zd*, and *Ze*, respectively. These fragments were fused to the structural gene of β-glucuronidase (GUS) of *Escherichia coli*. *Arabidopsis* was transformed with the resultant chimeric genes *Za-GUS*, *Zb-GUS*, *Zc-GUS*, *Zd-GUS*, and *Ze-GUS*, and examined for GUS activity by in-situ chromogenic reaction. The following figure schematically shows construction of the chimeric genes and the GUS activity patterns in heart-shaped embryos of the transgenic *Arabidopsis* carrying these chimeric genes.



Based on this result, identify the function of each upstream region of *Z*.

Upstream region

I. –1,500 to –1,201

II. –1,200 to –901

III. –900 to –601

IV. –600 to –301

Functions

A. promotes gene expression in a tissue-non-specific manner

B. promotes gene expression in cotyledons only

C. promotes gene expression in tissues other than cotyledons only

D. suppresses gene expression in cotyledons

E. suppresses gene expression in tissues other than cotyledons

F. little influence on gene expression

Plant Anatomy and Physiology

B8. (3 points) Deficiency of a particular mineral element in the soil elicits a specific pattern of leaf discoloration in plants (chlorosis), which is related to metabolic roles and mobility (translocation) of the mineral element in the plant. The following describes the deficiency symptoms (leaf discoloration), metabolic roles, and mobility of magnesium (Mg), iron (Fe), and nitrogen (N).

Deficiency symptoms

A. Deficiency of this mineral causes chlorosis initially in young leaves
B. Deficiency of this mineral causes chlorosis initially in old leaves

Mineral mobility

C. This mineral is highly mobile in plants.
D. This mineral is largely immobile in plants.

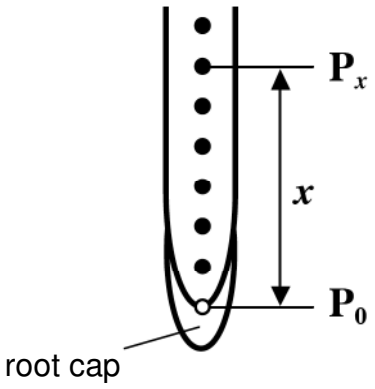
Metabolic roles

E. This mineral is involved as a component in the electron transfer system and is also required for the synthesis of some of chlorophyll-protein complexes.
F. This mineral serves as a constituent of many plant cell components including amino acids, nucleic acids, and chlorophyll.
G. This mineral is involved in the activation of various enzymes and serves as a part of the ring structure of chlorophyll.

Connect each mineral element to the appropriate descriptions of the above three

categories (A or B for Deficiency symptoms; C or D for Mineral mobility; E, F, or G for Metabolic roles).

B9. (3 points) Growing plant roots were analyzed with respect to spatial patterns of cell division and elongation growth. The roots were marked with graphite particles (P) at various positions along the root axis, where *x* was the distance from the root apex just behind the root cap to P_x.



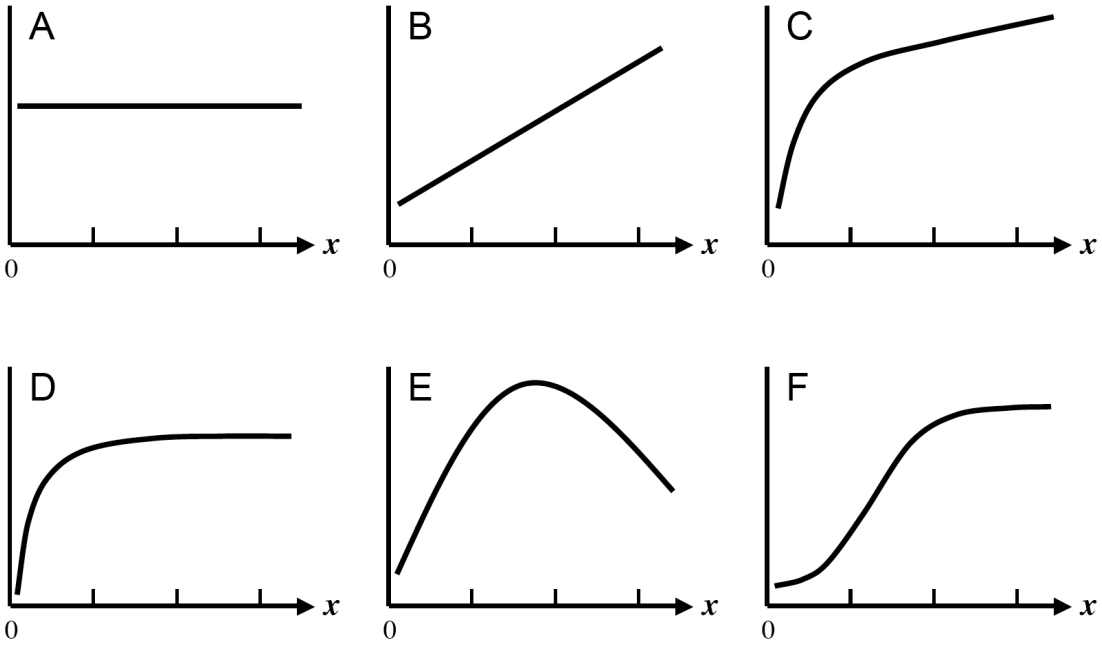
For each P_x, the following data were collected.

I. Number of total epidermal cells present between P_0 and P_x

II. Number of mitotic epidermal cells present between P_0 and P_x

III. Velocity of displacement (movement away) of P_x from P_0

When the data are plotted against *x*, what types of profiles do these data sets show? For each data set, choose the most appropriate profile from the followings.

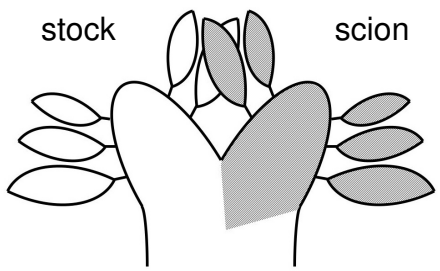


B10. (4 points) Henbane (*Hyoscyamus niger*) is a medicinal plant. Two varieties of this plant, one of which is annual and the other biennial, were characterized for flowering.

In the first experiment, effects of cold treatment and day length on flowering were examined in the annual and biennial varieties. For this purpose, cold-treated and untreated plants were grown under the short-day condition or the long-day condition. The following table indicates whether the plants flowered or not.

		Flowering	
Variety	Treatment	Short-day	Long-day
Annual	Cold-treated	No	Yes
	Untreated	No	Yes
Biennial	Cold-treated	No	Yes
	Untreated	No	No

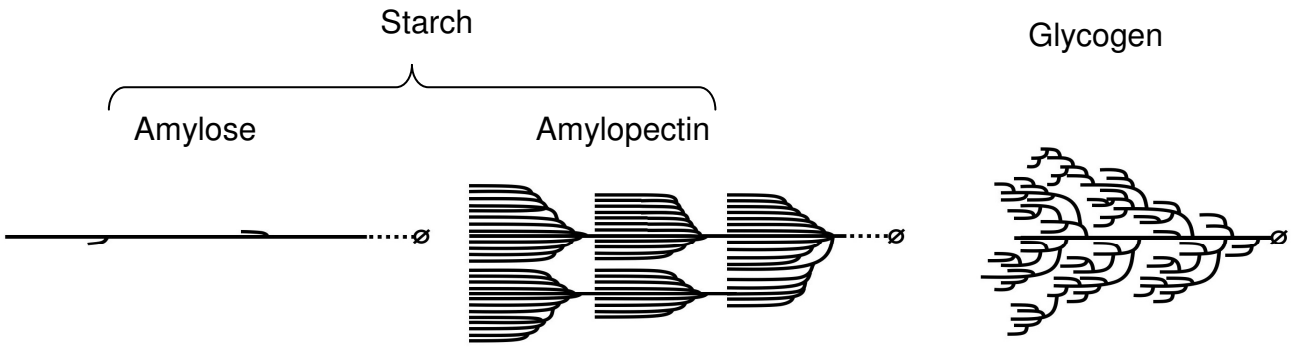
In the second experiment, cold-treated and untreated plants of the annual and biennial strains were grafted as shown in the following figure, and then grown under the long-day condition. Whether the stock and scion flowered or not was recorded. The results of the two types of grafts (#1 and #2) are summarized in the table.



		Strain	Treatment	Flowering
Graft #1	Stock	Annual	Untreated	Yes
	Scion	Biennial	Untreated	Yes
Graft #2	Stock	Biennial	Cold-treated	Yes
	Scion	Biennial	Untreated	Yes

Assuming the involvement of florigen in flowering of this species, identify the properties of the shoot apical meristems and leaves of the annual and biennial plants, based on the above results. Mark the appropriate boxes with "X" about florigen response (1) and florigen productivity (2).

B11. (3 points) Plants and animals accumulate starch and glycogen as a storage polysaccharide, respectively. Starch consists of two sorts of large, water-insoluble polymers of glucose, amylose and amylopectin. Amylose is essentially unbranched and linear while amylopectin is highly and regularly branched, which forms branch clusters. Glycogen is also a branched glucose polymer, but unlike amylopectin, it is relatively small and water-soluble. In the glycogen molecule, branches are shorter, irregular, and not clustered.



(1) Biosynthesis of starch involves three classes of enzymes: chain elongation enzymes, branching enzymes, and debranching enzymes. *Sugary*, a rice mutant, is deficient in a particular debranching enzyme. The endosperm of this mutant is characterized by the accumulation of glycogen-like polysaccharide instead of amylopectin. In consideration of this information, the role of the wild-type debranching enzyme in starch biosynthesis is:

A. to remove all branches from amylopectin to form amylose.
B. to shorten every branch of amylopectin.
C. to regulate the branching pattern of amylopectin.
D. to cut $\alpha 1 \rightarrow 4$ glycosidic bonds of amylopectin.

(2) The seeds of the *Sugary* mutant of rice are not different from the wild-type seeds in the size and appearance before desiccation which is associated with seed maturation. During desiccation, however, the *Sugary* seeds become shrunk and wrinkled. This phenomenon suggests that before desiccation, as compared with the wild-type seeds, the *Sugary* seeds contain:

	storage polysaccharide	water
A	more	less
B	more	more
C	less	more
D	less	less

(3) Bacteria including cyanobacteria accumulate a glycogen-like polysaccharide for storing glucose. Which of the following can reasonably explain the evolution of storage polysaccharides?

The common ancestor of plants and animals could synthesize:

A. both amylopectin and glycogen, but plants have lost the ability of glycogen synthesis during evolution.

B. both amylopectin and glycogen, but animals have lost the ability of amylopectin synthesis.

C. amylopectin but not glycogen, and animals have acquired the ability of glycogen synthesis.

D. glycogen but not amylopectin, and plants have acquired the ability of amylopectin synthesis.

B12. (3 points) Soybean roots form nodules when infected by *Rhizobium*. HN is a recessive mutant of soybean that exhibits a hypernodulating phenotype. As shown in Figure 1, the roots of the HN mutant form more nodules than the wild-type (WT) roots, and the shoot growth of the HN mutant is retarded compared to WT. Figure 2 schematically shows the nodulation phenotypes observed in grafting experiments with WT and the HN mutant. In the absence of *Rhizobium*, the HN mutant is not phenotypically different from WT in any aspects.

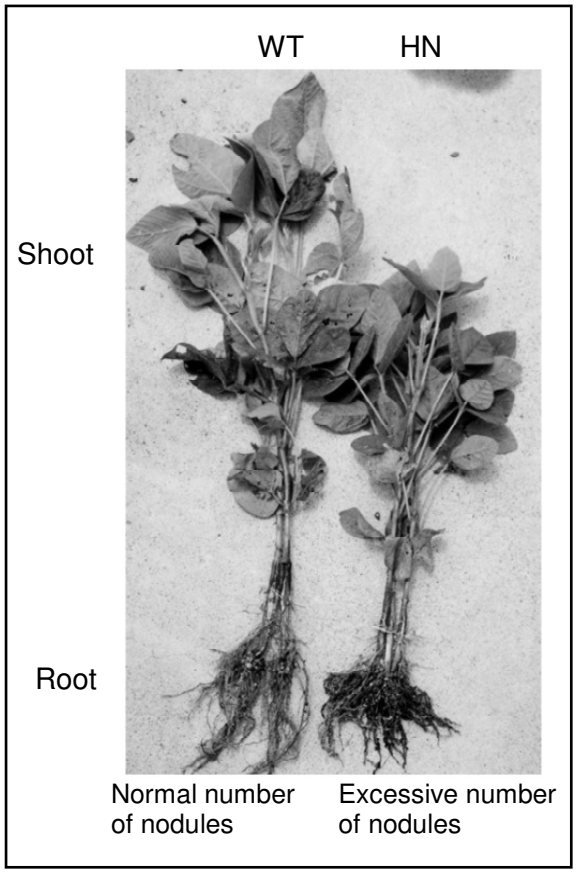


Figure 1

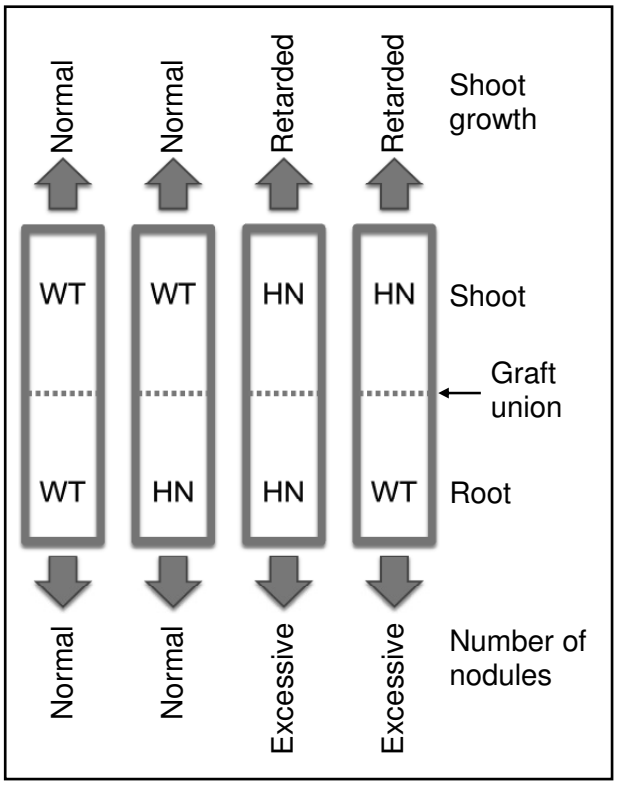


Figure 2

From the above information, what can be reasonably inferred? For each of the following statements, mark “X” in the appropriate box choosing the option in the bracket.

I. In the HN mutant, the {A. shoot / B. root} determines the hypernodulation phenotype.

II. The shoot of WT {A. positively regulates / B. negatively regulates / C. is neutral for the regulation of} the number of nodules.

III. In the HN mutant, hypernodulation is {A. the cause / B. the result / C. independent} of retarded growth of the shoot.

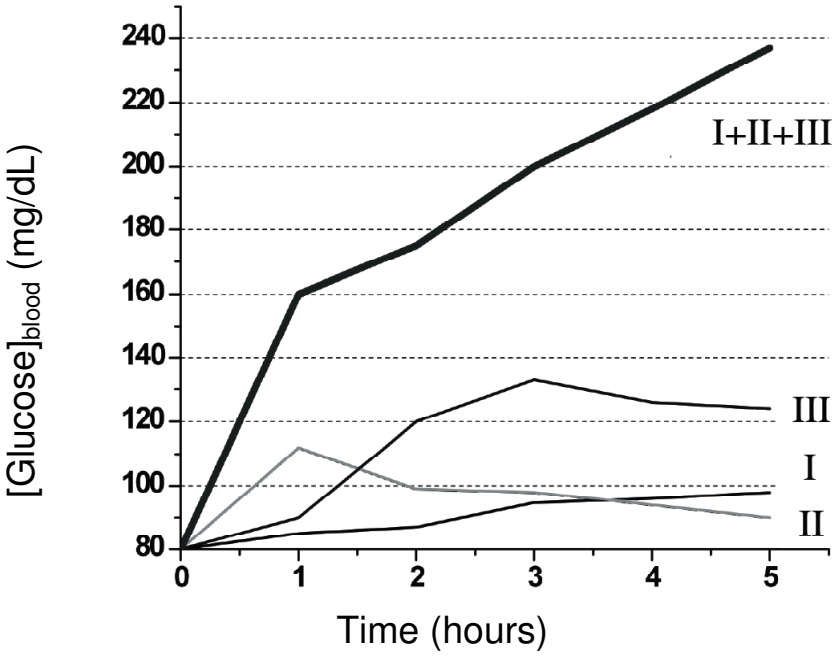
Animal Anatomy and Physiology

B13. (3 points) Three patients I, II and III show symptoms of low thyroxine levels. Defects are found in the hypothalamus for patient I, in the anterior pituitary for patient II, and in the thyroid for patient III. After thyroid-stimulating-hormone-releasing hormone (TRH) is given to these patients, the concentration of thyroid-stimulating hormone (TSH) before and after (30 min) TRH administration is measured in each patient.

	Before TRH administration	After TRH administration
Healthy person	Lower than 10	Between 10 and 40
A	Lower than 10	Between 10 and 40
B	Between 10 and 40	Higher than 40
C	Lower than 10	Lower than 10

Fill the letter of the appropriate data (A–C) for each patient (I–III).

B14. (2.5 points) The graph below shows the blood glucose level after three hormones I, II and III are administered separately or together.



(1) How do you classify these hormones?

A. Hypoglycemic

B. Hyperglycemic

(2) Choose the type of interaction between these hormones.

A. Additive

B. Antagonistic

C. Synergistic

D. None

(3) Pick the three possible hormones that are consistent with the results shown in the graph.

A. Insulin

B. ADH (Vasopressin)

C. Adrenalin (Epinephrine)

D. Renin

E. Glucagon

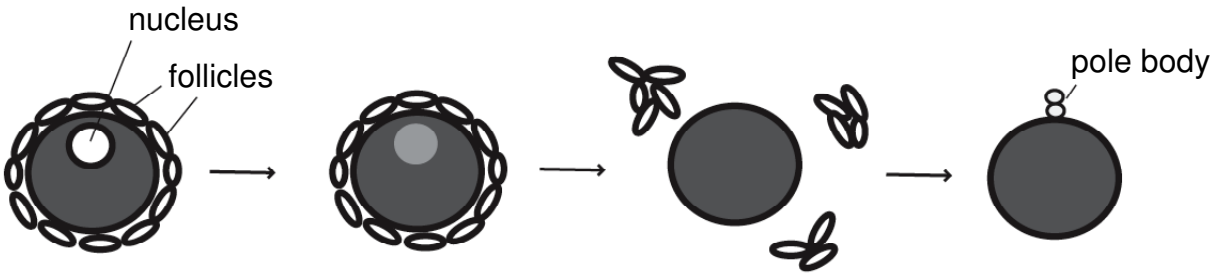
F. Angiotensinogen

G. Cortisol

H. Calcitonin

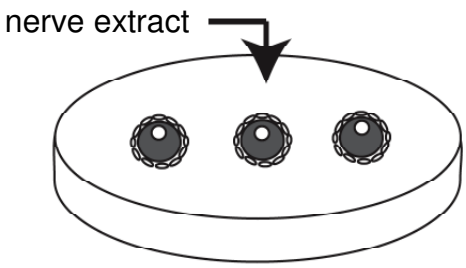
I. Atrial natriuretic peptide

B15. (4 points) The oocytes of a starfish grow within the provided follicle in the gonad. Eventually they cease meiosis at prophase I, and wait as a state of immature eggs. The immature eggs resume meiosis when stimulated and lose their nuclear envelop as shown below.

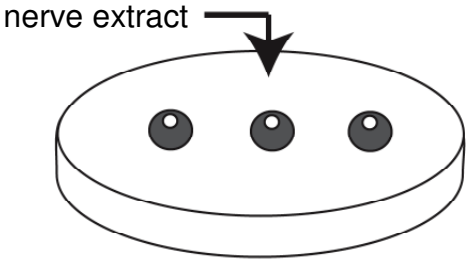


In order to understand the mechanism of this resumption, the following experiments were conducted.

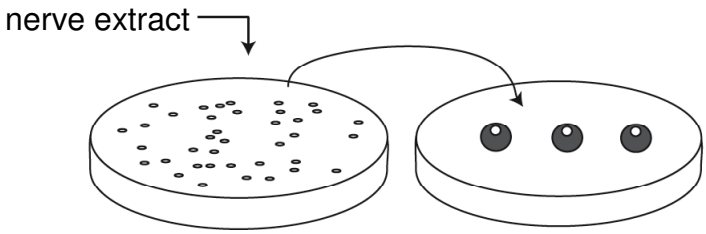
Experiment 1: When extract from the nerve tissue of adult starfish was added to immature eggs surrounded by follicles, meiosis resumed.



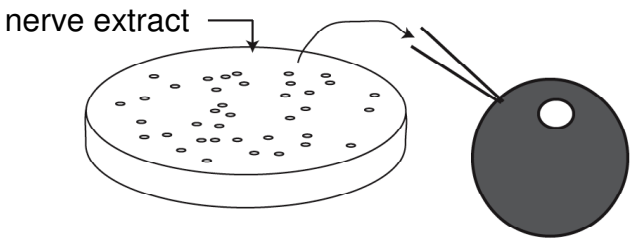
Experiment 2: When extract from the nerve tissue of adult starfish was added to immature eggs from which follicles were removed, meiosis did NOT resume.



Experiment 3: When extract from the nerve tissue of adult starfish was added to follicles after they had been separated from immature eggs, and subsequently the medium was added to immature eggs without follicles, meiosis resumed.



Experiment 4: When extract from the nerve tissue of an adult starfish was added to follicles after separated from immature eggs, and the medium was injected to immature eggs without follicles, meiosis did NOT resume.



Based on these results, four hypotheses were developed.

Hypothesis 1: The extract from the nerve tissue contains a substance which directly acts on immature eggs causing them to resume meiosis.

Hypothesis 2: The extract from the nerve tissue contains a substance which acts on immature eggs to resume meiosis, but the follicle blocks the substance from reaching the immature eggs.

Hypothesis 3: The extract from the nerve tissue contains a precursor of a substance that causes meiosis to resume, which is processed by the follicle into an active compound that causes immature eggs to resume meiosis.

Hypothesis 4: The extract from the nerve tissue induces follicles to secrete a substance which then acts on the cell surface of an immature egg to cause a resumption of meiosis.

Indicate whether each hypothesis is rejected or not.

B16. (2 points) After the nucleus is removed from a fertilized frog egg, it is re-transferred back into the enucleated egg. In another experiment, the nucleus from a gut epithelial cell is transferred to an enucleated egg. In both cases, the eggs grow well and develop normally into tadpoles.

(1) Choose the correct statement from A to E below.

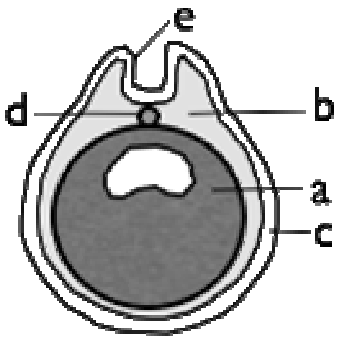
During differentiation from fertilized eggs to tadpole gut epithelial cells:

A. gene expression patterns do not change.
B. some genes are not expressed, but the genes themselves are not lost during development.
C. all the genes are expressed.
D. the amount of proteins does not change.
E. the amount of RNAs does not change.

(2) In the experiment above, frog gut epithelial cells were used. If this experiment were performed in mammals, theoretically almost all cell types can be used as a nucleus donor, but a few cell types cannot. Which of the following cell types is NOT appropriate as a donor cell?

A. B lymphocyte
B. Liver cell
C. Mammary gland cell
D. ES (embryonic stem) cell
E. Cone cell

B17. (2 points) The figure below represents a cross section of a vertebrate neurula stage embryo.



(1) The following are statements about the tissues and organs derived from (a), (b), (c) and (d) of the figure. Identify whether each statement is True or False and mark “X” in the appropriate box.

A. Tissues derived from (a) are always associated with those from (b).
B. The developmental fate of (c) sometimes changes.
C. (d) differentiates into the backbone (vertebra).
D. Most of the circulatory system arises from (b).

(2) Neural tube arises from (e). The following are statements about the formation and later development of the neural tube. Identify whether each statement is True or False and mark “X” in the appropriate box.

A. Cells in the wall of neural tube later differentiate into glial cells as well as nerve cells (neurons).
B. Lumen in the neural tube is later completely occluded.

C. Almost all nervous tissue derived from neural tube is central nervous system.

D. The retinal pigment epithelium in the eye derives from optic vesicle formed from the neural tube.

B18. (3 points) For intracellular infectious bacteria and viruses to successfully invade a cell, they must bind to receptors on the cell surface. HIV, specifically infects helper T cells, which express the CD4 molecule, but not CD8 on their cell surface, making it possible to distinguish helper T cells from other lymphocytes. Thus, CD4 is hypothesized to be a receptor for HIV.

(1) Which TWO of the following experiments would confirm this hypothesis?

Experiments that examine whether:

A. an antibody against CD4 added to a co-culture system of CD4-positive T cells and HIV can inhibit HIV infection of T cells

B. an antibody against CD8 added to a co-culture system of CD8-positive T cells and HIV can inhibit HIV infection of T cells

C. an antibody against HIV added to a co-culture system of CD4-positive T cells and HIV can inhibit HIV infection of T cells

D. forced expression of the CD4 gene in HIV-resistant CD4-negative T cells causes a recovery of susceptibility to HIV infection

E. forced expression of the CD8 gene in HIV-resistant CD8-negative T cells causes a recovery of susceptibility to HIV infection

(2) It is known that HIV cannot infect mice, although the mouse has CD4-positive helper T cells, because mouse CD4 cannot bind to HIV. To study further the mechanism of HIV infection in human cells, the following experiments were carried out, and the results are as follows:

1. When the human CD4 gene is expressed in mouse T cells, HIV can bind to the cells but cannot infect them.
2. When human chemokine receptor (CXCR4) is expressed in addition to human CD4 in mouse cells, HIV is able to infect the cells.
3. When human CD4 and CXCR4 genes are expressed in mouse cells and the cells are cultivated in the presence of SDF-1a, a ligand of CXCR4, infection by HIV is perturbed.

Which of the following sentences states the correct conclusion based on the above experiments?

A. If CXCR4 is expressed in mouse cells, CD4 is not required for the infection of HIV.
B. Human CD4 is required for the binding with HIV, and the binding is enhanced by the SDF-1a ligand.
C. Even if human CD4 is expressed in mouse T cells, CXCR4 is required for binding of HIV to the T cells.
D. Human CD4 is required for the binding with HIV, but infection of HIV into cells requires help of CXCR4.

B19. (3 points) The majority of humans have erythrocytes that express the Rh (Rhesus) antigen on their cell surface, but some are negative for the Rh antigen.

An Rh-negative woman marries to a heterozygous Rh-positive man and has three children.

(1) What is the probability that all three of their children become Rh-positive?

A. 1

B. 1/2

C. 1/4

D. 1/8

E. 0

(2) In which combination below could the second child suffer from hemolytic disease?

	First child	Second child
A.	Rh-positive	Rh-negative
B.	Rh-negative	Rh-positive
C.	Rh-negative	Rh-negative
D.	Rh-positive	Rh-positive

(3) Which molecules or cells are mainly involved in causing hemolytic disease in the fetus and newborn infant in case of Rh blood group antigen-incompatibility? Choose TWO correct options from A to F.

A. T cells

B. IgM antibody

C. Complement

D. Interferon gamma

E. IgG antibody

F. Perforin

Ethology

B20. (3 points)

(1) Foraging honeybees usually perform a waggle dance (Figure 1) when they find an attractive food source 100 m or more away from their hive. The duration of the waggle dance indicates the distance to the food source.

The duration of the waggle dance was studied in two honeybee species, *Apis cerana cerana* (*Acc*) and *Apis mellifera ligustica* (*Aml*), when food was placed at varying distances from the hives and the data shown in the graph below.

Figure 1

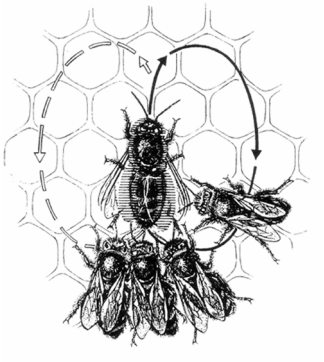
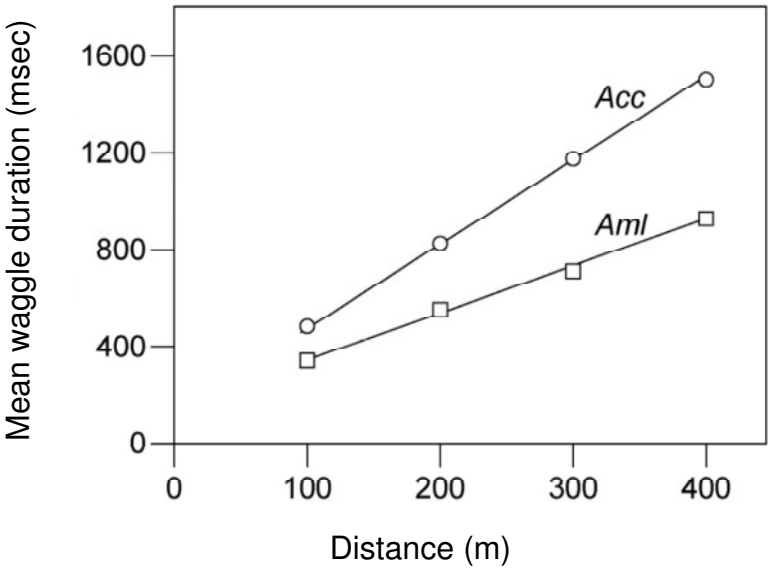


Figure 2



What were the distances (m) indicated when the average duration of the waggle dances of *Acc* and *Aml* both lasted 800 msec? Answer the distance for each species from the following numbers.

130 160 190 220 250 280 310 340 370 400

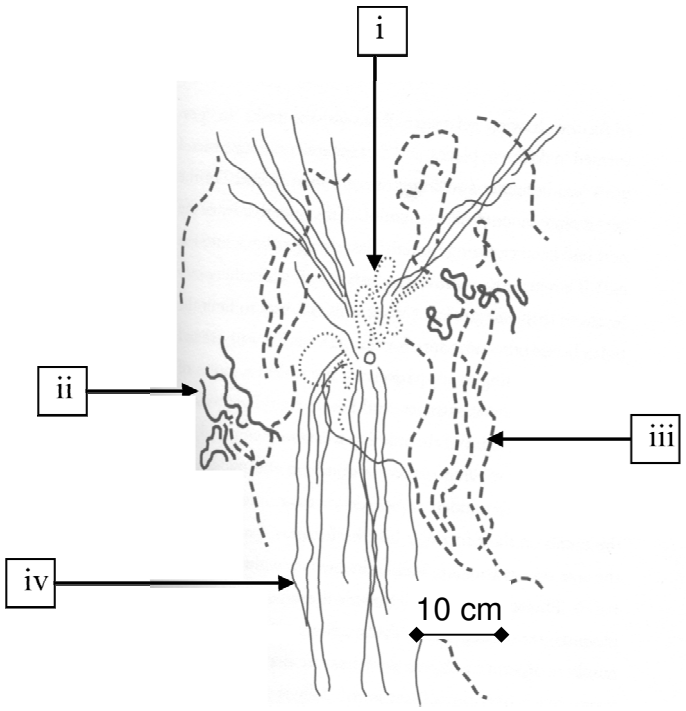
(2) Mixed colonies of *Acc* and *Aml* were successfully established by introducing *Aml* pupae into *Acc* colony and *vice versa*. The young individuals of both species were accepted by the colony members of the other species. When the same experiment (Figure 2) was performed on the mixed colonies, the introduced *Acc* and *Aml* workers each showed exactly the same patterns that these species had shown earlier.

In the final experiment, food was placed at 400, 500 and 600 m, all in the same direction, and the introduced *Aml* bees trained to forage at the food source 500 m away. When these bees recruited *Acc* bees from the hive, the latter were found to forage at the food site exactly 500 m away. This was also seen when the reverse experiment was done with *Acc* bees recruiting *Aml* bees.

From these experiments, what can we conclude about the transfer of the encoded and decoded information between the actor and receiver bees, respectively?

	Encoded information (the actor)	Decoded information (the receiver)
A.	genetically determined	genetically determined
B.	genetically determined	socially learnt
C.	socially learnt	genetically determined
D.	socially learnt	socially learnt

B21. (2 points) Red harvester ants (*Pogonomyrmex barbatus*) are social insects and live in underground colonies, in which various functions are carried out by different groups of ants. Below is a picture of one such ant colony. The open circle in the center is the nest entrance. The four types of lines (i to iv) indicate paths followed by different groups of these ants. Match the appropriate groups (A to D) with these lines:



Groups:

A. Foragers

B. Patrollers

C. Nest maintenance ants

D. Midden workers or refuse pile sorters (those who pile fecal matter outside the nest)

B22. (2 points) In birds, there are many ways of singing. This is caused by the fact that brain regulates the action of the syrinx (vocal organ of birds). In a certain species of birds, two kinds of vocalization can be recognized: longer **songs** produced by males in the breeding season, and other simpler **calls** heard outside the breeding season.

(1) If the young chicks of such birds are reared in an environment without sound, adult birds cannot produce the exact longer songs. Which of the following is the most appropriate as explanation of the above statement?

A. In an environment without sound, differentiation between males and females cannot be attained.
B. The song is a mode of behavior which is determined by learning after hatching.
C. In an environment without sound, imprinting of the gene responsible for the song cannot occur.
D. In an environment without sound, the auditory sense cannot develop.

(2) Although chicken and quail are closely related, their calls are different. An experiment was carried out in which the presumptive brain region of 5-day-old white chicken embryo was substituted by that of a brown quail embryo of the same age. Then the host chicken embryo was incubated. The hatched chicken had some brown parts in its brain, which indicates that these parts were derived from quail. The calls of this chicken were more similar to that of quail rather than that of chicken. Which of the following is the most appropriate conclusion deduced from the experiment?

I. Calls are species-specific and are determined genetically.

II. Calls are determined after hatching.

III. Calls are determined by the structure of the syrinx.

A. Only I

B. Only II

C. Only III

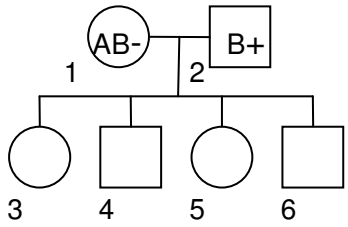
D. I and II

E. I and III

F. II and III

Genetics and Evolution

B23. (4 points) In an experiment on the members of a family with the pedigree shown below, blood plasma and blood cells from different individuals were mixed in pairs to test the presence (p) or absence (a) of coagulation. In this pedigree AB- means that the phenotypes of individual 1 (mother) are AB type and Rh negative (Rh^-), and B+ means that the phenotypes of individual 2 (father) are B type and Rh positive (Rh^+).



The results of this experiment are shown below. A blank box in this table indicates a combination that was not tested in this experiment.

Cell donor \ Plasma donor	1	2	3	4	5	6
1		p	a	p		p
2	p		a			p
3	p	p		p	p	p
4	a	a	a		p	
5	p	p				
6	a	p		p	a	

(1) What are the phenotypes of individual 6?

A. A type and Rh^+

B. A type and Rh^-

C. B type and Rh^+

D. B type and Rh^-

E. AB type and Rh^+

F. AB type and Rh^-

(2) Which member of this family is probably homozygous with respect to both the ABO blood group and the Rh loci?

A. Individual 2

B. Individual 3

C. Individual 4

D. Individual 5

E. Individual 6

B24. (4 points) In maize a single locus determines the color of the seed; allele *A* results in colored seeds, and allele *a* in colorless seeds. Another locus determines the shape of the seeds; allele *B* results in a smooth shape of the seeds, and *b* in wrinkled seeds.

In a crossbreeding between the plant that grew from a colored and smooth seed and the plant that grew from a colorless and wrinkled seed, the offspring were documented as:

376 had colored and smooth seeds

13 had colored and wrinkled seeds

13 had colorless and smooth seeds

373 had colorless and wrinkled seeds

(1) What are the genotypes of the parents?

A. *AABb* x *aaBb*

B. *AaBb* x *aabb*

C. *AAbb* x *aaBB*

D. *AaBb* x *AaBb*

E. *aabb* x *AABB*

(2) What is the frequency of recombinants?

A. 0.335%

B. 1.68%

C. 3.35%

D. 6.91%

E. 48.52%

(3) Three loci C, D and E are located on the same chromosome in this order. Using similar experiments to the above, we found that the frequency of recombinants between C and D is 10% and that between D and E it is 20%. Assuming that crossing over occurs randomly on the chromosome, what is the expected frequency of recombinants between C and E?

B25. (3 points) The evolutionary distance is defined as the number of nucleotide substitutions per nucleotide site between two DNA sequences, and the evolutionary rate is defined as the number of nucleotide substitutions per nucleotide site per year. We sampled two DNA sequences from two species (one sequence from each species), and found that the evolutionary distance between the two sequences is 0.05. We assume that the evolutionary rate is 10^{-8}.

(1) How many years ago did the two sequences diverge?

(2) What is the relationship between the divergence time between the two **sequences** (T1) and the divergence time between the two **species** (T2) in general?

A. T1 < T2

B. T1 = T2

C. T1 > T2

B26. (3 points) Preproinsulin is the primary product of the insulin gene, and consists of 4 major parts: signal, B-chain, C, and A-chain peptides. After several modifications including removal of the signal and C peptides, insulin is obtained.

(1) Which of the following peptides is responsible for the transport of polypeptide into the endoplasmic reticulum?

A. A-chain peptide
B. B-chain peptide
C. C peptide
D. signal peptide

(2) Comparisons of amino acid sequences among mammals show that the sequence similarity between species varies substantially among the peptides. Which of the following is the most likely explanation?

A. directional selection
B. frequency-dependent selection
C. overdominant selection (heterozygote advantage)
D. purifying selection (selection against deleterious mutations)

(3) Which peptide is likely to differ the most among mammals?

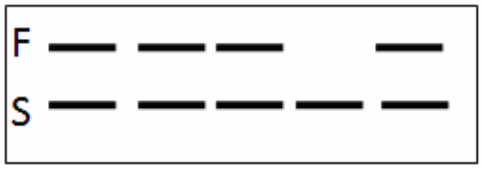
A. A-chain peptide
B. B-chain peptide

C. C peptide

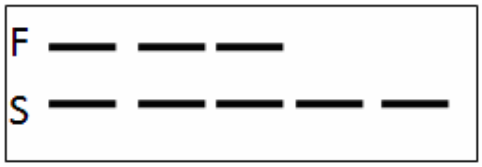
D. signal peptide

B27. (4 points) In order to quantify genetic diversity of an endangered plant species, genetic variation in subpopulations (I–IV) was examined at the protein level. Subpopulation I is the largest in this species, and the number of individuals in all other subpopulations II, III and IV are each 1/7 of that in subpopulation I. In each subpopulation 5 individuals were sampled. The diagram below shows the results of proteins separated by gel electrophoresis. The band pattern in each lane, which consists of alleles *F* and/or *S*, represents the genotype of each individual at a certain locus.

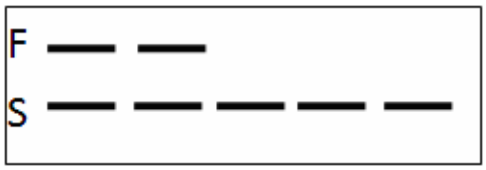
Subpopulation **I**



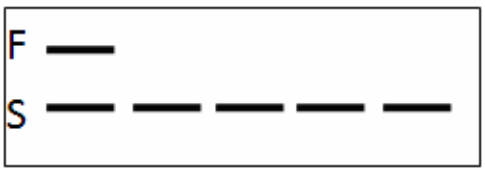
Subpopulation **II**



Subpopulation **III**



Subpopulation **IV**



(1) Estimate the frequency of *F* in this species.

(2) Which subpopulation is thought to be the most isolated group?

(3) After several generations, we found that the frequency of *F* changed substantially in subpopulations II, III and IV, compared with that of subpopulation I. What is the most likely explanation?

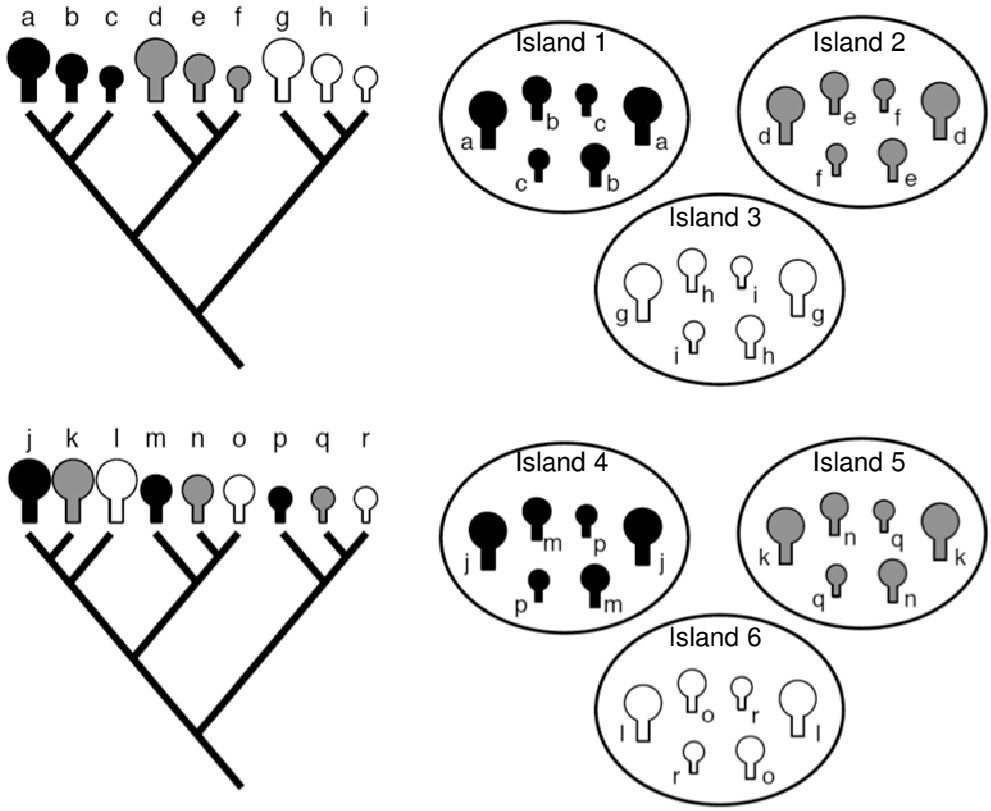
A. Genetic drift

B. Migration

C. Mutation

D. Natural selection

B28. (3 points) Islands are considered as “experimental sites” for biological evolution and community assembly. The diagram below shows two phylogenetic trees, each consisting of 9 species (a–i and j–r) and community assemblies on 6 islands. Phenotypic traits of the species are represented by size and color.

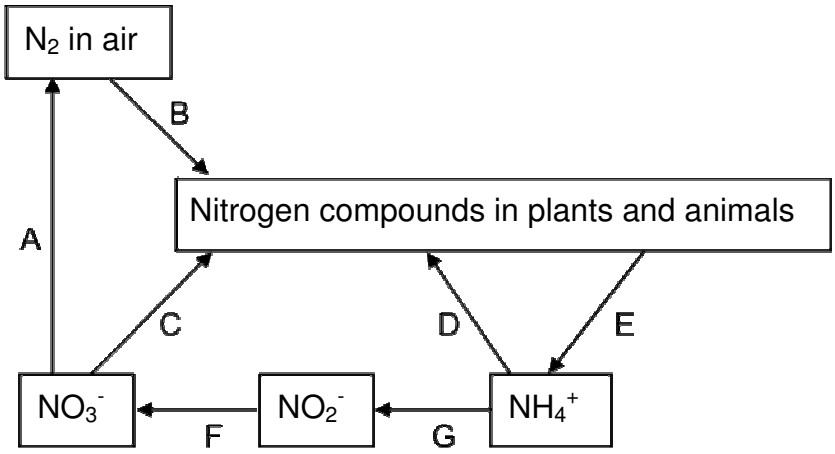


Which of the following explanations are responsible for the mechanisms of community assembly on these islands? Choose THREE correct options from A to H.

Options	Islands	Evolutionary and genetic structure of species	Ecological interactions between species
A	1, 2, 3	Phylogenetically closely related	Competitive exclusion in descendent species
B	1, 2, 3	Adaptive radiation	Niche specialization in descendent species
C	4, 5, 6	Adaptive radiation	Niche overlap in descendent species
D	4, 5, 6	Sympatric speciation	Niche specialization with competitive interaction
E	4, 5, 6	Phylogenetically distant species	Niche specialization with competitive interaction
F	1, 2, 3	Often seen in oceanic islands rather than land-bridge islands	
G	4, 5, 6	Often seen in isolated island rather than those close to the mainland	
H	1, 2, 3 vs 4, 5, 6	The community on 4, 5 and 6 are more sensitive to the invasion by an alien species than that on 1, 2 and 3	

Ecology

B29. (3 points) The following diagram shows the cycle of nitrogen compounds in an ecosystem.

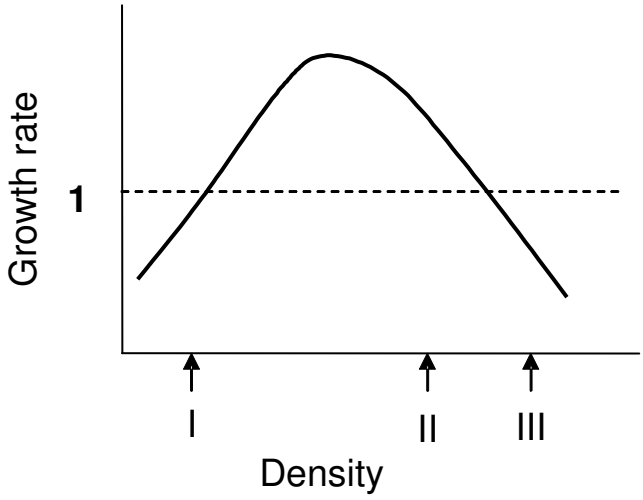


(1) In which of the processes do NOT bacteria participate? Choose TWO from A to G.

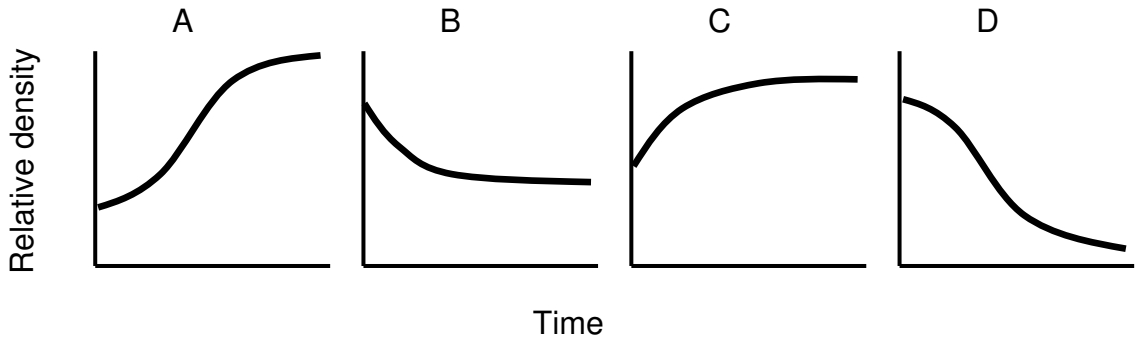
(2) Which of the processes may include a symbiotic relationship between a species of plant and a species of bacterium?

(3) Which of the processes do farmers want to inhibit in agricultural land?

B30. (3 points) The relationship between population density (N_t) and population growth rate ($R = N_{t+1} / N_t$) in a certain animal species is shown below.



Choose from the following graphs the appropriate population growth patterns that would be obtained if the population is at the densities (I, II, III) shown in the graph above. Note that the y-axis in A to D is relative density that cannot be compared to the absolute density in the figure.



B31. (2.5 points) Competitive exclusion among species is regulated by various ecological factors. Identify whether the following statements are True or False about this process, and mark “X” in the appropriate boxes.

Competitive exclusion:

A. is intense among species with similar ecological niches.

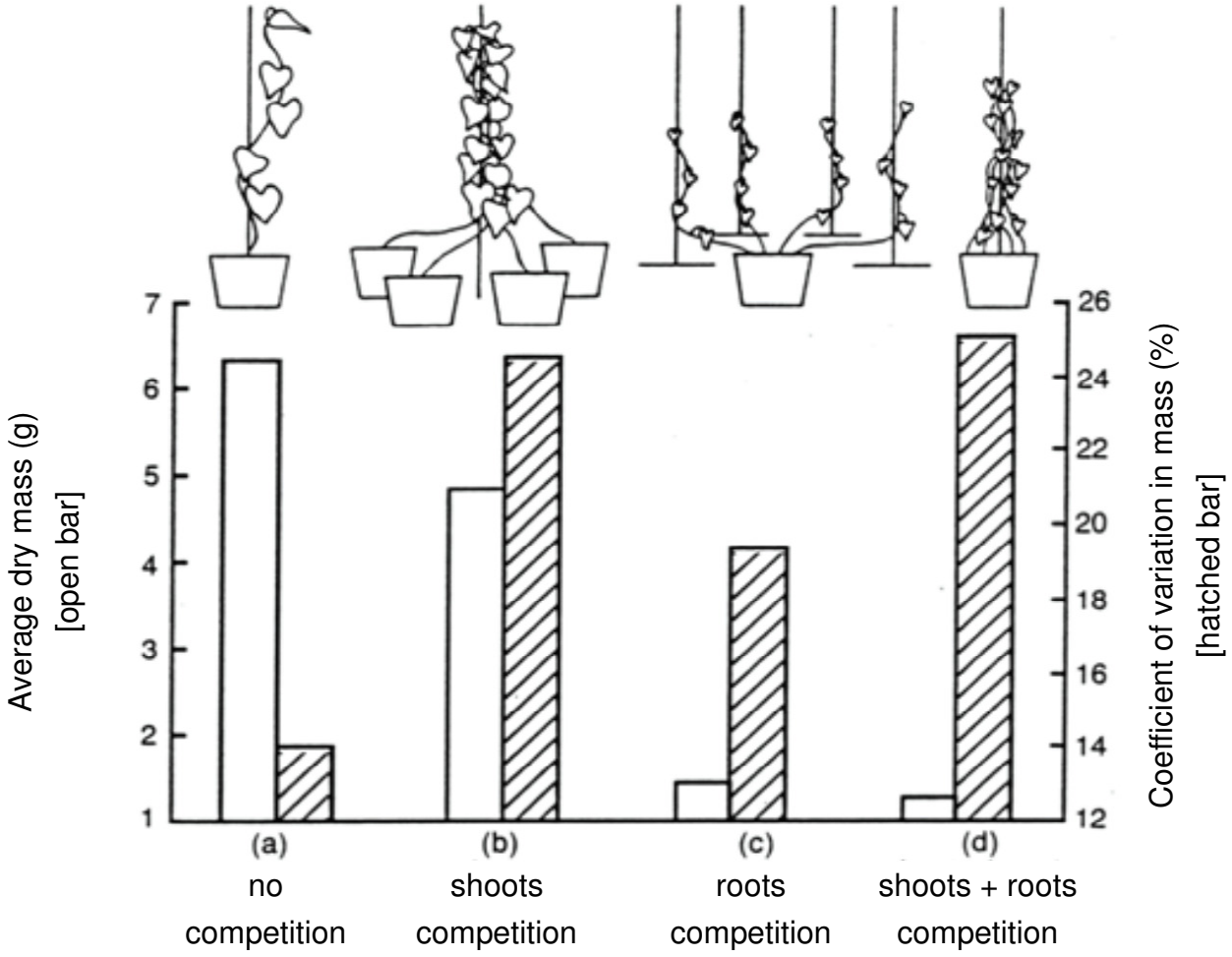
B. is occasionally interrupted by environmental disturbances.

C. is promoted by species succession.

D. is alleviated by habitat segregation among species.

E. occurs because of keystone species.

B32. (3 points) The diagram below shows the results of an experiment on the vine *Ipomoea tricolor*, in which root competition and shoot competition were separated. The average dry mass is indicated by open bars, and the coefficient of variation (ratio of standard deviation / mean) of mass among plants is indicated by hatched bars. Based on the data presented, identify whether the following statements are True or False about the competition mode of this plant species, and mark "X" in the appropriate boxes



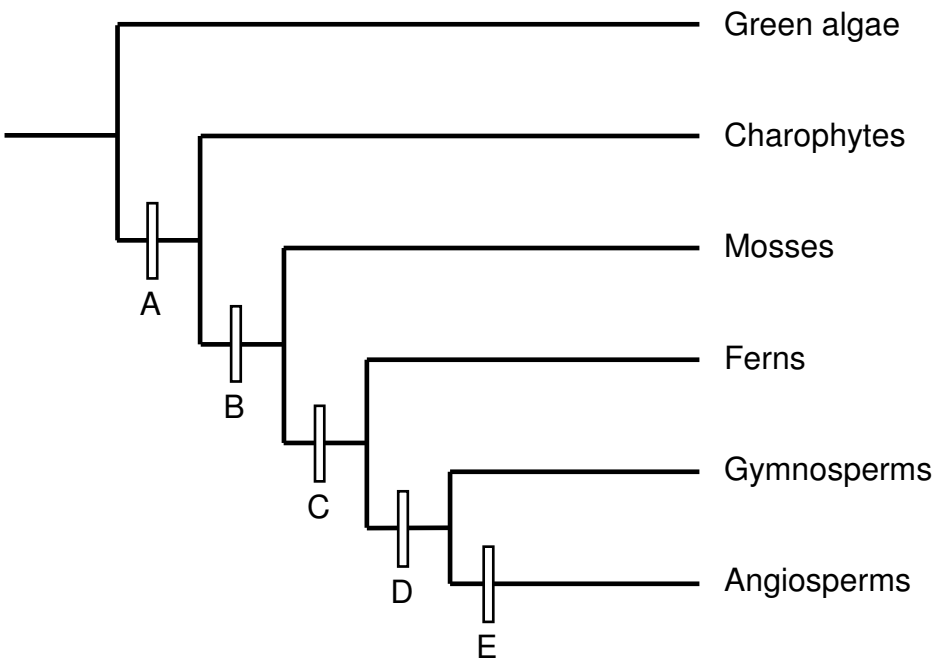
A. Competition for light has more influence on the average mass than competition for soil nutrients.

B. The differences in competitive strength among these plants are larger when competing for soil nutrients than for light.

C. When grown individually, soil nutrients constitute a limiting factor for growth, but light does not.

Biosystematics

B33. (3 points) At which branches A to E in this phylogenetic tree of green plants were the traits I to VI listed below acquired?



I. Pollen

II. Tracheid

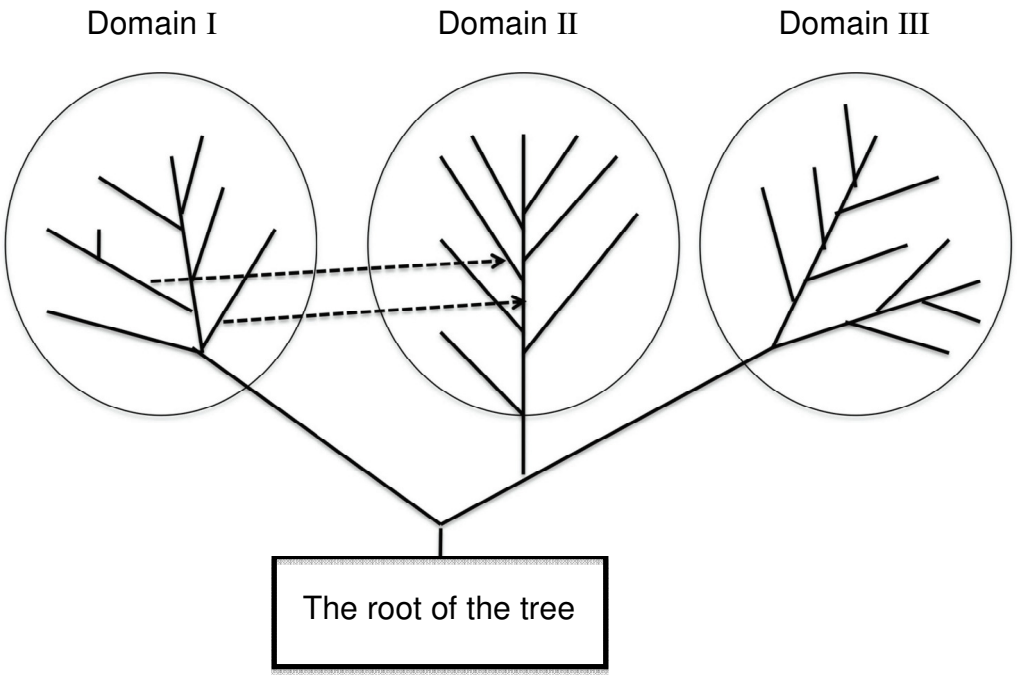
III. Cuticle

IV. Seed

V. Carpel

VI. Multicellular embryo

B34. (5 points) The universal phylogenetic tree based on molecular sequencing analysis shows three major groups of living organisms as shown below. Woese proposed the concept of three domains in living organisms in the 1990s based on such a tree.



(1) What was the molecule used for the construction of the universal phylogenetic tree? What was the benefit of this molecule for the universal tree? Choose the combination of the molecule and benefit.

	Molecule	Benefit
A	Ribosomal protein	Low substitution rate of amino acid sequences
B	Ribosomal protein	High substitution rate of amino acid sequences
C	Ribosomal RNA	Low substitution rate of nucleotide sequences
D	Ribosomal RNA	High substitution rate of nucleotide sequences
E	Globin	Low substitution rate of amino acid sequences
F	Globin	High substitution rate of amino acid sequences
G	Transfer RNA	Low substitution rate of nucleotide sequences
H	Transfer RNA	High substitution rate of nucleotide sequences

(2) The two broken arrows indicate hypothesized endosymbiotic events whereby members of Domain I became endosymbionts of Domain II. What are the two organisms that were involved in these events, what did they become in the cells of Domain II and what is their current biological function in the Domain II organisms?

	Domain I	Domain II	Function
Older symbiosis			
Newer symbiosis			

Domain I	Domain II	Biological function
1. Cyanobacteria 2. Chlorella 3. Gram-negative respiratory bacteria 4. Gram-positive fermentative bacteria 5. Spirochaeta 6. Virus	1. Mitochondria 2. Respiratory chain 3. Flagella 4. Chloroplast 5. Chlorophyll 6. Nucleus	1. Photosynthesis 2. Nitrogen fixation 3. Glycolysis 4. Respiration 5. Conjugation 6. Movement

(3) Which of the following corresponds to domains I, II or III?

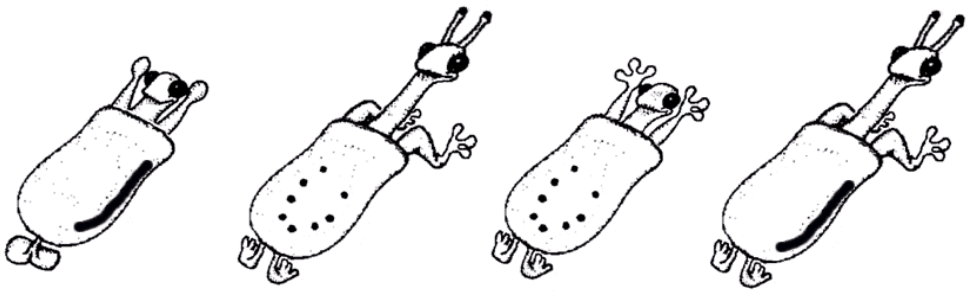
A. Archaea

B. Bacteria

C. Eukarya

B35. (4 points) Joseph Camin, a taxonomist, invented artificial non-existing creatures, the *Caminalcules*, for his students. Below are depicted four different Caminalcules.

Take a close look at the following four Caminalcules:

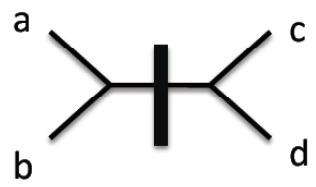


a b c d

(1) For these four Caminalcules, choose an appropriate cladogram by focusing upon the following characteristics. The most likely tree should be the one where the largest number of characters can be mapped in the internal branch.

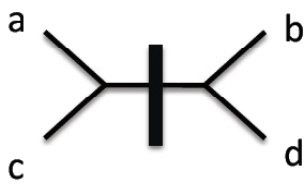
1. Antenna
2. Belly spots
3. Elbow
4. Fingers
5. Neck
6. Line at the side
7. Posterior legs

A



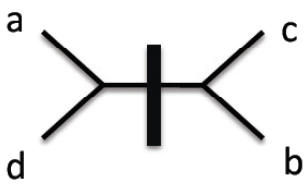
Internal branch

B



Internal branch

C

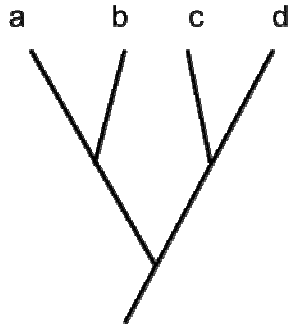


Internal branch

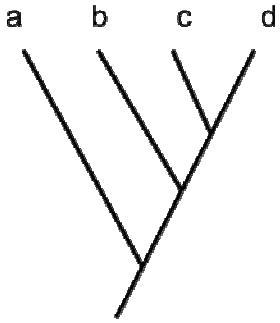
(2) Choose characteristics from the list in question (1) which presumably evolved convergently (independently lost or acquired) in two species of the four.

(3) Assuming that “Caminalcule a” is a sister taxon of the other species, choose an appropriate rooted tree from the following.

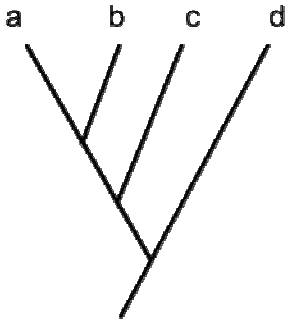
A



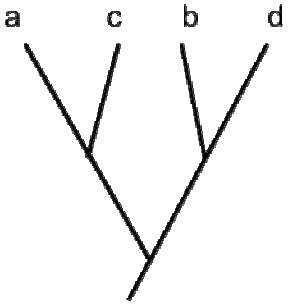
B



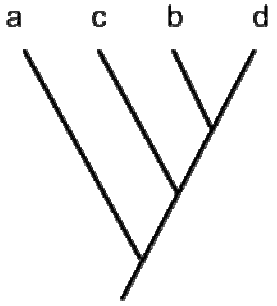
C



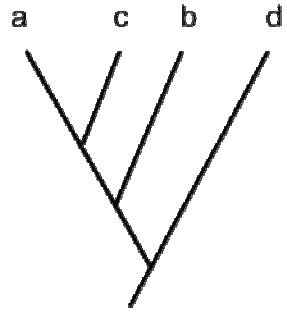
D



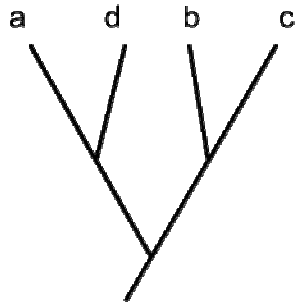
E



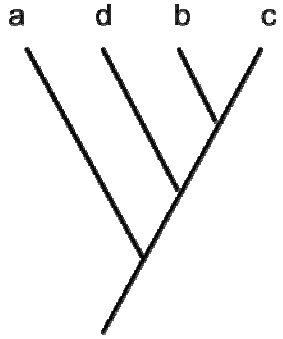
F



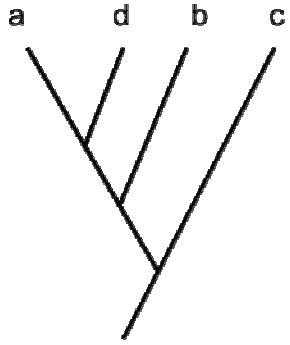
G



H



I



* * * * * END OF PART B * * * * *