ENVELOPE COVER SHEET

Student Code: ______________________

The 21st INTERNATIONAL BIOLOGY OLYMPIAD

Changwon, KOREA 11th – 18th July, 2010

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 the **Answer Sheet** with checkmarks (√), numbers, or characters to answer each question.

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

6. Some of the questions may be crossed-out. DO NOT answer these questions.

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

8. At the end of the test session you should leave all papers at your table. It is not allowed to take anything out.

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GENERAL INSTRUCTIONS

1. Write your 4-digit student code in every student code box.

2. The questions in Part B may have more than one correct answer. Fill the **Answer Sheet** with checkmarks (√), numbers, or characters to answer each question.

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

4. Some of the questions may be crossed-out. **Do not** answer these questions.

5. The maximal point of Part B is 107.1.

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

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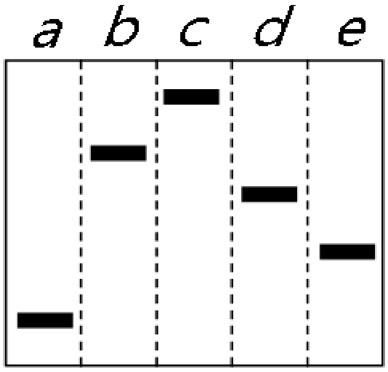
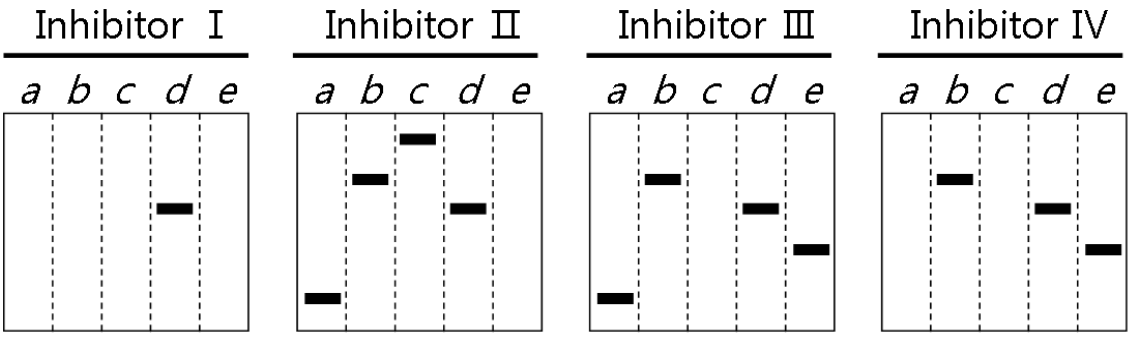
CELL BIOLOGY

B1. (2.7 points) The Western blot below shows migration distances of five signal molecules (*a~e*) involved in a growth hormone-regulated cell-signaling pathway.



To determine the order of molecules (*a~e*) in the signal cascade that occurs upon the growth hormone treatment, cells were treated with different inhibitors (I~IV) of cell signaling. The following blots show the changes in signal molecule expression patterns resulting from inhibitor treatment.



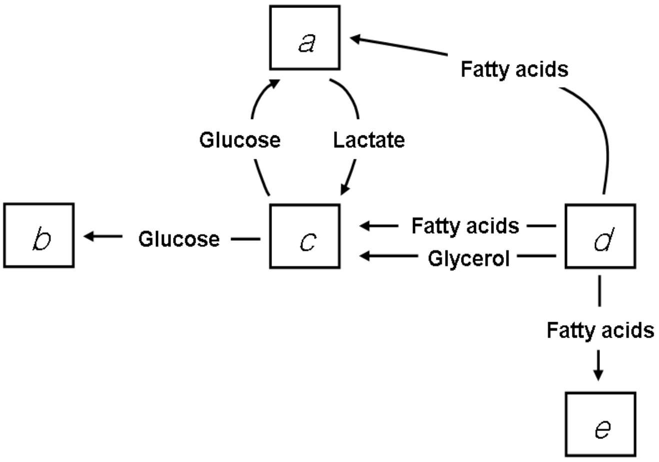
B1.1. (1.5 points) Fill in the boxes in the answer sheet to show the order of proteins (*a~e*) in the signaling cascade.

B1.2. (1.2 points) Fill in the circles in the answer sheet to show the site where each inhibitor (I~IV) exerts its action.

B2. (2.7 points) Match the molecular constituents (*a*~*f*) on the right with the cellular structures (A~D) that maintain cell morphology on the left. Each cellular structure can have more than one molecular constituent.

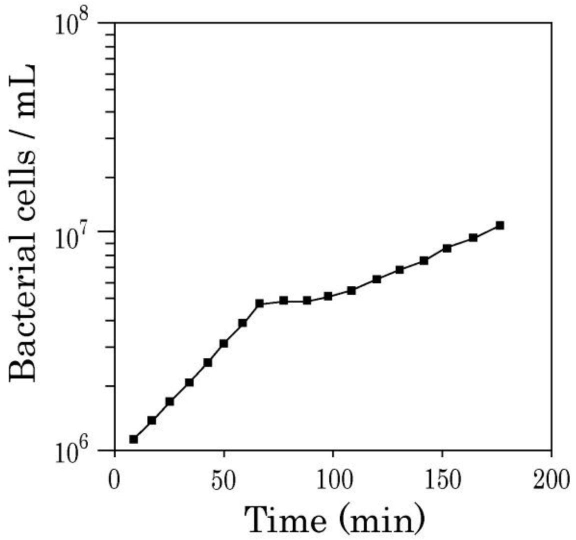
A. Cytoskeleton B. Cell wall C. Desmosome junction D. Extracellular matrix	*a*. Cadherin *b*. Cellulose *c*. Collagen *d*. Actin *e*. Keratin *f*. Lignin

B3. (1.5 points) In the figure, the letter in each box represents an organ or tissue.

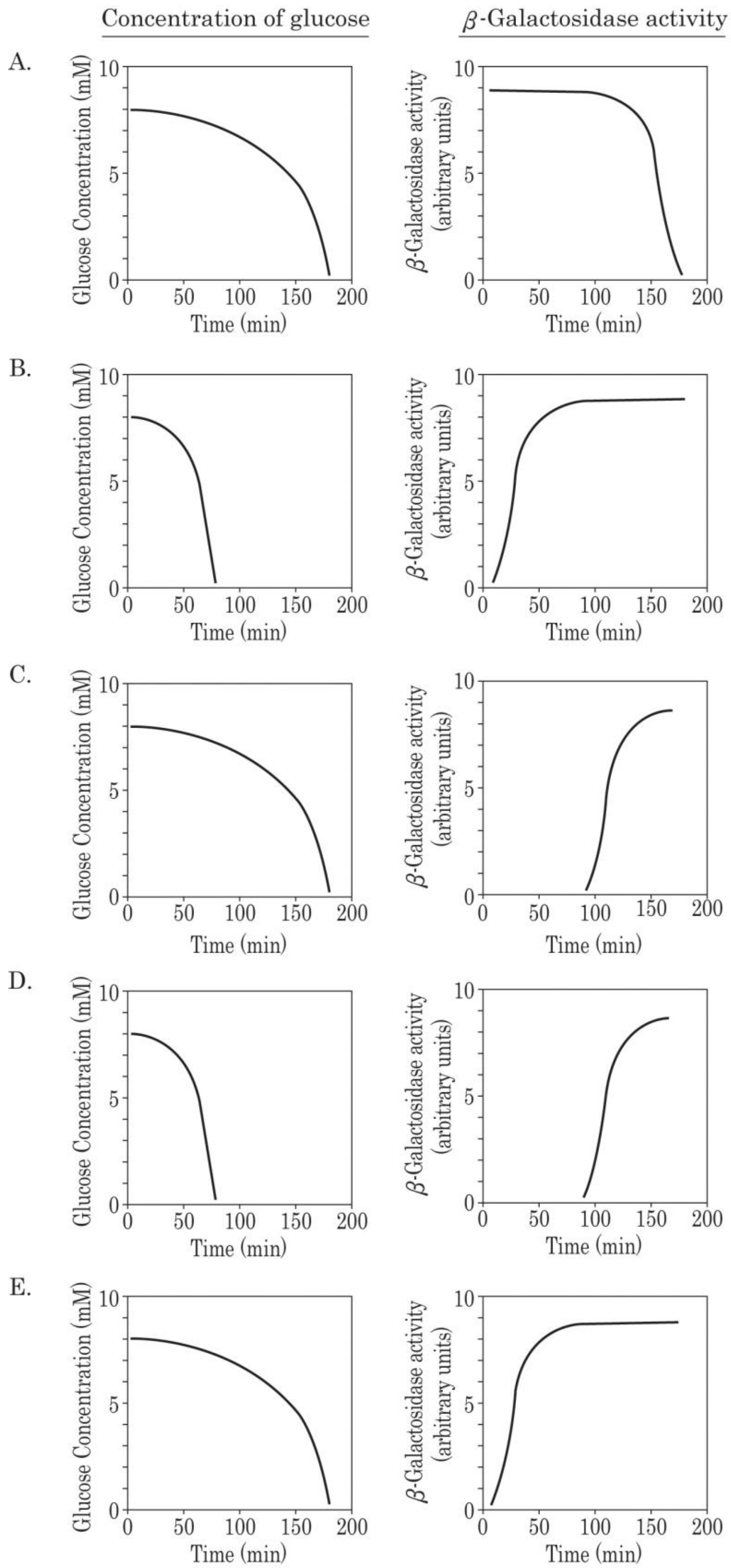


Match each listed organ or tissue in the answer sheet to the correct box in the figure.

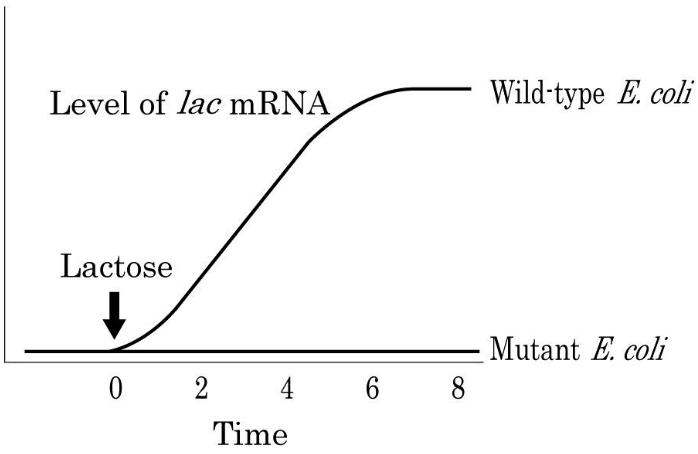
B4. (2.2 points) When *E. coli* is grown on a medium containing a mixture of glucose and lactose, it shows complex growth kinetics, as shown in the graph below.



B4.1. (1 point) Which pair of graphs correctly shows the changes in glucose concentrations in the medium and β-galactosidase activity within the cells?



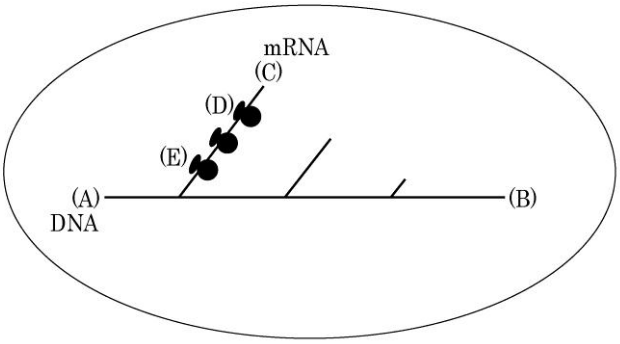
B4.2. (1.2 points) The graph below shows the expression pattern of *lac* mRNA in wild-type and mutant *E. coli* cells after lactose is added to a glucose-depleted medium.



Indicate with a checkmark (√) in the answer sheet whether each mutant is able or unable to show the mutant expression pattern.

	Mutant
I.	An *E. coli* mutant in which the repressor is not expressed.
II.	An *E. coli* mutant in which the repressor can bind to the operator, but not to lactose.
III.	An *E. coli* mutant in which the operator is mutated so that the repressor cannot bind to the operator.
IV.	An *E. coli* mutant in which RNA polymerase cannot bind to the promoter of the *lac* operon.

B5. (1.5 points) Transcription and translation of a gene in a prokaryote cell are depicted in the picture below.



Indicate with a checkmark (√) in the answer sheet whether each description is true or false.

Description
I. The direction of transcription is from (B) to (A).
II. Location (C) of the mRNA is the 5' - end.
III. The polypeptide on ribosome (D) is longer than the polypeptide on ribosome (E).

B6. (2 points) A part of the nucleotide sequence of one strand of a double-stranded DNA molecule and the corresponding amino acid sequence are shown. The table shows a portion of the genetic code.

Codon position		a	b	c	d	
DNA strand	5'........	TTT	AAG	TTA	AGC	.......3'
Polypeptide	....	Phe	Lys	Leu	Ser	....

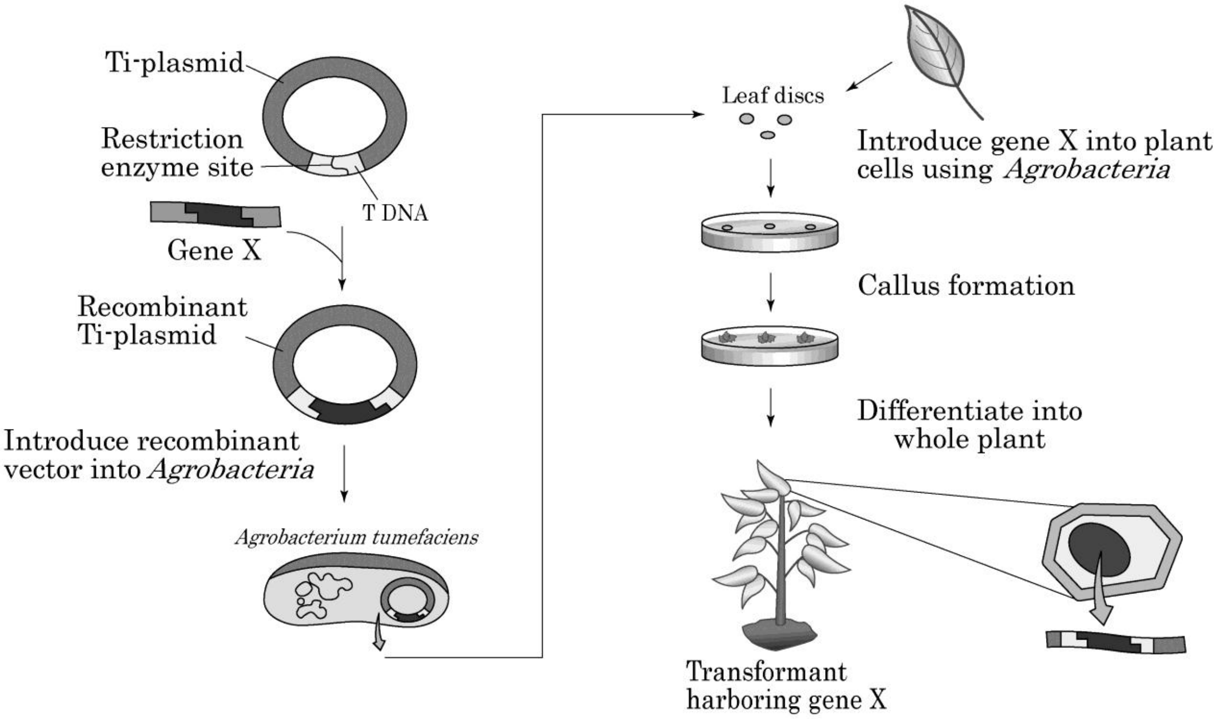
Codon	Amino acid
UUU	Phe
UUA	Leu
AAG	Lys
AGC	Ser

Indicate with a checkmark (√) in the answer sheet whether each description in true or false.

(Assume that the length of the DNA is the same as that of its primary transcript.)

	Description
I.	The DNA strand shown is a template strand.
II.	If the G+C content of the DNA strand shown is 40%, then the A+T content of its complementary DNA strand is 60%.
III.	If the G+C content of the DNA strand shown is 40%, then the A+U content of the primary transcript is 60%.
IV.	The nucleotide sequence of mRNA is 5' .... UUU AAG UUA AGC .... 3'.

B7. (2 points) The picture below shows the process of generating a transgenic plant harboring gene X using the *Agrobacteria* Ti-plasmid.



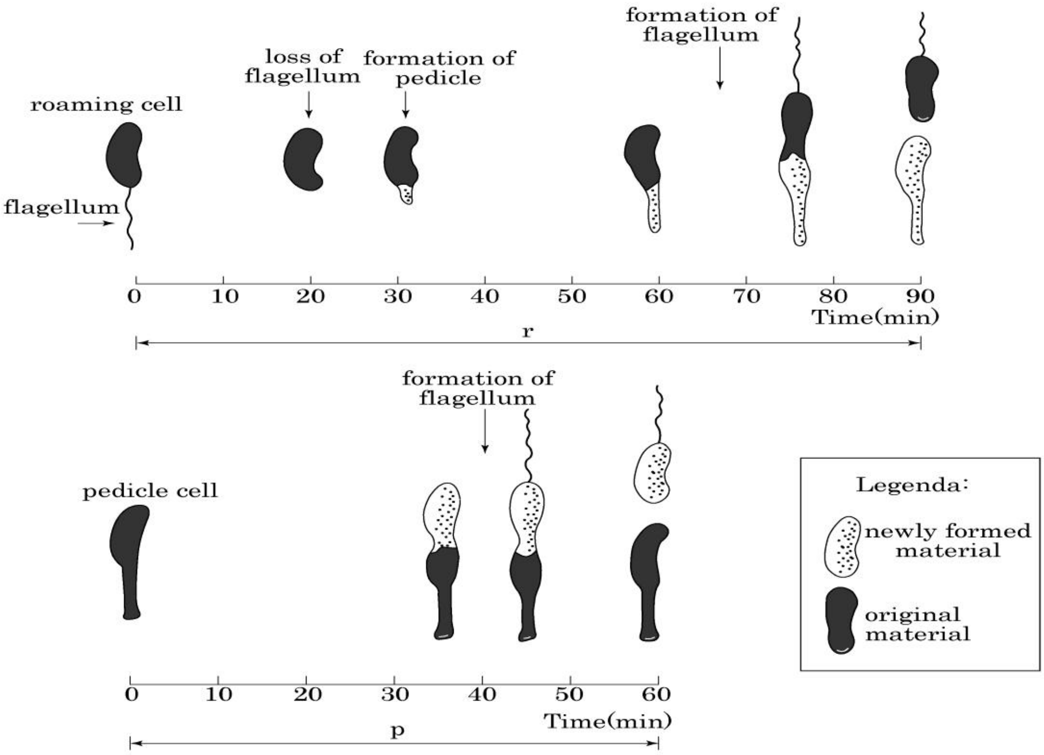
B7.1. (1 point) Which explanation about this process is true or false?

	Explanation
I.	Restriction enzymes and ligase are used to make the recombinant DNA.
II.	Plant tissue culture techniques are used to differentiate the leaf discs into a plant.
III.	The whole recombinant Ti-plasmid harboring gene X gets integrated into the plant genome.
IV.	The introduction of gene X into the transgenic plant genome can be confirmed by using genomic PCR or genomic Southern blot analysis.
V.	The expression of the introduced gene X in the plant cell can be checked by using RT(reverse transcriptase)-PCR, Northern blot analysis, or Western blot analysis.

B7.2. (1 point) Evaluate whether the following description is true or false for a plant expression vector in general?

	Description
I.	It should include the selection marker gene that is needed for selecting the transformed cell.
II.	It should include a promoter that can express the introduced gene within the plant cell.
III.	It usually contains a multiple cloning site used for insertion of the foreign gene.
IV.	It should have the same nucleotide sequence with the specific part of the plant genome because the foreign gene is inserted by homologous recombination.
V.	It should have the replication origin needed for cloning during the process of making the recombinant vector.

B8. (1.5 points) *Caulobacter* bacteria undergo a special cell division. Division of the mother cell results in two different daughter cells: a 'roaming' (r) cell and a 'pedicle' (p) cell. Roaming cells permit *Caulobacter* to spread out. Pedicle cells stay and use the pedicle to stick at that place. The picture below shows how roaming and pedicle cells divide.



The division cycle period when starting with a roaming cell (r = 90 min) is longer than when starting with a pedicle cell (p = 60 min). The extended length of period (r) is because the roaming cell

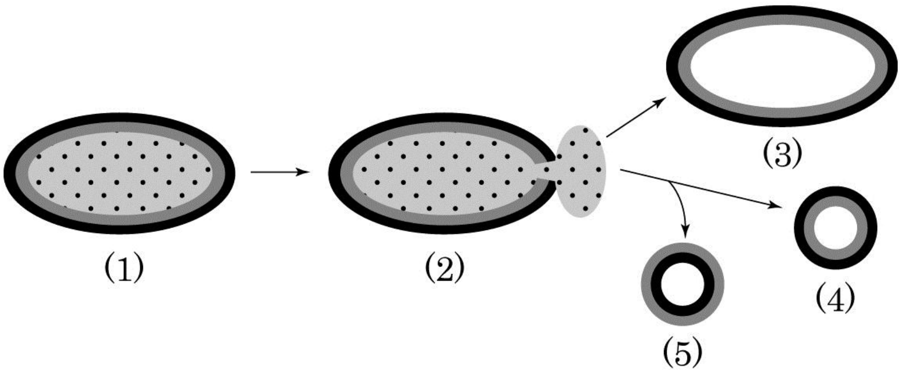
A. produces more DNA than the pedicle cell.

B. produces a pedicle before division.

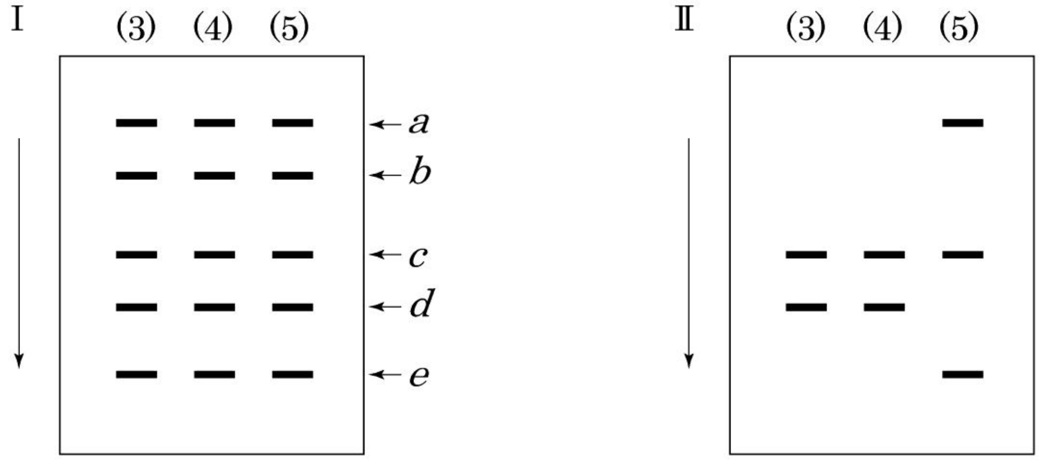
C. produces a flagellum during division.

For each of the above explanations, indicate with a checkmark (√) on the answer sheet whether it is true or false.

B9. (2 points) In the experiment described below, cells (1) were put in a medium with a salt concentration lower than the cytoplasm, causing them to swell and rupture at one location (2). Ruptured cells were then washed out and resealed to form 'ghosts' (3). This process also produced smaller vesicles whose membrane was either right-side-out (4) or inside-out (5), depending on the ionic conditions of the solution used for the disruption procedure.



Prepared ghosts/vesicles were then mixed with a radioactive labeling reagent that is water-soluble and could covalently attach to proteins (3~5). The proteins embedded in the membrane were then solubilized with detergent and analyzed by SDS polyacrylamide-gel electrophoresis. Segregated proteins were visualized by Coomassie Blue staining (I) and autoradiography (II).



Which of the proteins (*a*~*e*) is/are transmembrane protein(s)?

A. Protein *b*

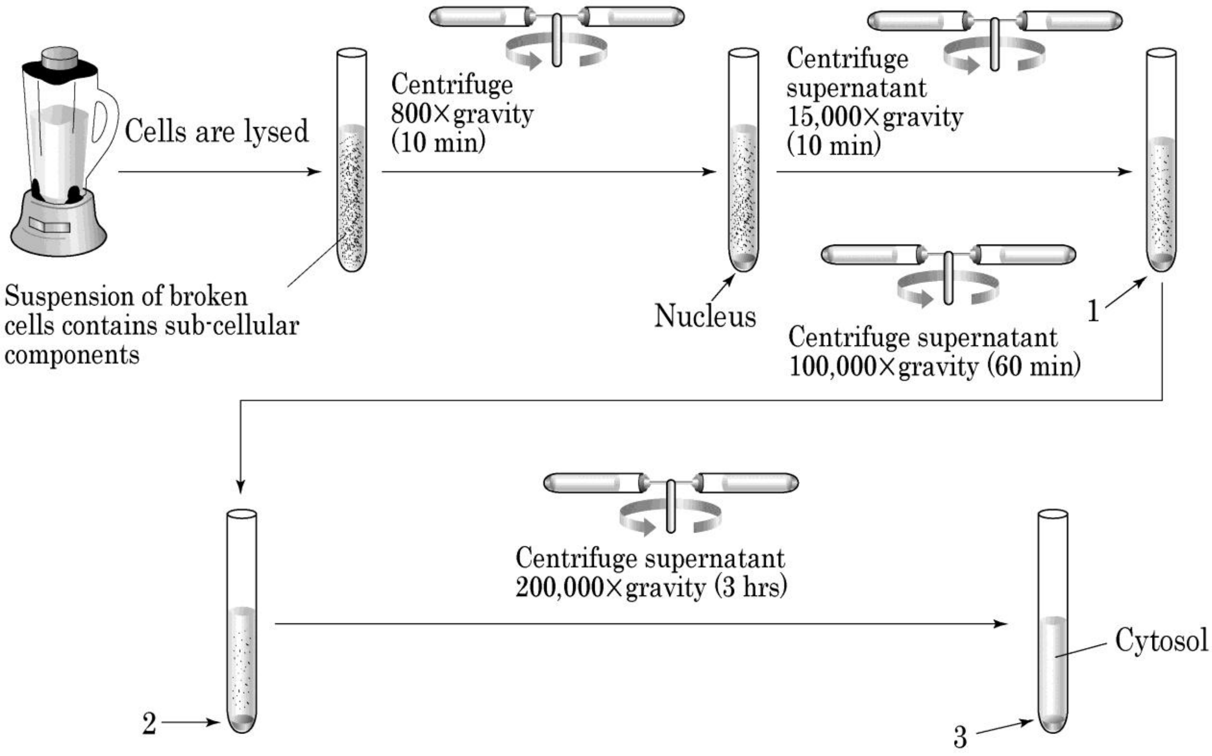
B. Protein *c*

C. Protein *d*

D. Proteins *a*~*e*

E. Protein *a* and protein *e*

B10. (1.5 points) Subcellular organelles and their cellular components can be easily separated by the size-fractionating differential centrifugation method, as depicted below. During the process, four pellets (nucleus and 1~3) are formed.



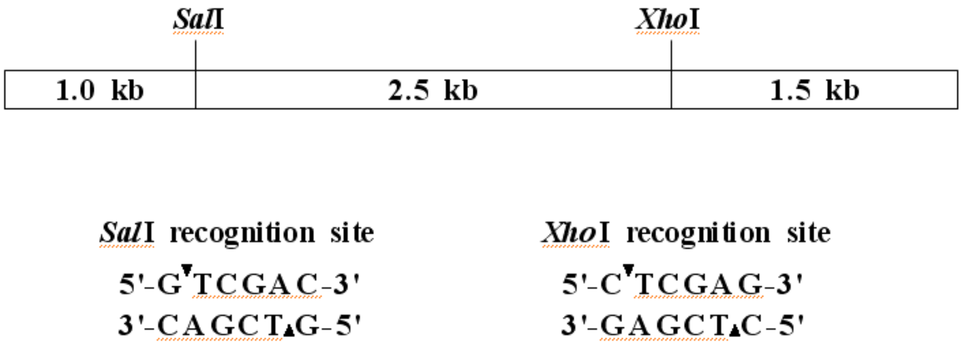
The table below shows descriptions about subcellular organelles collected in different centrifugation pellets.

Pallets	Description
Nucleus	An organelle containing a linear DNA harboring telomeric sequences.
Pellet 1	An organelle inheriting its genetic information by maternal inheritance.
Pellet 2	An organelle performing glycosylation of most proteins.
Pellet 3	An organelle composed of two subunits and synthesizing proteins.

Provided that the subcellular structures are not disrupted during the centrifugation process, determine whether descriptions A, B and C of different subcellular structures in the same pellets are true or false taking above information as a reference. Mark the appropriate box with a checkmark (√) in the answer sheet.

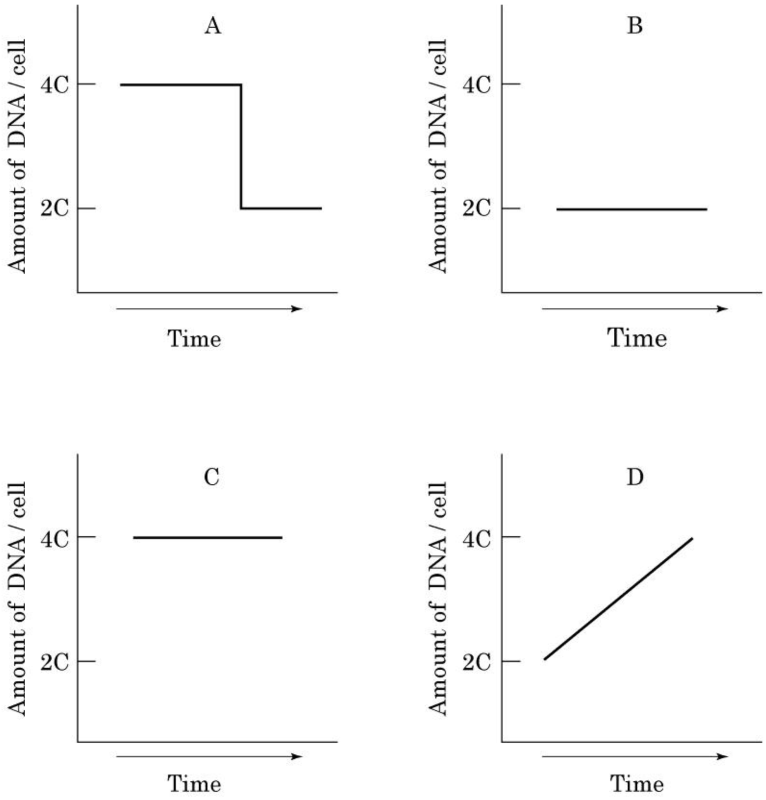
	Pellet	Description
A	Pellet 1	An organelle containing a bunch of proteases, lipases, and nucleases.
B	Pellet 2	An organelle carrying an enzyme catalyzing the conversion of hydrogen peroxide (H_2O_2) to water and oxygen.
C	Pellet 3	The infected intracellular virus covered with viral coat.

B11. (2 points) The *Sal*I and *Xho*I restriction map of a 5 kb linear DNA molecule is shown below.



The 3.5 kb DNA fragments obtained from a *Xho*I digestion were ligated with the 1.0 kb DNA fragments obtained from a *Sal*I digestion. The resulting 4.5 kb DNA molecules were digested with *Sal*I. Write down all the different lengths of DNA fragments you can get from this digestion. (Assume that restriction enzymes completely cut all the DNA molecules, and ignore blunt-end ligation.)

B12. (1.5 points) The following graphs show the quantitative change in DNA content at each of four stages in the cell cycle (G1, S, G2, M).



Select the graph (A~D) representing the stages described in I~III.

Cellular activity and response
I. Taxol treatment, which prevents microtubule deploymerization, arrests the cell at this stage.
II. With a mitogen treatment, such as an epidermal growth factor, an arrested cell at this stage proceeds to the next stage of the cell cycle.
III. The cell cycle check point at this stage confirms that DNA duplication is complete before the cell proceeds to the next stage.

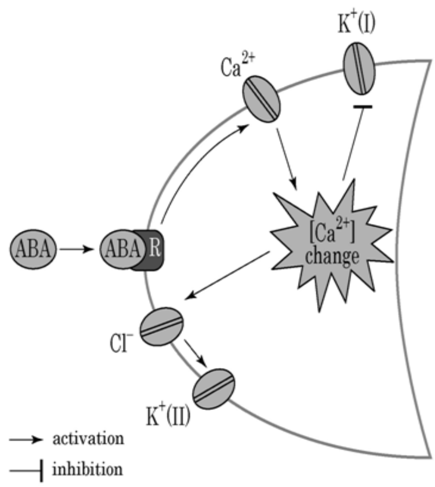
PLANT ANATOMY AND PHYSIOLOGY

B13. (2 points) A transgenic *Arabidopsis* plant (2n) has a total of two copies of a kanamycin-resistant gene in its nuclear genome, one on chromosome 1 and the other on chromosome 3. For each description of this plant, indicate with a checkmark (√) in the answer sheet whether the description is true or false.

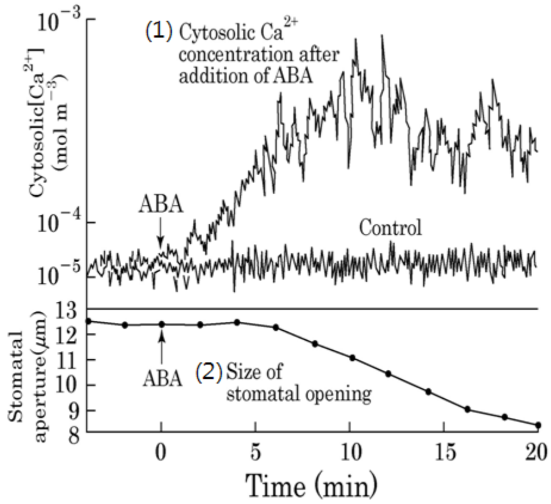
	Description
I.	All pollen grains of this plant have kanamycin-resistant genes.
II.	Endosperms formed by self-fertilization of this plant have 0~6 copies of the kanamycin-resistant gene.
III.	If seeds from self-fertilization of this plant are germinated, the ratio of kanamycin-resistant to kanamycin-sensitive seedlings is 3 to 1.
IV.	A cell containing 4 copies of the kanamycin-resistant gene exists among root cells at prophase of mitosis in this plant.

B14. (1.5 points) Figure *a* shows an ABA signal transduction pathway in a guard cell. Figure *b* shows changes occurring after ABA treatment in (1) the cytoplasmic Ca^{2+} concentrations of guard cell and (2) stomata aperture size.

a



b



For each description about ABA action, indicate with a checkmark (√) in the answer sheet whether the description is true or false.

	Description
I.	With ABA treatment, Ca^{2+} is moved from outside of the guard cell into the cell interior.
II.	With ABA treatment, the concentration of K^+ is increased in the cytoplasm of guard cells.
III.	The K^+ channel (I) is outward, and the K^+ channel (II) is inward.

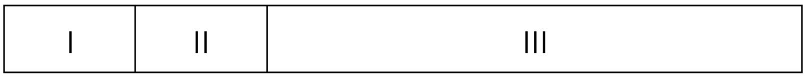
B15. (3 points) The chloroplast, a plant organelle, originated from ancestors of the cyanobacteria; however, many proteins in the chloroplast are encoded from genes in the nuclear genome.

B15.1. (1.2 points) For each property of chloroplast DNA, indicate a checkmark (√) in the answer sheet whether the property is similar to that of prokaryote or eukaryote genomic DNA.

Property
I. The DNA is a circular double strand.
II. Introns are found.
III. Component of 70S ribosome is encoded.
IV. Usually, polycistronic mRNA is transcribed.

B15.2. (1.8 points) Protein X, a thylakoid lumen protein, is transcribed in the nucleus and translated in the cytoplasm. Next, the protein is translocated into the stroma of the chloroplast by signal peptide I. In the stroma, signal peptide I is cleaved, and the remaining protein is targeted to the thylakoid lumen by signal peptide II. In the thylakoid lumen, signal peptide II is cleaved, and the remaining polypeptide III is usually observed.

Thylakoid lumen protein X



Several recombinant vectors of protein X are transformed into the nuclear genome and expressed. For each recombinant vector, fill the blanks in the 2nd column with the cellular location (A~D) where the expressed proteins are mainly observed. Fill the blanks in the 3rd column with the polypeptides (E~H) observed in that location.

< Cellular location of expressed proteins >

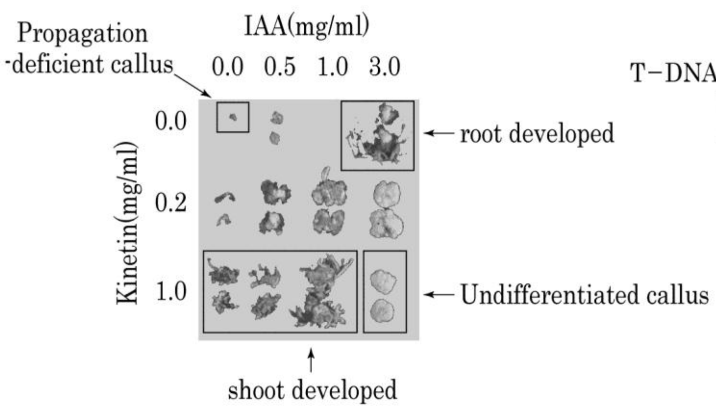
A. Cytoplasm B. Stroma C. Thylakoid membrane D. Thylakoid lumen

< Observed polypeptides >

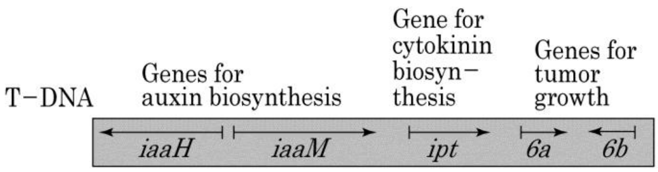
E. I-II-III F. I-III G. II-III H. III

B16. (1.5 points) Figure *a* shows organogenesis of plant calluses incubated on media containing different concentrations of IAA (an auxin) and kinetin (a cytokinin). In nature, *Agrobacterium*, a soil bacterium, induces crown gall tumors on the roots of legume plants. The bacterium induces these tumors by integrating its T-DNA into the plant genome and by expressing a group of genes necessary for gall formation (Figure *b*).

a



b



If an infecting *Agrobacterium* lacks or over-expresses the auxin-biosynthetic genes or cytokinin-biosynthetic genes, determine the most expected callus phenotype (A~D) for mutations (I, II, and III) described in the table below. Indicate with a checkmark (√) in the appropriate box in the answer sheet.

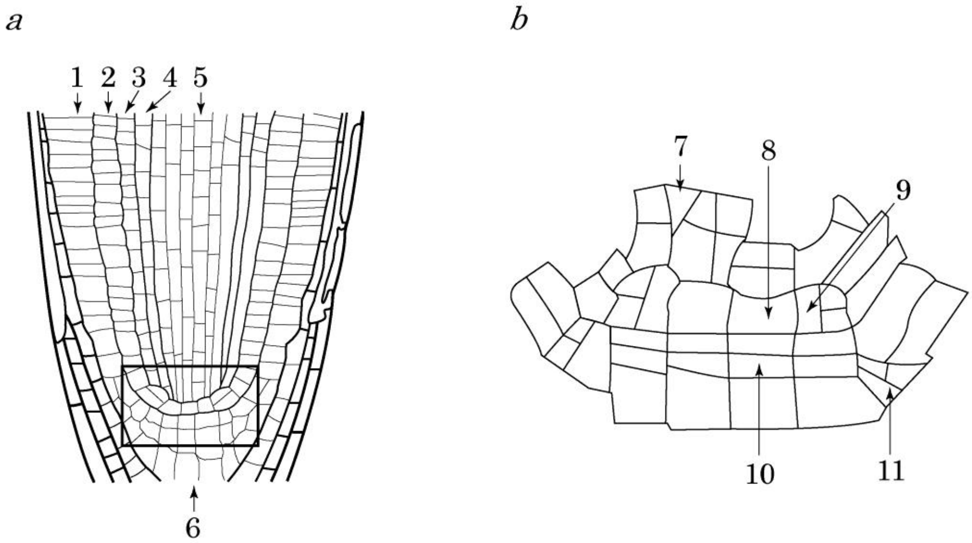
< Expected callus phenotypes >

A. Shooty callus B. Rooty callus

C. Undifferentiated callus D. Propagation-deficient callus

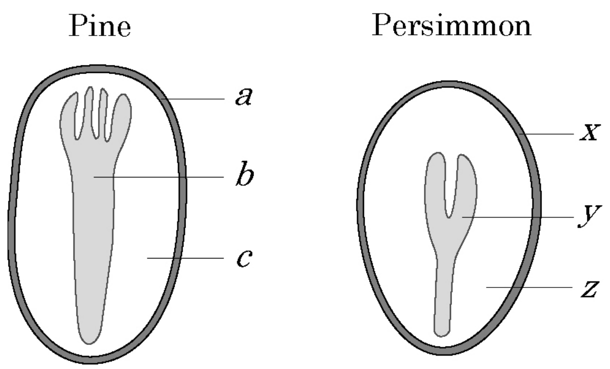
Gene mutation
I. Deletion of *iaaH*, overexpression of *ipt*.
II. Overexpression of *iaaH*, deletion of *ipt*.
III. Deletion of *iaaH* and *ipt*.

B17. (2.4 points) Plant root cell type is determined by the division and differentiation of a particular stem cell (meristematic cell). Figure *a* shows the whole microscopic structure of a longitudinally-sectioned *Arabidopsis* primary root. Figure *b* is an enlarged diagram corresponding to a region of the inset in Figure *a*, showing the arrangement of root primordia (stem cells).



Fill in the table to best match the listed function with the correct root cell type (1~6 in Figure *a*) and with the corresponding initial cell (7~11) in Figure *b*.

B18. (1.5 points) The figures below show the inner structures of pine and persimmon seeds.

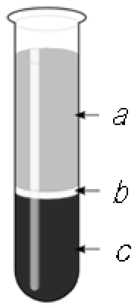


Indicate with a checkmark (√) whether the following statements are true or false.

I.	Structures *a* and *b* are the same in ploidy, but they differ in genetic composition.
II.	Structures *a*, *b*, and *c* consist of two different sporophytic structures and one gametophytic structure.
III.	Structures *x* and *y* are the same in both ploidy and genetic composition.
IV.	Structure *z* is three-times higher in ploidy than structure *c*.
V.	Structures *a* and *x* are both surrounded by the ovary.

ANIMAL ANATOMY AND PHYSIOLOGY

B19. (1.8 points) Human blood can be separated into three parts using a table top centrifuge, as shown in the following figure.

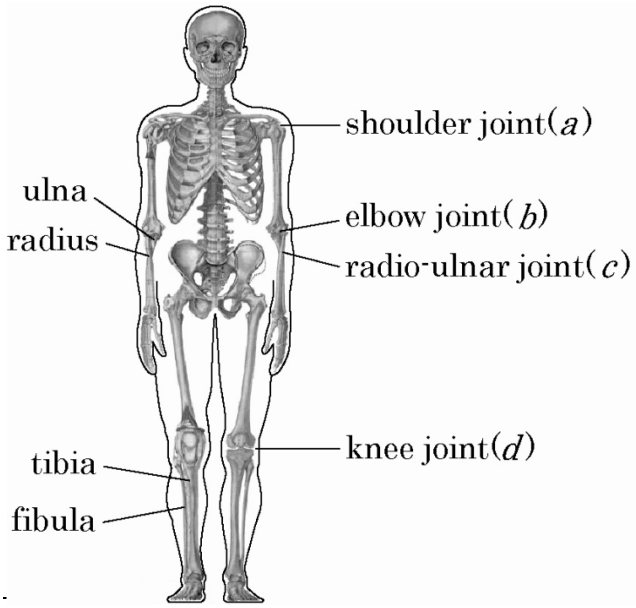


Of these blood parts (*a~c*), select the part that contributes most to the listed functions of blood.

Answer by placing a checkmark (√) in the appropriate box in the answer sheet.

Function
I. Antibody production.
II. Transport of carbon dioxide.
III. Transport of iron.
IV. Transport of oxygen.
V. Formation of blood clot.
VI. Neutralizing snake venom.

~~**B20**. (2.2 points) The picture depicts the adult human skeleton and the table lists different types of joints.~~



	Type of joint
A	Ball-and-socket joint
B	Hinge joint
C	Pivot joint

~~**B20.1**. (1.2 points) Choose the type of each joint by placing a checkmark (√) in the appropriate box in the answer sheet.~~

~~**B20.2**. (1 point) For each statement concerning the function of joints and bones, indicate with a checkmark (√) whether the statement is true or false.~~

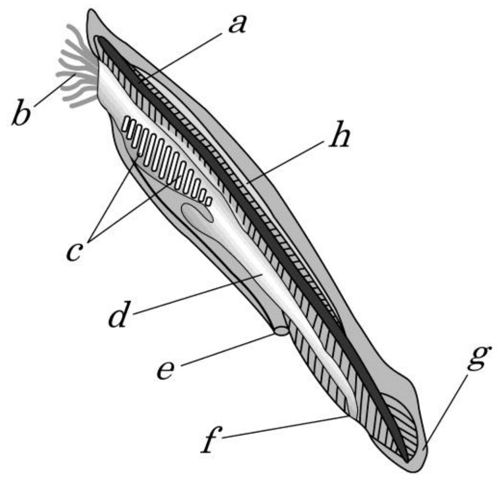
~~Function~~
~~I. The joint between the skull and the first cervical vertebra enables the rotation of the head.~~
~~II. The fibula, as well as the tibia, plays an important role in supporting the body weight.~~

B21. (2.4 points) Chordates are distinguished from other animals by 4 distinctive key morphological characters.

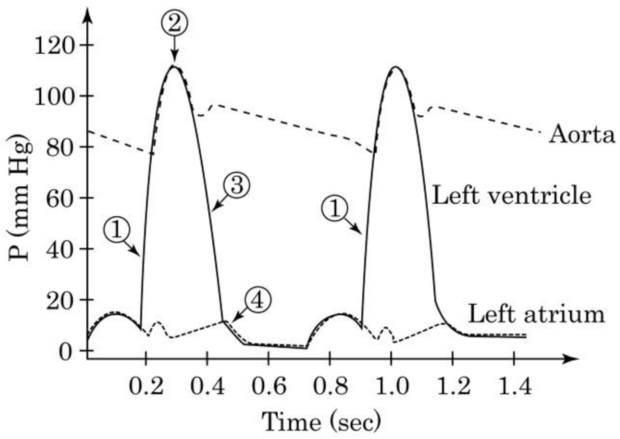
B21.1. (1.2 points) Choose the 4 key morphological characters from the following list and write their numbers in the left-hand column of the table in the answer sheet.

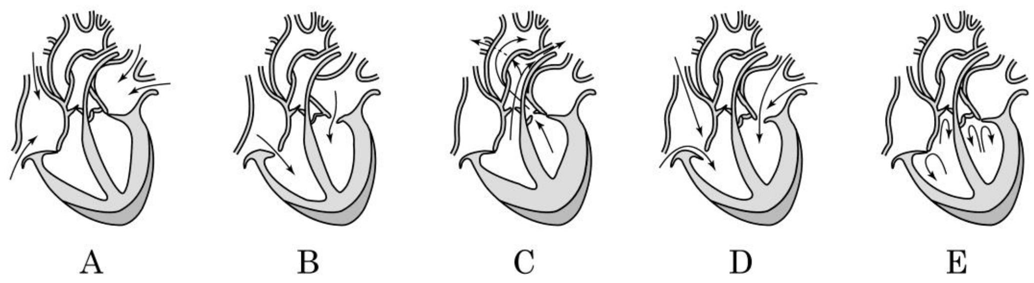
Morphological character			
1. Cirri,	2. Brain,	3. Pharyngeal slits,	4. Gills,
5. Notochord,	6. Intestine,	7. Tubular dorsal nerve cord,	
8. Anus,	9. Tail.		

B21.2. (1.2 points) The morphological characters of a lancelet (*Branchiostoma*) are shown in the illustration below. Find each of the morphological characters that you listed in the table (from **B21.1**) - write the corresponding letter code in the right-hand column of the table in the answer sheet.



B22. (2 points) The graph below depicts the pressure changes in an aorta, left ventricle, and left atrium that occur concurrently during the mammalian cardiac cycle. Below the graph are sketches of the heart illustrating blood flow and valve state (opened/closed).





Match each numbered event in the cardiac cycle graph with the letter of its corresponding heart sketch. Write the corresponding letter code in the right-hand column of the table in the answer sheet.

B23. (1.5 points) Fig. I shows the relationship between weight and the specific metabolic rate of the indicated animal species, and Fig. II shows the O_2 consumption rate of the indicated species as a function of running speed (on a treadmill machine).

Fig. I

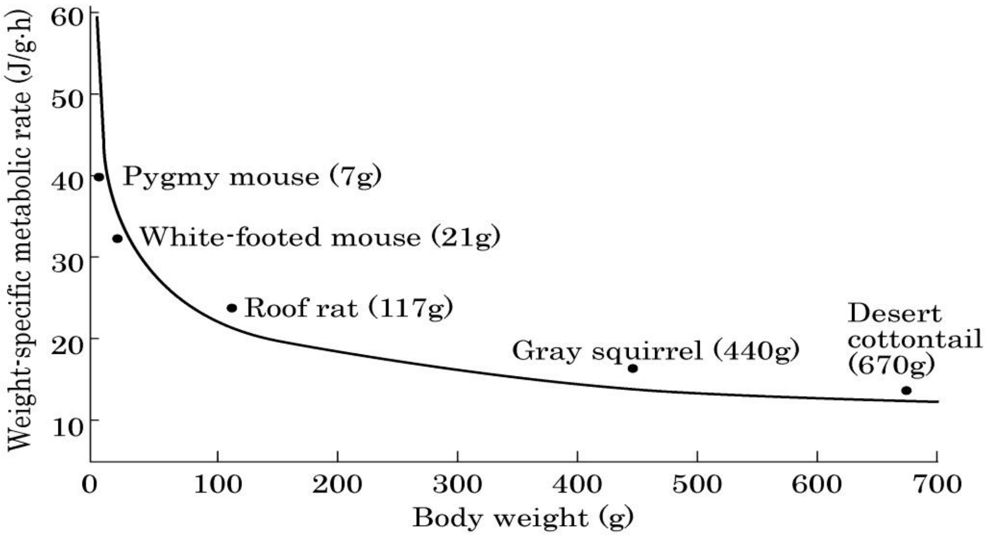
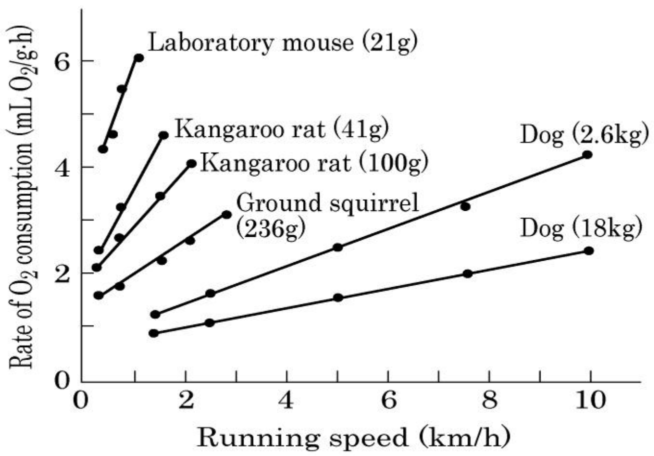


Fig. II



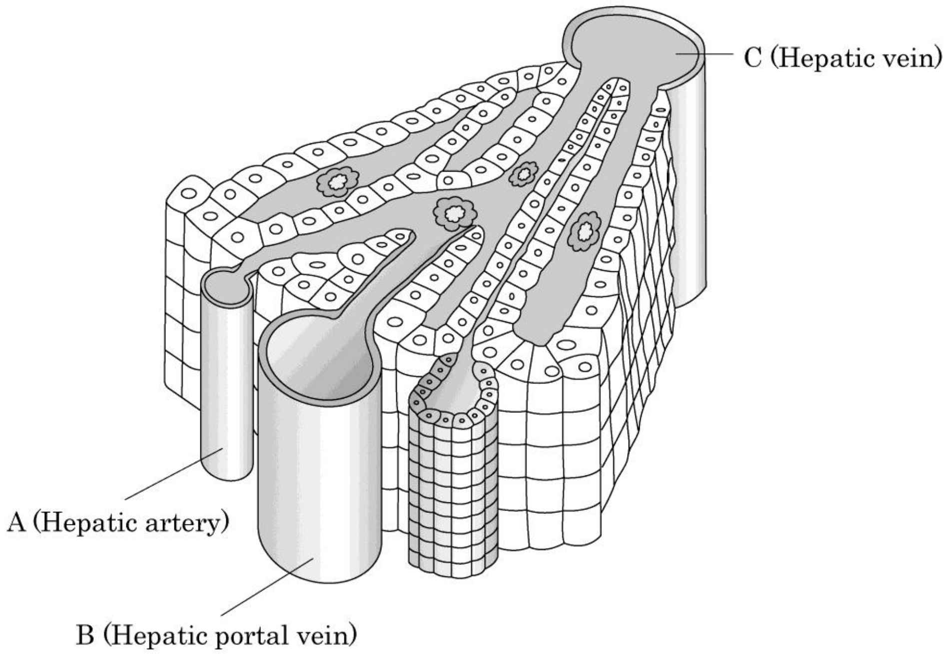
Read each of the following explanations, and indicate with a checkmark (√) in the answer sheet whether the explanation is true of false.

Explanation
A. At rest, smaller animals consume more energy per weight than the bigger animals consume.
B. Using the same amount of food per body weight, a smaller animal can travel a longer distance than a bigger animal can travel.
C. Using the same amount of food, bigger animals generate more ATP than the smaller ones generate.

B24. (1.8 points) If an astronaut lived on a heavier and larger planet than Earth, he would experience stronger gravitational forces. In that case, what would you expect to happen in this astronaut's body? For each symptom listed below, indicate with a checkmark (√) whether the symptom is expected or unexpected.(Assume that the composition of the atmosphere of the planet is the same as that of Earth.)

Symptom
A. Increase in blood pressure.
B. Decrease in the respiration rate.
C. Increase in muscle mass.
D. Increase in bone density.
E. Decrease in the number of red blood cell.
F. Increase in oxygen content in the blood.

B25. (1.5 points) The following dissection figure shows the blood vessels in liver tissue. The three main blood vessels are indicated by capital letters (A~C).



Following statements describes properties of blood that flows through particular blood vessels. For each description, indicate with a checkmark (√) in the appropriate box with matching vessel where that blood would be found.

Description
I. Blood with the highest oxygen content.
II. The blood shows the first increase in lipid content after the meal.
III. The blood shows the first increase in glucose content after the meal.

B26. (3 points) A Korean professor, Charlie Shin, was bilingual, such that he is fluent in Korean and English. He was also good at communicating using sign language. Unfortunately, he had a stroke while taking part in discussions at the 2010 IBO International Jury meeting. Dr. Oliver diagnosed that Charlie had damage in his left cerebral cortex which controls some part of his language output area and whole arm areas.


B26.1. (1 point) A novice nurse examined Charlie's language ability. Select a correct diagnosis among below.

A. Charlie had difficulty in understanding Dr. Oliver's talk.

B. Charlie had difficulty in understandings of the 2010 IBO theoretical questions written on a paper.

C. Charlie had a hard time to understand a word "LOVE" written on his back by Dr. YT Kim.

D. Charlie's ability to speak Korean fluently had disappeared.

E. Charlie's ability to write Korean poems with his right hand remained intact.

B26.2. (1 point) The ability of Charlie's sign language and the movement of upper extremity were also carefully examined by Dr. Oliver. The results showed that he was also incapable of proper execution of sign language expression in either arm and of moving his right arm. What can we conclude from this?

A. The damaged language area is responsible for both sign as well as spoken language.

B. Motor neurons in the right cerebral cortex govern the muscles of the right side.

C. The language comprehension region is located in the right hemisphere.

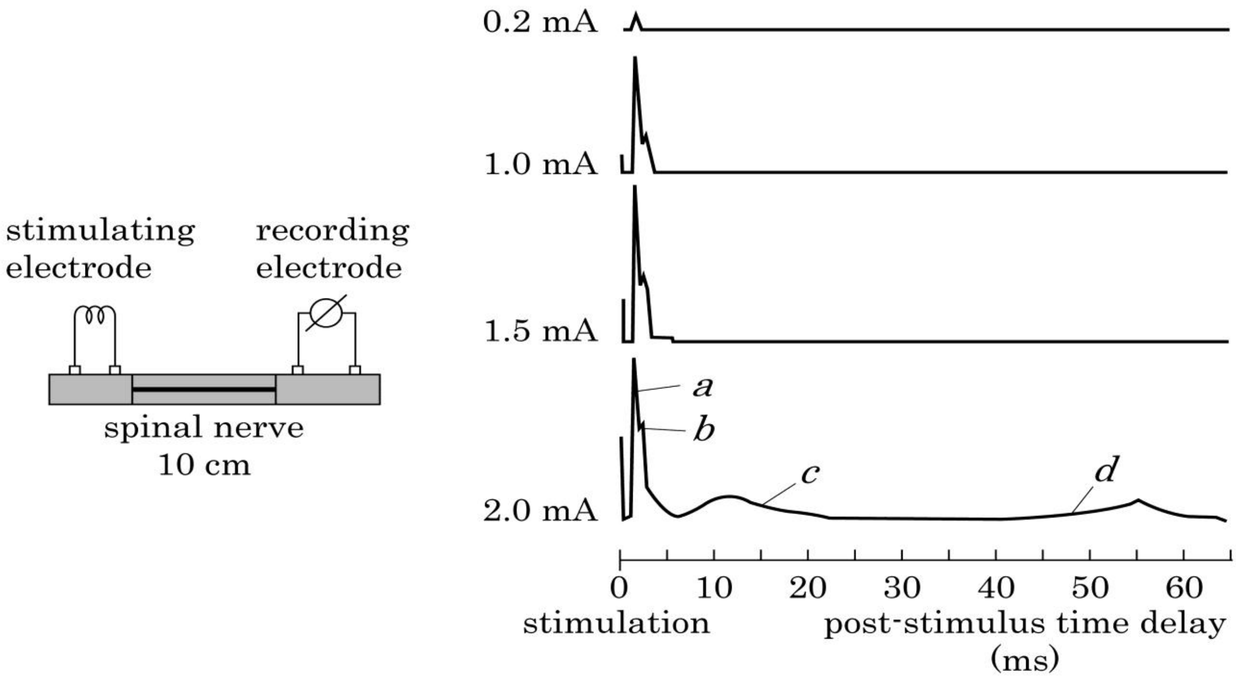
D. His visual system is also damaged.

E. His sign language expression with left arm is normal.

B26.3. (1 point) A brain-machine interface (BMI) study using a monkey was reported in the Science journal. An array of micro-wire recording electrodes was implanted in associative, arm movement planning area in the frontal cortex of a normal monkey. During upper arm movements electromyogram (EMG), recordings were taken from upper extremities, and at the same time neural recordings were made from implanted recording electrodes in the frontal cortex. Correlations between EMG and neural signals were obtained every 200 msec and used as commands for robot arm movement. The monkey intentionally controlled the robot arm with almost 100% success rate, without using arm muscles. Evaluate whether the following would be true or false if this BMI technology is used for human.

	Description
I	Immunological reaction is one of obstacles to overcome for future development of a prosthetic device for patients such as Charlie.
II	For accurate decoding of motor planning information, the number of simultaneously recorded neurons should be increased.
III	It is more difficult to design prosthetic robot fingers than a robot arm using this kind of BMI technology.
IV	This BMI technology is applicable to overcome Charlie’s language disability by decoding motor production information.
V	The described BMI technology can be classified as a motor (output) BMI, while artificial cochlea can be classified as an sensory (input) BMI.

B27. (3 points) A spinal nerve has four different kinds of axons carrying out physiological functions like muscle contractions and cutaneous sensory, thermal and pain sensations. Myelinated, large-diameter axons carry motor information, while unmyelinated, small-diameter axons carry pain information. An electrophysiological experiment was carried out using an isolated rat spinal nerve. Four different intensities of electrical stimulation were delivered to the nerve. Since the stimulation caused simultaneous activation of all axons in the nerve, including both small and large diameter axons, we observed different peaks (*a* to *d*) in the compound action potential (CAP) traces on an oscilloscope. The averaged post-stimulus time delays of these CAP peaks were: *a*, 2 ms; *b*, 2.5 ms; *c*, 12 ms; and *d*, 55 ms. The length of the spinal nerve was 10 cm.



B27.1. (1 point) Calculate the conduction velocity (m/sec) of the CAP peak ***a***.

B27.2. (1 point) After the middle part of the nerve is exposed to a local anesthetic that blocks Na^+ channels, which of the following is expected to occur?

A. The height of all CAP peaks is reduced.

B. The post-stimulus time delays of all CAP peaks are shortened.

C. Peaks are reduced and delays are shortened selectively in CAP peaks ***c*** and ***d***.

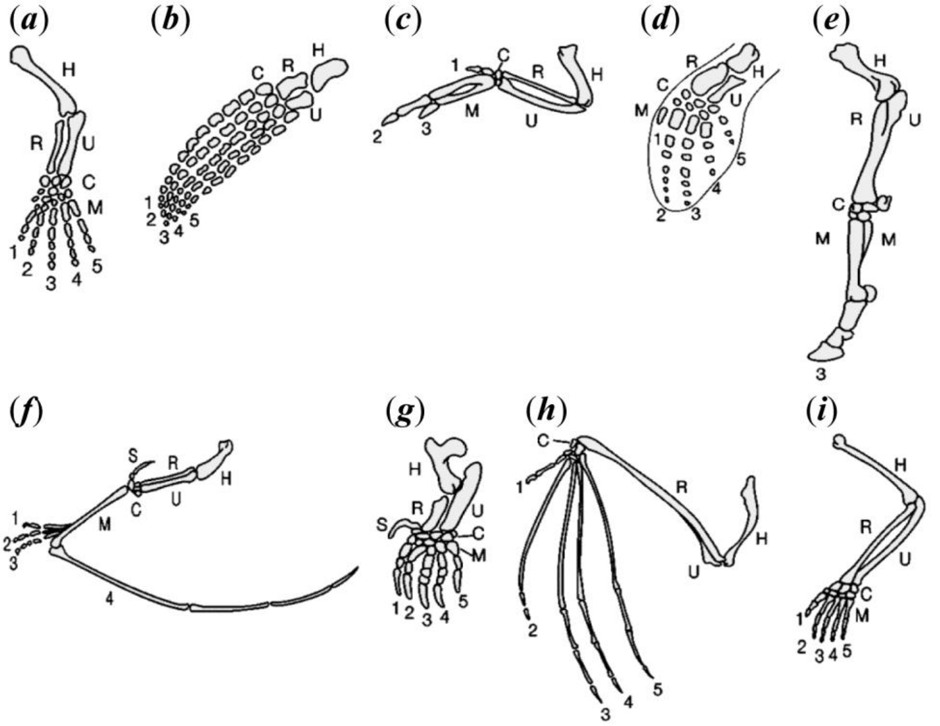
D. Peaks are reduced and delays are shortened selectively in CAP peaks ***a*** and ***c***.

E. Peaks are reduced and delays are shortened selectively in CAP peaks ***b*** and ***c***.

B27.3. (0.5 point) Which CAP peak is response to painful stimulation?

B27.4. (0.5 point) Which CAP peak is responsible for muscle contractions?

B28. (2.7 points) The figures below present the skeletal structures of Tetrapod anterior limbs. In the figure, (***a***) corresponds to an early amphibian limb. The numbers and letter codes with each limb represent different bones as indicated in the legend under the figure.



H: Humerus,	U: Ulna,	R: Radius,	C: Carpals,
M: Metacarpals,	S: Sesamoid bone,	1~5: Phalanges.	

B28.1. (1.8 points) Among the following statements, decide which statements are true or false?

I.	(***c***) and (***e***) show loss or fusion in the skeletons as compared to the ancestral condition.
II.	(***b***) and (***g***) show adaptation for life in the ocean.
III.	(*b*) and (***d***) show convergent evolution of the skeleton.
IV.	(***i***) shows adaptation for grasping.
V.	The sesamoid bones in (***f***) and (***g***) are evolutionary reversals.
VI.	The figures show homologous characteristics of Tetrapod anterior limbs.

B28.2. (0.9 point) Which of the anterior limbs in the figure above show adaptation for flight or no adaptation for flight? Indicate with checkmarks (√) in the appropriate box the answer sheet.

ETHOLOGY

B29. (3 points) In matriphagy, a spider female is cannibalized by her offspring who attack and eat her body, when they reach a specific age. The young then live in a group for a short time period and disperse from the nest individually after the third molt. However, some mothers avoid matriphagy. If a mother is not eaten by the first clutch, there is a 30% probability that she will be able to produce a second clutch. The table presents demographic data for this species.

	Clutch size at emergence	Survival rate at the 3rd molting	Body mass at dispersal	Survival rate from emergence until reproductive age
1st clutch with matriphagy	100	95%	3.5 mg	20%
1st clutch without matriphagy	100	70%	2.0 mg	10%
2nd clutch with matriphagy	40	95%	3.5 mg	20%

B29.1. (1 point) If spiders avoid matriphagy and attempt to produce a second clutch, what is the total clutch size, on average, that these spiders would produce?

B29.2. (1 point) Calculate and write down the reproductive success of the two strategies in which a female spider

(i) produces only a single clutch and is cannibalized, or

(ii) avoids being eaten and attempts to produce a second clutch?

(Reproductive success refers to the mean number of reproductively viable offspring one individual produces.)

B29.3. (1 point) From an evolutionary perspective and given the constraints above, which behavior would be selected for?

A. The female does not allow matriphagy because the behavior decreases her survivorship.

B. The female leaves the nest before emergence of the young from the egg sac.

C. The female is eaten by its second clutch after leaving the first clutch just before matriphagy.

D. The female is eaten by its first clutch.

E. The female does not produce the offspring which cannibalize the mother.

B30. (2.6 points) Honeybee workers (*Apis* species) perform dances to transmit information about the distance and direction of the food source.

B30.1. (1 point) What is the primary sensory mechanism involved in this communication between colony members in the nest?

A. Acoustic

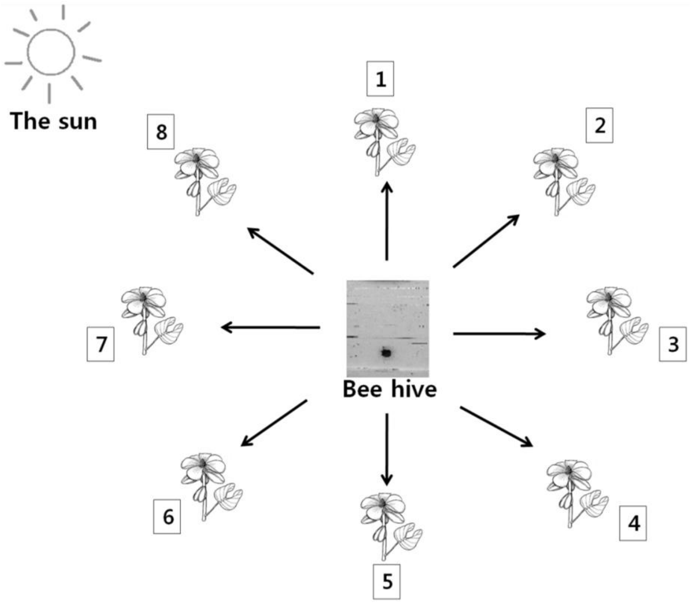
B. Gustatory

C. Olfactory

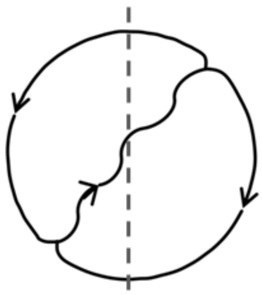
D. Tactile

E. Visual

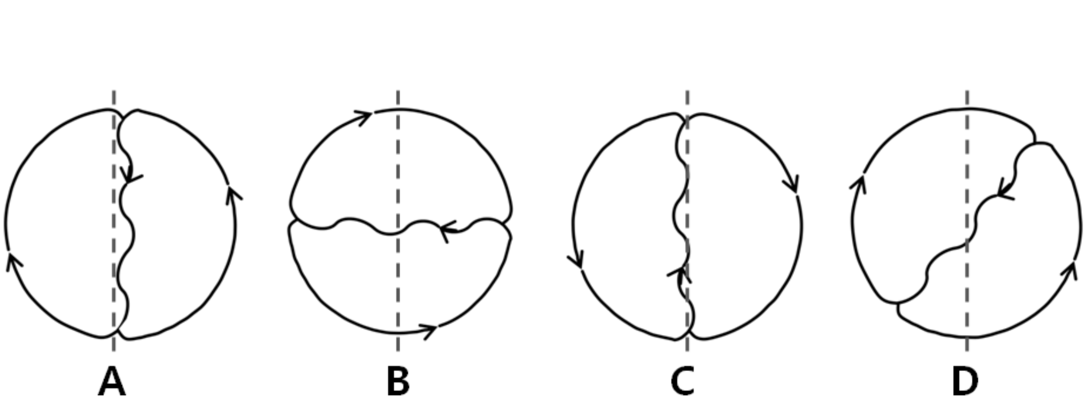
B30.2. (1.6 points) The figure below shows the location of 8 food sources (1~8) relative to the hive.



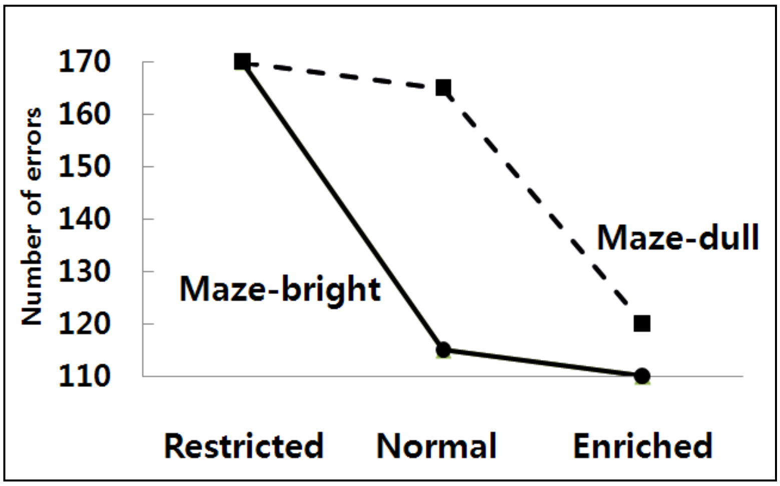
The next figure shows a waggle dance pattern for food source **1**. The dotted line indicates the direction of gravity.



Match each food source direction with its corresponding waggle dance pattern in the following figures.



B31. (1.5 points) Over a number of generations, two strains of rats were selected in a normal environment for their increased or decreased maze-learning ability: 'Maze-bright' rats vs. 'Maze-dull' rats. For the experimental test, rats from each strain were reared in three environments that differed in the amount of visual stimuli present: restricted, normal, and enriched. The graph below shows the behavioral performance of adults in terms of the number of errors committed in running a maze for the maze-bright and maze-dull rats.



Mark whether each of the conclusions below is true or false by putting a checkmark (√) in the appropriate box in the answer sheet.

	Conclusion
I.	This experiment proves that selection for a behavioral trait leads to genetic differences between strains.
II.	If the two strains of rats are raised in a normal environment, the two strains make a similar number of errors.
III.	This experiment shows that exposure to visual cues during early development influences behavioral performance in adult rats.
IV.	The threshold amount of visual stimuli that markedly improves adult behavioral performance is different for maze-dull and maze-bright rats.

GENETICS AND EVOLUTION

B32. (2 points) The fruit fly *Drosophila melanogaster* has a XX(female)-XY(male) system of sex determination. The Y chromosome determines maleness in humans, but not in *Drosophila*. Instead, sex determination in *Drosophila* depends on the ratio of the number of X chromosomes to the number of autosomal haploid sets in an individual fly.

The table below describes five mutants whose sex-chromosome complements and haploid sets of autosomes differ from the normal condition.

Indicate with a checkmark (√) the sex phenotype of all the mutant flies.

	Sex-chromosome complement	Haploid sets of autosomes
A	X	2
B	XXY	2
C	XXX	3
D	XXXY	3
E	XX	4

B33. (2.4 points) The following statements concern evolutionary patterns of animal morphological traits. Mark whether each statement is true or false by putting a checkmark (√) in the appropriate box on the answer sheet.

	Statements
I.	Evolution is invariably a phenomenon with direction; therefore, morphological complexities evolved from simplicities.
II.	Genetic mutations always lead to morphological changes.
III.	Increases in animal body size are not universal within evolutionary lineages.
IV.	Morphological changes of individuals do not result from allometric growth, the differential growth of body parts.
V.	Chordate species are more similar in the embryonic stages rather than in the adult stages.
VI.	Phylogenetic analyses have revealed trends of morphological evolution in some lineages.

B34. (3 points) The following tables present results of plant crosses involving three linked genes: *F* is a flower-color gene, *S* is a seed-color gene, and *L* is a plant-height gene. Each gene has two alleles with one allele exhibiting complete dominance over the other allele. Dominant phenotypes are red flowers, yellow seeds, and tall plants; recessive phenotypes are white, green, and short, respectively. Assume that crossing-over between two genes occurs once.

Parents	Red flower / Yellow seed (*FfSs*) X White flower / Green seed (*ffss*)			
F_1 phenotypes	Red flower / Yellow seed	White flower / Green seed	Red flower / Green seed	White flower / Yellow seed
Frequency of F_1	0.49	0.49	0.01	0.01

Parents	Tall height / Yellow seed (*LlSs*) : self fertilization			
F_1 phenotypes	Tall height / Yellow seed	Tall height / Green seed	Short height / Yellow seed	Short height / Green seed
Frequency of F_1	0.51	0.24	0.24	0.01

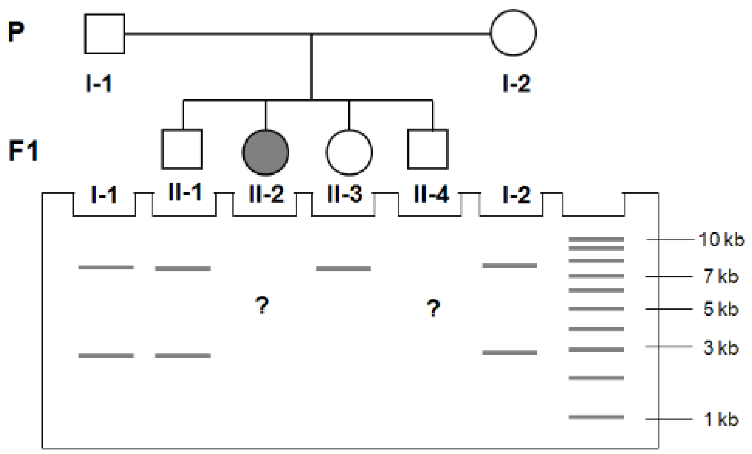
B34.1. (0.9 point) Indicate with a checkmark (√) in the answer sheet whether each description is true of false.

	Description
I.	*S* is closer to *L* than to *F*.
II.	Some of F_1 plants with tall height / green seed are due to crossing-over.
III.	Crossing-over occurs at prophase of meiosis I.

B34.2. (0.8 point) How many genotypes can be observed in F_1 plants having tall height/yellow seed?

B34.3. (1.3 points) Calculate the map unit between gene *L* and gene *S.* (One map unit = distance of 1% recombination)

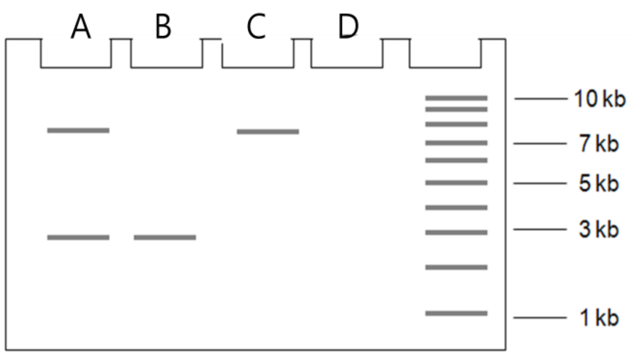
B35. (2 points) Shown below is a pedigree for the genetic trait PKU (phenylketonuria) that is caused by a recessive mutation of the PAH gene (that encodes phenylalanine hydroxylase). Under the pedigree is the RFLP (Restriction fragment length polymorphism) pattern of each individual for the PAH gene. II-2 individual has the PKU.



B35.1. (1 point) The RFLP phenotype for individual II-2 is not given. From the gel shown below (A~D), choose all the patterns that would be a correct match for II-2.

B35.2. (1 point) The RFLP phenotype for individual II-4 is not given. From the gel shown below, determine whether each molecular phenotype (A~D) could be a possible match for II-4.

<Example>



B36. (2 points) 10^5 cells of a triple-mutant yeast strain (*leu⁻ his⁻ trp⁻*) were spread either on minimal medium or on minimal medium supplemented with various combinations of histidine, leucine, or tryptophan. The cultures were grown at either 25℃ or 37℃ for 3 days. Colony numbers in each plate were counted, and the data are listed in the following table.

Supplements added on minimal medium	Number of colonies	
	25℃	37℃
None	None	None
His, Trp	None	None
Leu, His	8	7
Leu, Trp	Confluent	11
Leu, His, Trp	Confluent	Confluent

B36.1. (1 point) What kind of mutation most probably causes the *his*$^-$ phenotype?

A. Conditional mutation

B. Deletion mutation

C. Point mutation

D. Missense mutation

E. Nonsense mutation

B36.2. (1 point) What type of mutation most probably causes the *leu*$^-$ phenotype?

A. Conditional mutation

B. Deletion mutation

C. Point mutation

D. Missense mutation

E. Nonsense mutation

B37. (2 points) Human ABO blood type is determined by two genes (*H* and *I*). First, the *H* gene codes for the antigen precursor. The dominant allele (*H*) leads to expression of the precursor; the recessive allele (*h*) does not. Second, the *I* gene has three allele forms, I^A, I^B and *i*, and determines blood type (A, B, O or AB).

A male with blood type A and a female with blood type B marry. Each of them is heterozygous for both the *H* gene and the *I* gene. What is the probability of having a son with blood type O? Give your answer as a percentage (%) rounded to an integer (without any decimals).

B38. (2 points) The presence of a beard on some goats is determined by the *B* (beard) gene, which has two alleles: beardless (B^+) and bearded (B^b). The B^b allele is dominant in males but recessive in females. F_1 progeny were born from a cross between a beardless male and a bearded female; F_2 progeny were produced by crossing two F_1 individuals.

A beardless male (♂) × A beard female (♀)

↓

$F_1 \times F_1$

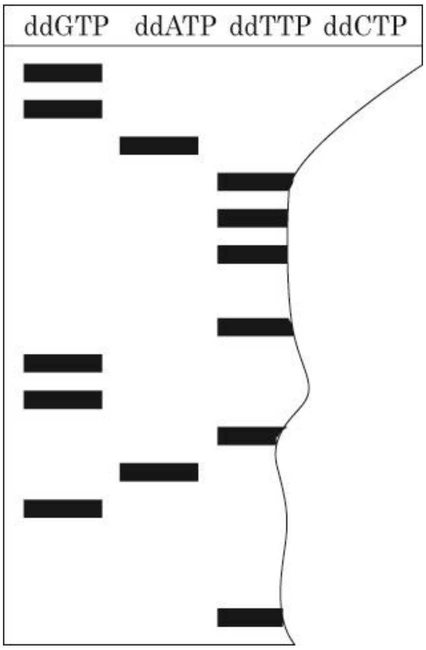
↓

F_2

Mark whether each statement is true or false by putting a checkmark (√) in the appropriate box on the answer sheet.

Description
A. F_1 females have beards.
B. One half of F_2 progeny have beards.
C. One fourth of F_2 females have beards.
D. The beard gene is sex-linked.
E. The beard gene is inherited according to Mendel's principles.

B39. (3 points) You sequence a 16 bp DNA molecule with the Sanger DNA sequencing procedure. Shown below is the high resolution electrophoretic pattern of the fragments. As you can see, the ddCTP lane was damaged.



B39 .1. (1 point) Indicate with a checkmark((√) which of the following components are required in the reaction mixture containing ddGTP?

Component
A. DNA polymerase
B. Primer
C. dATP
D. dGTP
E. Template DNA to be sequenced

B39.2. (1 point) How does the absence of a 3’-OH group in ddNTPs affect DNA synthesis?

A. It promotes DNA breakage.

B. It prevents the proper base pairing.

C. It destabilizes the phosphodiester bond.

D. It activates nucleases.

E. It prevents phosphodiester bond formation.

B39.3. (1 point) What would be the correct DNA sequence?

A. 5'-AGGCTACCAGAAATCC-3'

B. 5'-CCTAAAGACCATCGGA-3'

C. 5'-GGATTTCTGGTAGCCT-3'

D. 5'-TCCGATGGTCTTTAGG-3'

E. 5'-TGATGGTTTTAGG-3'

B40. (2 points) Answer the next two questions using the genetic code table provided below.

2nd base in codon

1st base in codon	U	C	A	G	3rd base in codon
U	Phe	Ser	Tyr	Cys	U
	Phe	Ser	Tyr	Cys	C
	Leu	Ser	STOP	STOP	A
	Leu	Ser	STOP	Trp	G
C	Leu	Pro	His	Arg	U
	Leu	Pro	His	Arg	C
	Leu	Pro	Gln	Arg	A
	Leu	Pro	Gln	Arg	G
A	Ile	Thr	Asn	Ser	U
	Ile	Thr	Asn	Ser	C
	Ile	Thr	Lys	Arg	A
	Met	Thr	Lys	Arg	G
G	Val	Ala	Asp	Gly	U
	Val	Ala	Asp	Gly	C
	Val	Ala	Glu	Gly	A
	Val	Ala	Glu	Gly	G

B40.1. (1 point) Which of the following mutations would create new template DNA from which the shortest peptide would be translated?

	5'-	ATG	GCT	GGC	AAT	CAA	CTA	TAT	TAG	-3'
Template strand DNA sequence	3'-	TAC	CGA	CCG	TTA	GTT	GAT	ATA	ATC	-5'
Nucleotide number		1	4	7	10	13	16	19	22	

A. a deletion of nucleotide number 7.

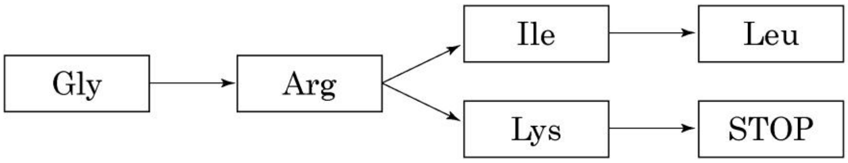
B. a G→C transversion of nucleotide number 9.

C. a G→A transition of nucleotide number 13.

D. insertion of -GGT- after nucleotide number 5.

E. a T→A transversion at nucleotide number 18.

B40.2. (1 point) A series of point mutations occurred in a bacterial gene, resulting in the substitution of amino acid residues in the order shown in the diagram below.



Which amino acid in the diagram can have more than one option for its codon given this particular process of point mutation?

A. Gly

B. Arg

C. Ile

D. Leu

E. Lys

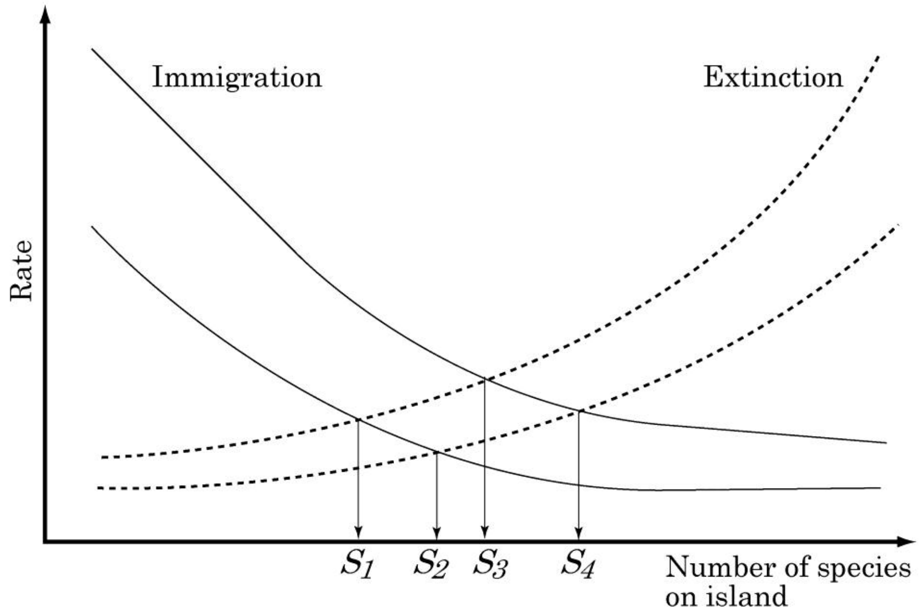
B41. (2 points) Suppose you have a population of flour beetles with 1,000 individuals. Normally the beetles are a red color; however, this population is polymorphic for a mutant autosomal body color, black, designated by *b*/*b*. Red is dominant to black, so *B*/*B* and *B*/*b* genotypes are red. Assume the population is in Hardy–Weinberg equilibrium, with f(*B*) = p = 0.5 and f(*b*) = q = 0.5.

B41.1. (1 point) What would be the expected *B* and *b* allele frequencies, respectively, if 1,000 black individuals migrated into the population? (Assume that all other Hardy–Weinberg conditions were met.)

B41.2. (1 point) What would be the frequencies of *B* and *b* alleles respectively, if a population bottleneck occurred and only four individuals survived: one female red heterozygote and three black males?

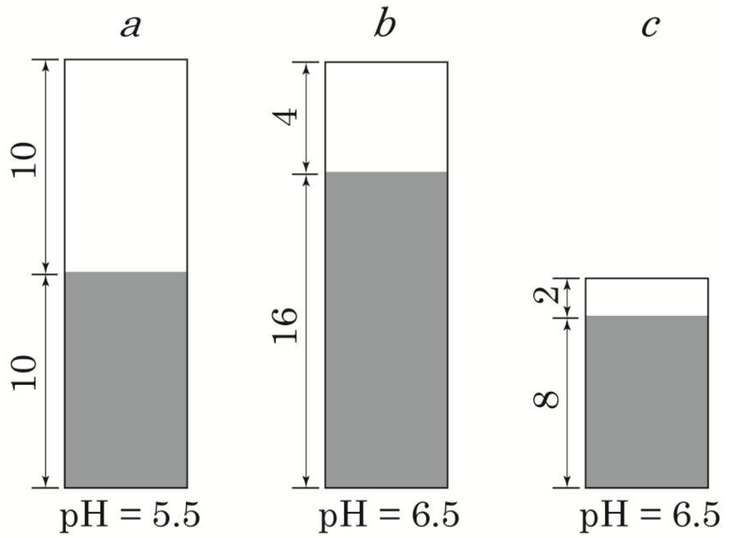
ECOLOGY

B42. (2 points) Island biogeography theory states that the number of species on an island is determined by immigration rates of new species to the island and extinction rates of species on the island. Immigration rates to an island decline as its distance from the mainland increases, and extinction rates decrease with increasing island size. When the immigration and extinction rates on an island are equal, the number of species on the island reaches equilibrium.



Give the correct equilibrium number of species (S_1~S_4), in the answer sheet, for each of four islands with different combinations of distance (near and far) and area (small and large) as shown in the figure above.

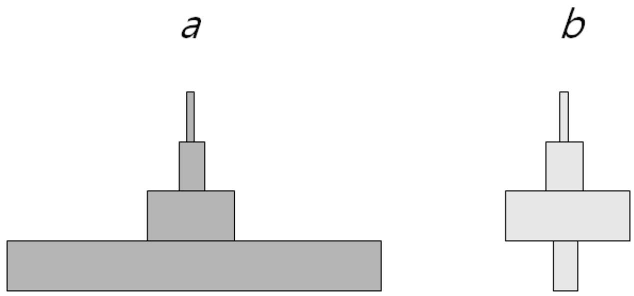
B43. (2 points) The contents of 3 soils (*a*, *b*, and *c*) were examined for soil pH and amounts of acidic cations (H^+, Al^{3+}) and other cations (Ca^{2+}, Mg^{2+}, K^+, Na^+). The figure below shows the results of that examination: the white and shaded portions of each column represent the amount of acidic and other cations, respectively. (Values given are in units of centimoles/kg.)



For each description below, indicate with a checkmark (√) whether it is true or false.

Description
I. Aluminum toxicity tends to be most severe in soil *a*.
II. Soil *b* contains the most nutrient minerals plants can use.
III. Anions such as NO_3^- and PO_4^- tend to be retained in soil more than cations are retained.
IV. As more H^+ displaces other cations, the soil becomes more acidic.

B44. (2.2 points) The figure below shows standing biomass pyramids of two ecosystems, each with four trophic levels.



B44.1. (1.2 point) Which of the following explanations are true or false? Indicate with a checkmark (√) in the answer sheet.

	Explanation
I.	Pyramid *a* reflects energy losses due to respiration within trophic levels and energy losses during energy transfer between trophic levels.
II.	Pyramid *b* represents an ecosystem with fast turnover in the primary producer level.
III.	For each ecosystem, its energy pyramid is opposite to its biomass pyramid.
IV.	For both ecosystems, production efficiency becomes higher as the trophic level increases.

B44.2. (1 point) Assuming an ecological efficiency of 10% between trophic levels, how much net primary productivity is required to harvest 2 g C/m^2 annually from the tertiary consumer level?

B45. (2.8 points) Recent changes in the mean global temperature are largely attributed to increases in levels of some atmospheric gases and aerosols (small particles suspended in air), many of which have been generated by human activities.

B45.1. (0.8 point) Evaluate whether the following statements are true or false in relation to the role of these gases and aerosols changing global temperature.

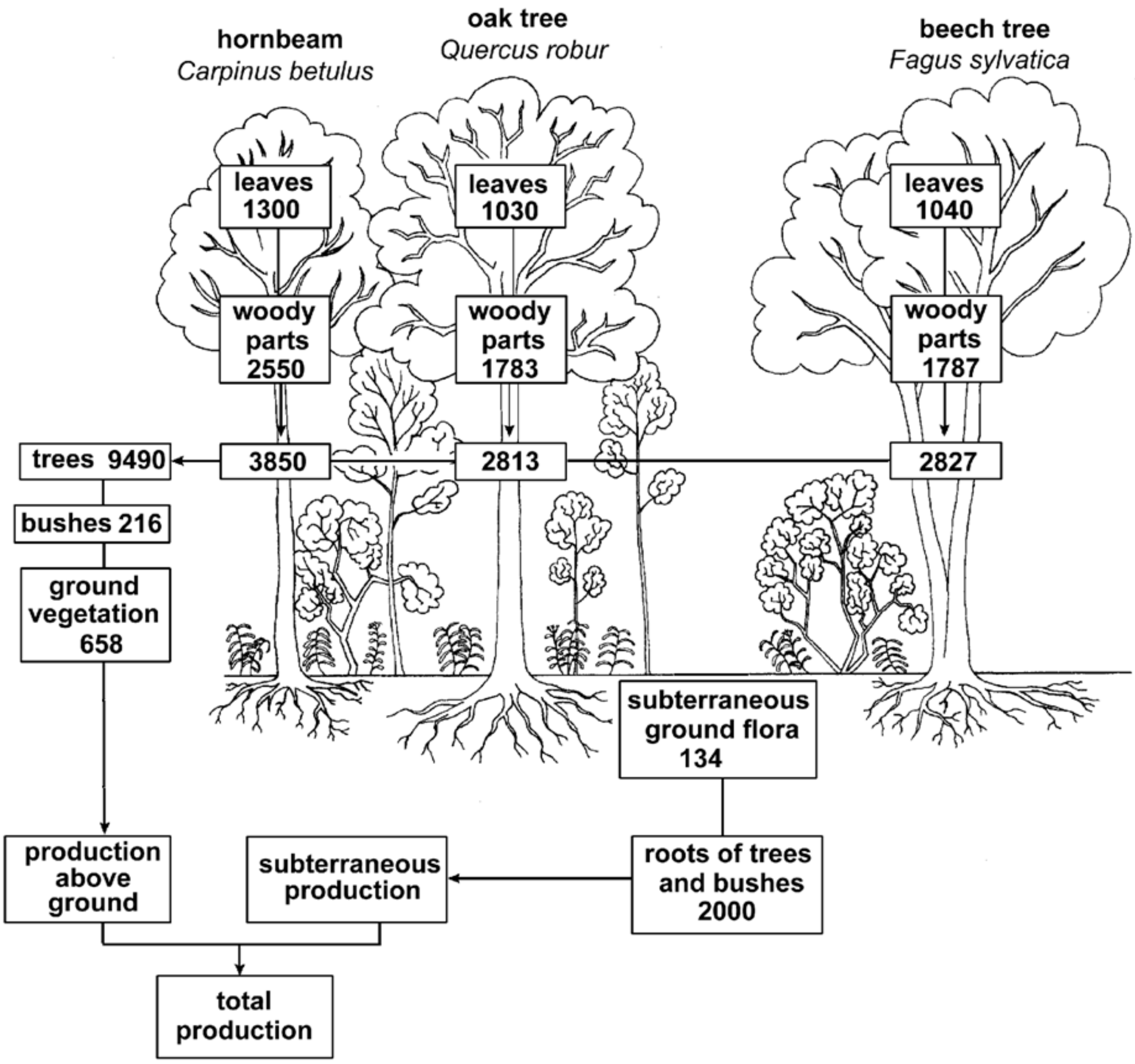
I.	These gases scatters short-wave radiation emitted from the sun.
II.	These gases absorb and re-radiate infrared radiation emitted from the earth's surface.
III.	Aerosols prevent heat convection into space.
IV.	Regardless of the presence of gases or aerosols, solar radiation itself has increased recently.

B45.2. (2 points) For each statement below, choose from the following list of gases the one that is most likely to be related to that description.

<List of gases>		
a. Hydrofluorocarbons (HFCs)	b. CH_4	c. CO_2
d. N_2	e. O_3	f. N_2O

Description
I. The gas largely derived from fossil fuels and clearing of forests that contributes the most to global warming.
II. The gas with the highest global warming potential (compared to CO_2).
III. A gas that in the stratosphere is essential to support human life on earth, while in the troposphere it exerts harmful effects on humans.
IV. A gas that is not thought to contribute to global warming.
V. A gas derived from landfills and the livestock sector that has increased most rapidly in the past 200 years.

B46. (2 points) The picture shows a schematic representation of the production of three well-known trees of a deciduous forest. The production is indicated in kg dry mass per hectare per year.



Calculate how much of the total production comes from above ground woody parts.

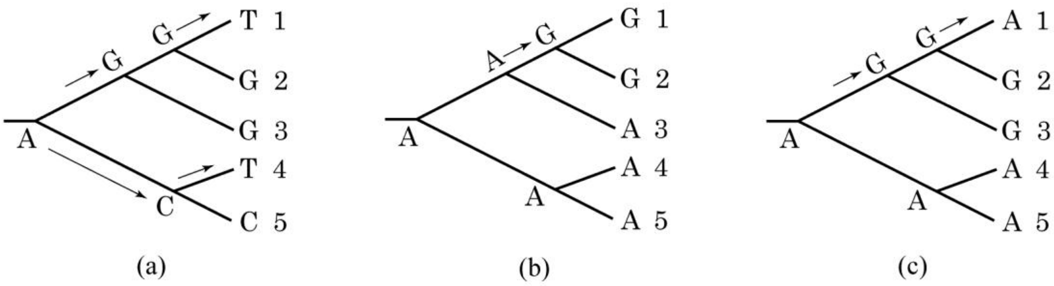
Give your answer as a percentage (%) rounded to an integer (without any decimals).

BIOSYSTEMATICS

B47. (2 points) Figures *a* and *b* show the characteristics of a cactus from the American desert and a spurge from the African desert, respectively. An evolutionary mechanism has been proposed to explain the morphological similarities between these nonrelated species. That same evolutionary mechanism has been reported to operate at the DNA sequence level.

a. Cactus	*b.* Spurge
	

c. Molecular evolution model



Which of the molecular evolutionary trees shown in Figure *c* is the best molecular model of the morphological evolutionary mechanism that we observe in the cactus and spurge? The symbols A, C, G, and T on the molecular evolutionary trees represent DNA bases.

A. Tree (a), 1 with 4.

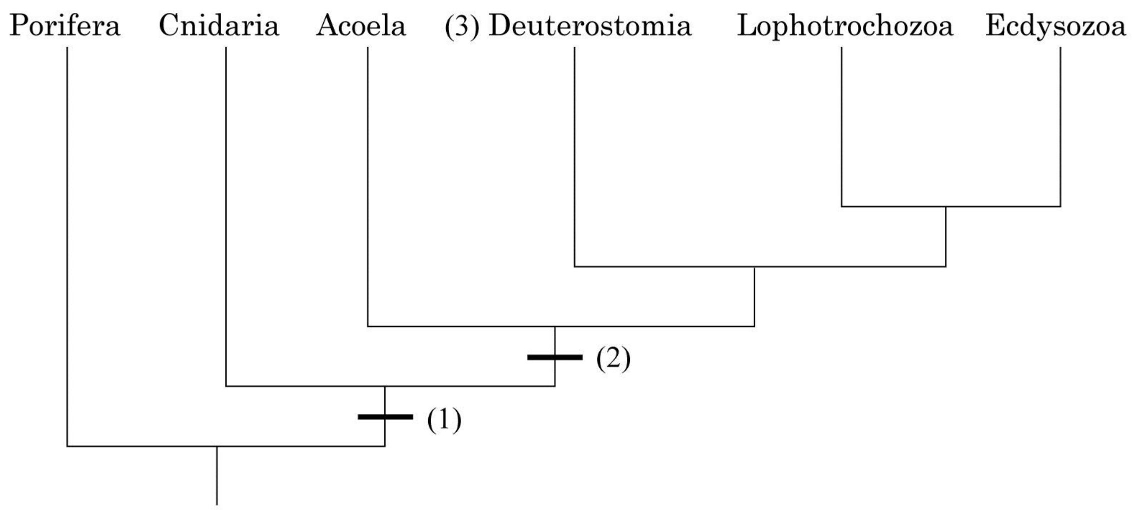
B. Tree (b), 1 with 2.

C. Tree (c), 1 with 5.

D. Tree (c), 2 with 3.

B48. (2 points) The following figure represents a recent phylogenetic tree for the animal kingdom.

Carefully observe the tree topology, and answer the following questions.



B48.1. (1 point) What are the most appropriate synapomorphic characters for the numbers (1) and (2), respectively? Mark appropriate boxes with a checkmark (√).

A. Segmented body

B. True tissue differentiation

C. Embryogenesis

D. Bilateral symmetry

E. Exoskeleton development

B48.2. (1 point) Which of the following groups are members of Deuterostomia (taxon number (3))?

A. Echinodermata, Arthropoda.

B. Echinodermata, Chordata.

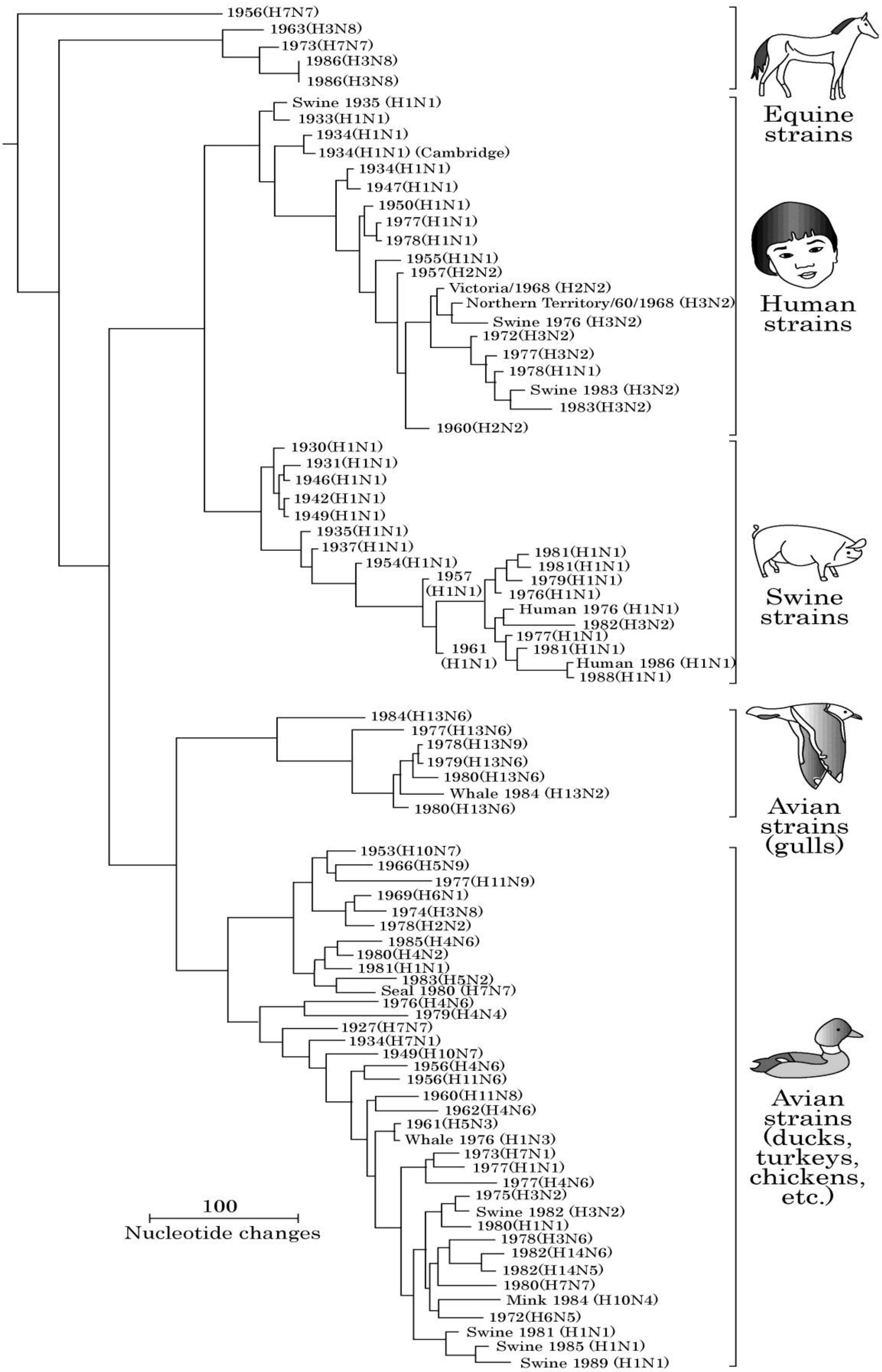
C. Mollusca, Arthropoda.

D. Annelida, Mollusca.

E. Chordata, Mollusca.

B49. (2 points) The Influenza A virus is responsible for annual flu epidemics and for occasional flu pandemics. Influenza A has a genome composed of eight RNA strands that encode a total of 11 proteins. Influenza A strains can be classified based on the combination of two coat proteins, Hemagglutinin (H1~H13) and Neuraminidase (N1~N9). In this way, various flu types such as H1N1, H3N1, H7N2, *etc*. can be recognized. The virus strains also can be classified by the host animal. The following figure represents the phylogeny of flu viruses based on the nucleoprotein gene of the flu virus genome. Indicated for each viral strain is the host species from which it was isolated, the year, and the type of Hemagglutinin and Neuraminidase it carries. Indicate with checkmarks (√). whether following statements are true or false.

I.	The avian flu virus consists of the most diverse types, and some avian flu types also are found in some mammalian species such as whales and dolphins. Therefore, the avian flu virus represents the most archaic type of flu virus.
II.	The phylogenetic tree suggests that the host shift and genetic recombination of flu virus have occurred between birds and pigs.
III.	The virulence of virus can be changed rapidly by host shifts and mutations. Therefore, vaccine developments are relatively difficult compared to other common diseases.
IV.	Swine flu strains are phylogenetically more closely related to the human flu strains than to other strains.


1956(H7N7)
1963(H3N8)
1973(H7N7)
1986(H3N8)
1986(H3N8)
Equine strains
Swine 1935 (H1N1)
1933(H1N1)
1934(H1N1)
1934(H1N1) (Cambridge)
1934(H1N1)
1947(H1N1)
1950(H1N1)
1977(H1N1)
1978(H1N1)
1955(H1N1)
1957(H2N2)
Victoria/1968 (H2N2)
Northern Territory/60/1968 (H3N2)
Swine 1976 (H3N2)
1972(H3N2)
1977(H3N2)
1978(H1N1)
Swine 1983 (H3N2)
1983(H3N2)
1960(H2N2)
Human strains
1930(H1N1)
1931(H1N1)
1946(H1N1)
1942(H1N1)
1949(H1N1)
1935(H1N1)
1937(H1N1)
1954(H1N1)
1957 (H1N1)
1981(H1N1)
1981(H1N1)
1979(H1N1)
1976(H1N1)
Human 1976 (H1N1)
1982(H3N2)
1977(H1N1)
1961 (H1N1)
1981(H1N1)
Human 1986 (H1N1)
1988(H1N1)
Swine strains
1984(H13N6)
1977(H13N6)
1978(H13N9)
1979(H13N6)
1980(H13N6)
Whale 1984 (H13N2)
1980(H13N6)
Avian strains (gulls)
1953(H10N7)
1966(H5N9)
1977(H11N9)
1969(H6N1)
1974(H3N8)
1978(H2N2)
1985(H4N6)
1980(H4N2)
1981(H1N1)
1983(H5N2)
Seal 1980 (H7N7)
1976(H4N6)
1979(H4N4)
1927(H7N7)
1934(H7N1)
1949(H10N7)
1956(H4N6)
1956(H11N6)
1960(H11N8)
1962(H4N6)
1961(H5N3)
Whale 1976 (H1N3)
1973(H7N1)
1977(H1N1)
1977(H4N6)
1975(H3N2)
Swine 1982 (H3N2)
1980(H1N1)
1978(H3N6)
1982(H14N6)
1982(H14N5)
1980(H7N7)
Mink 1984 (H10N4)
1972(H6N5)
Swine 1981 (H1N1)
Swine 1985 (H1N1)
Swine 1989 (H1N1)
Avian strains (ducks, turkeys, chickens, etc.)
100
Nucleotide changes

B50. (1.5 points) Following table summarizes the main characteristics of the four major phyla of seed plants. Check (√) in the answer sheet whether each characteristics is absent (−) or present (+) for A~E.

Character / Phylum	Flagellated sperm	Double fertilization	Vessel in xylem	Flowers and fruits	Development of the secondary xylem
Cycadophyta	+	**B**	−	−	−
Ginkgophyta	**A**	−	−	−	**E**
Pinophyta	−	−	−	**D**	+
Magnoliophyta	−	+	**C**	+	+

B51. (2.4 points) All organisms use carbon as well as energy in order to live and function. Organisms can be divided into four nutrition modes based upon the species' main sources of energy and of carbon.

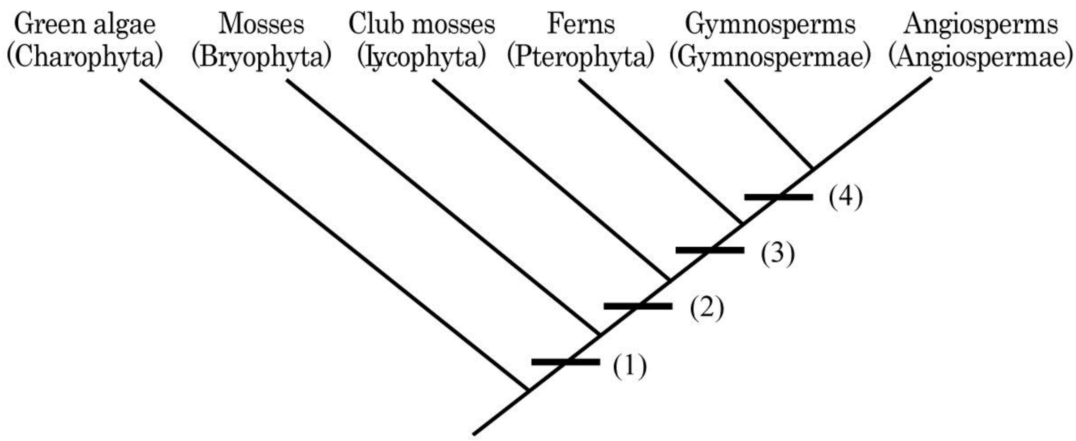
B51.1. (1.2 points) From the following list of nutrition modes, fill in the answer sheet with the correct term corresponding to each combination of carbon and energy source.

<Nutrition mode>	
I. Photoautotroph,	II. Chemoautotroph,
III. Photoheterotroph,	IV. Chemoheterotroph.

B51.2. (1.2 points) From the list of organisms provided, choose **<u>two</u>** organisms belonging to each nutrition mode.

<Organisms>	
a. Cyanobacteria,	b. Green nonsulfur bacteria,
c. Purple nonsulfur bacteria,	d. Fungi,
e. Most archaebacteria,	f. Most plants,
g. Animals,	h. Nitrifying bacteria.

B52. (2 points) The following figure represents a recent phylogeny for the plant kingdom.



For each number (1)~(4), select the appropriate apomorphic trait from the list provided.

< Apomorphic traits >

A. Leaves with well-developed vascular bundles,

B. Embryos,

C. Seeds,

D. Vascular tissues,

E. Phragmoplast.