ENVELOPE COVER SHEET

Student Code: _____

The 21st INTERNATIONAL BIOLOGY OLYMPIAD

Changwon, KOREA 11th – 18th July, 2010

THEORETICAL TEST: PART A

Time available: 120 minutes

GENERAL INSTRUCTIONS

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

A	B	C	D	E
		√		

5. Use pencils and erasers. You may use a scale 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.

Country: _____

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A	B	C	D	E
		√		

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

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

5. The maximal point of Part A is 51 (1 point for each question).

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

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

CELL BIOLOGY

A1. Select the chemical property that is shared by all types of lipids forming the plasma membrane.

A. Polar head

B. Sugar component

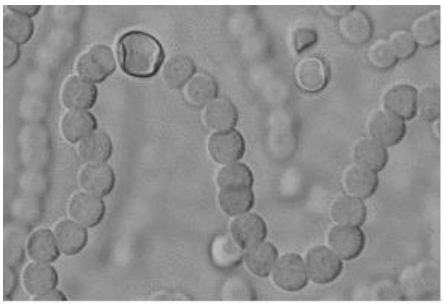
C. Glycerol backbone

D. Phosphate group

E. Hydrophobic region

-

A2. The following photograph shows filamentous growth of a kind of cyanobacteria, *Nostoc* sp. The bacteria form heterocysts (thick-walled cells), when nitrogen sources such as ammonia or nitrates are deficient in the environment.



Which of the following statements describing these heterocysts is/are true?

I.	Nitrogen is fixed in the heterocyst.
II.	Photosystem I does not function in the heterocyst.
III.	Photosystem II does not function in the heterocyst.

A. Only I

B. Only II

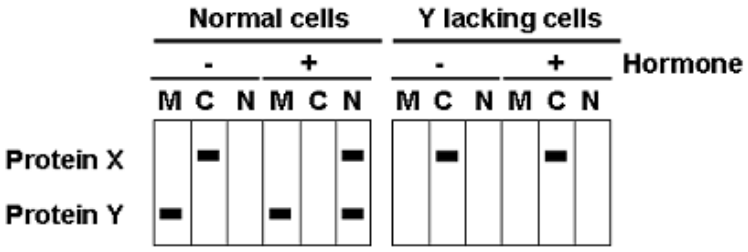
C. Only I and II

D. Only I and III

E. Only II and III

A3. A gene–regulatory protein X controls cell proliferation. Protein X is found in the cytosol and has no typical nuclear localization signal (NLS). When cells are treated with a specific growth hormone, protein X re-localizes from the cytoplasm into the nucleus where it activates the transcription factors involved in cell proliferation.

Recently, a protein (Y) that interacts with protein X has been identified in unstimulated cells. To investigate the function of protein Y, a mutant lacking the gene encoding protein Y was generated. Fractionation of cells from the wild type and mutant produced membrane (M), cytoplasmic (C), and nuclear (N) fractions for each cell type. Proteins extracted from each fraction were separated by SDS-PAGE and analyzed by Western blotting for the presence of proteins X and Y.



On the basis of the results shown above, which of the following statements is the most plausible characterization of protein Y?

A. In the absence of growth hormone, protein Y associates with protein X, and the X/Y complex is subjected to a degradation pathway.

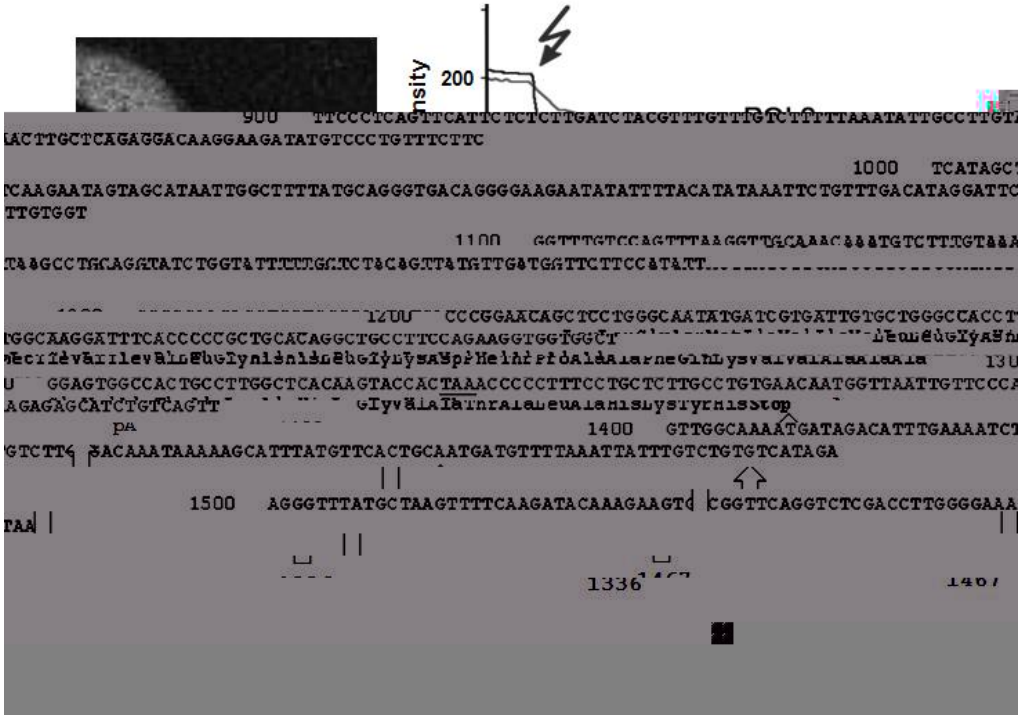
B. In the presence of growth hormone, protein Y interacts with protein X, and the complex remains in the cytoplasm.

C. Protein X interacts with protein Y in the absence of growth hormone. Upon growth hormone treatment, protein X is released from protein Y and re-localizes to the nucleus.

D. Protein Y is a membrane-associated protein and re-localizes with protein X to the nucleus upon the growth hormone treatment.

E. Protein Y is one of the nuclear import proteins and the growth hormone does not induceprotein Y to translocate protein X to the nucleus.

A4. A GFP (green fluorescent protein) – tagged form of protein P was expressed in fibroblast cells. The subcellular distribution of protein P can be observed using fluorescence microscopy. To determine the precise movement mechanism of protein P in the cells, fluorescence recovery after photobleaching (FRAP) was performed. As shown below, protein P is expressed in the nucleus (ROI 1) and in the cytoplasm (ROI 2). Protein P in the ROI 1 area was photobleached using a laser beam. Photobleaching causes an irreversible loss of flouorescence. Changes in the fluorescence intensity of protein P in ROI 1 and ROI 2 following photobleaching are shown in the graph and figures below.



Which of the following is the best explanation for the distribution and movement of protein P?

A. P is a nuclear membrane protein.

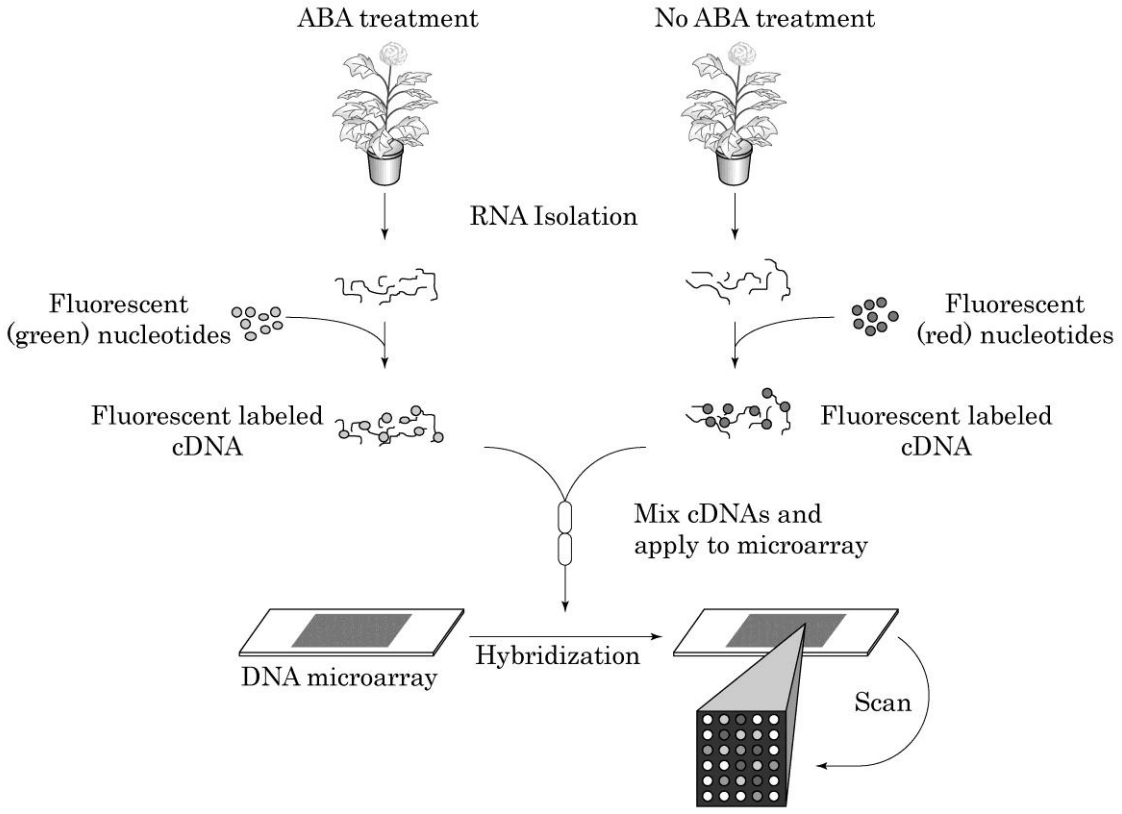
B. P is imported to the nucleus through a nuclear pore.

C. P binds to the nuclear pore complex.

D. P is imported to the nucleus via vesicular trafficking through Golgi and ER.

E. P is capable of moving from the nucleus to the cytoplasm.

A9. As shown in the picture below, microarray was used to find genes whose expression is regulated when a plant is treated with the ABA hormone.



Which of the following explanations is **not** correct about the microarray experiment?

A. All cDNAs of the expressed mRNA from both the experimental group and the control group hybridizes competitively with the corresponding genes on the DNA chip.

B. Genes whose expressions are induced by ABA appear red after hybridization.

C. Because we used different colored probes with each sample, we can measure the relative amount of genes which are expressed differentially.

D. We can only know the expression profile of genes which are included on the microarray.

E. This process includes reverse transcription and hybridization.

PLANT ANATOMY AND PHYSIOLOGY

A10. Self-incompatibility (SI) in flowering plants is the most common mechanism preventing self-pollination, which is mediated by a single S locus with multiple alleles. In gametophytic self-incompatibility (GSI), the incompatibility of pollen is determined by the haploid pollen genotype at the S locus. In sporophytic self-incompatibility (SSI), the incompatibility is determined by the diploid S genotype of the parent pollen wall. The table below shows the SI type and pollen/style S-gene genotypes of two plants crossed for fertilization. S_1 and S_2 alleles are codominant in pollen wall.

	SI type	Expressed genotype	
		Pollen of plant 1	Style of plant 2
I	GSI	S_1 or S_2	S_2S_3
II	GSI	S_2 or S_3	S_2S_3
III	SSI	S_1 or S_2	S_1S_3
IV	SSI	S_1 or S_2	S_3S_4

Which of these crosses (I, II, III, and IV) result in successful fertilizations?

A. I and II

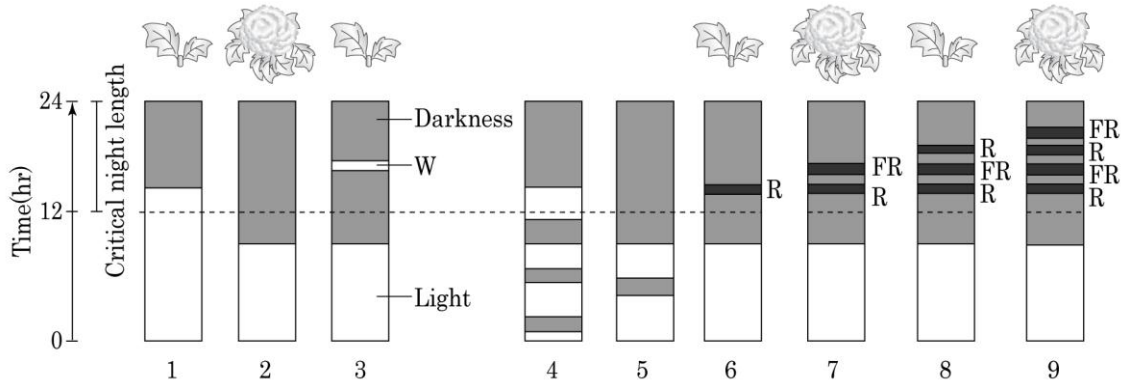
B. I and III

C. I and IV

D. II and III

E. II and IV

A11. Phytochrome is one of the plant photoreceptors involved in photoperiodism. It exists in two spectophotometrically different forms: red-light absorbing P_r and far-red light absorbing P_{fr}. An investigation explored how plant flowering was affected by different light flashes [white (W), red (R), or far-red (FR) light] applied during the dark period or darkness in the light-period of plant growth. The figure below shows the experimental results.



Based on this experiment, find the most accurate explanation or expectation for the light control of flowering in this plant,

A. This plant flowers whenever the total night length exceeds a 12 hr threshold (out of the 24 hr night/light period) with or without light interruption.

B. This plant is likely to be a short-day plant that requires a certain length of uninterrupted light period for flowering.

C. The plant in experiment 3 will flower if it is irradiated with a flash of far-red light, instead of white..

D. The plant in experiment 4 will flower.

E. The plant in experiment 5 will not flower.

A12. Which statement correctly describes the differentiation and development of cells and organs in flowering plants?

A. Organomorphogenesis involves cell movement as one of the important mechanisms.

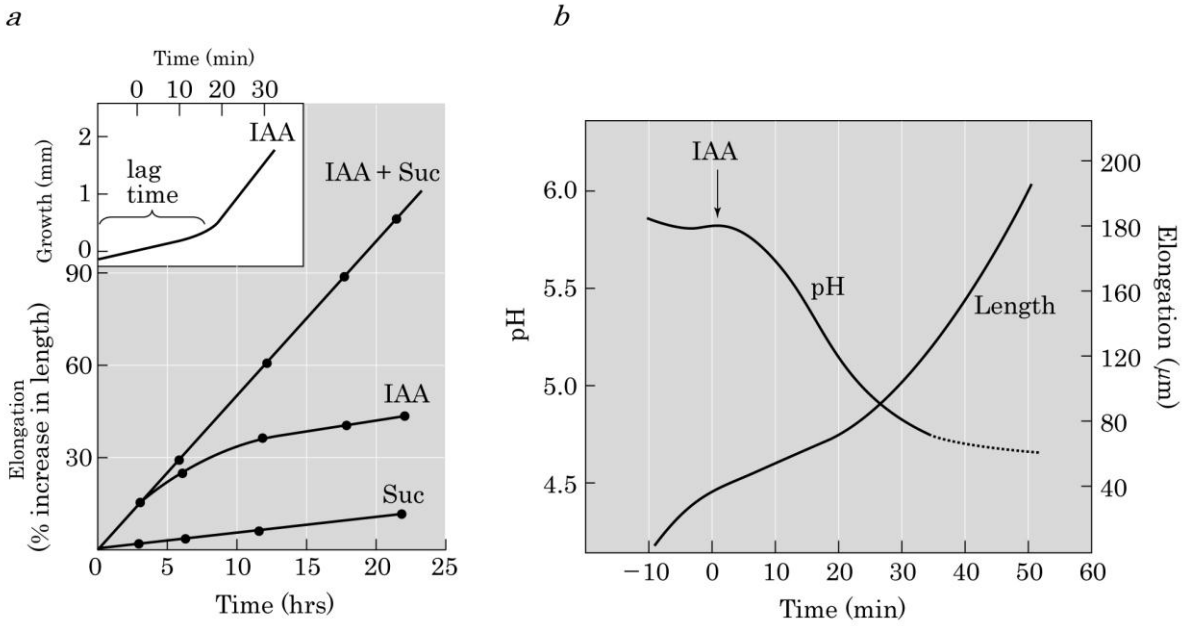
B. Post-embryogenesis is a growth process, as all of the plant organs are pre-formed during embryogenesis.

C. Totipotency of plant tissues provides the original source of power to develop a complete plant by re-differentiation, without going through the de-differentiation process.

D. The direction of cell division determines cell type and function.

E. Lineage information obtained by genetic inheritance overides environmental factors in determining the time for organ development.

A13. The graphs below show sucrose (Suc)- and/or indole 3-acetic acid (IAA, an auxin)-induced cell growth (Figure *a*) and the kinetics of IAA-induced cell elongation and cell wall acidification in coleoptiles (Figure *b*). Based on these results, together with the fact that these processes are delayed by cold treatments or inhibitors of protein synthesis, the "acid-growth hypothesis" was proposed as the best model to explain auxin-induced cell growth.



Which of the following statements is most accurate?

A. IAA-driven protons, pumped into the cell wall, are utilized to synthesize the ATP required for cell elongation.

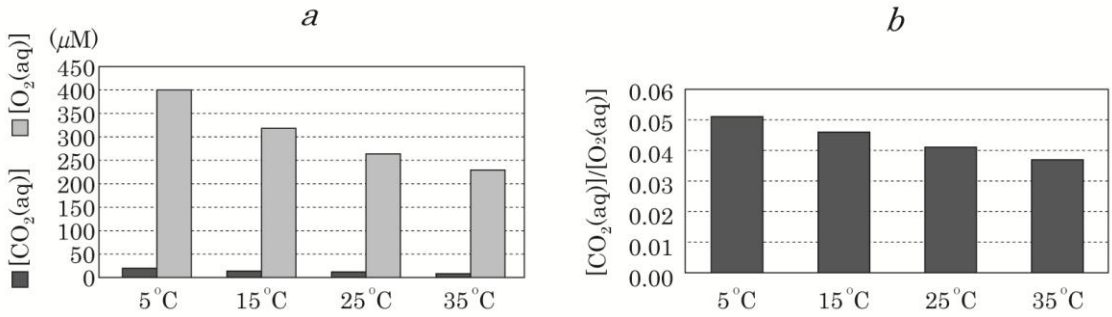
B. IAA-induced acidification of the cell wall is an ATP-dependent process, and can be delayed by a treatment of a metabolic inhibitor.

C. IAA-induced loosening of the cell wall is mainly caused by an acidification-induced weakening of the covalent bonds in cell wall proteins.

D. IAA- or sucrose-induced cell elongation shares a common action mechanism, such as an increase in the cell wall acidity and the following change in turgor pressure.

E. Cell wall acidification and stimulation in the elongation is an IAA-specific process, thus it is not induced by treatment with Fusicoccoin, an activator of the proton pump, in the absence of the IAA.

A14. Rubisco is an enzyme crucial for carbon fixation in plants. In addition to the predominant carboxylation reaction, this enzyme catalyzes an oxidation reaction as well. For an aquatic plant, the frequency of the oxidation reaction depends on the relative concentrations of the reagents CO_2 and O_2 in the aquatic solution, which in turn are coupled to temperature. The figures show the absolute (*a*) and relative (*b*) concentrations of CO_2 and O_2 dissolved in water that is at equilibrium with the atmosphere.



Choose the following statement that is correct.

A. The frequency of the oxidation reaction decreases with increasing temperature.

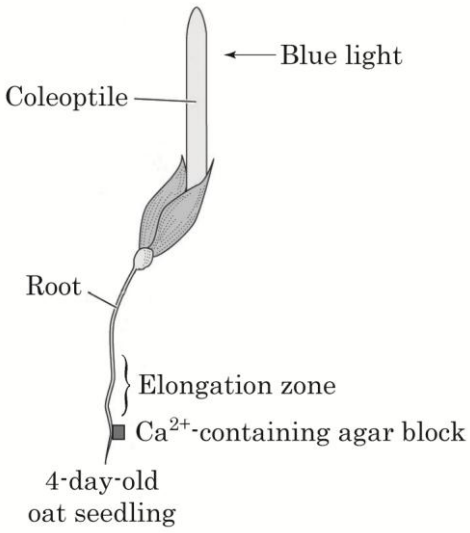
B. In water at equilibrium with the atmosphere, the relative concentration change with temperature of CO_2 is larger than of O_2.

C. Rubisco has a higher affinity for O_2 than for CO_2.

D. At a temperature of 90°C, Rubisco catalyzes only one of the above two reactions in vascular plants.

E. This sensitivity to temperature matters for submerged aquatic plants only.

A15. As depicted in the following figure, an oat seedling was germinated in the dark. A blue light was given unilaterallyto the right side of the coleoptile, and an agar block containing Ca^{2+} was attached to the right side of root tip below the elongation zone.

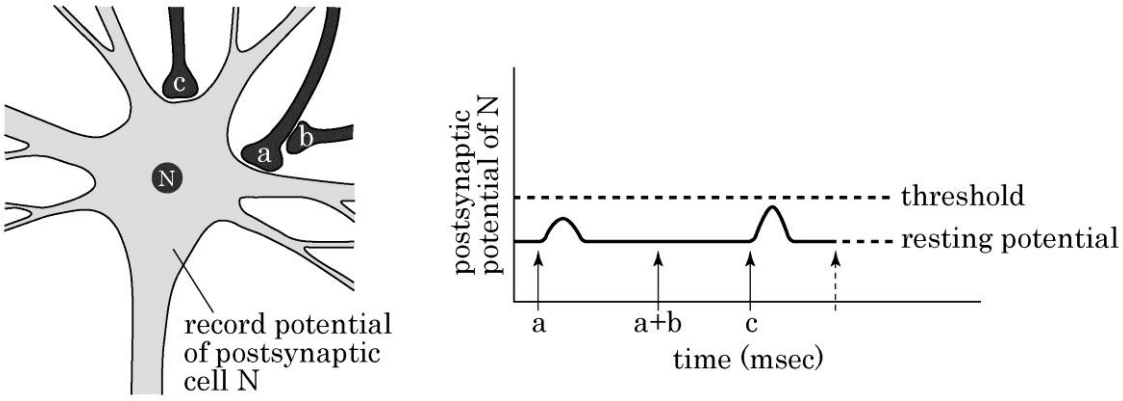


What do you expect the bending responses of the oat seedling will be in a few days?

	Coleoptile	Root
A	Bending towards the light.	Bending towards the Ca^{2+} block.
B	Growing upright.	Bending towards the Ca^{2+} block.
C	Bending away from the light.	Bending towards the Ca^{2+} block.
D	Bending towards the light.	Growing downwards.
E	Growing upright.	Bending away from the Ca^{2+} block.

ANIMAL ANATOMY AND PHYSIOLOGY

A16. As shown in the left-hand picture below, neuron (N) receives signals directly from two separate nerve terminals (a and c). Nerve terminal (b) is synaptically connected to nerve terminal (a). The right-hand graph shows various postsynaptic potentials recorded in neuron (N) caused by input signals from the three presynaptic terminals.



Which of the following statements about the signal transmissions of these synapses are correct?

I. Action potentials would be generated in neuron (N) if nerve terminals (a) and (c) were stimulated simultaneously.

II. The neurotransmitter released from nerve terminal (b) is inhibitory.

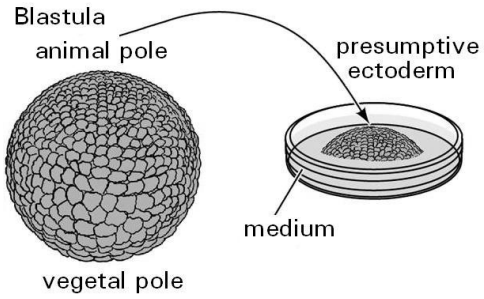
III. When nerve terminal (b) is stimulated alone, an inhibitory postsynaptic potential (IPSP) would be recorded in neuron (N).

IV. When nerve terminals (b) and (c) are stimulated simultaneously, the excitatory postsynaptic potential (EPSP) recorded in neuron (N) is smaller compared to when only nerve terminal (c) is stimulated.

A. Only I and II B. Only I and IV C. Only II and III

D. Only III and IV E. I, II and III

A17. Animal cap cells from the animal pole were removed from a *Xenopus b*lastula embryo. These cells were then incubated in culture media containing different concentrations of activin. As seen in the table below, the cells differentiated into various tissues or cells depending on the concentration of activin.



Concentration of activin in medium	Tissues or cells differentiated
0 (control)	epithelial cells
~ 0.1 ng/mL	blood cells
~ 1 ng/mL	muscles
~ 10 ng/mL	notochord
~ 100 ng/mL	heart

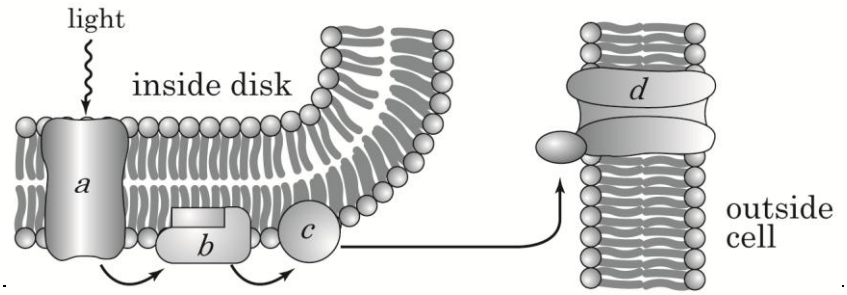
Which of the following statement(s) regarding this experiment is/are correct?

I. Ectodermal tissues are induced to differentiate into endodermal tissues according to the level of activin concentration.
II. The fate of the animal cap cells was determined prior to the blastula stage.
III. Initially animal cap cells differentiate into epithelial tissue.
IV. Cells from the vegetal pole are also able to differentiate into muscle or heart tissues if exposed to high activin concentrations.

A. Only I B. Only III C. Only I and III

D. Only II and IV E. II, III, and IV

A18. This illustration shows the molecular mechanism of the signal transduction pathway that occurs in rod cell membranes when rod cells receive light.



Which of the following statements are correct?

When rod cells receive light, retinal molecules are converted to their active form, and protein (*a*) is activated.

Component (*b*) is a G-protein which activates enzyme (*c*).

Component (*c*) is an adenylyl cyclase which increases the intracellular concentration of cAMP when activated.

Component (*d*) is a Na^+ channel that causes the membrane to depolarize when the rod cell receives light.

Only I and II

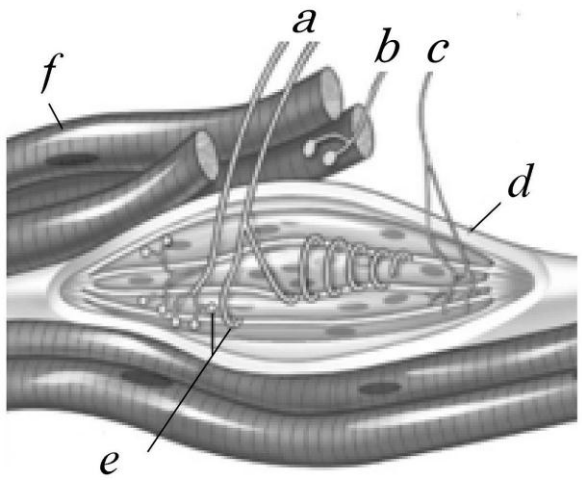
Only I and III

Only III and IV

I, II, and IV

II, III, and IV

A19. The figure shows muscle fibers, muscle spindle, and their nerve innervations of biceps of human arm.



a: afferent nerves innervating muscle fibers of the spindle
b: efferent nerve innervating muscle fibers outside of spindle
c: efferent nerve innervating muscle fibers of the spindle
d: muscle spindle
e: nerve endings of (*a*)
f: muscle fibers outside of spindle

Nerve (*a*) is sensitive to the stretch of muscle fibers outside of the spindle when muscle fibers within the spindle are relaxed. Choose a case when the afferent signals in nerve (*a*) increase?

A. Signals in (*b*) are increased.

B. Signals in (*c*) are decreased.

C. Triceps are contracted.

D. (*f*) are contracted.

E. The lenght of (*d*) remained constant.

A20. The following experiments are designed to investigate the differentiation mechanism of skeletal muscle.

<Experiment 1> Cultured mouse muscle cells were chemically induced to fuse with undifferentiated human cells.

Result 1: Many of the fused cells had human muscle-specific proteins.

Result 2: Unfused cells had no human muscle-specific proteins.

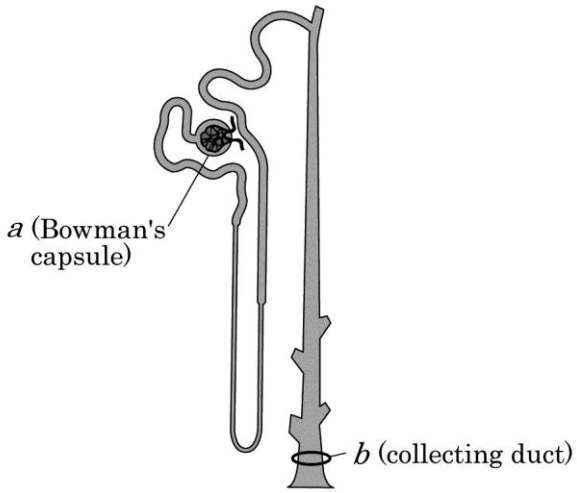
<Experiment 2> Cytoplasmic portions of human muscle cells were injected into undifferentiated mouse stem cell.

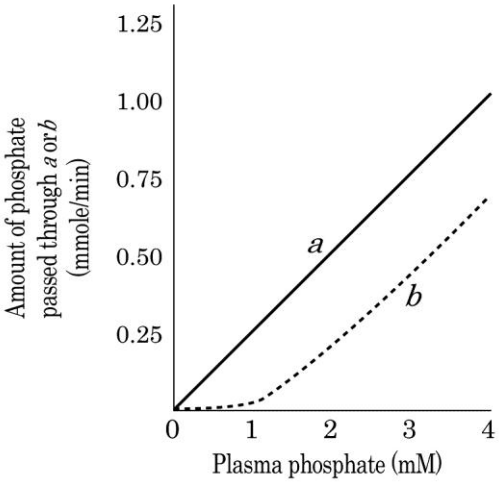
Result: The cells injected with the cytoplasm of human muscle cells transiently expressed mouse muscle-specific genes. However, the expression of muscle specific gene was disappeared after 24 hours.

What do these experiments suggest?

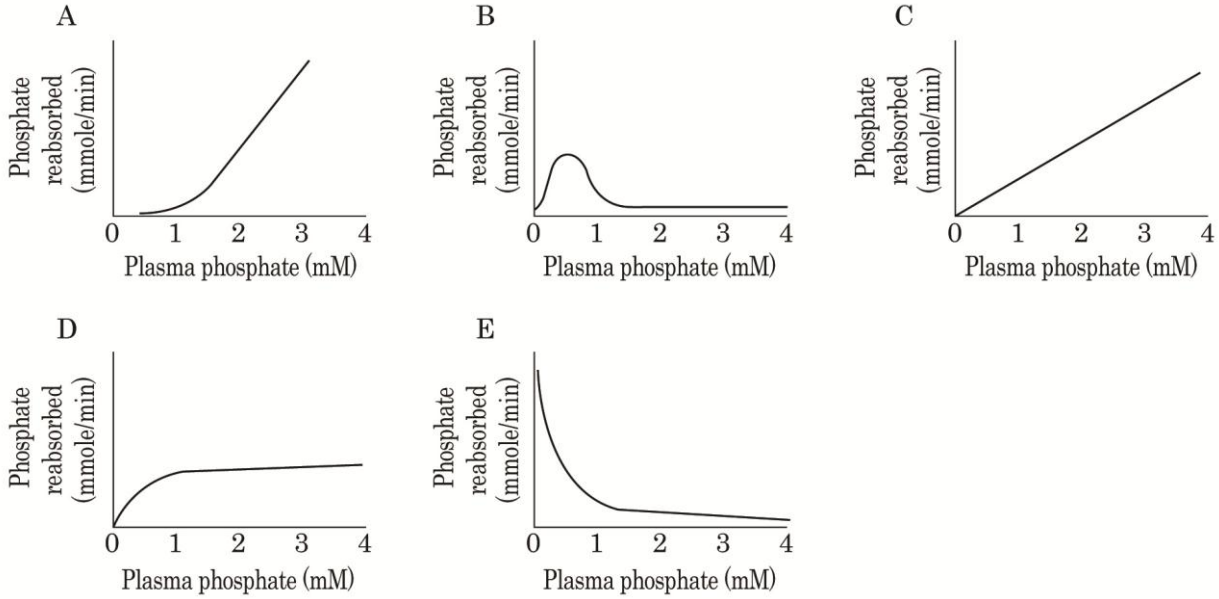
A. The nucleus of muscle cell should be fused with human cell nucleus to induce human muscle-specific proteins.
B. The expression of muscle specific gene in human undifferentiated cell is suppressed by cytoplasmic factor.
C. The continuous production of cytoplasmic factor(s) is indispensible for maintaining the differentiation state of the muscle cell.
D. The cytoplasm of muscle cell induced a mutation of DNA to differentiate into muscle cell.
E. The induction of muscle differentiation is a species-specific phenomenon.

A21. The following figures indicate changes in phosphate concentration as the filtrate passes through regions *a* and *b*, according to the increase in plasma phosphate concentration.





Using this information, choose the most appropriate graph that depicts the changes in the renal reabsorption rate of phosphate ions according to the increase of its concentration in the plasma.



A22. The table below shows the results of experimental tests on skin graft rejection between two different mouse strains. (Strains [A] and [B] are genetically identical except for the MHC loci.)

Exp.	Skin donor mouse	Skin recipient mouse	Skin rejection	
			6~8 d	10~13 d
I	[A]	[A]	did not occur	did not occur
II	[A]	[B]	did not occur	occurred weakly
III	[A]	[B] mouse which had previously received strain [A] skin	occurred strongly	
IV	[A]	[B] mouse which has received lymphocytes from a strain-[A]-skin-grafted [B] mouse	occurred strongly	

Which of the following explanations for the results is **not** correct?

A. Graft rejection is considered to be the result of immune responses.

B. MHC genes are mainly responsible for the graft rejection.

C. If strain [B] skin is grafted onto mouse [A], the result would be the same as the result of Exp. II.

D. If strain [A] skin is grafted onto an offspring from a mating between [A] and [B] mice (e.g. F1, [A] x [B], the result would be the same as that of Exp. III.

E. The result observed in Exp. III is due to the formation of memory cells in the previously-exposed [B] mouse against strain [A] MHC antigens.

A23. The phagocytic activity of macrophages against a certain pathogenic bacteria is described below.

Experiment conditions	Degree of phagocytosis
1. macrophages + pathogenic bacteria (P)	+
2. macrophages + pathogenic bacteria (P) + complement	++
3. macrophages + pathogenic bacteria (P) + Anti-P Ab	++
4. macrophages + pathogenic bacteria (P) + complement + Anti-P Ab	+++

Which of the following conclusions best explains the results above?

A. Non-specific immunity enhances acquired immunity.

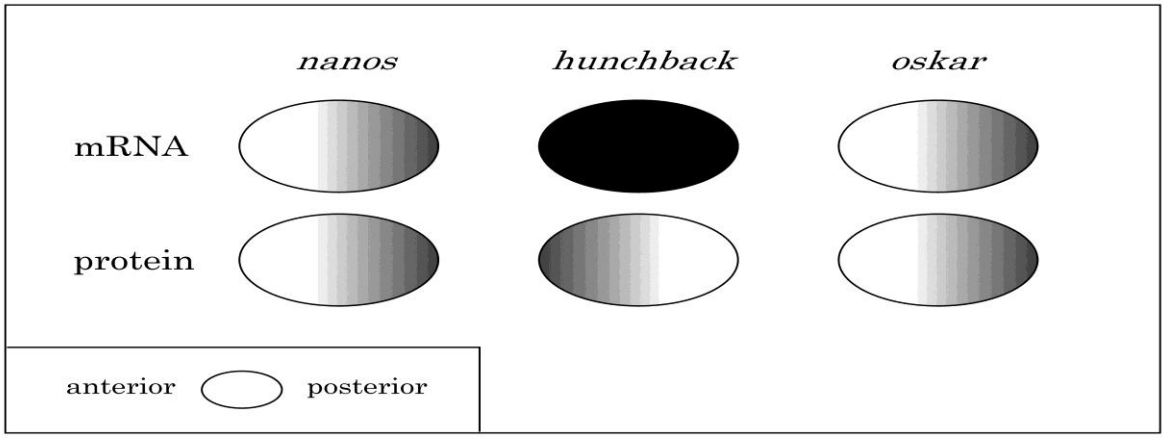
B. Humoral immunity enhances acquired immunity.

C. Humoral immunity enhances non-specific immunity.

D. Cell-mediated immunity enhances humoral immunity.

E. Cell-mediated immunity enhances non-specific immunity.

A24. *Oskar*, *nanos* and *hunchback* are three major genes that establish the anterior-posterior (A-P) axis during *Drosophila* embryogenesis. The diagram below shows how the mRNA and protein products of these three genes are distributed in *Drosophila* eggs (darker shades represent higher concentrations). The table below lists the outcome of disrupting one of these genes, as reflected in protein distribution and anterior-posterior development.



	Mutation in *nanos*	Mutation in *hunchback*	Mutation in *oskar*
Distribution of the Nanos protein	-	normal	abnormal
Distribution of the Hunchback protein	abnormal	-	abnormal
Distribution of the Oskar protein	normal	normal	-
Establishment of normal A-P polarity	abnormal	abnormal	abnormal

Based on these data, which of the given statements correctly describes the interaction among the three genes?

A. The transcription of *hunchback* gene is suppressed by the Nanos protein.

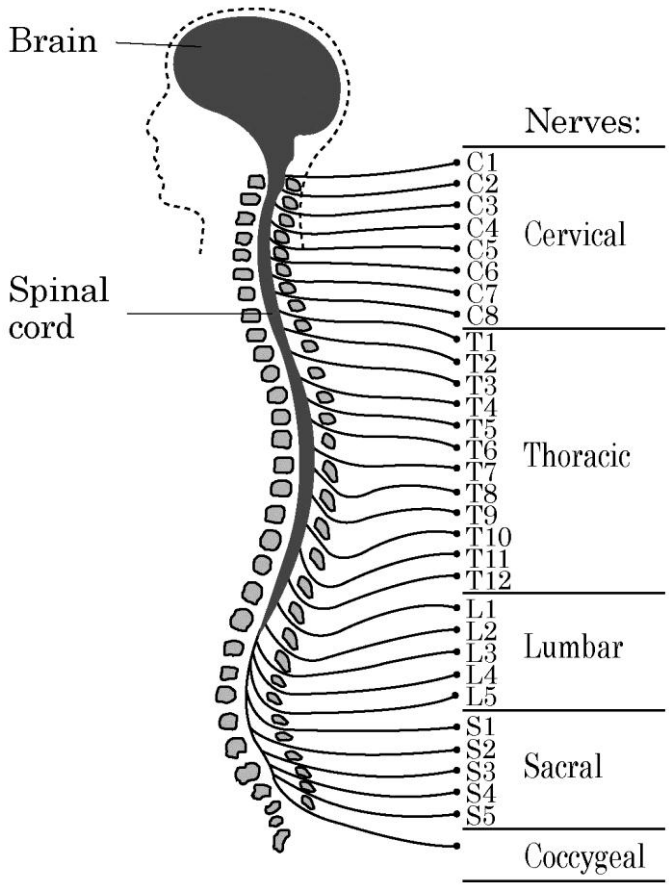
B. The Oskar protein activates the translation of *nanos* mRNA.

C. The Hunchback protein suppresses the translation of *oskar* mRNA in the anterior.

D. The Oskar protein suppresses the transcription of *hunchback* gene in the posterior.

E. The Hunchback protein suppresses the transcription of *nanos* gene in the anterior.

A25. The diagram on the left depicts the different areas of the spinal cord from the cervical region to the coccyx. The statements on the right provide descriptions about the spinal cord.



1. Cutaneous sensory information from the skin ascends through the corresponding side of the spinal cord.
2. Pain information from the skin only ascends through the contralateral side of the spinal cord.
3. Motor neurons of the spinal cord cause muscle contraction on the corresponding side of the body.
4. Cervical nerves innervate the upper limb.

Suppose that an athlete injures the left half of the spinal cord T4 during a football game.

Choose the correct statement concerning this patient's sensory or motor function.

A. Abnormal touch sensation in the right foot.

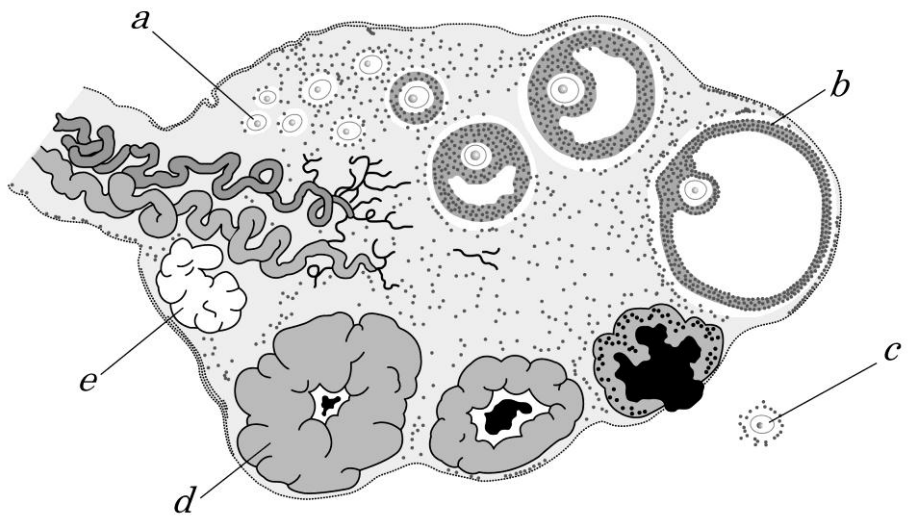
B. Disability in the movement of the right leg.

C. Normal pain perception in the left leg.

D. No cutaneous sensation in the left hand.

E. Normal pain perception in the right leg.

A26. This picture illustrates monthly changes in the human ovary during the reproductive cycle.



Which of the following statements most accurately describes each structure?

A. Before puberty, the oocyte (*a*) has not started the process of meiosis.

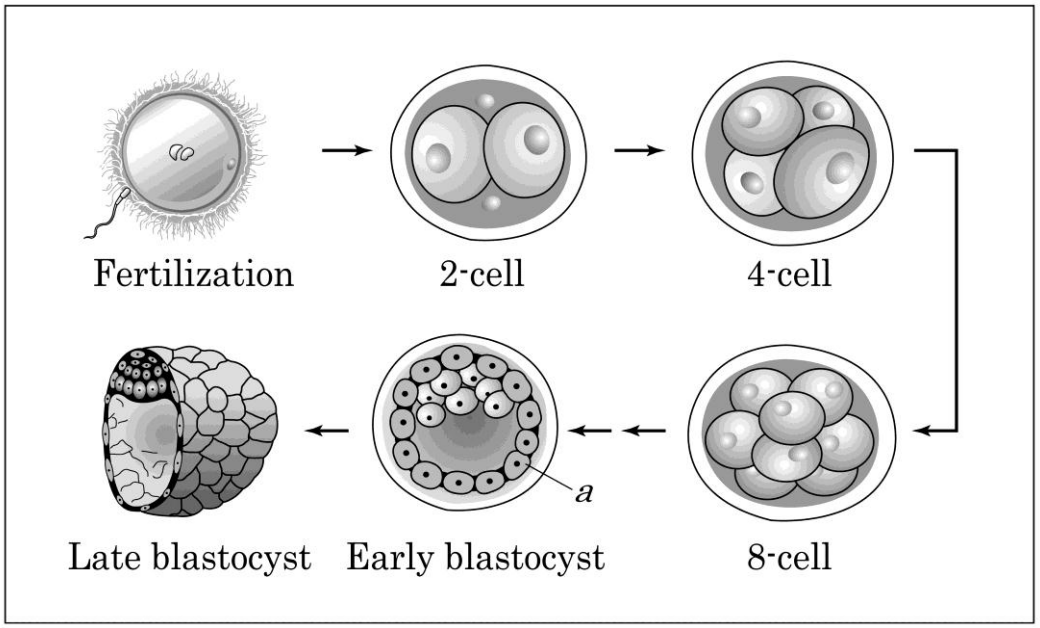
B. The hormone produced by structure (*b*) causes thinning of the uterine cervical mucus to allow passage of sperm.

C. During ovulation, structure (*c*) stays at the interphase between meiosis I and meiosis II.

D. The hormone produced by structure (*d*) stimulates the pituitary gland to secrete luteinizing hormone.

E. The hormone produced by structure (*e*) causes the proliferation of the uterine endometrium.

A27. The diagram below represents the development of a human zygote from fertilization to the late blastocyst stage.



Choose a correct statement from the following choices.

A. If two sperm penetrate the oocyte membrane at the time of fertilization, conjoined twins with shared body parts will be born.

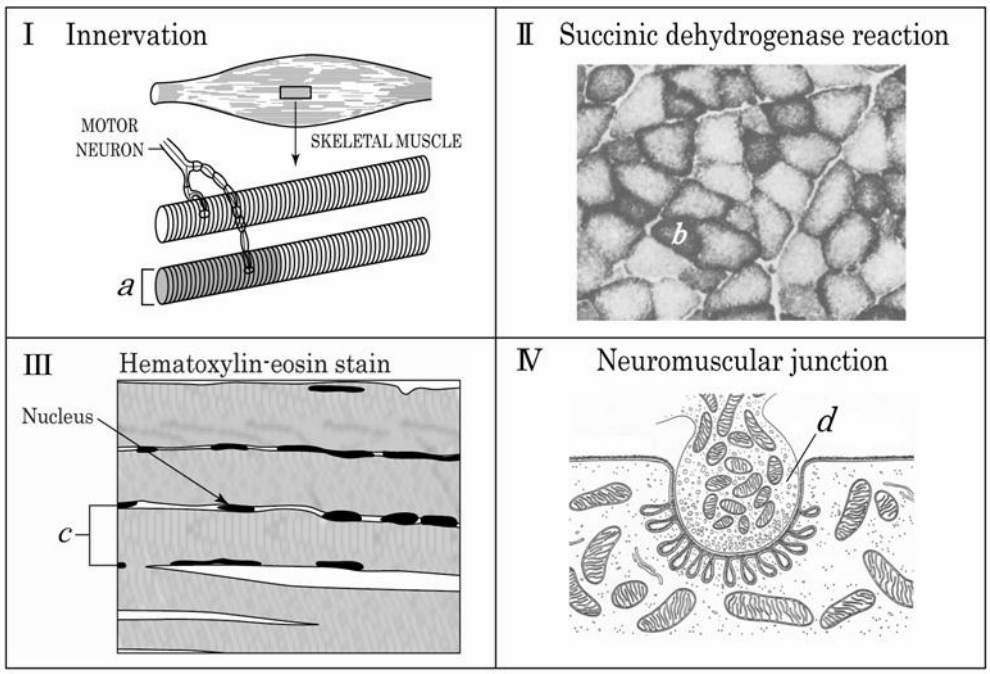
B. During the process of *in vitro* fertilization with embryo transfer (IVF-ET), the embryo is transferred at the 2-cell stage to the mother's uterus.

C. The most appropriate stage for the collection of 'Embryonic stem cells' for regenerative-therapeutic purposes is the 8-cell stage.

D. The outer cells (structure *a*) of the early-blastocyst embryo will eventually form the fetus.

E. During the late blastocyst stage, the embryo is implanted in the uterine endometrium.

A28. Figure I illustrates a skeletal muscle and its innervation. Figures II and III depict cross and longitudinal sections of the muscle, respectively. Figure IV shows an electron micrograph of neuromuscular junction.



Which of the following statements gives the most accurate description of each structure?

A. The number of muscle cells innervated by a single motor neuron is larger in a muscle that controls fine movement than in one that controls unskilled movement.

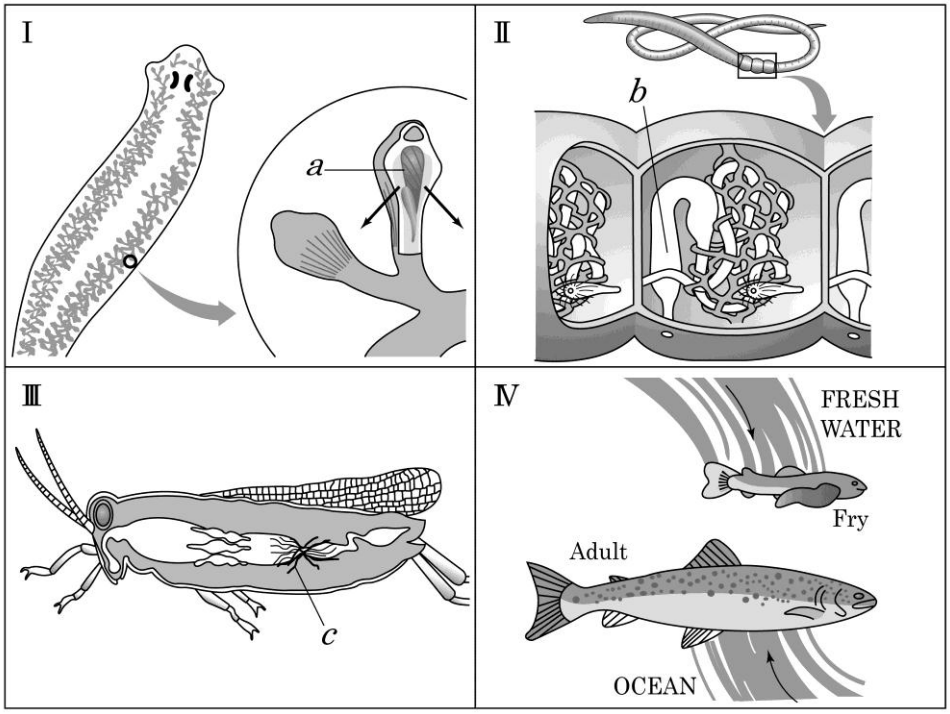
B. During embryonic development, structure (*a*) is derived from a single cell.

C. Within the same muscle, the population of small-diameter cells (*b*) is increased after several weeks of intense exercise.

D. Structure (*c*) is called a myofibril, which is the structural unit of the skeletal muscle.

E. The main mechanism to terminate the action of secreted acetylcholine at the neuromuscular junction is neurotransmitter reuptake into the nerve terminal (*d*).

A29. Figures I~III depict the excretory systems of planaria, earthworms, and grasshoppers. Figure IV illustrates the habitat of the salmon life cycle.



Which of the following statements concerning excretory structures is correct?

A. In a planarian, the beating of cilia (*a*) within each flame bulb releases filtrate in the direction of the arrows.

B. A pair of mesonephridia within each segment of the earthworm collects coelomic fluid from the adjacent anterior segment and excretes that collected fluid.

C. Structure (*b*) is called a collecting duct, which collects and excretes concentrated urine that is hyper-osmotic to body fluids.

D. In a grasshopper, reabsorption of the filtrate occurs mainly in the Malpighian tubules (*c*), where most solutes are pumped back into the hemolymph, with water following by osmosis.

E. In freshwater, salmon take up salt from the gills and produce dilute urine; in the ocean, they excrete excess salt through their gills.

A30. Which of the following statements is correct concerning gas exchange organs in animals?

A. In starfish, the gill plays a role in gas exchange, but the tube feet do not play a role in that process.

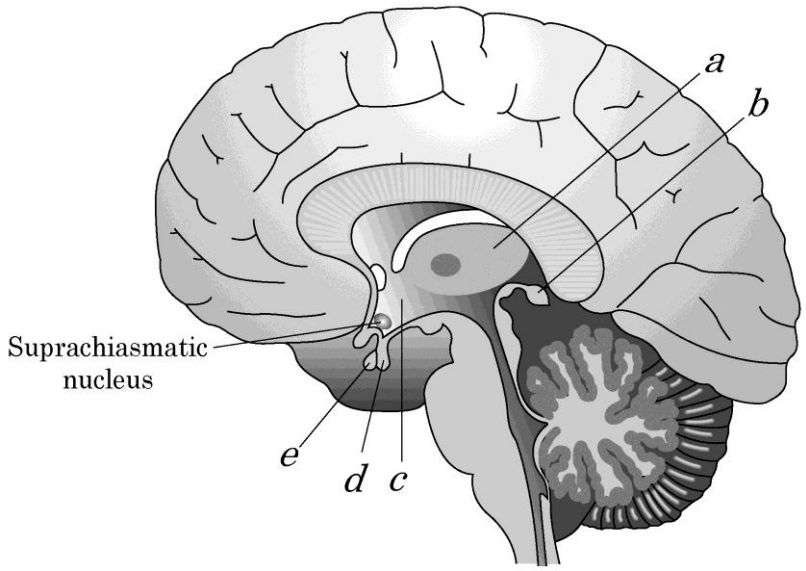
B. In grasshoppers, well-developed muscles surrounding the tracheae control movement of air inward and outward through an external opening.

C. In fish, blood flows through the gill-filament capillaries in the same direction as that of water exiting from the mouth and pharynx to the outside.

D. In birds, during exhalation both air sacs deflate, forcing air to the outside, whereas the lung is filled with air.

E. In humans, surfactants are required to increase the surface tension in the trace amount of fluid coating the inner alveolar surface; in the absence of surfactants, the alveoli collapse during exhalation, blocking the entry of air during inhalation.

A31. The following picture of the midsagittal section of the human brain illustrates diencephalic structures.



Choose a correct statement.

A. Structure (a) plays a role in the maintenance of temperature, hunger, and thirst.

B. Structure (*b*) produces melanin, a hormone that is involved in photoperiodic function.

C. Almost all of the incoming, somatosensory information is sorted in structure (*c*) and is sent to the appropriate cerebral centers for further processing.

D. Structure (*d*) is under the direct control of the suprachiasmatic nucleus.

E. Structure (*e*) is derived from epithelial cells; thus, its embryological origin is different from that of structure (*d*).

A32. Which of the following statements about the regulation of male reproduction is **not** correct?

A. Follicle stimulating hormone (FSH) promotes the activity of Sertoli cells located within the seminiferous tubules.

B. Luteinizing hormone (LH) regulates Leydig cells located in the interstitial space between the seminiferous tubules.

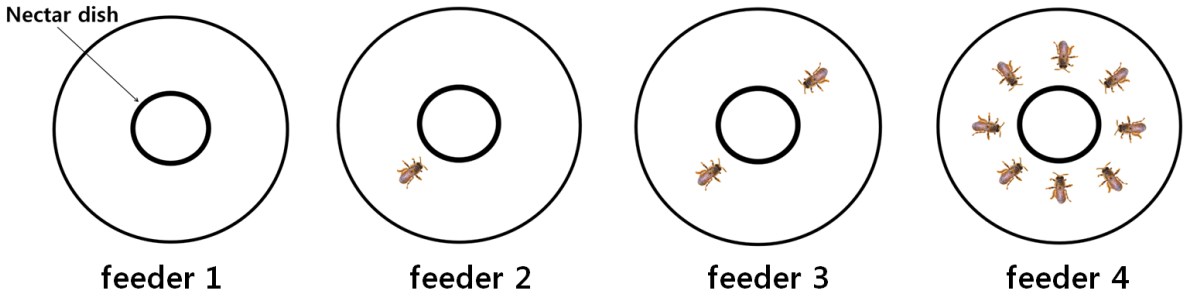
C. In response to LH, Leydig cells secrete testosterone and other androgens, which promote spermatogenesis in the tubules.

D. Testosterone regulates blood levels of gonadotropin releasing hormone (GnRH), FSH, and LH through inhibitory effects on the hypothalamus and anterior pituitary.

E. Inhibin, a hormone produced by Leydig cells, acts on the anterior pituitary gland to reduce LH secretion.

ETHOLOGY

A33. An experiment is designed to test this hypothesis: the number of yellowjacket wasps at a feeding site visually affects the feeding-site choices of workers collecting nectar.. Four feeders with zero, one, two or eight individual decoys are prepared, as shown in the figure below. One nectar dish is placed in the middle of each feeder. You then observe the feeding-site choice made by each worker.



Which of the followings should **not** be included in this experimental design?

A. Using live individuals as decoys.

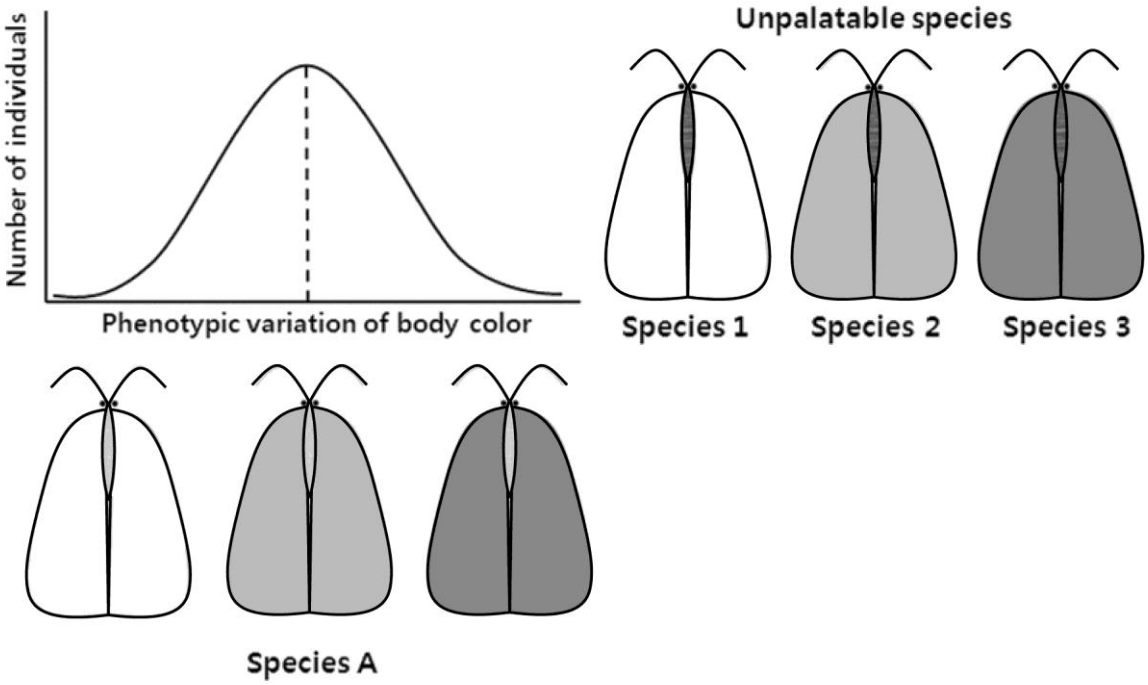
B. Placing the four feeders with nectar dishes randomly and alternatively.

C. Using the nectar solutions of equal concentration among the feeders.

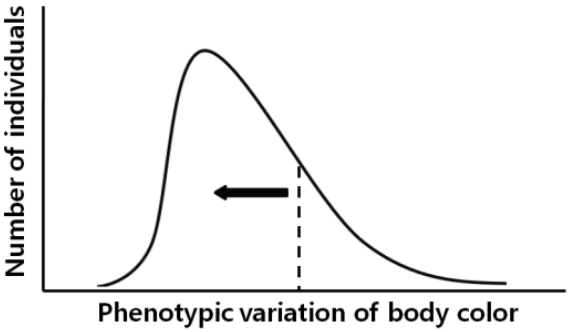
D. Preventing other species from visiting the feeders.

E. Preventing successive visits by the same worker.

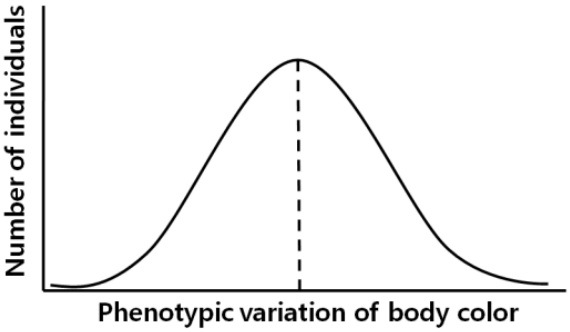
A34. As seen in the left-hand graph, a population of moth species A exhibits individual variation in body color. The environment in which this population lives includes predators, such as birds, which find species A palatable. The environment also includes other moth species unpalatable to birds: one individual from each of three species (1~3) is shown in the right-hand illustration. Species 1, 2, and 3 are similar to different phenotypes found within species A: species 1 to lighter individuals, species 2 to individuals with intermediate phenotype, and species 3 to darker individuals. After capturing and tasting species 1, 2 and 3, birds learn to avoid eating them. Species A is considered a Batesian mimic of the other species. If species 3 becomes most abundant in this habitat, which graph accurately predicts what you would observe in species A? (The dotted line represents the mean value of the original population of species A.)



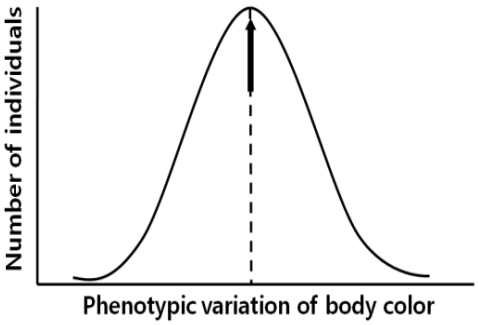
A


Number of individuals
Phenotypic variation of body color

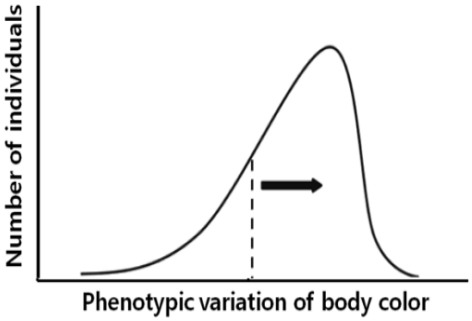
B


Number of individuals
Phenotypic variation of body color

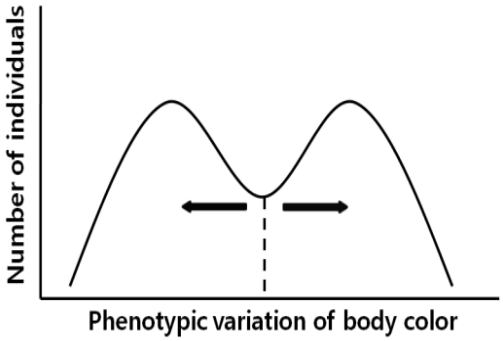
C


Number of individuals
Phenotypic variation of body color

D


Number of individuals
Phenotypic variation of body color

E


Number of individuals
Phenotypic variation of body color

A35. Eusocial honeybees have a specific system of sex determination. Females are diploid (2n) and develop from fertilized eggs; males are haploid (n) and develop from unfertilized eggs. Assuming that the queen copulated with a single male, which of the following is/are most likely true for this social group?

I. The males have mothers but not fathers.

II. A female should foster her brothers to increase her inclusive fitness rather than trying to increase her direct reproduction.

III. It is advantageous to females' (workers') fitness if the queen produces sons and daughters in equal proportions.

IV. A female should remove the eggs of other females (workers) from the nest to increase her fitness.

A. Only I and II

B. Only I and III

C. Only I and IV

D. Only II and III

E. Only III and IV

GENETICS AND EVOLUTION

A36. Which of the following can children only inherit from their mother?

A mutation:

A. on the X chromosome.

B. on the Y chromosome.

C. in the mitochondrial genome.

D. in a maternally imprinted gene.

E. in the hypervariable region of an antibody gene.

A37. In *Drosophila melanogaster*, yellow body and white eye are both X-linked recessive genes. Wild-type males were crossed with yellow females with white eyes, and F_1 progenies were produced in the numbers and phenotypes shown in the table below.

Progeny group	Progeny phenotype and sex	Progeny number
(*a*)	wild-type female	3,996
(*b*)	yellow males with white eyes	3,997
(*c*)	yellow females with white eyes	4
(*d*)	wild-type male	3

Which of the following is the best explanation for how progeny groups (*c*) and (*d*) were produced?

A. Genetic recombination during meiosis I.

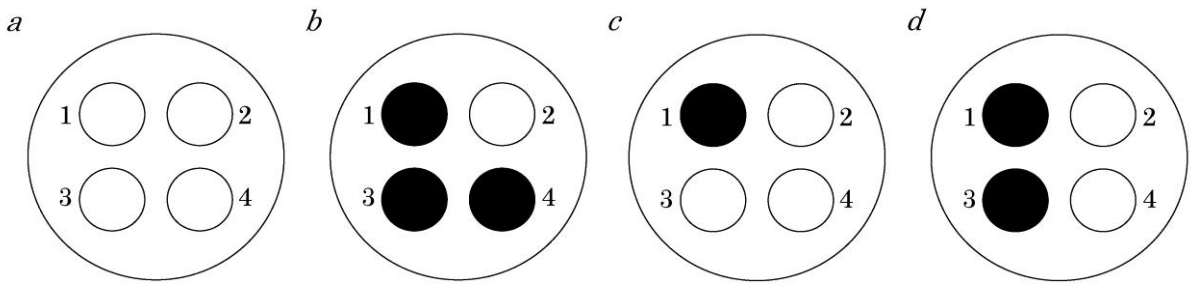
B. Genetic recombination during meiosis II.

C. Somatic mutations in the eye and body of wild-type flies.

D. Nondisjunction of sex chromosome.

E. Dosage compensation for X-linked genes.

A38. Four mutant strains of bacteria (1~4) all require substance S to grow (each strain is blocked at one step in the S-biosynthesis pathway). Four plates were prepared with minimal medium and a trace of substance S, to allow a small amount of growth of mutant cells. On plate *a*, mutant cells of strain 1 were spread over entire surface of the agar to form a thin lawn of bacteria. On plate *b*, the lawn was composed of mutant cells of strain 2, and so on. On each plate, cells of each of the four mutant types were inoculated over the lawn, as indicated in the figure by the circles. Dark circles indicate excellent growth. A strain blocked at a later step in the S substance metabolic pathway accumulates intermediates that can 'feed' a strain blocked at an earlier step.



What is the order of genes (1~4) in the metabolic pathway for synthesis of substance S?

A. $2 \rightarrow 4 \rightarrow 3 \rightarrow 1$

B. $2 \rightarrow 1 \rightarrow 3 \rightarrow 4$

C. $1 \rightarrow 3 \rightarrow 4 \rightarrow 2$

D. $1 \rightarrow 2 \rightarrow 4 \rightarrow 3$

E. $3 \rightarrow 4 \rightarrow 2 \rightarrow 1$

A39. By using modern technology, the gene that determined height in Mendel's pea plants was discovered to be the gene *Le* that codes for the enzyme involved in biosynthesis of the gibberellin hormone GA_1. The two alleles for this gene, *T* and *t*, differ in only one nucleotide. The enzyme produced by the recessive *t* allele has efficiency as low as 1/20 of the normal enzyme. Which of the following statements is correct?

A. GA_1 is directly involved in auxin biosynthesis in the pea plant.

B. The product of the *T* allele is responsible for the normal gibberellin hormone.

C. A F_1 plant from a cross between *TT* and *tt* plants will have 1/20 enzyme activity of that of normal plant.

D. Treatment of a *tt* plant with gibberellin hormone fails to make it grow to become a tall plant.

E. The mutation is due to a deletion of the gene *Le*.

A40. Glucose-6-phosphate dehydrogenase (G6PDH) is encoded by a single X-linked gene in humans. There are multiple functional alleles for this gene, such as A_1, A_2, etc. G6PDH dimers are made in cells and secreted into blood.

If a woman has both A_1 and A_2 allele for G6PDH, what type(s) of dimers is/are found in her blood?

A. Only A_1A_1

B. Only A_2A_2

C. Only A_1A_2

D. Only A_1A_1 and A_2A_2

E. A_1A_1, A_2A_2 and A_1A_2

A41. The direction of shell coiling in the snail *Limnaea peregra* is either dextral or sinistral. Coiling direction is determined by a pair of autosomal alleles. The allele for dextral (S^+) is dominant over the allele for sinistral (s). Experimental results of two reciprocal monohybrid crosses are shown below.

P	Dextral ♂ × Sinistral ♀ (S^+S^+) (ss)	P	Sinistral ♂ × Dextral ♀ (ss) (S^+S^+)
	↓		↓
F_1	All of the F_1 progeny have sinistral shells. (S^+s)	F_1	All of the F_1 progeny have dextral shells. (S^+s)
	↓ self-fertilization		↓ self-fertilization
F_2	All of the F_2 progeny have dextral shells. $^1/_4S^+S^+$: $^1/_2S^+s$:$^1/_4ss$	F_2	All of the F_2 progeny have dextral shells. $^1/_4S^+S^+$: $^1/_2S^+s$:$^1/_4ss$

What is the genetic phenomenon that explains the inheritance pattern for coiling direction?

A. Cytoplasmic inheritance.

B. Epistasis.

C. Genetic imprinting.

D. Maternal effect.

E. Sex-limited inheritance.

A42. Some fruit flies (*Drosophila melanogaster*) have a mutation that makes them shake. These fruit flies are called ‘shakers’.

An experimental cross is shown below:

P	a shaker male (♂) × a normal homozygous female (♀)
	↓
F_1	All males were normal. All females were shakers.
F_2	$F_1 \times F_1$
	↓
	136 shaker males, 131 normal males 132 shaker females, 137 normal females

What kind of inheritance best explains the inheritance pattern for the shaker gene?

A. Somatic dominant.

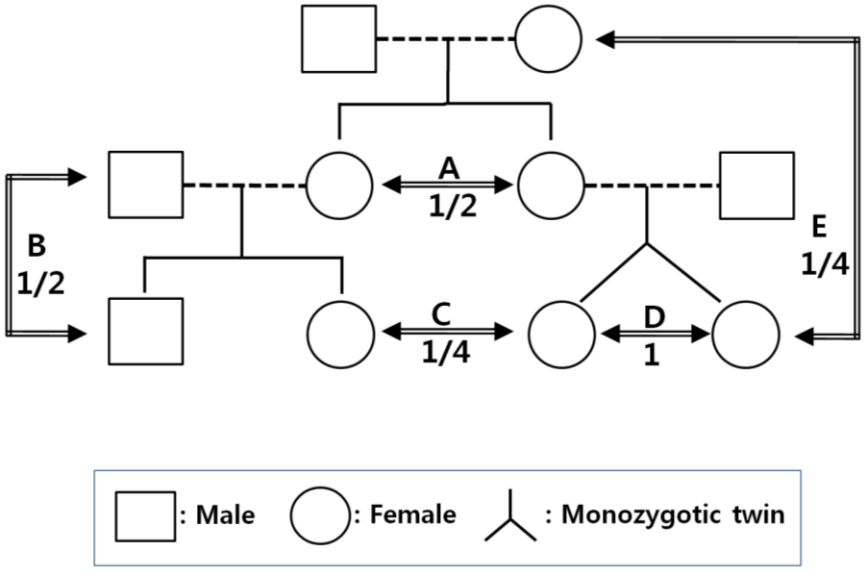
B. Somatic recessive.

C. X-linked dominant.

D. X-linked recessive.

E. Y-linked dominant.

A43. 'Coefficient of relatedness' (or 'genetic relatedness') refers to the probability of two related individuals inheriting a particular allele of a single gene from their common ancestor.



In this family tree of diploid individuals, which of the following 'coefficient of relatedness' is **not** true?

Coefficient of relatedness of

A. A being 1/2

B. B being 1/2

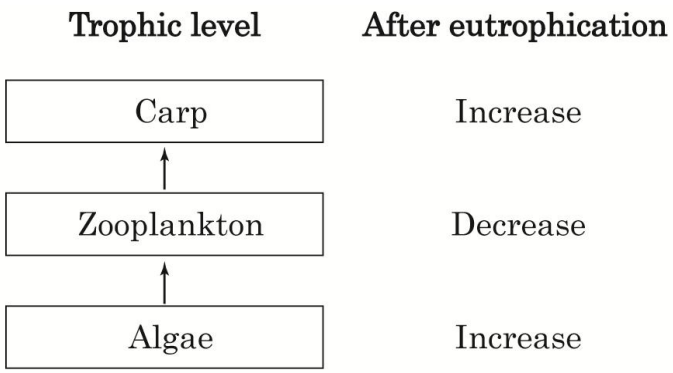
C. C being 1/4

D. D being 1

E. E being 1/4

ECOLOGY

A44. The figure below shows the change in the abundance pattern of three trophic levels in a lake when it was polluted by city sewage. Ground-feeding carps increase in frequency because they benefit directly from additional mineral nutrients.



Which ecological control methods could improve the water quality of the lake?

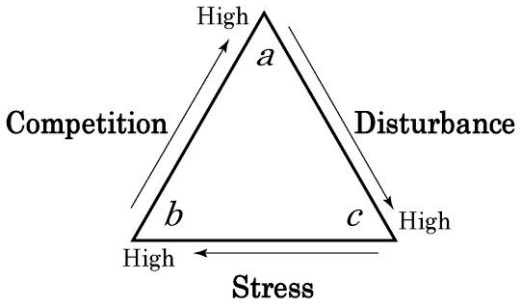
<Ecological control methods>

	Mechanism	Control methods
I.	Top-down control:	Attempt to introduce predatory fish on carp.
II.	Top-down control:	Attempt to reduce the nutrients in the river entering the lake.
III.	Bottom-up control:	Attempt to inhibit recycling of nutrients accumulated in the substrate of the lake.
IV.	Bottom-up control:	Attempt to reduce primary producers as well as consumers by introducing more carp.

A. Only I and II B. Only I and III C. Only I and IV

D. Only II and III E. Only II and IV

A45. The figure below depicts life-history strategies for three plant species (*a*~*c*) along 3 axes: strength of competition with other organisms, level of disturbance in the habitat, and level of environmental stress in the habitat. Species *a* grows in habitats where competition among species is high but disturbance and stress are low. Species *b* grows in habitats with high environmental stress but with low interspecies competition. Species *c* grows in highly disturbed habitats with low environmental stress.



Which of the statements below is/are correct?

I	Characteristics of "*a*-type" plants are slow growth rate and short-lived leaves.
II	Desert annual plants are "b-type" species. They have rapid growth and produce large amount of seeds in a short time after rains.
III	Most plants belonging to "*c*-type" species would be herbaceous while "*a*-type" and "*b*-types" species are likely to be trees or shrubs.

A. Only II

B. Only I and II

C. Only I and III

D. Only II and III

E. I, II, and III

A46. In the photic zone of freshwater and marine environments, where light penetrates, cyanobacteria are found in the upper part of the zone, and purple and green bacteria are in the lower part of the zone. Which of the following statements best explains the vertical distribution of the photosynthetic bacteria?

A. Green and purple bacteria are anaerobic, while cyanobacteria are aerobic.

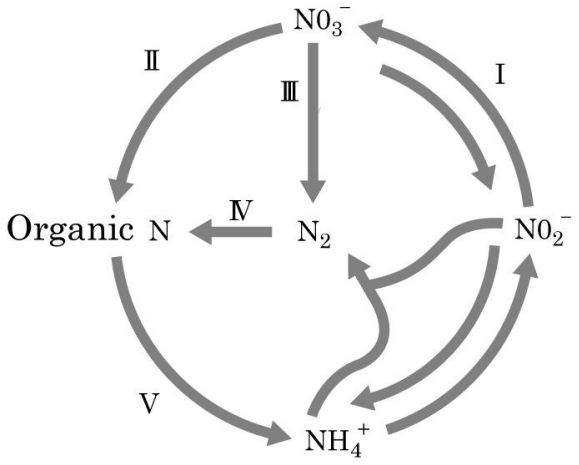
B. Green and purple bacteria are better able to use light wavelengths that cyanobacteria do not use as efficiently.

C. Habitat isolation develops due to competition for nutrient and oxygen.

D. Cyanobacteria are better able to use oxygen as an electron donor for photosynthesis.

E. It is the result of adaptation to lower temperatures in purple and green bacteria.

A47. The following figure shows nitrogen cycling in an ecosystem. Numbers I~V represent different chemical conversion steps in the cycle.



Which process (I ~ V) is correctly paired with the organismal group performing that step?

A. I- photoautotrophs.

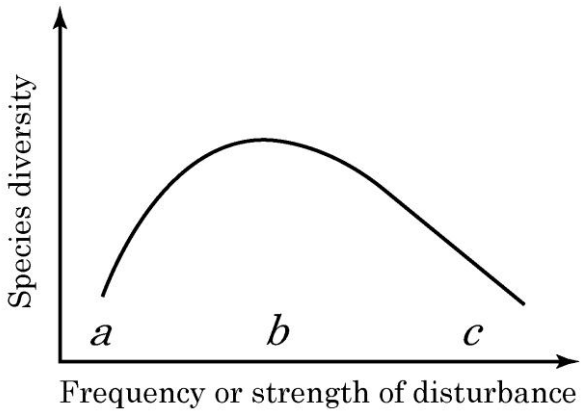
B. II- bacteria symbiotic with plants.

C. III- anaerobic bacteria living in conditions such as wetland ecosystem.

D. IV- eukaryotic organisms.

E. V - nitrogen fixing bacteria such as *Rhizobium* or *Cyanobacteria*.

A48. The following graph shows the relationship between the frequency or strength of disturbance and species diversity.



Which of the following statements is **not** correct?

A. The low species diversity of community (*a*) is due to the presence of dominant species in the community.

B. In community (*c*), species diversity is low because there is not enough time between disturbances for a wide variety of species to colonize.

C. The degree of competitive exclusion among species is highest in community (*b*).

D. In community (*c*), late successional species will be replaced rapidly by early successional species.

E. Community (*c*) consists of environmental stress-tolerant species.

A49. Which of following statements is/are correct?

With increasing atmospheric CO_2,

I.	inorganic nutrients in soil will be increasingly limiting for plant growth.
II.	C4 plants will grow increasingly better than C3 plants in environments where water is limiting.
III.	the increased C:N ratio in litter will cause an increase in decomposition rate by soil microorganisms.

A. Only I

B. Only II

C. Only III

D. Only I and II

E. Only II and III

BIOSYSTEMATICS

A50. The following summaries describe recently published research results.

Research 1. Wu and Li (1985): The comparative analysis of homologous genes between human and mouse genomes suggests that the evolutionary rate of homologous genes was higher in the mouse lineage than in the human lineage.

Research 2. Smith and Donohue (2008): The plant families Caprifoliaceae, Asclepiadaceae, and Lamiaceae are composed of both herbaceous and arborescent species. The comparative analysis of homologous genes between the herbaceous and the arborescent species within a single plant family suggest that the evolutionary rates of homologous genes in herbaceous lineages were faster than that of arborescent lineages in all three plant families.

Research 3. Gilman *et al*. (2009): The comparative analysis of 130 homologous mitochondrial genes between a sister species pair of vertebrates from the temperate region and from the tropical region indicate that the base substitution rates of homologous genes from the tropical region are 1.7 times faster than that of the temperate region.

Based on these studies, which of the following statements best describes the common evolutionary processes in plant and animal genes?

A. The evolutionary rates of genes are accelerated in short-lived animals and plants.
B. The evolutionary rates of genes are accelerated in higher animals and plants.
C. The evolutionary rates of genes are accelerated in animals and plants which lived in higher temperature regions.
D. Direct comparisons of homologous genes between animals and plants show that plants evolve faster than animals.
E. The fast evolutionary rates of mitochondria genes make them ideal for phylogenetic comparison between distant lineages.

A51. Which of the following pairs does **not** show a monophyletic group - paraphyletic group relationship?

A. Monocots - Dicots

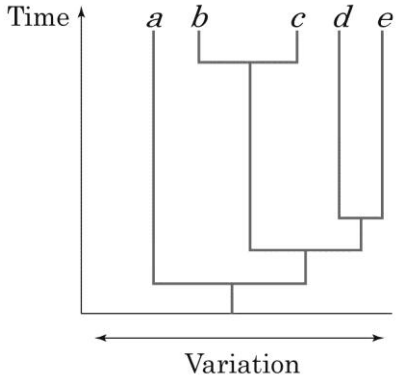
B. Tetrapods - Bony fishes

C. Echinoderms - Chordata

D. Birds - Reptiles

E. Vascular plants - Nonvascular plants

A52. The following figure shows a hypothetical evolutionary tree of species *a*~ *e* along with the variability between pairs of these species.



Choose a statement that is correct.

A. The speciation rate shows a linear relationship to evolutionary time.

B. Species variation shows a linear relationship to evolutionary time.

C. The species pair *a* - *b* and the pair *c*- *d* shows sister group relationship.

D. The tree contains three monophyletic groups.

E. Species *a* can be used as an outgroup for the other four species.

A53. Which of the following statements about speciation is correct?

A. Sympatric speciation occurs more gradually and more slowly than allopatric speciation.

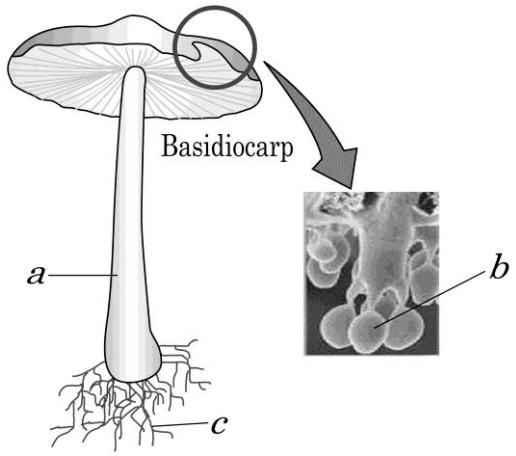
B. The divergence of two maggot fly races is an example of allopatric speciation due to mating time differences.

C. The evolution of cultivated wheat is associated with polyploidization. This is an example of sympatric speciation.

D. Allopatric speciation is usually associated with stronger secondary reproductive barriers than sympatric speciation.

E. Different species of *Drosophila* inhabit the different islands of Hawaii. This is an example of sympatric speciation.

A54. The following figure shows a mushroom belonging to the Basidiomycetes.



Which of the following combination is correct for the nuclear ploidy states of structures *a*~ *c*?

	Ploidy state of structure		
	a	*b*	*c*
A	n	2n	n+n
B	2n	n	n+n
C	n	n	n
D	n+n	2n	n
E	n+n	n	n+n