Entrance Examination
For October 2026 and April 2027 students

Master's Course
(Specialized subjects)

Notes

- Select and answer 3 QUESTIONS from the total 12 QUESTIONS. The 3 QUESTIONS can be selected from any subjects.
- One sheet should be used for each selected QUESTION. The reverse side could be used, if necessary.
- Name, examinee's number and subject name should be written on each answer sheet.
- QUESTION number should also be written on each answer sheet.

Division of Biosphere Science
Graduate School of Environmental Science
Hokkaido University

QUESTION No. 1. (Subject on Field Science)

Read the following sentences (I and II) and answer the questions.

I. ⓐDeciduous forests are widespread in central and northern Japan. Light conditions on the forest floor change greatly throughout the seasons. It is bright in early spring, becomes darker when the canopy trees leaf out in early summer, is shaded under the closed canopy during summer, and becomes brighter again when the canopy trees lose their leaves in autumn. In response to these seasonal changes in light conditions, the plants inhabiting the forest floor have evolved diverse leaf habits. The main types are: ⓑspring ephemerals, which emerge soon after snowmelt and disappear by early summer; summer-green plants, which produce leaves in spring and lose them by autumn; ⓒevergreen plants, which retain their leaves throughout the year; and summer-deciduous plants, which shed their leaves only during a shaded period in summer. These various leaf habits reflect the diverse carbon fixation strategies of plants through photosynthesis.

Question 1-1. Regarding the underlined ⓐ, write down two of the main tree species that form deciduous forests in Japan.

Question 1-2. Regarding the underlined ⓑ, choose one of the appropriate explanations from (A) to (E) that are general characteristics of spring ephemerals.

(A) High photosynthetic ability with high respiration rate
(B) Rapid leaf turnover during a short growth period
(C) Generally tall stature
(D) Thin, large leaves and low cold tolerance
(E) Commonly annual life form

Question 1-3. Regarding the underlined ⓒ, choose three appropriate explanations from (A) to (E) that are general characteristics of evergreen plants inhabiting forest floor.

(A) High photosynthetic ability with high respiration rate
(B) Stopping photosynthesis under dark conditions
(C) Large leaf toughness with low nitrogen contents
(D) Low light compensation point
(E) Low growth rate and high cold tolerance

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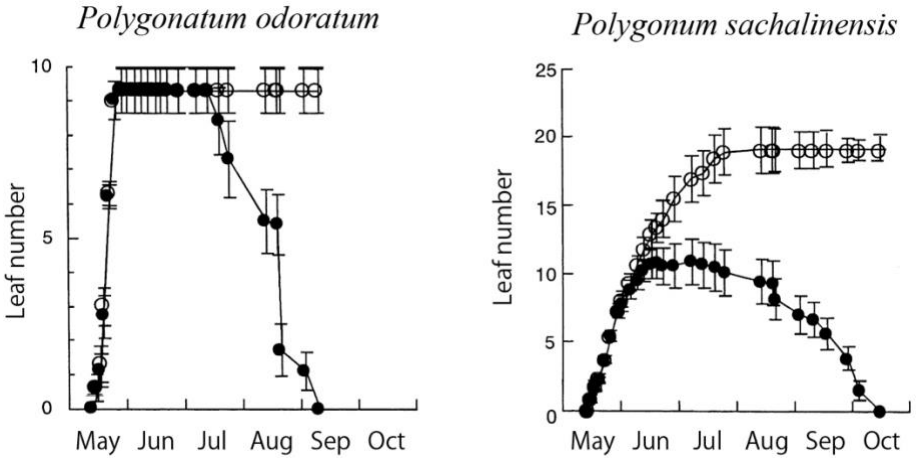
II. *Polygonatum odoratum* is a summer-green herb that inhabits the understory of deciduous forests. In contrast, *Polygonum sachalinensis* is a summer-green herb that inhabits open habitats without shade. The figure below compares the seasonal patterns of leaf production and shedding in the two species.



Leaf emergence and leaf-fall patterns in two herbaceous species. open circles: number of leaves emerged on a shoot; closed circles: number of actual leaves attached to a shoot. Mean ± SE. Reference: Kikuzawa (2003) *Functional Ecology* 17, 29-38.

Question 1-4. The leaves of *Polygonatum odoratum* emerge simultaneously in May, whereas the leaves of *Polygonum sachalinensis* emerge continuously from May to July. Explain the possible reasons for the difference in leaf emergence patterns between the two species in about 80 words.

Question 1-5. The foliage period (photosynthetic duration) of *Polygonatum odoratum* is shorter than that of *Polygonum sachalinensis*. Explain the possible reasons for the difference in foliage period between the two species in about 80 words.

Question 1-6. *Polygonum sachalinensis* produces around 20 leaves per growing season. However, at most, a plant retains 10 leaves at any one time. Explain the possible reasons for this limited leaf retention in about 80 words.

QUESTION No. 2. (Subject on Field Science)

Read the following passage and answer the questions.

Modern animal agriculture has developed into resource-intensive production that inputs large amounts of feed, water, energy, and pharmaceuticals, and has dramatically increased productivity. This has become an essential foundation for supplying animal protein to a growing world population. Behind this, however, a range of problems is emerging. An environment in which large numbers of livestock are kept at high density can become a hotbed for ⓐ diseases transmitted between humans and animals. In addition, ⓑ the antimicrobials that have been used to manage disease, caused by pathogens, promote the increase of antimicrobial-resistant bacteria, and the resistant bacteria and their genes spread into the environment. Furthermore, methane released from the digestive tract of cattle and ⓒ the gases produced during the treatment of manure have a strong greenhouse effect and thus contribute to climate change. In other words, ⓓ a farm can be understood not as a production site isolated from the outside world, but as an open system that exchanges organisms, nutrients, and gases with the surrounding environment and human society.

Question 2-1. What are diseases such as the one in underlined part ⓐ called? In addition, in approximately 50 words, explain the routes by which such diseases are transmitted from the farm environment to humans.

Question 2-2. Regarding underlined part ⓑ, explain in approximately 50 words why antimicrobial resistant bacteria spread, from the perspective of natural selection.

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Question 2-3. Livestock and humans sometimes have interspecific interactions with the organisms associated with them. For each of the relationships 1)–3) below, state which of the options A–C it corresponds to.

1) Lice and ticks attach to the body surface of an animal and obtain an environment suitable for their survival and reproduction, while causing itching and disease in the host.
2) Some of the resident microbes on an animal's skin or in its gut obtain nutrients and a habitat from the host, but provide the host with neither clear benefit nor harm.
3) Some bacteria living in the gut of chickens and pigs obtain nutrients and a habitat from the host while contributing to the host's health by inhibiting the colonization of pathogens and by supplying vitamins.

Options: A: Mutualism B: Commensalism C: Parasitism

Question 2-4. Regarding underlined part ⓒ, the following passage explains the conditions and mechanisms by which greenhouse and related gases are produced during the storage and treatment of livestock manure. Choose the appropriate term for each blank A–E from the options below.

In (A) manure storage such as slurry storage, methane gas is produced through the decomposition and fermentation of organic matter by (B) and the methane-synthesizing reaction by (C). Under conditions where aerobic and anaerobic zones coexist, such as during composting or after application to soil, nitrous oxide gas is produced through the (D) and denitrification of nitrogen. Furthermore, when pile turning or moisture management is inadequate, the emission of (E) may increase in addition to N_2O.

Options: high temperature, low temperature, aerobic, anaerobic, fungi, eubacteria, protozoa, archaea, ammonia, fixation, nitrification, sulfuration, catalyst, enzyme, nitrogen molecule (N_2), NOx

Question 2-5. In relation to underlined part ⓓ, suppose that a situation arose in which a massive bloom of blue-green algae (cyanobacteria) developed in summer in a lake near a certain livestock farm, and large numbers of fish died. Explain how this situation could be related to the farm, describing the causative substances and the process involved, and then discuss the measures the farm could take, in approximately 80 words.

QUESTION No. 3. (Subject on Field Science)

Read the following sentences (I and II) and answer the questions.

I. Currently, many species are facing the threat of extinction due to the impacts of human activities and climate change. Because of its scale and speed, it has been pointed out that the world has now entered a (①) mass extinction. To assess and compare the extinction risk of species worldwide, the (②) publishes the "Red List," which compiles threatened species. In this list, evaluated species are classified into categories according to their risk of extinction, such as Extinct (EX), Extinct in the Wild (EW), Critically Endangered (CR), Endangered (EN), (③), Near Threatened (NT), and Least Concern (LC).[*1] To date, more than 150,000 species have been assessed, and the number of extinct species (EX) amounts to approximately (④).

[*1] In addition to these categories, there are also Data Deficient (DD) and Not Evaluated (NE).

Question 3-1. Answer the most appropriate ordinal number to fill in blank ①.

Question 3-2. Provide the name of the organization that fits in blank ② (abbreviations are acceptable).

Question 3-3. State the category for blank ③ (abbreviations are acceptable).

Question 3-4. Select the number closest to the value for blank ④ from the choices below and write the corresponding letter (A)–(E).

(A) 1,000, (B) 10,000, (C) 100,000, (D) 500,000, (E) 1,000,000

Question 3-5. When a population declines due to habitat degradation or the introduction of invasive species, a positive feedback mechanism may occur in which the decline accelerates further. Explain this phenomenon, known as the "extinction vortex," using all of the following terms in no more than 150 words.

(A) stochasticity, (B) genetics, (C) inbreeding depression

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II. Many organisms exhibit geographic variation in traits such as morphology and coloration in response to differences in their habitats. Among these variations, phenomena that change continuously along latitude are referred to as *latitudinal clines*.

With regard to body size, it is generally known that ⓐorganisms tend to become larger at higher latitudes. For example, in moose inhabiting Sweden, it has been reported that individuals of the same species increase in body size toward the north. Similarly, interspecific comparisons within the family Ursidae show that the polar bear, which inhabits high latitudes, is large, whereas the sun bear, which inhabits low latitudes, is small. However, it should be noted that phylogenetic differences also influence such comparisons.

Furthermore, in terms of appendage length, there is a tendency ⓑfor ears and limbs to become shorter in colder regions. For instance, within the genus *Lepus*, species distributed at higher latitudes tend to have shorter ears and limbs, whereas those in lower latitudes tend to have longer ones. These latitudinal clines in body size and appendages have been widely reported mainly in mammals and birds and are considered adaptations related to heat balance.

On the other hand, latitudinal clines are also often observed in body coloration, with ⓒlighter forms tending to increase in frequency toward higher latitudes. For example, even among the same species of owl, the subspecies *Strix uralensis japonica* (Ezo owl) found in Hokkaido has a paler body color than the subspecies found in Kyushu and Shikoku (*S. u. fuscescens*). In Japanese macaques as well, populations on Yakushima Island in southern Japan are dark in color, whereas those on the Shimokita Peninsula in northern Honshu tend to be lighter and more grayish. However, it has been pointed out that patterns of body coloration are not simply dependent on latitude but are strongly associated with environmental factors such as humidity and precipitation. Latitudinal clines in body coloration have been reported not only in mammals and birds but also in insects such as the ladybird beetle *Harmonia axyridis*.

As described above, it is known that ⓓsimilar geographic patterns repeatedly appear in various traits of organisms across different taxa. This indicates that, in the process of adapting to environmental conditions, different lineages often undergo changes in similar directions. At the same time, these shared patterns are often produced by different factors and mechanisms depending on the trait in question—such as heat balance, humidity, and light environment in the case of body size, appendages, and coloration. Thus, it is important to understand geographic variation in organisms from both perspectives: common trends and diverse underlying mechanisms.

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Question 3-6. Because tendencies such as those in the underlined parts ⓐ–ⓒ have been confirmed in different taxonomic groups, they are considered general phenomena and are referred to as "XXX rule/law." For each of ⓐ–ⓒ, choose the correct term from (A)–(F) below and answer with the corresponding letter.

(A) Gloger's rule, (B) Allen's rule, (C) Hamilton's rule,
(D) Gause's law, (E) Allometric law, (F) Bergmann's rule

Question 3-7. The underlined parts ⓐ – ⓒ can be regarded as examples of environmental adaptation. Choose one of ⓐ–ⓒ and explain why the trait is adaptive in about 50 words.

Question 3-8. Many evolutionary processes take place over timescales beyond direct human observation, so their underlying mechanisms must often be inferred from indirect evidence. The phenomenon described in underlined part ⓓ suggests that adaptive evolution has occurred through natural selection. In approximately 50 words, explain why this phenomenon is considered strong evidence supporting natural selection as a mechanism of evolutionary change.

QUESTION No. 4. (Subject on Field Science)

Question 4-1. For research topics ①–④, select the most appropriate field of ecology from the options below a)–d). Each option corresponds to one research topic only.

① Research investigating the effects of leaf litter supplied by forests on nutrient cycling in mountain streams
② Research analyzing the geographic patterns of species diversity using data collected from multiple continents and oceans
③ A study investigating the effects of river water temperature on the population of the Siberian stone loach through its survival and reproduction
④ A study investigating the effects of the introduction of non-native fish into a lake on the species composition of native fish and the structure of the food web

Options
a) Community ecology
b) Global ecology
c) Population ecology
d) Ecosystem ecology

Question 4-2. Consider a food chain consisting of four trophic levels: large fish species, small fish species, zooplankton species, and phytoplankton species. Suppose that human fishing has caused a significant decline in the population of large fish species. In this case, how are the populations of each of the biological groups ①–③ expected to change under (1) top-down control and (2) bottom-up control, respectively? Select the most appropriate option from "increase," "decrease," or "remain largely unchanged."

(1) Under top-down control
① Small fish species
② Zooplankton species
③ Phytoplankton species

(2) Under bottom-up control
① Small fish species
② Zooplankton species
③ Phytoplankton species

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Question 4-3. It is known that in certain bird species, the number of eggs laid in a single breeding attempt is smaller than the maximum number the parents can rear during that attempt. Using the two terms “iteroparity” and “trade-off,” explain in approximately 100 words why this breeding strategy evolved.

Question 4-4. In a biological community composed of many species that use similar resources, species diversity is lower both in areas where disturbances such as floods, fires, or logging occur frequently and in areas where disturbances rarely occur, compared with areas where disturbances occur at an intermediate frequency. Explain the reason for each case in about 50 words.

Question 4-5. Define keystone species and ecosystem engineers. In addition, explain what characteristics an organism would need to possess in order to be considered both a keystone species and an ecosystem engineer (Approximately 100 words in total).

QUESTION No. 5. (Subject on Life Science)

I. Read the following sentences and answer the questions.

Gene expression in eukaryotic cells consists of multiple steps, each of which is subject to regulation. Genomic DNA, together with histone and non-histone proteins, forms a complex called (①), which is packaged within the nucleus. Cellular traits are determined by which genes are selectively transcribed, and ⓐ epigenetic regulation serves as a mechanism for stably maintaining transcriptional states. RNA polymerase II typically cannot bind DNA by itself. Instead, ⓑ multiple proteins cooperatively recruit RNA polymerase II to DNA and initiate transcription. The transcribed RNA undergoes splicing and several other types of ⓒ processing to become mature mRNA, which is exported from the nucleus through (②). After transport into the cytoplasm, mature mRNA is ⓓ translated by ribosomes. In addition, ⓔ microRNAs (miRNAs) are known to bind target mRNAs and suppress gene expression. After translation, polypeptides that fail to fold properly are often degraded by a protein complex called (③).

Question 5-1. Answer appropriate words for blanks from (①) to (③).

Question 5-2. Regarding the underlined part ⓐ, describe specific chemical modifications involved in epigenetic regulation and explain the mechanisms of their cellular memories through epigenetic regulation. Use the following words and answer in approximately 40–80 words.

cytosine, histone

Question 5-3. Regarding the underlined part ⓑ, explain the process by referring to the cis-regulatory sequences and relevant proteins. Answer in approximately 30–50 words.

Question 5-4. Regarding the underlined part ⓒ, answer two types of RNA processing other than splicing.

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Question 5-5. Regarding the underlined part ⓓ, determine whether each statement is correct or incorrect. If incorrect, provide a correct statement by modifying the underlined part.

a) Initiator methionine tRNA has a different sequence from the elongator methionine tRNA.

b) Multiple ribosomes can bind to a single mRNA and translate it simultaneously.

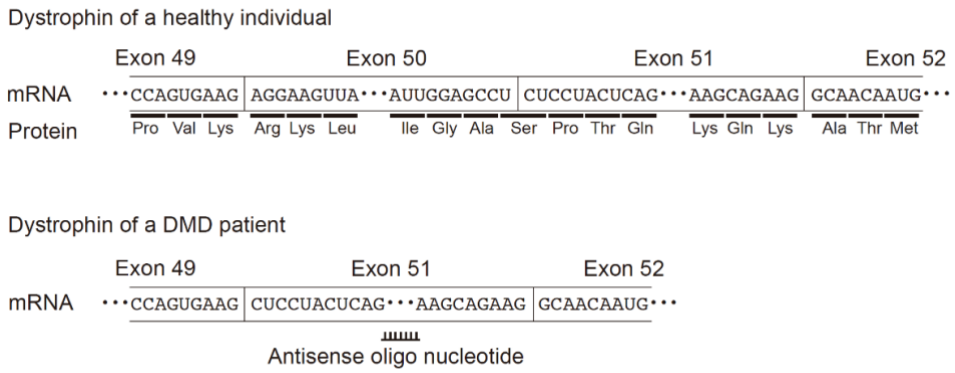
c) Ribosomes are complexes composed solely of RNA.

d) In eukaryotes, mRNAs lacking a stop codon become targets of cellular quality-control mechanisms for degradation.

Question 5-6. Regarding the underlined part ⓔ, explain how miRNAs suppress gene expression and describe the fate of the target mRNAs. Answer in approximately 20–50 words.

II. Read the following sentences and answer the question.

Duchenne muscular dystrophy (DMD) is a severe disease characterized by progressive muscle degeneration throughout the body. It is caused by mutations in the dystrophin gene, a giant gene consisting of 79 exons that is expressed in muscle tissue. The following figure shows part of the mRNA sequence of the dystrophin gene and the corresponding amino acid sequence in a healthy individual, as well as part of the mRNA sequence in a patient with DMD. In this patient, deletion of exon 50 results in no production of dystrophin protein. To treat the disease, an antisense oligonucleotide complementary to exon 51 was administered and taken up by muscle tissues. As a result, inclusion of exon 51 during splicing was inhibited, and ⓕan mRNA in which exon 49 was joined directly to exon 52 was produced in muscle cells. Consequently, a partially functional dystrophin protein was produced, leading to alleviation of muscle degeneration.



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Question 5-7. Explain why production of the mRNA described in ⓕ resulted in the synthesis of a partially functional dystrophin protein. Answer in approximately 60–90 words.

QUESTION No. 6. (Subject on Life Science)

Read the following sentences and answer the questions.

Gibbs free energy (hereafter, free energy: G) is a very useful function for estimating whether a specific chemical reaction will proceed spontaneously or not. Free energy is generally expressed by the following function:

$$G = H - TS \qquad \text{(Eq. 1)}$$

In this equation, H represents (①), T represents absolute temperature, and S represents (②). H is further expressed by the following equation using internal energy U (which may be denoted as E depending on the textbook), pressure P, and volume V.

$$H = U + PV \qquad \text{(Eq. 2)}$$

Let us consider the free energy change (ΔG) of the following reaction (Eq. 3), which is the first reaction of glycolysis.

$$\text{glucose} + \text{ATP} \rightarrow \text{glucose-6-phosphate (G6P)} + \text{ADP} \quad \text{(Eq. 3)}$$

This reaction can be considered by dividing it into the following two reactions:

$$\text{glucose} + \text{phosphate (Pi)} \rightarrow \text{G6P} + \text{H}_2\text{O} \quad \text{(Eq. 4)}$$
$$\text{ATP} + \text{H}_2\text{O} \rightarrow \text{ADP} + \text{Pi} \quad \text{(Eq. 5)}$$

Considering the molecular structures of these substances, when comparing glucose and G6P, G6P is expected to have a (③) value for U or H. When comparing ATP and ADP, ATP is expected to have a (④) one. In principle, the ΔG for Eqs. 3 through 5 can be calculated if ΔH and ΔS during the reaction at the reaction temperature are known. However, when actually estimating the ΔG of chemical reactions inside a cell, the free energy change in ⓐthe standard conditions in biochemistry, $\Delta G^{\circ\prime}$ (denoted as ΔG° in some textbooks), has often already been calculated. Therefore, there is usually no need to calculate ΔH and ΔS, and ΔG is frequently estimated based on $\Delta G^{\circ\prime}$.

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Here, let $\Delta G°'$ for Eq. 4 be 13.8 kJ mol^{-1}, and for Eq. 5 be -30.5 kJ mol^{-1}. Using $\Delta G°'$, the ΔG of the reaction can be estimated from the following equation:

$$\Delta G = \Delta G°' + RT\ln(Q) \quad \text{(Eq. 6)}$$

In this equation, R is the gas constant, and T is the absolute temperature. Q indicates the reaction quotient, which is the ratio of the concentrations in mol L^{-1} of the compounds involved in the chemical reaction, calculated as [products]/[reactants]. For example, if compounds A and B react with each other producing compounds C and D, Q is described as Eq. 7. (Note: Although some textbooks such as Molecular Biology of the Cell state that Q is the equilibrium constant K, in this question it is fine to consider the reaction quotient and the equilibrium constant as equivalent.)

$$Q = \frac{[C][D]}{[A][B]} \quad \text{(Eq. 7)}$$

Considering $\Delta G°'$, it is expected that the reaction of Eq. 3 (⑤) under the standard conditions. When an enzyme catalyzes this reaction, ΔG (⑥) compared to when no enzyme is involved.

One of the enzymes that catalyzes the reaction in Eq. 3 is an enzyme called hexokinase. In this enzyme, the side chain of a specific amino acid residue X of the enzyme interacts with glucose (one of its substrates) as shown in Figure 1 below. Through such interactions, the enzyme lowers the (⑦) of the reaction. The modes of bonding and interaction among various molecules within a cell are ⓑclassified into 5 types including covalent bonds, among which this specific mode of bonding/interaction in Figure 1 is called (⑧).

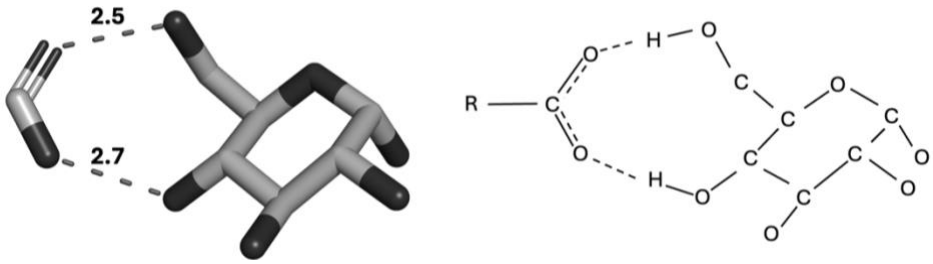

Figure 1. Interaction between hexokinase amino acid residue X and glucose
R in the figure represents part of the side chain of the amino acid residue X in hexokinase. The left diagram shows a structural model and the distance (Å) between the oxygen atoms of the enzyme and the substrate. The right diagram shows the atomic arrangement of this model. Atoms irrelevant to the question have been omitted.

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Question 6-1. Answer the appropriate words or phrases to fill in blanks (①), (②), (⑦), and (⑧) respectively.

Question 6-2. Select the appropriate word to fill in blanks (③) and (④) respectively from the choices below and provide your answer.

higher lower equal

Question 6-3. Select the appropriate phrase to fill in blank (⑤) from the choices below and provide your answer. Additionally, state the rationale behind your choice.

proceeds spontaneously does not proceed spontaneously

Question 6-4. Select the appropriate word/phrase to fill in blank (⑥) from the choices below and provide your answer.

increases is unchanged decreases

Question 6-5. Regarding the underlined part ⓐ, "the standard conditions" refers to a set of defined conditions including a pressure of 1 atm and pH 7.0 at 25°C (or 37°C). Explain any other condition or conditions included in the standard conditions, using specific numerical values.

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Question 6-6. In the case where the compounds listed below are present at the following concentrations in the cytosol of a human cell at 37°C, calculate the ΔG (kJ mol^{-1}) for each reaction in Eq. 3, Eq. 4, and Eq. 5. Round your answers to three significant figures. Your answers must also include the calculation steps. The concentration of H_2O can be ignored (do not include it in the calculation). In the units below, K stands for Kelvin. Additionally, in Eq. 6, let R = 8.31 J mol^{-1} K^{-1}, T = 310 K, and $\ln(Q) = 2.30 \times \log_{10}(Q)$. Calculate $\log_{10}(Q)$ as a dimensionless value (without units).

Compound Name	Concentration in Cytosol (mol L^{-1})
glucose	2.00×10^{-3}
ATP	4.00×10^{-3}
G6P	4.00×10^{-4}
ADP	2.00×10^{-5}
Pi	2.00×10^{-3}

Question 6-7. Provide the names of two amino acids that can be considered as amino acid residue X in Figure 1.

Question 6-8. Among the five bonding/interaction modes indicated by the underlined part ⓑ, name the most appropriate mode of bonding/interaction where (②) in the text is the primary driving factor.

QUESTION No. 7. (Subject on Life Science)

Read the following sentences and answer the questions.

Numerous polypeptides with physiological and pharmacological activity have been identified in nature. In 1992, Eng et al. isolated and identified Peptide A from the saliva of *Heloderma suspectum*, a species of lizard native to North America. This peptide acts on the cells of the rat pancreas's (①), increasing intracellular (②) levels.

In vertebrates, when blood glucose levels rise, Peptide B is secreted from β-cells in the (①). Secreted Peptide B acts on the liver, fat cells, and skeletal muscle cells, promoting glucose uptake and lowering blood glucose levels. Conversely, when blood glucose levels drop, Peptide C is secreted from α-cells in the (①). Peptide C promotes glycogenolysis in the liver, thereby raising blood glucose levels.

Peptide C is initially produced in α-cells as a precursor polypeptide. It is then cleaved at specific sites to become mature Peptide C. This precursor is also produced in L cells in the intestinal mucosa; however, in L cells, it is cleaved at sites distinct from those in α-cells, yielding Peptide D rather than Peptide C.

Peptide D exhibits a variety of physiological activities. These include promoting the secretion of Peptide B from β-cells, inhibiting the secretion of Peptide C from α-cells, suppressing glucose production in the liver, inhibiting gastrointestinal motility, suppressing appetite, and inducing satiety.

When Peptide D binds to a specific receptor on the surface of β-cells, the GDP-bound inactive form of G protein is converted to the GTP-bound active form. The activated G protein activates adenylate cyclase, increasing intracellular (②) levels. Increased (②) activates protein kinase A, and, through several subsequent steps, the intracellular (③) ion concentration rises; ultimately, Peptide B in the secretory vesicles is released into the extracellular space via (④).

Molecules such as Peptides B, C, and D, which convey changes in the extracellular environment, are called extracellular signals. The process that begins with the binding of extracellular signals to specific receptors and leads to a cellular response is called signal transduction. Small chemical substances responsible for intracellular signal transduction, such as (②) and (③) ion, are called (⑤). Based on their structure, cell-surface receptors are primarily classified into the three major groups. The first is G protein-coupled receptors. This group includes receptors to which peptides C and D bind. The second group is (⑥). Receptors that recognize peptide B belong to this type. The third group is (⑦), which undergo structural changes upon ligand binding, thereby regulating their opening.

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Question 7-1. Answer the most appropriate words in the blanks from (①) to (⑦).

Question 7-2. Answer the name of the Peptide B and Peptide C.

Question 7-3. Many signal transduction processes consist of multistep reactions involving multiple molecules and enzymes. Answer three possible advantages of this in approximately 50–80 words.

Question 7-4. Based on the fact that the amino acid sequence of Peptide A from *Heloderma suspectum* shares 53% identity with human Peptide D, Göke et al. conducted the following experiment in 1993.

In addition to Peptide A and Peptide D, they prepared Peptide E, in which the N-terminal 8 amino acid residues of Peptide A had been removed, as an experimental peptide. (①) isolated from rats were incubated in a solution containing 10 mM glucose, and the amount of secreted Peptide B was measured as the control value. The test peptides were added to this solution, and the secreted Peptide B was quantified. Figure 1 shows the increase in Peptide B relative to the control.

The graph on the left shows the results when Peptide A was added, and the graph on the right shows the results when Peptide D was added. The ▲ symbols on the plot indicate cases where 0.1 nM of peptide E was added simultaneously. The ■ symbols indicate cases where 100 nM of peptide E was added simultaneously, while the ● symbols indicate cases where it was not added. The average values from six experiments are plotted, and the standard errors are shown as error bars.

Describe what these experimental results indicate and discuss the mechanism of action of Peptide E using the term “antagonist” in approximately 100–150 words.

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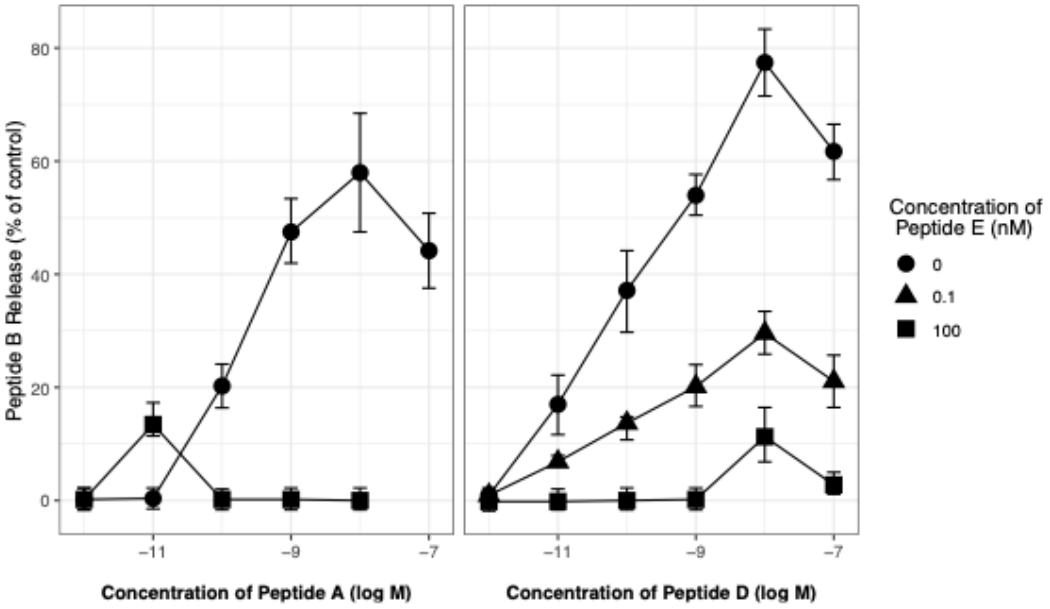

Figure 1. The effect of Peptide E on the release of Peptide B. * Göke et al. (1993) *Journal of Biological Chemistry* 268 (26), 19650-19655. (partially modified)

QUESTION No. 8. (Subject on Life Science)

Answer the following questions related to cell membrane, cell wall and solute transport.

Question 8-1. Cell membranes are primarily composed of a phospholipid bilayer.

Question 8-1-1. Describe the molecular structure of phospholipids that gives rise to this bilayer and the location of each component within the bilayer in approximately 30–60 words.

Question 8-1-2. Explain the arrangement of the various domains of transmembrane proteins within the cell membrane in approximately 20–40 words.

Question 8-1-3. Answer the name of the molecular model of the cell membrane, which reflects the character of the lipid bilayer and the arrangement of proteins within it.

Question 8-2. For the following explanation regarding the movement of molecules across cell membranes, determine whether each statement is correct or incorrect. If the answer is incorrect, provide a correct statement by modifying the underlined part.
a) Although each molecule moves randomly, they appear to diffuse from where it is less concentrated to where it is more concentrated in the case of passive diffusion.
b) As many non-polar molecules cannot pass through the lipid bilayer, their transport involves membrane-spanning transport proteins.
c) Channel proteins expend energy, moving molecules against their concentration gradients.

Question 8-3. If a cell without a cell wall is immersed in a solution that is isotonic to the cell, there will be no net movement of water across the plasma membrane. Explain net movement of water and morphology of cells when they are transferred to a hypertonic or a hypotonic solution in the following two types of the cells.

Question 8-3-1. Explain the case of red blood cells among animal cells, in approximately 20–40 words.

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Question 8-3-2. Explain the case of plant cells with cell walls, in approximately 50–100 words.

Question 8-4. Read the following sentences and answer the most appropriate words in the blanks from (①) to (③).

Plant tissues have two major compartments – the (①) and the (②). The (①) consists of everything external to the plasma membranes of living cells and includes cell walls, extracellular spaces, and the interior of dead cells such as vessel elements and tracheids. The (②) consists of the entire mass of cytosol of all living cells as well as plasmodesmata, the cytoplasmic channels that interconnect them. The compartmental structure of plants provides three routes for transport within a plant tissue: the (①), (②), and transmembrane routes. Water and minerals from the soil enter the plant through the epidermis of roots, cross the root cortex, and pass into the vascular cylinder. The endodermis is the innermost layer of cells in the root cortex. Within the transverse and radial walls of each endodermal cell is the (③) strip, a belt of waxy material that blocks the passage of water and dissolved minerals. Water and minerals that are moving through the (①) must cross the plasma membrane before they can enter the vascular cylinder.

Question 8-5. In contrast to the unidirectional transport of xylem sap from roots to leaves, the direction of phloem sap transport changes depending on the developmental stages of plants. In general, phloem sap moves from sites of sugar production to sites of sugar use or storage. A sugar source is a plant organ that is a net producer of sugar by photosynthesis or by breakdown of starch. In contrast, a sugar sink is an organ that is a net consumer or depository of sugar.

Question 8-5-1. Give at least two examples each of sources and sinks, and explain which organs act as sources or sinks under what conditions, in approximately 40–80 words.

Question 8-5-2. Explain how the sugar concentration gradient between sources and sinks is formed, in approximately 20–40 words.

QUESTION No. 9. (Subject on Aquatic and Marine Science)

Read the following sentences and answer the questions.

Animal sperm, and gametes of algae and some land plants possess flagella, long organelles that enable movement in water. ⓐEukaryotic flagella are mainly composed of microtubules, and a basal body is located at the base of each flagellum. The basal body has a structure similar to that of the centriole in animal cells. In general, the basic structure of flagella is conserved among eukaryotes. However, ⓑthe number, morphology, and associated appendages of flagella vary among phylogenetic groups. ⓒBacteria also have flagella, although their structure differs from that of eukaryotic flagella.

ⓓIn some algae with alternation of generations, both sporophytes and gametophytes produce flagellated reproductive cells.

Question 9-1. Regarding the underlined part ⓐ, the following sentences explain the structure of eukaryotic flagella. Insert the most appropriate numbers in blanks ①, ③, and ④, and words in blanks ② and ⑤.

Microtubules (MTs) in flagella are arranged as (①) sets of (②) microtubules arranged in a ring and (③) central singlet MTs, which is called as "(①)＋(③)". In contrast, the basal body displays "(①)＋(④)" pattern from the number of the central singlet MTs. In basal body, (①) sets of (⑤) MTs are arranged like a cartwheel.

Question 9-2. Regarding the underlined part ⓑ, the following sentences (1) ~ (3) explain the structure of animal sperm, stramenopiles, and dinoflagellates. Select the group that matches each description below.

(1) Possess two flagella extending along the transverse and longitudinal grooves on the cell surface.
(2) Possess a single flagellum extending toward the posterior end of the cell.
(3) Possess two flagella, including a hairy flagellum bearing mastigonemes and a whiplash flagellum lacking hairs.

Question 9-3. Regarding the underlined part ⓒ, explain the structural characteristics of bacterial flagella in approximately 50 words. Be sure to include the following three keywords.
Keywords: cell membrane / fiber / motor (Continued on next page)

Question 9-4. Flagellar movement is closely related to cellular taxis. Explain what taxis is.

Question 9-5. Regarding the underlined part ⓓ, the member of kelp undergoes alternation of generations between sporophyte and gametophyte. Explain each of the following items (1) ~ (4) related to the life cycle of kelps.

(1) Morphological characteristics of the sporophyte and gametophyte
(2) The timing of meiosis
(3) Features of asexual reproductive cells
(4) Features of gametes released by male and female gametophytes

QUESTION No. 10. (Subject on Aquatic and Marine Science)

Read the following sentences about fish reproduction and answer the questions.

While animals generally reproduce through either ⓐ sexual or asexual reproduction, nearly all fish reproduce sexually. In many fish, the undifferentiated gonads differentiate into ovaries or testes during the post-hatching growth process. When the gonads differentiate into ovaries, the germ cells are called oogonia. Once germ cells have proliferated by mitosis, they enter meiosis, but the process is arrested at (①) of meiosis (②). With the ⓑ onset of puberty, meiosis—which had been arrested—resumes upon reaching maturation; however, it is arrested again at the (③) of meiosis (④). As a result, the eggs are spawned in a state where meiosis has not been completed, as fertilizable eggs.

Question 10-1. Insert the most appropriate words in the blanks from (①) to (④) by selecting the term that follows. The term may be used repeatedly.

Terms: I, II, prophase, metaphase, anaphase, telophase

Question 10-2. Regarding the underlined part ⓐ, in sexual reproduction, the chromosome constitution of parents and offspring differs. Explain the reason for producing this genetic diversity from the perspective of the mechanism of meiosis, using all of the following terms.

Terms: homologous chromosome pairs, paternal chromosomes, maternal chromosomes, sister chromatids, non-sister chromatids, recombinant chromosomes

Question 10-3. Regarding the underlined part ⓑ, when puberty begins, the ovarian follicle—composed of an oocyte and the surrounding somatic cells—develops in response to hormones secreted by the pituitary gland. Explain the endocrine regulatory mechanism by which the ovarian follicle develops as a result of puberty, starting with the pituitary gland.

Question 10-4. Although some fish species reproduce asexually from eggs, almost all fish reproduce sexually. Sexual reproduction involves a complicated process of gametogenesis, and offspring cannot be produced unless a male and a female mate. Discuss why sexual reproduction remains overwhelmingly dominant despite paying these costs.

QUESTION No. 11. (Subject on Aquatic and Marine Science)

Answer the following questions about population growth.

Question 11-1.

Consider the growth of population A, whose population size is N. Assume that there is no immigration or emigration, resources are not limiting, and the per capita birth rate and per capita death rate remain constant. The symbols used below are defined as follows.

Δt	Time interval over which population growth is observed
ΔN	Change in population size during the time interval Δt
B	Number of individuals born per unit time
D	Number of individuals dying per unit time
b	Per capita birth rate per unit time
m	Per capita death rate per unit time

Question 11-1-1. Express the change in population size per unit time, $\Delta N / \Delta t$, using B and D.

Question 11-1-2. Express B in terms of b and N, and express D in terms of m and N. Using these expressions, express $\Delta N / \Delta t$ in terms of b, m, and N.

Question 11-1-3. For population A, let the per capita rate of increase be defined as $r = b - m$. Express the equation derived in Question 11-1-2 in terms of r.

Question 11-1-4. Under what condition does the population size N increase in terms of the per capita rate of increase r? In addition, explain how the population size N increases under that condition.

(Continued on next page)

Question 11-2.

Consider the same population A as in Question 11-1. In Question 11-1, population growth was examined under conditions without resource limitation. Here, consider a situation in which resource limitation occurs as the population size N increases. Let K denote the carrying capacity, defined as the maximum population size that can be supported by the environment.

Question 11-2-1. When the population size is N, express the number of additional individuals that can still be supported by the environment using N and K. Then, using N and K, express the proportion of the carrying capacity available for population growth, which becomes 0 when the population reaches the carrying capacity K and approaches 1 when N is very small.

Question 11-2-2. Incorporate the proportion of the carrying capacity available for population growth obtained in Question 11-2-1 into the equation derived in Question 11-1-3, and derive an equation describing the change in population size under resource limitation.

Question 11-2-3. Using the equation derived in Question 11-2-2, express $\Delta N / \Delta t$ in terms of r and K when the population size is 10%, 50%, and 90% of the carrying capacity ($N = 0.1K$, $N = 0.5K$, and $N = 0.9K$, respectively). In addition, identify under which of these three conditions the population growth rate is greatest.

Question 11-2-4. For the condition identified in Question 11-2-3 explain biologically why the population growth rate is greatest, focusing on population size and the strength of resource limitation (Within 50 words).

QUESTION No. 12. (Subject on Aquatic and Marine Science)

Answer the following questions regarding food webs and primary production in aquatic environments.

Question 12-1. Explain the microbial loop in aquatic environments in approximately 200 words.

Question 12-2. Light is an important factor controlling primary production in aquatic environments. Explain the attenuation of light in the water column and its relationship with photosynthesis in approximately 200 words. You may express and explain them using equations and/or figures as appropriate.

Question 12-3. Nutrients are also important factors controlling primary production. However, the occurrence of harmful algal blooms (HABs) due to excessive nutrient input has a significant impact on fishery resources. HABs are mainly classified into three or four types. Briefly explain each type.