Entrance Examination
For October 2023 and April 2024 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 text 1) and 2) and answer the questions.

1) Biomes are the largest geographical biotic communities with certain characteristics, and broadly correspond with climatic regions. Typically, terrestrial vegetation is classified into 8 biomes such as tropical rainforest, savannah, desert, temperate grassland, temperate deciduous broad-leaved forest, temperate evergreen broad-leaved forest, taiga, and tundra. The (①) are considered as the main determinant factors of biomes, although other environmental factors are sometimes important. In general, the primary production of biome shows higher value with increasing these two factors. Furthermore, the biodiversity also shows spatial variation globally, and the number of species tends to be greater at (②) region.

Question 1-1. Select one alphabet which shows most appropriate pair of factors for ①.
   A. soil nutrient content and annual precipitation
   B. annual mean temperature and annual precipitation
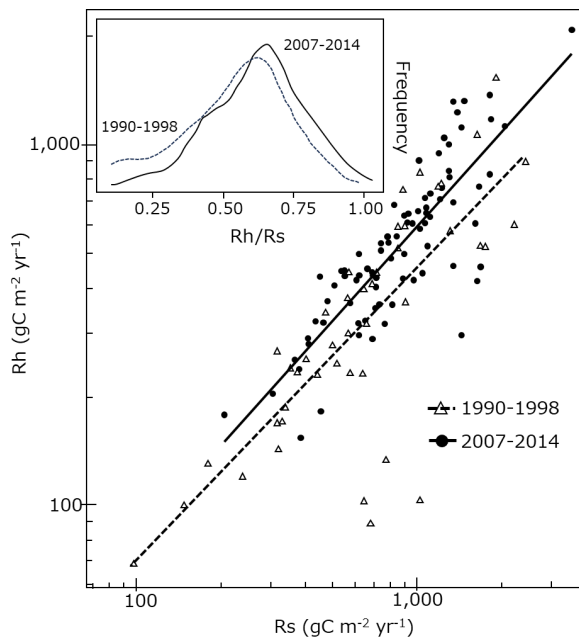   C. soil nutrient content and annual mean temperature

Question 1-2. Select one alphabet which shows most appropriate term for ②.
   A. low latitude
   B. mid-latitude
   C. high latitude

Question 1-3. Explain the definition of gross primary production and net primary production in about 50 words.

2) Total soil respiration (Rs) in terrestrial ecosystems is expressed as the sum of autotrophic respiration (Ra) and heterotrophic respiration (Rh). Bond-Lamberty *et al.* (2018) mainly focused on the relationship between Rh and Rs, and they analyzed the recent trend and causes of variations in Rh and Rs by using the global dataset of carbon flux observed between 1990 and 2014. Figure 1 shows the part of their results. Referring the result, answer the following questions.
(Reference: Bond-Lamberty *et al.* 2018, Nature, 560, https://doi.org/10.1038/s41586-018-0358-x)

Figure 1. Relationship between Rh and Rs and histogram of Rh/Rs (upper small figure in scatter plot). The data for two different periods (1990-1998 and 2007-2014) are shown. Table indicates the result of significance test for explanation of variation in Rh/Rs. The *p* value indicates the probability that the factor is selected as the explanatory variables by chance.

Question 1-4. Select one alphabet which shows most appropriate text explaining the result of analysis in Figure 1 (including table).

A. The relationship between the globally observed Rh and Rs was negative.

B. Rh/Rs showed constant value without spatial variation in both periods.

C. Rh/Rs tended to be rising during recent decades, and observation year affected this variation at over 99% probability.

D. There was no significant effect of MAT and SOC on the Rh/Rs variation.

Question 1-5. The authors in this study also found that the ratio of Rh to gross primary production showed significant increase during recent decades. Based on the results in Figure 1 and this finding, mention the current trend and the expected mechanism of the variation in CO_2 emission from soil in about 100 words using the following 3 keywords.
Keywords: litter, soil organic carbon, temperature

QUESTION No. 2 (Subject on Field Science）

Read the following text 1) and 2) and answer the following questions.

1) Events that remove organisms from biotic communities and alter the availability of resources due to natural disasters such as storms and fires or human activities are called (①). After a (①) such as a volcanic eruption or glaciation, where the existing vegetation has been completely removed, various other species move in and the established species gradually get replaced. This process is known as (②). In particular, (②) that occurs in places where the soil has not yet formed is called (③).

This kind of change is particularly evident in bare land formed by the retreat of glaciers (glacier foreland). A well-known study was conducted in Glacier Bay, Alaska. Only limited species, such as (A) are initially growing on the bare land, but gradually photosynthesizing (B) start to invade, which lower the pH and enable (C) to grow in the soil. Afterward, (D) which form symbiotic relationships with (E) dominate the plant community, and several decades later (F) which also form symbiotic relationships with (E) invade and form dense forests. This forest remains stable for a while, but is replaced by (G) over hundreds of years, forming a new forest.

**Question 2-1.** Write the terms that apply to ① to ③.

Question 2-2. Select the species that applies to A to G from the following list.
Species: dwarf shrubs (mountain avens), mosses, broadleaf trees (alder), lichens, coniferous trees (spruce), bacteria, nitrogen-fixing bacteria

Question 2-3. Species that alter the environment, as indicated by the underline, influencing other organisms, are called "ecosystem engineers." Name an organism that could be an ecosystem engineer* and explain in about 30 words how that organism alters the environment, including its ecology and impact on other species.
Note: *Any types of species are acceptable to name.

2) The following figure is modified from a research paper comparing the biomass of microorganisms living in various environments. Answer the following questions. (Reference: Fierer *et al.* 2010. Changes through time: Integrating microorganisms into the study of succession. Research in Microbiology, 161(8), 635–642. https://doi.org/10.1016/j.resmic.2010.06.002)
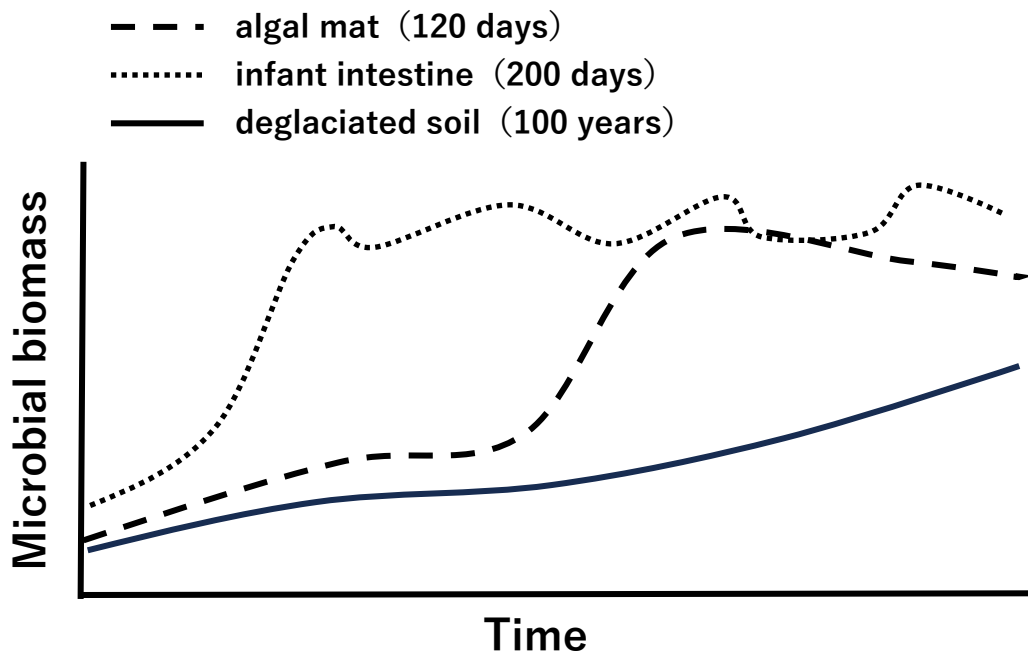
Note: The horizontal axis "Time" in the figure is the age scale of each environment in the figure legends, with the starting point being the timing when the changes began. The vertical axis is the change in relative biomass in each environment, and this is not quantitative for comparison with other environment.

Question 2-4. Describe how the bare land formed by the retreat of glaciers (glacier foreland) differs in the pattern of increase in biomass from other environments (no word limit). Also, explain the reason for this in about 40 words using the following keywords. Keywords: oligotrophic, temperature, limitation

Question 2-5. The increase in biomass stagnates midway through the period in the infant intestine and the algal mat. This suggests that unlimited population growth, known as exponential growth, does not occur in nature. Instead, this type of growth is referred to as logistic growth. Explain the "carrying capacity", which is essential to understanding logistic growth. Additionally, explain the "logistic growth" in relation to the carrying capacity in about 40 words.

QUESTION No. 3 (Subject on Field Science）

Read the following text 1) to 3) and answer the questions.

1) Biological classification for living organisms

Until the mid-20th century, many biologists acknowledged the existence of either two or five kingdoms for classification of all living organisms, based on morphological and/or developmental features. With the advance of molecular biology and phyletic analysis theories, detailed phyletic relationship of living organisms was assessed using genetic data. Owing to phylogenetic analyses, ⓐthe Three Domain System was proposed. One of these domains includes a large phyletic group of Eukaryote (e.g., Plantae, Animalia, and Fungi). In addition, Fungi are classified into four groups[※1]: Chytrids, Zygomycetes, Ascomycetes, and (①) [※2].

Notes:

[※1]There is another theory which classifies Fungi into five groups: Chytrids, Zygomycetes, Glomeromycetes, Ascomycetes, and (①).

[※2]In general, (①) are known as mushrooms.

Question 3-1. Regarding the underlined words ⓐ, phylogenetic relationships of the three domain are shown on the right. Answer appropriate domain names for A and B.

Eukaryote A   B
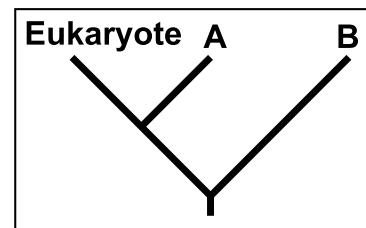
Question 3-2. Fill in the most appropriate term to blank (①).

2) Lifecycle of Fungi

Almost all Fungi reproduce by producing spores, either sexually or asexually. In particular, plasmogamy is the first stage for sexual reproduction in Fungi, which is characterized by the fusion of complementary mycelium (monokaryotic = n). Heterokaryon (dikaryotic = $n + n$) is formed by the combination of mycelia. In particular, for (①) and Ascomycetes, ⓑKaryogamy occurs at the cells after the stages of heterokaryon is maintained for a certain

<u>period</u>, and hence spores (*n*) which retain high genetic diversity are reproduced through meioses.

Question 3-3. Regarding the underlined part ⓑ, explain a merit of being dikaryotic (= *n* + *n*), in about 20 words.

3) Fungi mutualism interaction with vascular land plants

©<u>Almost all vascular land plants on Earth form mycorrhizae with Fungi, developing a mutualistic relationship under the ground.</u> There is a hypothesis that mutualistic relationship with Fungi enabled plants to be adapted to land environment because most ancient fossils of land plants have mycorrhizae.

Question 3-4. Regarding the underlined sentence ©, Fungi which form mycorrhizae with vascular land plants are defined as mycorrhizal fungi, which are classified in two types based on morphologic features of the mycorrhizae. Answer the name of these two types of mycorrhizal fungi, and explain each morphologic feature and niche comparing each other in about 50 words using the words "cellar walls of root cells".

Question 3-5. Mutualistic relationship between leguminous plant (Fabaceae) and rhizobium in rhizosphere is a well-known example between land plants and other living organisms. Explain this relationship in about 80 words.

QUESTION No. 4 （Subject on Field Science）

The following is the sentences about an experiment. Read the sentences carefully and answer the questions.

Temperate trees become （X） when they are exposed to low temperature. The （X） temperate trees form winter buds that are resistant to low temperature. In temperate forests, many of the trees open the winter buds after they are exposed to the warm temperature for a certain period in spring. On the other hand, as in the case of maple species, it is known that small individuals show earlier bud-burst (leaf flushing) as compared to large individuals within the same species. As the mechanisms driving such a size-dependent difference of the bud-burst timing, two following hypotheses are thought.

Hypothesis 1: the warm temperature required for the bud-burst is less for small individuals as compared to large individuals physiologically.
Hypothesis 2: the air temperature is warmer around the winter buds of small individuals as compared to those of large individuals.

To test either of the hypotheses is more proper, the following field experiment was conducted.

Experimental design: In the experimental site shown as in Figure A), we compared the progress of the bud-burst of 1) small individuals standing at the soil (Treatment ①, tree height was about 50cm), 2) large individuals standing at the soil (Treatment ②, tree height was 20m), 3) small individuals which were excavated from the soil, planted in the pots, and put on the forest floor (Treatment ③, tree height was about 50cm), and 4) small individuals which were excavated from the soil, planted in the pots, and put on the platform (Treatment ④, tree height was about 50cm, platform height was about 20m). As the results of the monitoring, the results shown in the Figures B-1～4) were obtained. Figure B-1), Figure B-2), Figure B-3) and Figure B-4) shows the data of Treatment ①, Treatment ②, Treatment ③ and Treatment ④, respectively.

Question 4-1. Write a proper word which can fit into (X).

Question 4-2. Describe the scientific reason why the Treatment ③ was conducted and what was clarified by conducting the Treatment ③ in about 50 words.

Question 4-3. Based on this experiment, which of the Hypothesis 1 or 2 was supported? Answer the supported hypothesis and describe the evidence you chose the hypothesis in about 30 words.

7

Question 4-4. What are the beneficial points of the earlier bud-burst for smaller trees at the forest floor as compared to larger trees? Describe them by considering that earlier bud-burst can result in the earlier start of the sunlight interception while earlier bud-burst can result in the increase of the late frost-damage on the opened buds within 100 words.
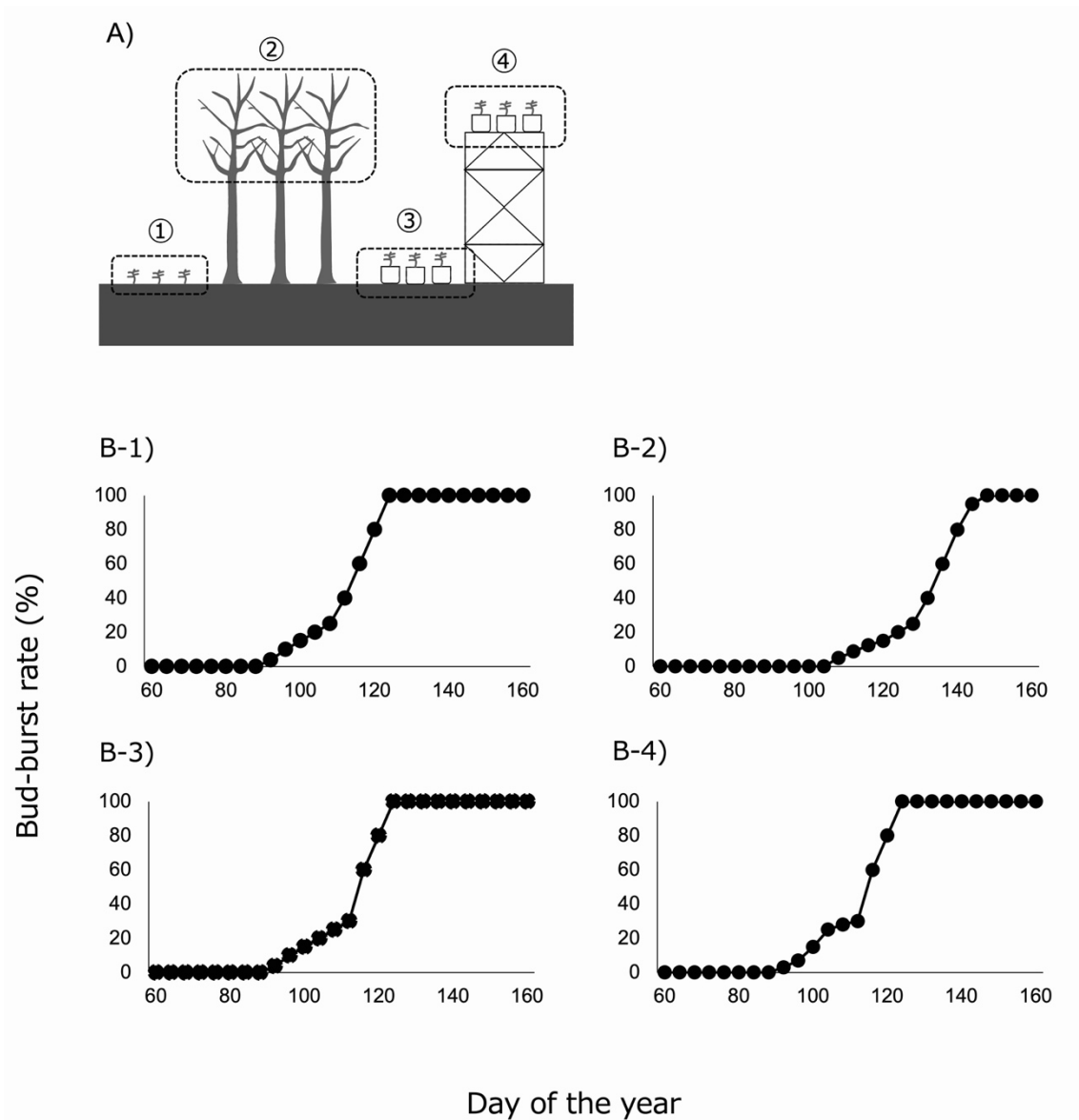
Notes

※1 Day of the year: the sequential day number starting with day 1 on January 1st. 31st December is shown as 365.

※2 Bud-burst rate: the relative percentage of the bud-burst among all buds within the canopy. 0% means none of the buds opened while 100% means all of the bud opened.

QUESTION No. 5 (Subject on Life Science)

Read the following text and answer the questions in English.

    Protease is a general term for a group of (1) that catalyze the breakdown of proteins into smaller polypeptides or single amino acids. These enzymes cleave peptide bonds within proteins by the addition of a (2). Proteases can be classified into several types based on their mode of action or the structure of their active center. Proteases that release a terminal amino acid residue at the end of a target polypeptide are called (3), while those that cleave internal peptide bonds of the protein are referred to as (4). Alternatively, proteases are often classified into serine proteases, aspartate proteases, thiol proteases, and metalloproteases based on the amino acid residues involved in the active center.

    Most serine proteases have three catalytic residues in the active center: serine (Ser), histidine (His), and aspartate (Asp), although some may have histidine or aspartate residues replaced by other amino acids. These three residues are not adjacent to each other in the amino acid sequence but are spatially arranged so that they are linked by hydrogen bonds in the order Ser-His-Asp, enhancing the (5) of the oxygen atom at the γ-position in the side chain of the serine residue.

    The physiological functions of proteases are diverse, and their activities are ingeniously regulated. In many cases, proteases are strictly regulated to function through (6)the inhibition of their activity with protease inhibitors, environmental factors such as pH, and intracellular or tissue localization. Moreover, (7)some proteases regulate the enzymatic activity of other enzymes by selectively degrading certain parts of them.

Question 5-1. Select the appropriate word(s) in the blanks (1) - (5) from the following options.

oxidoreductases / transferases / hydrophilic / hydrophobic / oxygen molecule / hydrogen molecule / amino / carboxy / exopeptidases / endopeptidases / hydrolases / water molecule / isomerases / hydrophilic / hydrophobic / nucleophilicity / electrophilicity

Question 5-2. Regarding the underlined part (6), in general, enzyme inhibition can be either reversible or irreversible. Explain the difference between competitive and non-competitive inhibition among reversible inhibition in approximately 100 words.

Question 5-3. Regarding the underlined part (7), provide an example and explain it in approximately 100 words.

Question 5-4. Trypsin, a serine protease, specifically cleaves peptide bonds on the carboxy side of lysine and arginine in polypeptides. This substrate specificity, along with mass spectrometry, is utilized for protein identification. Explain the method in approximately 200 words.

QUESTION No. 6 (Subject on Life Science)

Read the following sentences and answer the questions in English.

Hemoglobin is the major protein in red blood cells that carries oxygen molecules to the tissues. It is a multi-subunit protein consisting of two α-globin chains, two β-globin chains, and a haem containing an iron atom attached to each globin chain.

In the human genome, the β-globin locus on chromosome 11 contains a group of six (a)β-like globin genes: ε, ^{G}γ, ^{A}γ, ψ, δ, and β, arranged in this order. Of these, the ψ gene is a pseudogene.

Each β-like globin gene is expressed in a developmentally specific manner: (b)ε-globin is expressed specifically during the embryonic period, while the two γ-globins are expressed mainly during the fetal period. In addition, δ- and β-globin are expressed postnatally—however, δ-globin accounts for only a tiny proportion and β-globin for the majority.

The genetic disorder sickle cell disease is caused by a single-base substitution (S-type) mutation in the β-globin gene that changes the amino acid sequence. If a person is homozygous for this mutation, the mutant hemoglobin molecules tend to aggregate into chains in low-oxygen conditions, such as in peripheral tissues, resulting in a sickle-shaped deformation of red blood cells. Therefore, it causes symptoms such as the formation of blood vessel blockages and the rupture of sickled cells, whereas people who are heterozygous for the S allele do not usually have sickle cell disease.

Despite having the genotype that causes such severe symptoms, some people do not develop sickle cell anemia. In these human erythrocytes, γ-globin, which is expressed only during the fetal period, is known to continue to be expressed after birth, reducing the symptoms caused by S-type β-globin, known as hereditary persistence of fetal hemoglobin (HPFH).

Recently, genome-wide association studies (GWASs) were used to search for the genes responsible for HPFH. The results showed that HPFH is strongly associated with single nucleotide polymorphisms (SNPs) in the second intron of the *BCL11A* gene on chromosome 2.

11

The *BCL11A* gene had been known to be a transcriptional regulator expressed mainly in lymphocytes and erythroblasts, the precursors of red blood cells. Therefore, (c)when the second intron of the *BCL11A* gene, including the location of the SNPs associated with HPFH, was deleted in erythroblast cells expressing BCL11A and β-globin, the expression of the *BCL11A* gene disappeared, and γ-globin was expressed in addition to β-globin.

Question 6-1. For the underline (a), how is the β-like globin gene cluster thought to have evolved? Answer in about 50 words.

Question 6-2. For the underline (b), why is the substitution of β-globin for γ-globin presumed to occur? Answer in about 30 words.

Question 6-3. It is known that the gene frequency of the β-globin gene mutation that causes sickle cell disease is significantly higher in Central Africa than in other regions. What are the reasons for this? Answer in about 50 words.

Question 6-4. What is a genome-wide association study? Answer in about 50 words.

Question 6-5. What function is thought to exist in the second intron of the *BCL11A* gene? Answer in about 30 words.

Question 6-6. For the underline (c), what is the possible function of BCL11A from this experiment? Answer in about 20 words.

QUESTION No. 7 (Subject on Life Science)

Read the following text and answer the questions in English.

To determine DNA sequences, the (1) method is generally utilized. First, the complementary base sequence of the target DNA fragment is extended by using (2) substrates, and (3) substrates with different fluorescent markers for each base is added to the extending end, causing the extension reaction to stop. The reaction products are then separated by (4) electrophoresis according to their molecular weight, and the fluorescence is detected in the order of (5) molecular weight, thereby determining the base sequence of the target DNA fragment. Compared to this conventional Sanger sequencer, (6) sequencer allows rapid determination of DNA sequences in a cost-effective manner. As a result, the entire (7) sequence analysis has become more convenient, and various genes responsible for specific biological functions are disclosed and the existence of numerous genes with unknown functions has also been revealed. Various methods are being employed to analyze the functions of the unknown genes, (8)such as inactivating (or activating) gene functions within a cell to understand their roles.

Question 7-1. Select the most appropriate word(s) in the blanks (1) - (7) from the options below to complete the abovementioned text.

ddNTP / dNTP / dATP / next generation / next era / increasing / decreasing / dye primer / dye terminator / genome / cell / amino acid / capillary / SDS-PAGE

Question 7-2. The mechanism of synthesizing proteins from the corresponding genes differs significantly between eukaryotes and prokaryotes. Select all the descriptions related to eukaryotes from (a) to (d).

(a) mRNA is translated on the ribosome in the cytoplasm.
(b) Multiple genes are transcribed onto a single mRNA.
(c) Transcription occurs in the nucleus by RNA polymerase.
(d) Unnecessary proteins are degraded by the proteasome.

Question 7-3. (8) The powerful new technology called CRISPR-Cas9 system has been developed to edit the genomes of cells and organisms in order to inactivate gene functions. Explain this genome editing technique in about 60 words by using the following terms.

・guide RNA(gRNA)　　・Cas9　　・double-strand break (DSB)

13

Question 7-4. The CRISPR-Cas9 system is expected to be applied to improvement of agricultural productions toward better quality and quantity. Describe the difference of CRISPR-Cas9 system from the conventional genetic engineering in about 20 words.

QUESTION No. 8 (Subject on Life Science)

Read the following text and answer the questions in English.

Lysosomes of animal cells are organelles containing enzymes that allow cells to hydrolyze macromolecules. Lysosomal enzymes are most active in (1) environments within lysosomes. Hydrolytic enzyme groups are synthesized in the (2) and then transported to the (3), where they are subsequently modified. Lysosomes undergo intracellular digestion in a variety of situations. Amoebas, for example, take in small organisms and granules that serve as food through a process called (4). Among human cells, (5), one of the white blood cells, perform (4). They play a role in protecting the body by taking in and digesting bacteria and other organisms.

Question 8-1. Write the most appropriate words in the blanks (1) through (5).

Question 8-2. Select one of the following sentences that is incorrect and write its symbol. And correct the incorrect word(s).
Example e) photosynthesis → respiration

a)   Lysosomal hydrolytic enzymes may work to recycle the cell's own organic matter.
b)   Vacuolar membranes (tonoplasts) are selective for solute transport.
c)   Many unicellular eukaryotes in seawater have contractile vesicles that drain excess water out of the cell.

Question 8-3. In plant cells, certain organic compounds contained in vacuoles play a role in interactions with animals. Give two examples.

Question 8-4. A mature plant cell has a large central vacuole. Describe one possible primary role of the central vacuole other than being a storage site for ions. In addition, explain the advantage of having a large vacuole in the role you answered.

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

Read the following text about the photosynthetic pigments in seaweeds and answer each question below.

　　　　Seaweeds have unique pigments specific to each taxonomic group in addition to the photosynthetic pigments shared with land plants. Depending on the composition of these photosynthetic pigments, different species dominate in the intertidal zone, which receives direct sunlight, and the subtidal zone, which only receives weak light due to seawater. The light rapidly reduces in water, with (i) light being the most quickly reduced, while (ii) and (iii) light can reach the deepest. The primary photosynthetic pigment common to all taxonomic groups is (iv), and in green algae, chlorophyll *b* and (v) act as light-harvesting (accessory) pigments. Brown algae have (vi) and (vii) as lineage-specific pigments, while red algae have (viii) and (ix) as their specific pigments. Particularly, (vii) and (ix) can efficiently absorb (ii) light that reaches deep into the sea, effectively utilizing it for photosynthesis. Green algae, like *Codium* growing at the subtidal zone, possess (x), which can absorb (ii) light.

Question 9-1. Select appropriate words from the word list below to fill in the blanks (i) to (x).

blue, red, yellow, green, carotene, chlorophyll *a*, chlorophyll *c*, siphonaxanthin, phycoerythrin, phycocyanin, fucoxanthin, lutein

Question 9-2. In red algae, individuals growing at the upper and lower parts of the intertidal zone often have different body colors, even within the same species. Explain in 60 words what could have caused this phenomenon.

Question 9-3. Describe the life history of the green alga *Ulva australis* (Ana-aosa) and the red alga *Pyropyra yezonensis* (Susabi-nori) in about 100 words using the following keywords, focusing on changes in the ploidy, the timing of the meiosis, the shape of reproductive cells, and differences in body size between generations.

Keywords
Ulva australis: gamete, gametophyte, sporophyte, zoospore
Pyropyra yezonensis: conospore, spermatangia, carospore, carposporangium, carpogonia, gametophyte, sporophyte, monospores

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

The following sentences mention the fishery resources and fisheries. Read the text and answer each question.

Marine finfish are diverse but can be divided broadly into (i) and (ii). The former inhabits the water column, whereas the latter dwells near or on the sea bottom. (i) includes Anchovy, Mackerel, and Tuna. (ii) includes Hake, Haddock, and Cod. Most of the world's oceans are sparsely populated with organisms because their water has low concentrations of dissolved nutrients and thus lower (iii). Consequently, commercially important fish stocks tend to aggregate in two areas of the oceans: in the water of the (iv), where food abounds because of the proximity of the continents and their rich river supply of nutrients, and in a few (v) of the world, such as off western Africa, western United States and western South America along Peru and northern Chile. The (iv) is a gently sloping shelf-like topographical area around the continent, and the (v) is an area with currents that carry nutrients from the lower layer to the surface layer.

Ocean fishing is a big business because fish cluster in the relatively shallow water that surrounds the continents. There they feed and breed and, for the most commercially important species, aggregate tightly into schools composed of thousands and even millions of individual fish. <u>They are relatively easy to detect with acoustic measuring equipments</u>. Using the equipments, vast fishing fleets deploy a variety of nets to catch them, including stern trawl nets, purse nets, and drift nets.

Question 10-1. Fill in the blanks from (i) to (v) with the most appropriate term, and describe it on the answer sheet (an example of an answer, (i)-term).

Question 10-2. Regarding the underlined sentence, please explain in about 100 words what type of acoustic measuring equipments are used to search for fish schools, and how they work.

Question 10-3. Please explain in about 150 words the problems regarding the use of drift nets in sustainable use of marine biological resources.

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

Answer the following questions on the Beverton-Holt and Ricker stock-recruitment models, which are widely used in reproduction model to quantify stock-recruitment relationships.

The Beverton-Holt stock-recruitment model is given by

$R = \alpha S/(1+\beta S)$ where, S: Stock, R: Recruitment, α and β: constant

In this model, when S is small, R is approximately equal to (i), but as S increases, R asymptotically approaches (ii).

While, the Ricker stock-recruitment model is given by

$R = \alpha S\, e^{-\beta S}$ where, S: Stock, R: Recruitment, e: Napier's constant, α and β: constant

In this model, when S is small, R is approximately equal to (iii), but at $S =$ (iv) , R takes the maximum value (v) and as S increases, R asymptotically approaches (vi).

Question 11-1. Choose the most appropriate number or equation from the following that falls into (i) to (vi) in the above description on the two stock-recruitment models (duplicate choice allowed, where e is the Napier's constant).
(1): α, (2): β, (3): e, (4): $1/\alpha$, (5): $1/\beta$, (6): $1/e$, (7): $\alpha\beta$, (8): α/β, (9): β/α,
(10): $\alpha/(\beta e)$, (11): $\beta/(\alpha e)$, (12): α/S, (13): β/S, (14): αS, (15): βS, (16): 1, (17): 0

Question 11-2. Schematically illustrate the Beverton-Holt and Ricker stock-recruitment models, with "Stock (S)" on the X-axis and "Recruitment (R)" on the Y-axis. At that time, show in the diagram the numerical values or equations for (ii), (iv), (v) and (vi) of the **Question 11-1**.

Question 11-3. Write the meaning of the constants α and β in the Beverton-Holt stock-recruitment model in 20 words or less each, in terms of organisms.

Question 11-4. The Ricker stock-recruitment model is often adapted to salmonids species. Give the reasons for this in about 30 words or less.

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

Question 12-1. Indicate the two concepts of salinity used in oceanography and explain each in around 100 words including definitions, units, and measurement methods.

Question 12-2. Illustrate the variation of salinity in surface oceans from 40°N to 40°S to show how the salinity averaged for surface waters varies with latitude. Note that you should indicate latitude on the x-axis and salinity on the y-axis with clearly indicating the scales and values on each axis. Furthermore, briefly explain why salinity shows such a latitudinal change within 100 words.

Question 12-3. Answer the residence time of sodium in the ocean using the data below with briefly explaining the calculation process and units. The sodium concentration in the ocean is assumed to be in a steady state.

Parameter	Value
Surface area of ocean	4.0×10^8 km^2
Mean ocean depth	4000 m
Salinity of seawater	35
Percentage of sodium in salt	30 % in weight
Annual freshwater flux from rivers to the ocean	3.0×10^7 km^3
Sodium concentration in river water*	6.0 mg/L

Note *Corrected for cyclic salt

Question 12-4. When the residence time of silicon is calculated as in **Question 12-3**, it is about three orders of magnitude smaller than that of sodium. Explain the reason for this within 100 words.