Entrance Examination

For October 2022 and April 2023 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 and answer the questions.

Almost all animals don't have (a) enzymes that digest (A). (A) is a structural (B) which is the main component of plants as structural material. (C) inhabit the digestive tract of (b) certain kind of animals and convert (A) to a substance that the host can digest. Another example of the function for host metabolism by intestinal (C) is the synthesis of (D). (D) is necessary for blood coagulation and (c) Aves (d) must take (D) from food because of their lack of intestinal (C).

Question 1-1. Fill in the correct words from (A) to (D).

Question 1-2. For the underlined sentence (a), describe the functions of digestive enzymes and hormones secreted by the stomach of mammals in about 100 words.

Question 1-3. For the underlined sentence (b), ruminant is one of such kind of animals. Describe the characteristics of the gastrointestinal tract of ruminants in about 100 words.

Question 1-4. Describe the functions of crops and characteristics of stomach of underlined Aves (c) comparing with mammals in about 100 words.

Question 1-5. For the underlined sentence (d), write down the term of such substances which is necessary for animal health, but they cannot make themselves. And give 2 examples of the substance and each deficiency disease.

QUESTION No. 2 (Subject on Field Science)

Read the following text related to nitrogen and answer each question below.

A) Environmental load in agriculture

Nitrogen is one of (a) the three most important elements for fertilizer. In nature, N_2 circulates in the ecosystem; N_2 in the air is fixed by rhizobium and other bacteria. In addition, nitrogen has been used in various applications such as nitrogen fertilizer because of artificial ammonia synthesis by the Haber-Bosch process.

Excessive synthesized nitrogen compounds are released into the atmosphere as air pollutants and greenhouse gases; (1) and ammonia. They have a significant impact on the natural world. As a global warming countermeasure in agricultural production, (b) it is important to reduce emissions of (1) and (2) from paddy fields and livestock, as well as carbon dioxide.

Question 2-1. Regarding underlined words (a), answer the two major elements except nitrogen.

Question 2-2. Fill in the most appropriate word(s) in blanks (1) and (2).

Question 2-3. Regarding underlined sentence (b), consider for reduction of greenhouse gas on crop production and summarize them in about 150 words.

B) Amino acids and proteins

Nitrogen is a major constituent of proteins. Proteins in living organisms have diverse structures and many functions. However, (c) proteins are merely assemblies of only twenty sorts of amino acids.

Question 2-4. Regarding the underlined sentence (c), answer one for each of the three groups of amino acids that make up living organisms: polar amino acids, nonpolar amino acids, and aromatic amino acids.

Question 2-5. Regarding the underlined sentence (c), answer how amino acids are bound using the keywords below about 150 words.

Keywords; dehydration reaction, disulfide bond, polarity, electric charge

QUESTION No. 3 (Subject on Field Science)

Read the text below and answer the questions 1-5.

The three elements of biodiversity are referred to as (a) species diversity, (b) genetic diversity, and (c) ecosystem diversity. Threats to the diversity of wild plants are increasing, and about 25 % of wild vascular plant taxa in Japan are listed in the Red List (the Ministry of the Environment, Japan, 2020). Major threats that increase the risk of extinction include (d) habitat fragmentation and loss by land-use change, excess collection or harvesting, overgrazing by herbivorous animals, and so on. To evaluate the population dynamics of an endangered plant species, i.e., whether specific population is increasing, decreasing or keeping stable, under the condition without drastic environmental change, construction of (e) life table based on the age constitution of the population is a useful method in population ecology.

Question 3-1. This is a question regarding the underlined term (a). Assuming that a large geographic area is subdivided into small unit (site), how "alpha diversity", "beta diversity", and "gamma diversity" are calculated on the basis of the number of species? Explain in about 60 words.

Question 3-2. This is a question regarding the underlined term (b). Gene diversity is a measure of the extent of allelic diversity at each locus, and it is quantified using the frequency of heterozygotes. First, write the general formula for expected heterozygosity (He) under the assumption of random mating, using pi that is the frequency of the i-th allele within a population. Second, explain two phenomena that cause the deviation of observed heterozygosity from expected heterozygosity in about 40 words.

Question 3-3. Regarding the underlined term (c), ecosystem diversity is evaluated based on two different aspects of ecosystem. Explain these in about 60 words.

Question 3-4. Regarding the underlined term (d), explain how habitat fragmentation causes genetic degradation of the population, using the following two terms: “recessive harmful allele” and “weakly harmful mutation” in about 40 words.

Question 3-5. Regarding the underlined term (e), explain how net reproductive rate R_0 is calculated using the following two terms, where x indicates age, in about 60 words.

- survivorship l_x
- age-specific fecundity m_x

QUESTION No. 4 (Subject on Field Science)

Answer each question about cross-pollination and ploidy levels in plants.

Question 4-1. When cross-pollination was conducted between a diploid plant and a tetraploid plant in same species, answer the ploidy level of the hybrid plants.

Question 4-2. In the case of cross-pollination between diploid and tetraploid plants (as stated in Question 4-1), explain the differences in the genetical properties between the hybrid offspring produced by diploid plant (i.e., their father is tetraploid) and the hybrid offspring produced by tetraploid plant (i.e., their father is diploid).

Question 4-3. When pollen fertility of the hybrid plants between diploid and tetraploid plants (as stated in Question 4-1) was tested, it was proved that the pollen did not have germination ability. Explain the possible reason of this phenomenon.

Question 4-4. Explain a method producing tetraploid plants from diploid plants.

Question 4-5. Explain a method producing haploid plants from diploid plants.

Question 4-6. Explain the following terms:

(1) Aneuploid

(2) Alloploidy / Autoploidy

(3) Double fertilization

(4) Horizontal gene transfer

QUESTION No. 5 (Subject on Life Science)

Read the following sentences and answer the questions.

The endomembrane system (ES) is a complex membrane network that structurally divides the functions of eukaryotic cells. ES includes nuclear membrane, endoplasmic reticulum (ER), Golgi bodies, lysosomes, vesicles, endosomes, and (①) membrane. Each membrane system does not exist independently but is interacted with each other. Most of ES are occupied by ER. In addition to the biosynthesis of cellular compounds as well as the processing and transport of membrane or secretory proteins, ER plays a central role in the storage and release of the signaling molecule, (②) ion. ⓐThere are two structurally different regions in ER: those with ribosomes scattered on the surface are called (③)-surfaced ER, and those with almost no attachment are called (④)-surfaced ER. They act differently in the production of cellular compounds.

ⓑCompounds made from ER are transported to the Golgi bodies by transport vesicles and undergo chemical modifications such as glycosylation, while some of them remain inside ER. The Golgi bodies exist as a multilayer of separate sacs. The receiving side from ER is called the (⑤) plane, and the side sending out secretory vesicles is called the (⑥) plane. Compounds completed in the Golgi bodies are stored in secretory vesicles and finally transported outside the cell or to the target site. The normal functions of ES are essential for maintaining homeostasis of cells. When exposed to cellular stresses, it falls into a disfunction specific for ES. In particular, when severe stresses are applied to ER, accumulations of unfolded proteins are observed, which may eventually lead to cell death. Thus, ER stress has been postulated to be involved in various diseases. ©The cell that senses ER stress tries to recover to a steady state by inducing 1) translational suppression of nascent proteins, 2) recruitment of the molecular chaperone, and 3) activation of the proteasome pathway.

Question 5-1. Answer the most appropriate words in the blanks from (①) to (⑥).

Question 5-2. Even in the same organelle, mitochondria and chloroplasts are often distinguished from other endomembrane systems. Answer the reason in about 100 words.

Question 5-3. Regarding the underlined part ⓐ, explain the differences in the functions of the endoplasmic reticulum with two distinct structures in about 100 words.

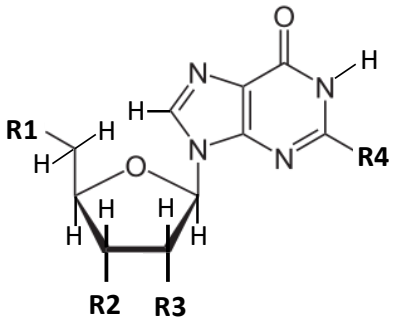
Question 5-4. Regarding the underlined part ⓑ, the text below explains the characteristics of the primary structure of a protein. Select the most appropriate protein with characteristics that is likely to remain inside ER.

a) It has a signal peptide centered on 5-10 hydrophobic amino acids at the N-terminus.
b) It has hydrophobic helix structures that span the biomembrane 7 times in the molecule.
c) It has a signal sequence K-D-E-L at the C-terminus.
d) It has a signal sequence rich in basic amino acids of P-P-K-K-K-R-K-V in the molecule.
e) It has an N-X-S/T glycosylation site of sugar chain in the molecule.

Question 5-5. Regarding the underlined part ⓒ, explain the mechanism of recovery from ER stress, in which unfolded proteins have accumulated, in about 200 words, including the specific functions of the three response reactions shown in the text.

QUESTION No.6 (Subject on Life Science)

Question 6-1. The figure depicts the structure of deoxyguanosine triphosphate. Choose the most appropriate answers that apply to R1-R4 from the choices given (a, b, c, d, e, f). The same choice may be used more than once.



(a) $-H$ (d) $-NH_2$

(b) $-OH$ (e) $-SH$

(c) $-CH_3$ (f) $-P_3O_{10}H_4$

Question 6-2. Select all correct answers from the following sentences.

(1) DNA primers are indispensable for the elongation of the lagging strand during DNA replication.
(2) RNA editing does not occur in eukaryotes.
(3) Methylated GTP is added to the 5 end of eukaryotic mRNA.
(4) Both the large and small subunits of the ribosome contain RNA.
(5) No tRNA recognizes nonsense codons.

Question 6-3. Nierenberg and his colleagues found that when artificially synthesized RNA in addition to ATP and amino acids was added to a crude extract of *E. coli*, the suspension functioned as a cell-free translation system and synthesized polypeptides. Khorana and his colleagues further proceeded to decipher the codons by adding artificially synthesized RNA with two- or three-base repeats to the above cell-free translation system. Assuming that a codon is specified by three bases, answer the following questions based on the results of Experiments 1, 2, and 3 below.

[Experiment 1]
When a repeat sequence of GU (GUGUGU...) was synthesized as RNA and added to the cell-free translation system described above, a polypeptide with alternating cysteine (Cys) and valine (Val) repeats was synthesized.

[Experiment 2]
When a repeat sequence of GGU (GGUGGUGGU...) was synthesized as RNA and added to the cell-free translation system described above, three polypeptides were synthesized: a polypeptide consisting only of glycine (Gly), another consisting only of valine (Val), and another consisting only of tryptophan (Trp).

[Experiment 3]
When a repeated sequence of AUG (AUGAUGAUG...) was synthesized as RNA and added to the cell-free translation system described above, only two polypeptides were synthesized, one consisting only of methionine (Met) and the other consisting only of aspartic acid (Asp).

(1) Briefly explain, using the term "tRNA", why not only amino acids but also ATP were required in the experimental system for synthesizing polypeptides.

(2) From the results of Experiments 1 and 2, answer one codon each encoding cysteine and valine.

(3) The results of Experiments 1 and 2 suggest that two codons possibly specify tryptophan. Answer these two codons.

(4) Describe two possible reasons why only two polypeptides were synthesized in Experiment 3 while three polypeptides were synthesized in Experiment 2 in 40 words or less.

QUESTION No. 7　(Subject on Life Science)

Question 7-1. The following sentences mention the intercellular adhesion. Read the text and fill the blankets from （ a ） to （ j ） with the most appropriate term. Select the term from ① ～ ⑩ showing below. Describe the answer as 'a : term'.

Of all the social interactions between cells in a multicellular organism, the most fundamental are those that hold the cells together. Cell junctions are largely divided into three categories, based upon their functions:（ a ）junctions,（ b ）junctions, and（ c ） junctions.

（ a ） junctions connect the plasma membranes of adjacent cells in a sheet, preventing small molecules from leaking between the cells. This allows the sheet of cells to act as a wall within the organ, keeping molecules on one side or the order.

In （ b ） junctions, there are several types.（ b ） junctions called 'desmosome' connect the （ d ） of adjacent cells, which hemidesmosomes anchor epithelia cells to a （ e ）. Proteins called （ f ）, most of which are single-pass transmembrane glycoproteins, create the critical link. And,（ b ） junctions called 'adherens junctions' connect the actin filaments of once cell with those of neighboring cells or with the extracellular matrix. The linking proteins in these junctions are members of a large superfamily of cell surface receptors called （ g ） that bind to a protein component of the extracellular matrix.

（ c ） junctions establish direct physical connections that link the cytoplasms of two cells together, permitting small molecules or ions to pass from one to the other. In animals, these direct communication channels between cells are called gap junctions, and in plants, these channels are called （ h ）.

（ h ） in plants are organized on different principles from those of animals. This is because plant cells are imprisoned with tough（ i ） composed of rich in（ j ） and other polysaccharides.

① : cadherin　② : cell walls　③ : plasmodesmata
④ : cytoskeletons　⑤ : basement membrane　⑥ : anchoring (occluding)
⑦ : intergrin　⑧ : tight　⑨ : cellulose
⑩ : communicating

Question 7-2.

Explain ‘gap junctions’ in animal cells using all the following four terms in about 150 words. You can use the same term several times. Underline the terms that you used in the text.

1) connexin
2) connexon
3) hemichannel
4) opening and shutting function of the channel

QUESTION No.8 (Subject on Life Science)

Question 8-1. The following text mentions energy conservation in cells. Read the text and answer to questions.

An oxidation is the removal of electrons from a substance and a reduction is the addition of electrons to a substance. The (①) reaction, which is also the reduction, adds electrons and (②) to a substance, and the reverse reaction is the dehydrogenation reaction. Part of the energy from the redox reaction is conserved in activated carriers as high-energy chemical bonds and/or electrons at high energy levels. ATP, NADH and NADPH are representative activated carriers. ATP is formed by the phosphorylation of ADP. Addition of two electrons and (②) to NAD^+ and $NADP^+$ generates NADH and NADPH, respectively. The activated carriers are formed by the (③) reactions in which an energetically unfavorable reaction is driven by an energetically favorable reaction. These reactions are catalyzed by enzymes, which accelerate the reaction rates by lowering (④). These energy-rich compounds fuel energy-requiring cell functions.

(1) Describe the most appropriate term on the answer sheet to fill the blankets (①) to (④).

(2) Answer the full names of the underlined compounds.

Question 8-2.

Choose one correct sentence and describe the selected number on the answer sheet.

① Organisms live by creating energy.
② The reaction that desaturates fatty acids is oxidation.
③ Acetyl-coenzyme A contains a high-energy phosphate bond.
④ Cells are primarily composed of four elements, C, H, P, S.

Question 8-3.

The substrate-level phosphorylation and chemiosmosis are representative reactions in cellular energy metabolism. Explain these reactions in 80 words or less.

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

Question 9-1. Fisher's sex ratio, one of the adaptation strategy models, is an evolutionary stable strategy of frequency-dependent selection type. Fill ( ) in the next sentence.

Consider a group with two tactics. The evolutionary stability is a state in which the average adaptation of the two tactics that changes depending on the frequency in the group is equal. Taking the two tactics of "male" and "female" as an example, individuals in low frequency sex has more opportunities to meet the opposite sex, but when individuals in the same sex increases, the advantage disappears. Let's consider this in a formula. First, if the female male is "1: x", and the total number of individuals in the group is "n", the number of females is "(①)" and the number of males is "(②)". If "f" is the average number of offspring that one female produce is, the total number of offspring in the group is "(③)", and the average number of offspring sired by one male is (total number of offspring)/(total number of male) = "(④)". The average number of offspring produced by one female and sired by one male is the ratio of "(⑤ :)", which is (⑥) to the sex ratio. Therefore, less either of sex individual can leave many offspring and gradually increases individuals in the same sex. However, as the number of the same sex individuals increases, their chances to meet opposite sex individuals decreases, so the gender ratio is eventually stable at "(⑦ :)".

Question 9-2. Following text asks about the principles of mating system. Fill ( ) in the next sentence.

There is a group with the Fisher's sex ratio, that is, the 0 -year -old sex ratio is stable at "(⑧ :)". After mature, experimentally examining the breeding interval, it was found that male could breed five times a day and female once every two days. In other words, the potential breeding speed is different for male and female, and (⑨) is expected to be male: female ="(⑩ :)". However, in the wild population, the male was the maximum four times a day, the female breed only once every three days, and the ratio of mature individuals was "N" times of females. Therefore, the (⑨) is considered to be "(⑪ :)". In this way the reason why many mature males inhabit may be that males have lower (⑫) or (⑬) than females.

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

Question 10-1. Read the following text about the fundamental properties of water and answer each question below.

Water consists of two atoms of hydrogen that are chemically bounded to one atom of oxygen. It is well known that the (a) and boiling temperatures of water are much higher than expected when compared with chemically related (b) compounds((c), H_2Se, H_2Te). In fact, water is the only substance that can coexist naturally as a gas, a liquid, and a solid on the earth's surface. Therefore, it is not surprising to discover how fundamental it is to all forms of life.

The higher-than-expected (a) and boiling temperatures of water depend directly on the (d) structure of the water molecule. More energy is required than expected to vaporize liquid water and to melt ice because (b) bonds that join water molecules together must first be broken before the solid can melt and the liquid can vaporize. The unusually high (e) of water prevents extreme variation in the temperature of the oceans.

Because of the open-crystal structure of solid water, the (f) of ice is less than that of liquid water. That is, ice floats on water. ①When ice is warmed to 0℃, it begins to melt as thermal vibrations of the molecules cause the crystalline structure to break apart.

Pure water freezes at 0℃, but ②the addition of salt to the water lowers its freezing point. For example, seawater with salinity of 35‰ freezes at a temperature of (g) ℃.

Also, ③the (f) of water increases with salinity because solutes have a greater atomic mass than water molecules have.

(1) Fill the blanks (a) to (g) with the appropriate words.
(2) In the underlined part ①, how is the (f) of water changed as temperature continues to increase after melting. Explain it in about 20 words.
(3) In the underlined part ②, why is the freezing temperature depressed relative to that of pure water? Explain it in about 20 words.
(4) In the underlined part ③, if there is contact between fresh water and sea water without their turbulence, how phenomenon would occur? Explain it in about 10 words.

Question 10-2. Explain each pair of terms in limnology to make the difference clear. Explain it in about 60 - 100 words.

(1) Biochemical oxygen demand (BOD) and chemical oxygen demand (COD)
(2) Epilimnion and hypolimnion
(3) Dimictic lake and monomictic lake
(4) Surface seiche and internal seiche

Question 10-3. Read the following text about lacustrine food web and fill the blanks (a) to (e) with the appropriate words.

In pelagic food webs, it was recently elucidated that the carbon produced by phytoplankton was not enough to explain the growth capacity of animals higher up the food web in many lakes. One of the major missing links in many attempts to quantify energy flow was the (a) community, consisting of (b), heterotrophic flagellates, and (c). (b) retrieve part of their carbon from phytoplankton, zooplankton, and fish excreta in the form of (d) carbon, and then they are eaten by heterotrophic flagellates and (c), which in turn are eaten by rotifers, crustaceous zooplankton, and even small fish. Thus, part of the carbon lost from the pelagic system is returned to the traditional food web by (a) components. This recycling of carbon is termed the (a) (e).

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

Question 11-1. Primary factors limiting primary production in the ocean include solar radiation and nutrient concentrations. In about 250 words, explain how each factor regulates primary production. You may use diagrams in your explanation.

Question 11-2. As shown in the table below, total annual primary production in the oceanic area accounts for more than 80% of the total primary production, but fish production accounts for less than 1%. On the other hand, total annual primary production in the upwelling area is only 0.5% of the total primary production, but fish production accounts for 50% of the total production. Explain in about 250 words why the percentages of total primary production and fish production are reversed in the oceanic and upwelling areas, using the all following words. Underline the words when they are used in a sentence.

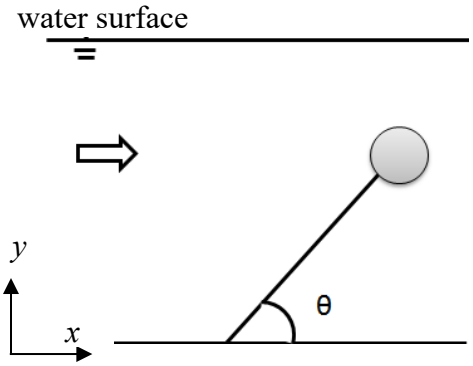
Words: transfer efficiency, ocean area, average number of trophic steps, size of primary producer, nutrients, number of transfers, diatom

Table. Primary production and fish production in each area.
(Invitation to Oceanography, Pinet, 4th ed. partly modified)

Area	Primary production ($gC/m^2/yr$)	Ocean area (km^2) (%)	Total primary production (t C/yr) (%)	Average number of trophic steps	Transfer efficiency per trophic level (%)	Fish production (t C/yr) (%)
Oceanic	50	$325x10^6$ 90.0	$16.3x10^9$ 81.5	6	10	$0.16x10^6$ <0.7
Coastal	100	$36x10^6$ 9.9	$3.6x10^9$ 18.0	4	15	$12x10^6$ 50
Upwelling	300	$0.36x10^6$ 0.1	$0.1x10^9$ 0.5	2.5	20	$12x10^6$ 50

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

As shown in the figure, a spherical float is moored by a thin metal wire in water with uniform flow. When trying to estimate the magnitude of the velocity of this uniform flow from the angle of inclination θ of the wire, answer the following questions. Assume that the wire is sufficiently thin that its mass and the fluid force acting on it are negligible, and that the floats are in equilibrium without oscillation.



Question 12-1. Buoyancy, gravity, drag, and other forces act on the float. Draw the above figure on your answer sheet and use arrows to indicate all the vectors of forces that are considered to act on the float. The arrows, however, should clearly indicate what the forces are.

Question 12-2. Assuming that the magnitude of the buoyancy force acting on the float is B, the magnitude of the gravitational force is G, and the magnitude of the drag force is D, express the inclination angle θ of the wire using B, G, and D.

Question 12-3. Assuming that the velocity of uniform flow is U ($\mathrm{m \cdot s^{-1}}$), the density of water is ρ_w ($\mathrm{kg \cdot m^{-3}}$), and the volume, projected area (area of the object viewed from the front), and drag coefficient of the floats are V ($\mathrm{m^3}$), S ($\mathrm{m^2}$), and C_d, respectively, express the magnitude of the buoyancy force B and drag force D acting on the float using these parameters. Let the gravitational acceleration be g ($\mathrm{m \cdot s^{-2}}$).

Question 12-4. Assuming that the object density of the float is ρ_M ($\mathrm{kg \cdot m^{-3}}$) (where $\rho_w > \rho_M$), express the inclination angle θ of the wire using the parameters given in Question 12-3.

Question 12-5. If θ represents an angle of 45 degrees, what is the approximate velocity U? Indicate the value using one significant digit. Let g=9.8 ($m \cdot s^{-2}$), ρ_w=1000 ($kg \cdot m^{-3}$), ρ_M=998 ($kg \cdot m^{-3}$), C_d=0.5, and the diameter of the float is 1.0 (m).