Entrance Examination
For October 2017 and April 2018 Students

Master's Course
# (Specialized Subjects)

Notes

- Select and answer <u>3</u> QUESTIONS from the total <u>12</u> QUESTIONS. The <u>3</u> 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 course 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 1　(Subject on Field Science)

Question 1-1. Read the following sentences, and answer the questions below.

　　The following figures indicate the typical patterns of trait change of organisms (quantitative variable) under different types of selective forces. Broken lines and solid lines indicate the distribution of trait values before and after selection, respectively. Arrows indicate the direction of selective forces.
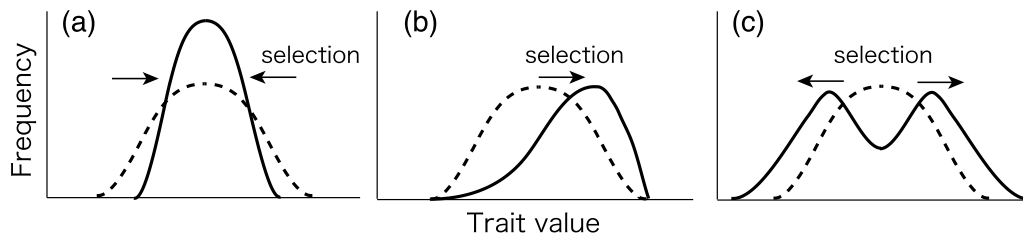
(1) Answer how each of the three types of selection shown as (a), (b), and (c) is called.
(2) Explain the ecological situation in which the trait change of type (b) is caused by interspecific interaction using a specific example.

Question 1-2. Choose three of the following five terms of evolutionary ecology, and explain the meaning for each.

(1) Trophic cascade effect
(2) Batesian mimicry and Müllerian mimicry
(3) Allopatric speciation and sympatric speciation
(4) Phenotypic plasticity
(5) Interference competition and exploitative competition

QUESTION 2 (Subject on Field Science)

The following text describes experiments and results concerning population dynamics. Read it and answer the **Questions** on the next page.

Three laboratory experiments about population dynamics of a prey-predator system were conducted (Fig 1).

Experiment 1 . A prey species A (hereafter referred to as Prey A) and its food were put into an experimental plot. Then the number of individuals of Prey A was recorded every 10 days for 110 days.

Experiment 2. Under the same conditions as Experiment 1, a predator species B (hereafter referred to as Predator B), which eats Prey A, was added to an experimental plot. Then each of the number of individuals for Prey A and Predator B was recorded every 10 days until they become extinct. Here, Predator B does not eat the food for Prey A.

Experiment 3. The plot was divided into small compartments of the same area. Both species can move between any of these compartments, while Prey A can move more easily compared to Predator B. Initially, the amount of the food for Prey A per unit area was the same among the compartments. In addition, the total amount of the initial food for Prey A in Experiment 3 was the same as in Experiments 1 and 2. The initial number of individuals of Prey A and Predator B introduced into each compartment was randomly determined. Other experimental conditions were the same as in Experiments 1 and 2. Each of the number of individuals for Prey A and Predator B was recorded every 10 days for 110 days.
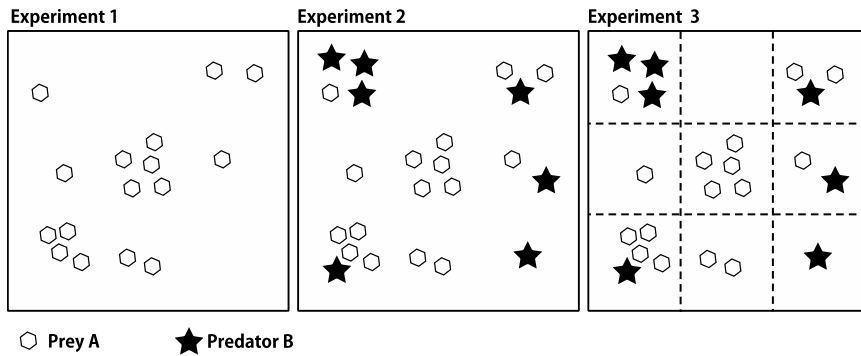
Fig 1.   A schema of the three experimental plots.

Then the following results were obtained (Fig 2).
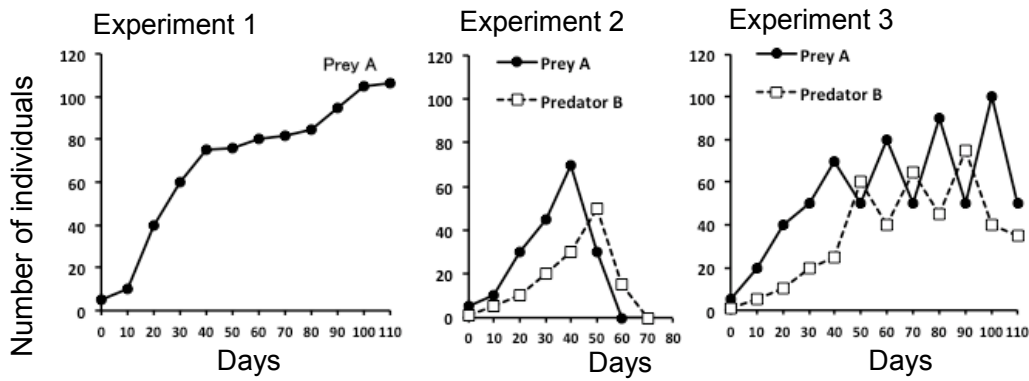
Fig 2. Results of the three experiments.

Question 2-1.

(1) Was the initial amount of the food of Prey A appropriate for conducting Experiment 2 and Experiment 3? Answer this question, stating the reason why you judged so.

(2) State whether or not the extinction of Prey A in Experiment 2 was caused by the initial amount of the food.

Question 2-2.

(1) In Experiment 2, both species (Prey A and Predator B) were ultimately extinguished. Explain a possible reason for this result.

(2) In Experiment 3, both species coexisted over the experimental period. Explain a possible reason for this result.

If necessary, all or a part of the key words below may be used in your answer to (2).

Key words: habitat, patch, metapopulation, immigration (movement), extinction

QUESTION 3 (Subject on Field Science)

Question 3-1.

In areas normally flooded with sea water or brackish water, <u>plants such as mangroves adapt to a saltwater environment with some parts submerged</u>. Read the text and answer each question.

(1) For a plant species such as the one described in the underlined text, explain the morphological features and their roles that allow for the submerged parts to remain alive.

(2) Explain the mechanisms for adjusting the salinity balance within the body of a plant species as described in the underlined text.

Question 3-2.

Leaf life span can be defined by the length of time from leaf emergence to leaf fall. It varies between plants of the same species according to their growth conditions, or between plants of different species according to their life form (e.g., herbaceous or woody, deciduous or evergreen). Deciduousness means that a plant has a leafless period within a year, whereas evergreeness means that a plant has no leaf-less period, though replacement of leaves may occur within a year.

State why some trees are deciduous and others are evergreen, from the viewpoint of differences in

(1) leaf photosynthetic rate,

(2) leaf structural materials, and

(3) environmental conditions of their habitats.

QUESTION 4 (Subject on Field Science)

Question 4-1. Read the following sentences, and answer the questions on the next page.

The logistic equation is a function that is widely used to describe the growth of a population. The logistic equation is defined as follows;

$$\mathrm{d}N/\mathrm{d}t = NR(1-N/K),$$

where N represents the population density; R, the inherent per-capita growth rate; and K, the carrying capacity. The competitive Lotka-Volterra equations, which are derived from the logistic equation, have been used to describe fluctuation of the populations of two species competing for the same resource. The competitive Lotka-Volterra equations are as follows;

$$\mathrm{d}N_A/\mathrm{d}t = N_A R_A(1- (N_A+E_{AB}N_B)\ /K_A)$$
$$\mathrm{d}N_B/\mathrm{d}t = N_B R_B(1- (N_B+E_{BA}N_A)\ /K_B),$$

where N_A and N_B represent the population density of species A and B, R_A and R_B are the inherent per-capita growth rates of species A and B, K_A and K_B are the carrying capacities of species A and B, E_{AB} is the negative effect of one individual of species B on the population growth of species A, and E_{BA} is the negative effect of one individual of species A on the population growth of species B.

These equations cannot be solved analytically. However, it is possible to draw the lines which satisfy $\mathrm{d}N_A/\mathrm{d}t = 0$ or $\mathrm{d}N_B/\mathrm{d}t = 0$ on a N_A-N_B plane. These lines are called isoclines. When population densities of species A and B are plotted as a point on a N_A-N_B plane, the position of this point relative to the isoclines indicates whether $\mathrm{d}N_A/\mathrm{d}t$ and $\mathrm{d}N_B/\mathrm{d}t$ are positive or negative. Thereby the fates of the population densities of species A and B can be examined.

(1) The isoclines of species A and B were obtained on a N_A-N_B plane as in Fig 1. Assume that the points C and D represent two cases of current population densities of species A and B. To which direction will these points C and D move? Choose the proper direction of arrow and answer by one of the numbers ①–⑧ for each of the points C and D.

(2) The isoclines of species A and B were obtained on a N_A-N_B plane as in Fig 2. Assume that the point F represents the current population densities of species A and B. Answer the population densities of the species A and B after a sufficiently long time.
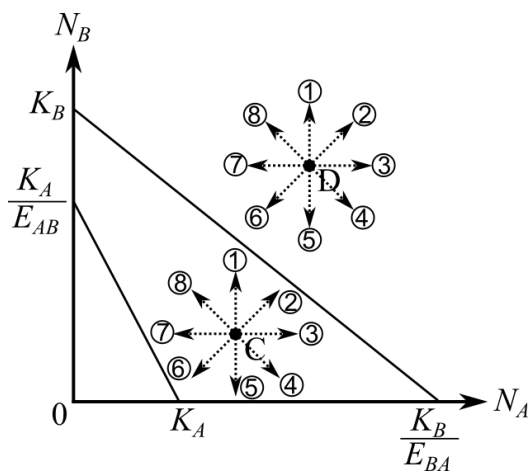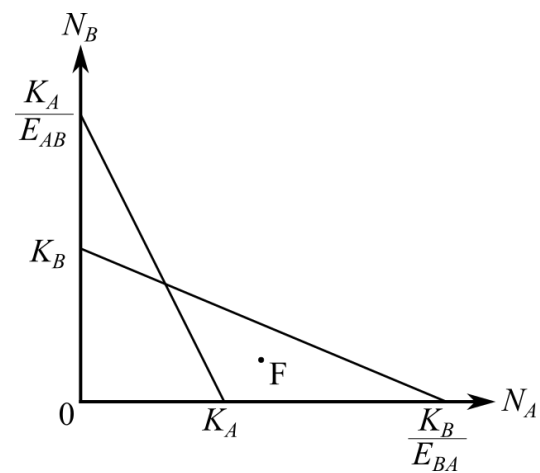
Fig 1

Fig 2

Question 4-2. Read the following sentences, and answer the questions below.

The mark-recapture method is one of powerful methods for estimating the size of an animal population in the field. In this method, some individuals in a target population are captured and their numbers are counted. They are then marked and released to the original population. After a given time interval, the second (or later) capture is conducted, and the number of marked/non-marked individuals are counted. The Petersen method is well known as a classic and simple method for estimating the size of a population.

The Petersen method estimates the size of a target population under (a)an assumption that the ratio of the number of marked individuals to that of the captured individuals at the second capture is equal to the ratio of the number of the captured individuals to that of all individuals of the population at the first capture.

(1) The Petersen method was conducted for a population of an animal species. At the first capture, 40 individuals were captured, marked, and released. At the second capture, 60 individuals were captured, of which 15 individuals had a mark. Estimate the population size using the Petersen method.

(2) It is often the case that the Petersen method overestimates the population size. This is likely because several assumptions of the Petersen method do not meet the reality. The Petersen method is based on several assumptions (other than the assumption underlined above marked (a)). Choose three of other assumptions on which the Petersen method is based, and state them.

QUESTION 5 (Subject on Life Science)

Read the following sentences and answer to each question.

Enzymes are biomacromolecular catalysts and accelerate chemical reactions. The molecules that enzymes act upon are called substrates and the enzyme increase reaction rates without altering the chemical equilibrium between substrates and products. Most chemical catalysts speed up a wide range of reactions. They are not usually very selective with their reactant. In contrast (a)enzymes are usually highly selective, catalyzing specific reactions only. (b)The substrate binds to a specific region of the enzyme, called the active site. While bound to the active site, the substrate is converted into the product of the reaction, which is then released from the enzyme.

The catalytic activity of enzymes is affected by temperature and pH. (c)Each enzyme has an optimal temperature and pH that favor the native conformation for maximum activity. (d)Some chemical materials, called as inhibitors, reduce or block the activity of enzymes. Since inhibitors modulate the function of enzymes they are often used as drugs.

(e)Some enzymes require non-protein helper molecules known as cofactors for catalytic activity. Enzymes activities under physiological conditions are controlled through various regulatory mechanisms such as (f)allosteric modulation, reversible covalent modification, (g)proteolytic activation of proenzyme and control of enzyme quantity.

Question 5-1. Regarding the underlined sentence (a), what is called the ability of an enzyme to select exact substrate?

Question 5-2. Regarding the underlined sentence (b), explain briefly in about 100 words "the lock-and-key model" of enzyme action.

Question 5-3. Regarding the underlined sentence (c), explain why enzyme activity declines at higher temperatures than the optimum temperature in about 150 words, using terms "the secondary structure" and "the tertiary structure" of a protein.

Question 5-4. Regarding the underlined sentence (d), there are four main types of inhibition (competitive, noncompetitive, uncompetitive and mixed inhibition) that are most commonly used to describe the binding of an inhibitor to a target enzyme.
Explain competitive inhibition among them in about 100 words.

Question 5-5. Regarding the underlined sentence (e), write the names of two representative groups of cofactors.

Question 5-6. Regarding the underlined terms (f), describe briefly about allosteric enzymes in about 150 words.

Question 5-7. Regarding the underlined terms (g), give some examples and explain briefly in 150 words.

QUESTION 6　(Subject on Life Science)

Read the sentences and answer the following questions.

　Protein is synthesized in cells through the expression of genomic information: DNA → mRNA →protein. The process of protein synthesis from mRNA is called (　①　).The protein synthesis machine in cells is (　②　) and is constituted by more than 50 kinds of　(　③　) and several kinds of rRNA. The size of this machine in procaryotes represents (　④　)S. (　②　) consists of two subunits, a lage and a small subunit. The large subunit and the small subunit in in procaryotes represent(　⑤　)S and (　⑥　)S, respectively. S is the unit for sedimentation coefficient. (1) The total size of the machine (　④　)S does not correspond with the value by the simple addition of the two subunits, (　⑤　)S and (　⑥　)S.

　In bacteria, protein synthesis starts with the binding between the conserved sequences present upstream of a start codon in mRNA and the small subunit of　(　②　). In this binding, the conserved sequences in mRNA form base pairs with (　⑦　)S rRNA in the small subunit of　(　②　). (2) The sequences of(　⑦　)S rRNA are used for phylogenetic analysis in procaryotes.

Question 6-1. Fill in the blanks from (　①　) to (　⑦　) with the most appropriate term or number, and describe on the answer sheet (an example of answer, ①-term).

Question 6-2. Among the three kinds of RNA polymerases in eucaryotes, answer the name of the enzyme which plays a role in transcription of mRNA.

Question 6-3. Explain the modified structures present in 5´ and 3´ of matured mRNA in eucaryotes, respectively. Explain the functions of the respective structures briefly.

Question 6-4. Regarding the underline (1), explain the reason with approximately 30 words.

Question 6-5. Regarding the underline (2), explain the reason with approximately 30 words.

Question 6-6. SDS Poly-Acrylamide Gel Electrophoresis (SDS-PAGE) is the method used for separation of proteins by molecular size. Explain the principles of SDS-PAGE with approximately 100 words.

QUESTION 7 (Subject on Life Science)

The next sentence mentions the multicellular system of the living organisms. Read the text carefully and answer each question in English.

The living organisms are divided into the unicellular and the multicellular organisms. Since the higher organisms including the animal and plant kingdoms are all multicellular cells, the appearance of multicellular system should be an epoch-making event occurred in a long history of the organisms. The multicellular system might have also evolved the crucial cellular functions that have been utilized by the modern organisms. When the multicellular organisms make up the individual, active interplays among a variety of cells are necessary to maintain the life of the whole body, so that the mechanisms for cellular signaling have been developed. ①The method of cellular signaling is classified into the four types, including a) the direct contact, b) the paracrine-type, c) the endocrine-type, and d) the synaptic-type signaling, depending mainly on the distance between the sending and the receiving cells of the signal. Detailed processes evolved from the unicellular to the multicellular organisms are largely unknown, while animals, plants, and fungi appeared to be independently multicellularized. It is assumed that the organisms have acquired the multicellular system several times during the evolution. ②As the species that have acquired the multicellular system recently, the order of colony Volvox belonging to the green algae is known.

Question 7-1. The figure below shows the cell size of various organisms schematically. Answer the correct unit of the length to enter the blank parenthesis (①)～(④).
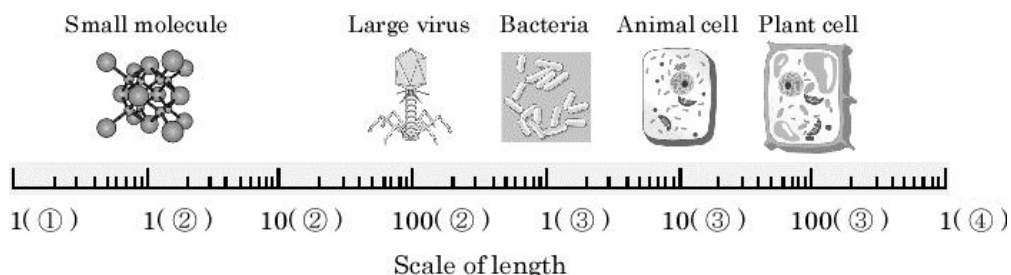
Question 7-2. For the underlined part ①, the method of cellular signaling by the soluble molecules can be classified into the four types. Briefly compare the differences among the four methods by explaining each characteristic within each 50 words.

Question 7-3. The figure below shows the synaptic-type signal in the nervous system. Answer the name of each part (①) ～ (④). Additionally, raise two names of the actual chemical transmitters released by the synaptic vesicles, and explain their physiological functions within each 50 words.
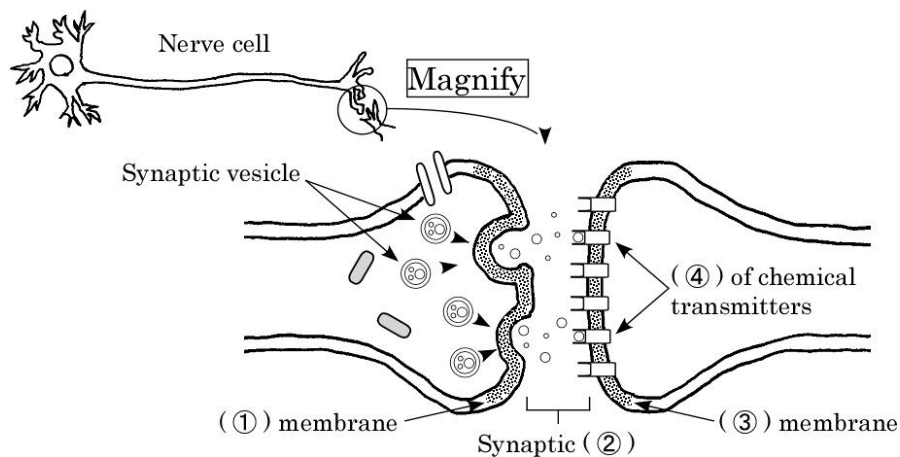

Question 7-4. For the underlined part ②, the order of colony Volvox is thought to be originated from the unicellular Chlamydomonas, and various types of multicellular forms are known. In order to investigate the processes evolved from the unicellular to the multicellular organisms, the researchers focused on the species of Gonium, which exhibits an intermediate nature between the unicellular and the multicellular organisms. When comparing the genomic information with the unicellular Chlamydomonas and the multicellular Volvox, the species of Gonium have newly acquired the genes encoded for RB (retinoblastoma) and cyclin D1 proteins that regulate the cell cycle widely distributed in the modern organisms. Based on this research report, consider what kind of cell function would be necessary at the initial stage of multicellularization of the organisms within 150 words.

QUESTION 8   (Subject on Life Science)

Question 8-1. There are various similarities between the energy metabolism of mitochondria and chloroplasts. For example, both mitochondria and chloroplasts contain an electron transport chain, which generates a proton motive force that allows for ATP synthesis. Answer the following two questions.

(1) Explain the differences in the phosphorylation system that allows ATP synthesis between mitochondria and chloroplasts in about 50 words.

(2) State the name of an electron donor for the mitochondrial electron transport chain and an electron donor for the non-cyclic (linear) electron transport chain in the chloroplast.

Question 8-2. Below is a figure showing the results that Blackman observed on the rate of photosynthesis, which led to the formulation of "Blackman's law of limiting factors". Answer the following questions relating to this graph.
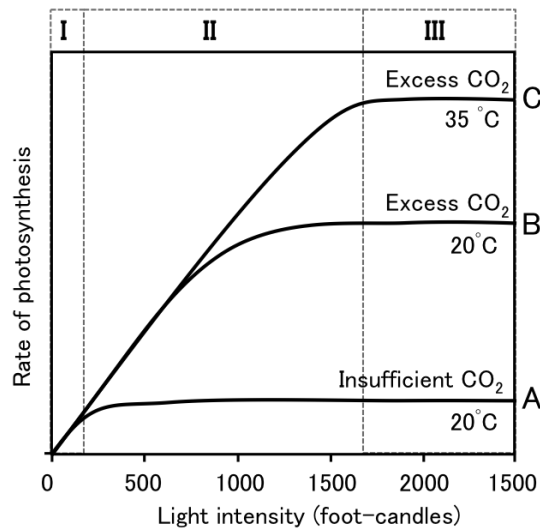

(1) List the three factors affecting the rate of photosynthesis displayed in this graph.

(2) State the limiting factor affecting photosynthesis at high light intensities for each of the conditions labeled A and B on the graph.

(3) Condition C is considered the maximum rate of photosynthesis. Explain (in around 20 words) a reason why further increasing the temperature does not increase the rate.

(4) Through the findings displayed in the graph, Blackman came to the conclusion that there are light-<u>dependent</u> and light-<u>independent</u> aspects of photosynthesis ("light reaction" and "dark reaction"). Explain how he came to this conclusion in less than 100 words. If necessary, use the phases marked in the graph (I, II, or III) in your explanation.

Question 8-3. The figure below shows the rate of net CO_2 assimilation for a C_3 plant and a C_4 plant at varying external CO_2 concentrations. Answer the following questions.
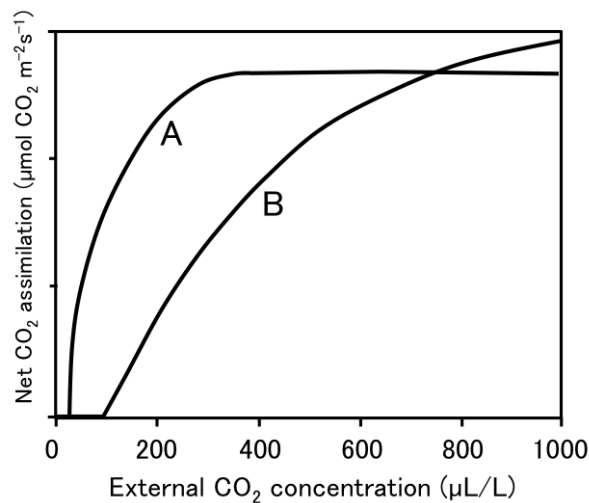

(1) Explain the main differences in photosynthesis between C_3 and C_4 plants. (In less than 100 words.)

(2) Is the curve labeled "A" in the figure above showing the CO_2 assimilation of a C_3 or a C_4 plant?

(3) Why does the plant represented by the curve labeled"A"have higher net CO_2 assimilation levels at low external CO_2 concentrations compared to the plant represented by curve"B"? Explain this phenomenon in around 50 words.

QUESTION 9 (Subject on Aquatic and Marine Science)

The figure shows a typical seasonal variation of phytoplankton biomass in surface waters in the temperate or subpolar regions.
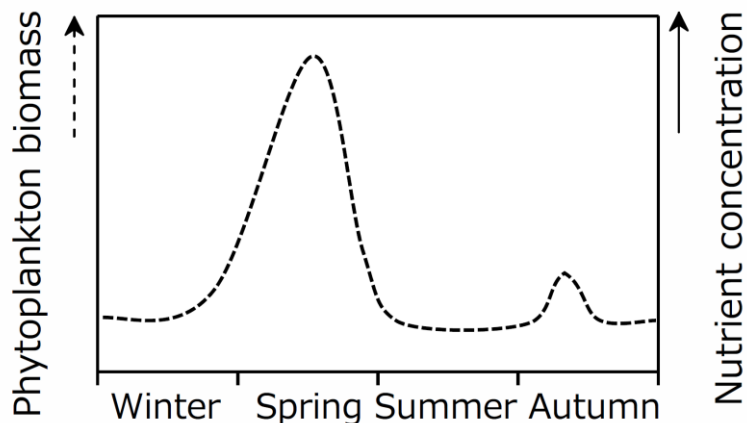
Question 9-1. Transcribe the figure on your answer sheet, and then add a line illustrating a typical seasonal variation of nutrient concentration. Do not consider a relative quantitative relationship between phytoplankton biomass and nutrient concentration.

Question 9-2. Explain the reason why phytoplankton biomass and nutrient concentration show those seasonal variations. Describe the answer for each season (winter, spring, summer, and autumn) approximately 50 words. Note that the following five terms must be used at least once.
- Vertical mixing
- Solar radiation
- Euphotic zone
- Thermocline
- Phytoplankton bloom

QUESTION 10 (Subject on Aquatic and Marine Science)

Read the following descriptions on the characteristics of diadromous fish and answer the questions.

Diadromous fish are classified to (①), (②) and (③) whether their hatching, growth, and spawning are performed in river or ocean. These diadromous fish are known to vary in geographical distribution by each type of fish. That is, (①) are tended to distribute in higher latitude, (②) are tended to distribute in lower latitude, and (③) are tended to distribute in middle latitude between (①) and (②). It is thought that these types depend on differences of their spawning areas and biological production in river or ocean by latitude.

For example, (④) born in the ocean of lower latitude where biological productivity is relatively low, and migrate to the river of lower or middle latitude where biological productivity is relatively high, and finally, move to the spawning area in the ocean of lower latitude. In contrast, (⑤) born in the river of higher latitude where biological productivity is relatively low, and migrate to the ocean of higher latitude where biological productivity is very high, and finally, they return to their mother river for spawning. Then, (③) are typed seawater form such as (⑥) and freshwater form such as (⑦), and both forms are characterized between (①) and (②).

Question 10-1. Fill in the blankets from (①) to (③) with appropriate words.

Question 10-2. Fill in the blankets from (④) to (⑦) with the appropriate name of fish from the following list.

Sweetfish, Common carp, Japanese eel, Japanese sea perch, Japanese sardine, Chum salmon, Pacific Bluefin tuna

Question 10-3. Briefly explain the following terms regarding fisheries management.

    (1) TAC (Total Allowable Catch)
    (2) CPUE (Catch Per Unit Effort)
    (3) VPA (Virtual Population Analysis)
    (4) IQ (Individual Quota)
    (5) MSY (Maximum Sustainable Yield)

QUESTION 11 (Subject on Aquatic and Marine Science)

Question 11-1. The following technical terms mean the reproductive modes shown in some fishes. Explain them exactly. Each term has plural patterns.

   (1) sequential hermaphroditism
   (2) unisexual reproduction

Question 11-2. Read the following sentences concerning mate-choice, and answer each question.

   (1) Sexually reproducing organisms can reproduce by mating with opposite sex. In most fishes, males and females choose their mates by different criterion. Explain the reason with considering "difference of gamete".

   (2) In seahorses and pipefishes, sexual role in mate-choice is done reversely in comparing most fishes. Explain the reason.

QUESTION 12 (Subject on Aquatic and Marine Science)

Read the following sentences and answer the questions.

Soft-bottom benthic community is commonly observed in estuaries where wave and water current are mild. The soft bottom ecosystem consists of various habitats such as salt marsh, tidal flat and seagrass bed which have high biodiversity and ①offer various ecosystem services highly valuable to human living.

One of the most prominent characteristics of estuaries is a steep salinity gradient caused by the mixture of freshwater and marine water. Furthermore, ②river input causes changes in water quality such as temperature, nutrient concentration and turbidity, which in turn affect organisms living in estuaries.

③Estuaries are highly vulnerable to human-induced stresses and impacts. In fact, tidal flats and seagrass beds, which are important habitats to marine organisms, have been disappearing worldwide. It is urgently required to develop plans for conservation and sustainable use of estuaries.

Question 12-1. Concerning ①, ecosystem services (defined as all the benefits that human received from natural ecosystems) are classified to provisioning services (providing resources that human can use directly), regulating services (control and regulation of climate, water, soil, etc.), cultural services (non-material benefits human obtains from natural ecosystems) and supporting services (all processes needed to support the direct services written above, such as nutrient recycling, primary production and soil formation). List up a specific service for each of four services by estuaries, and explain them briefly (approximately 20 words each).

Question 12-2. Concerning ②, the figure below shows the relationship between salinity and species richness/biomass of benthic animals in a typical estuary.

(1) Which line (A or B) represents changes in species richness?
(2) Explain why species richness and biomass of benthic animals change with salinity in these ways.
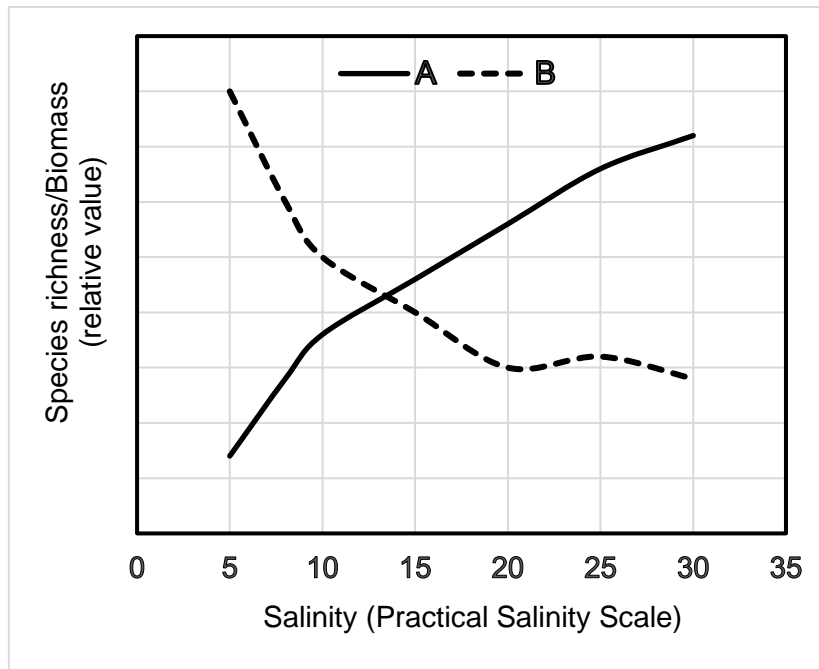
Question 12-3. Concerning ③, explain why biodiversity and ecosystem of estuary is highly vulnerable to human impacts using all of the following terms at least once.

Landfill, Nutrient, Sea level rise, Non-native species, Climate change, Port, Heavy rain, Human population, Agriculture, Sewage drainage