Entrance Examination
For October 2021 and April 2022 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.

- Examinee's number, Name, Subject and Question No. should be written on each answer sheet.

Division of Biosphere Science
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QUESTION 1 (Subject: Field Science)

Answer the following questions.

Question 1-1. Explain each pair of terms in (1) to (4) in the following to make clear the difference between the two terms. The answer should be no longer than 4 lines (two terms combined) for each of (1) to (4).

(1) Primary succession and secondary succession
(2) α diversity and β diversity
(3) Self-thinning and $-3/2$ power law
(4) Net primary productivity and gross primary productivity

Question 1-2. Explain the equilibrium theory of island biogeography proposed by R.H. MacArthur and E.O. Wilson, using all of the following terms. Write in about 2 lines.

colonization, extinction

Question 1-3. Explain the biomes of the Earth, using all of the following terms. Write in about 5 lines. If necessary, a figure may be used for explanation.

annual precipitation, mean annual temperature, tundra, desert, forest

Question 1-4. Explain the vegetation classification of the Japanese Archipelago, using all of the following terms. Write in about 5 lines. If necessary, a figure may be used for explanation.

subtropical forest, evergreen broad-leaved forest, deciduous broad-leaved forest, coniferous forest, alpine vegetation

QUESTION 2 (Subject: Field Science)

Read the text below and answer the following questions.

To discuss the mechanisms of speciation, we first need to define species. Among various definitions of species, (a) the biological species concept coined by the evolutionary biologist E. Mayr is widely known. The geneticist T. Dobzhansky defined species as a group of individuals which share a common gene pool. This means that there exist (b) mechanisms to prevent gene flow between different species.

Speciation occurs via divergence of initially identical populations and maintenance of differences that arise by (c) genetic drift and/or natural selection. Gene flow has the homogenizing effect but when gene flow only occurs between populations that are in contact, (d) allopatric speciation is likely in geographically isolated populations. (e) On a geological time scale, periodic geographic isolation promoted species formation. For example, in New Zealand, multiple species of alpine buttercup *Ranunculus* spp., that grow sometimes sympatrically in rocky crevices among outcrops within glacial areas, are considered to have evolved from a common ancestor as caused by repeated fragmentation of the distribution ranges in the Pleistocene.

Question 2-1. Explain the idea of the underlined term (a). Write in no more than 30 words.

Question 2-2. Regarding the underlined phrase (b), explain two types of prezygotic isolation mechanisms. Write in about 20 words for each mechanism.

Question 2-3. Explain the underlined term (c), using the words, Hardy-Weinberg equilibrium, founder effects, and the bottleneck effect. Write in about 100 words.

Question 2-4. The opposing concept of the underlined term (d) is sympatric speciation. Explain the process of sympatric speciation with chromosome polyploidization. Write in about 70 words.

Question 2-5. This is a question regarding the underlined sentences (e). Provide an explanatory hypothesis for the process of speciation from a common ancestor and

development of sympatric distribution of multiples species growing within glacial areas, based on the Pleistocene glacier expansion and retreat and the development of reproductive isolation. Write in about 80 words.

QUESTION 3 (Subject: Field Science)

The following sentences state an ecological explanation of the population of an organism. Read the explanation, and answer Question 3-1 to Question 3-3 below.

A group of individuals of the same species inhabiting a certain space at a particular time is called a population. Various kinds of interactions are involved in population dynamics, including (a)biological interactions with other individuals of the same species and with different species. One of major examples of interspecific interactions is (b)competition. The resources that a species requires and the environmental conditions in which it can survive are called (①). In the case of competition for the same (①), local extinction of one species can often be observed. Based on this observation, (②) was proposed by G. F. Gauze.

In addition, habitats in nature are neither homogeneous nor continuous. These have spatial structures (e.g., patch structures). In this case, there are sub-populations within the population, and a structure is formed in which the sub-populations interact with each other through limited individual migration. Such a population is called (③). The following mathematical model describes the patch occupancy dynamics of (③).

$$\frac{dp}{dt} = mp(1-p) - ep$$

p : A percentage of habitat patches occupied by sub-populations.
m: A probability that a vacant patch will be newly colonized by immigrating individuals
e: A probability that the sub-population occupying the patch will go extinct.

In order to find the condition for the persistence of (③), we can calculate the equilibrium condition of the model, that is, dp/dt = 0. If we replace the left-hand side of the above equation with 0, we can get the solution p = (④). p must be positive, so based on (④), we can express the persistence condition in terms of m and e as (⑤). In other words, when the probability that a new sub-population emerges (the probability that a vacant patch will be newly colonized) exceeds the probability that sub-populations will go extinct, the population should persist.

Question 3-1. For the underlined part (a), answer the name of the interaction between different species, which provides benefits each other while paying costs. Moreover, shortly explain such an interaction in terms of costs and benefits, raising a specific example in nature in 300 words or less.

Question 3-2. Answer the appropriate words, phrases, and expressions that fit in the blanks (①) to (⑤).

Question 3-3. To examine the effects of the underlined interaction (b), a graduate student proposed a following experimental plan. However, there are problems with his/her plan to test the effect of interspecific competition. Choose all appropriate criticisms from (A) to (G) below.

--- Graduate student's experimental design ---

Based on grassland observation, interspecific competition between species A and species B may have an important role for the spatial distribution and abundance of them. Therefore, I will conduct a field manipulative experiment to examine the effects of interspecific competition on the growth of these two species. The field manipulation experiment is conducted by planting different number of both species in pots. The total number of plants of two species in one pot is constantly 12 individuals in total. But the number of species A and B individuals varies as (i) 12:0, (ii) 9:3, (iii) 6:6, (iv) 3:9, and (v) 0:12, respectively. In each of (i) to (v), 10 pots will be used as replicates. Two months after planting, I will measure plant height, and then compare that among treatments (i) to (v). This will allow us to determine the strength of interspecific competition between the two species.
-- (END of the design explanation)--

(A) The experimental treatments of 9:3 and 3:9 are unnecessary and such unnecessary experimental treatments should not be added to the design.
(B) The data obtained from this experiment cannot correctly detect the effect of interspecific competition because it is not possible to distinguish whether it is due to density effect of the same species or the different species.

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(C) The effect cannot be fairly compared without measuring the height and stem diameter at the beginning of planting as well as two months later.

(D) In order to achieve the purpose of this research, it is necessary to combine the experimental treatments in which both the total number of individuals and the mix ratio of the two species are independently changed.

(E) Because it is impossible to distinguish whether the effect is due to intraspecific competition or interspecific competition, the strength of the effect of interspecific competition cannot be examined from the experimental data.

(F) Differences among treatments may not result from resource competition but from herbivory. Hence, toward detecting effects of resource competition exactly, it is critical to provide a mesh net to prevent herbivory or measure the amount of herbivory.

(G) It is sufficient to examine whether the field distributions of the two species are mutually exclusive. Manipulative experiments are not necessary for the purpose.

QUESTION 4 (Subject: Field Science)

Question 4-1. Read the text and answer each question.

In understanding the morphology, behavior, or life history of an organism, we should consider "why" and "how" the species has acquired such a trait. For example, the red body of flamingos can be explained as follows. Why: flamingos are reddish because individuals with red body are preferred by the opposite sex, thereby increasing the number of offspring. How: flamingos are reddish because their foods, such as seaweeds and crustacean, contain chemical compounds that produce red color. Why explanation is called as (1) factor, whereas how explanation is called as (2) factor.

Niko Tinbergen, who won the Nobel Prize in Physiology or Medicine, proposed that there are four answers to the question "Why is a certain behavior (or phenomenon) observed?" This can be considered as the further divisions of (1) and (2) factors. The "Tinbergen's Four Questions" is now widely recognized in various fields of life science, especially in animal behavior.

(1) Fill in the most appropriate word in blanks (1) and (2), respectively.

(2) Explain "Tinbergen's Four Questions" in 2-3 sentences each.

Question 4-2. Read the text and answer each question.

Many ecologists used to consider that biological communities are hardly to change and can quickly return to the (1) states even if they are influenced by human activities or natural disturbances. In addition, such stability was usually considered to be brought about as a result of (2).

Recently, this way of thinking has been reexamined. It has

been recognized that biological communities are constantly changing as a result of climate change, the invasion of new species, and disturbances. As a result, many ecologists are now advocating (3) models that emphasize change rather than stability. Ecological studies have particularly focused on (a) the role of disturbance in community structure and species diversity.

Source: The Raven & Johnson's *Biology* textbook (partly modified)

(1) Choose the most appropriate word from the following for blanks (1) to (3), respectively.

"succession, neutral, climate change, equilibrium, non-equilibrium, conflict, inter-specific competition, speciation"

(2) For the underline (a), how species diversity changes with increasing the level of disturbance? Explain the relationship with underlying mechanisms in 3-5 sentences.

Question 4-3. Over 90% of bird species are socially monogamous. It is also known that more than 90% of monogamous birds have offspring with other than their mating partners (called "extra-pair paternity"). For males, extra-pair paternity directly increases reproductive success. However, since the number of eggs that females can lay or the number of offspring that they can raise is limited, mating with extra-pair males may not necessarily increase the number of her fledgling. Then, what are the possible reasons for females to mate with extra-pair males? Explain three reasons in 2-3 sentences each.

QUESTION 5 (Subject: Life Science)

Question 5-1. Eukaryotic cell division consists of mitosis and cytokinesis. Answer the following questions.

(1) Explain the following terms in about 50 words each.
"chromosome", "chromatin", "chromatid"

(2) Explain the similarities and differences in cytokinesis between animal and plant cells.

Question 5-2. Answer the following questions about bacterial chromosome replication.

(1) The following table shows the bacterial DNA replication proteins and their function. Fill in the blanks ① ~ ⑤ with the appropriate sentences.

Protein	Function
Helicase	Unwinds parent double helix at replication forks
Single-strand binding protein	Binds to and stabilizes single-stranded DNA unit it is used as a template
Primase	①
DNA ligase	②
DNA polymerase I	③
DNA polymerase III	④
Topoisomerase	⑤

(2) Which is the correct description of the elongation of the leading strand during DNA synthesis? Choose the correct one from the following options.
(A) occurs in the 3′ → 5′ direction.
(B) produces Okazaki fragments.
(C) depends on the action of DNA polymerase.
(D) progresses away from the replication fork.

(3) Choose one reason why the leading and lagging strands of DNA molecules replicate in different ways.

    (A) The origins of replication occur only at the 5′ end.

    (B) DNA polymerase can add new nucleotides only to the 3′ end of a pre-existing strand, and the strands are antiparallel.

    (C) Helicases and single-strand binding proteins work at the 5′ end.

    (D) DNA ligase works only in the 3′ → 5′ direction.

Question 5-3. Bacteriophages are well-understood of all viruses. Some phages have two replication mechanisms, the lytic cycle and the lysogenic cycle. Explain their difference in about 100 words.

Question 5-4. SARS-CoV-2 is an RNA virus responsible for the coronavirus disease 2019 (COVID-19) pandemic. Explain the method and principle of detecting RNA viruses using PCR in about 100 words.

QUESTION 6 (Subject: Life Science)

Question 6-1. Read the text and answer the following questions.

Certain globular proteins are reversibly denatured by treatments such as heat, extremes of pH, or denaturing agents. If the protein is then gradually returned to its pre-treatment conditions, its original activity is restored. This process is called (①), which is exemplified in the following experiment.

First, purified ribonuclease A is completely denatured in a high concentration urea solution in the presence of a reducing agent. At this step, the reducing agent cleaves the four (②) bonds to yield eight thiol groups, and the urea breaks the (③) bonds that contribute to stabilization. As a result, it is released from its folded state and the activity of ribonuclease is completely lost. Then, the urea and the reducing agent are gradually removed, and the randomly coiled ribonuclease spontaneously refolds into its correct (④) structure and its activity is restored.

(1) Fill the blanks (①) to (④) with the appropriate words.

(2) Explain the process by which proteins are folded into the correct structure during synthesis in the cell, considering auxiliary proteins, in about 100 words.

Question 6-2. Describe the similarities and differences in the structural features of each of the following combinations.
(1) cellulose and glycogen
(2) D-glucose and D-fructose
(3) maltose and sucrose

Question 6-3. Read the sentences and answer the following questions.

Fatty acids generally have a long carbon skeleton consisting of 12 to 24 carbon atoms. The carbon at one end of the skeleton is part of a carboxyl group and the rest of the skeleton consists of a (①) chain. (②) have one or more double bonds between carbons, which reduces the number of hydrogens attached to the carbon. Nearly every double bond in naturally occurring fatty acids exist in (③)-form, which creates a kink in the (①) chain wherever it occurs. Therefore, the melting point of (②) is significantly lower than that of (④) with the same chain length. Fatty acids are present in (⑤) of phospholipids that are components of biological membranes.

(1) Choose the most appropriate word(s) to fill in the blanks (①) to (⑤) from the following terms.
   steroid, hydrophobic region, hydrocarbon, *trans*, saturated fatty acids, polycarbonate, unsaturated fatty acids, carbohydrate, *cis*, lipids, hydrophilic region, geometric isomer

(2) In many plants that tolerate extreme cold, such as winter wheat, the fatty acid composition of phospholipids changes in the fall. In addition, the composition of phospholipid fatty acids in insects adapted to cold regions is different from that in other species. Consider the cold adaptation of living organisms from the perspective of fatty acids, and describe it in about 100 words.

Question 6-4. For each the underlined part of the following sentences, replace it with the appropriate word(s), if it is not correct. Write "○" if it is correct.

(1) In bacteria, part of the RNA polymerase itself specifically

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recognizes and binds to a promoter. In eukaryotes, <u>repressor proteins</u> form a transcription pre-initiation complex and mediate the initiation of transcription by RNA polymerase.

(2) Eukaryotic mRNA maturation generally needs RNA processing, which includes the addition of a modified 5' cap to the 5' end, the addition of <u>a poly-T tail to the 3' end,</u> and RNA splicing.

(3) Many eukaryotic genes consist of multiple exons which are interrupted by introns. In RNA splicing, introns are removed, and exons joined to form a mature mRNA molecule. RNA splicing is usually carried out by <u>ribosomes</u>

(4) In some cases of RNA splicing, RNA alone catalyzes its own splicing. RNA molecules with an RNA splicing ability are called <u>protease</u>, and were first found in a protozoa called *Tetrahymena*.

(5) A tRNA molecule folds into a compact three-dimensional structure that is roughly L-shaped. The protruding 3' end acts as the attachment site for an amino acid. The loop extending from the other end of the L-shape includes an <u>anticodon</u>.

QUESTION 7 (Subject: Life Science)

The following sentences describe the transfer of substances through plasma membranes. Read the text carefully and answer each question.

(a)<u>Phospholipid bilayers constituting plasma membranes are hardly permeable to most polar molecules and ions</u>. Instead, (b)<u>ion and water (H_2O) channels</u>, and various (c)<u>membrane transporters</u> are embedded in plasma membranes, and these proteins transfer ions, sugars, amino acids etc. to create (proper) concentration gradients between the intracellular and extracellular space. For instance, the Na^+-K^+ pump in animal cells and the H^+-K^+ pump in bacteria generate concentration gradients of these monovalent cations and contribute to establishing (d)<u>membrane potential</u>. On the other hand, (e)<u>cholesterol, which is highly hydrophobic, is transported through the blood flow in a form that is encapsulated in lipoprotein particles. When the lipoprotein particles bind to specific receptors on the plasma membrane, the membrane becomes internalized, and as a result, the cholesterol is taken into the cell with the lipoprotein particles</u>.

Question 7-1. Regarding the underlined part (a), write the following substances in the order of "easily permeable", "moderately permeable", and "almost impermeable" when they permeate the lipid bilayer by simple diffusion without the aid of membrane proteins, including channel proteins and membrane transporters.

$$H_2O, \quad O_2, \quad Na^+$$

Question 7-2. Regarding the underlined part (b), the channels in plasma membranes are different from simple pores in two ways. Explain them in about 10 words each.

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Question 7-3. Regarding the underlined part (c), explain the three modes of membrane transport using all of the following terms in about 60 words in total.

    facilitated diffusion, ATP hydrolysis, coupled transport

Question 7-4. Regarding the underlined part (d), the following two processes are well known to illustrate an importance of membrane potentials in living organisms. ① neural transmission and ② ATP synthesis in mitochondria. Choose either ① or ②, and explain how the membrane potential is used in the process you choose in about 60 words.

Question 7-5. Regarding the underlined part (e), answer the following questions.

(1) Answer the name of the biological process in which cells import extracellular substances by the plasma membrane internalization.

(2) The low-density lipoprotein receptor (LDLR) is a receptor for lipoprotein particles. The gene expression of LDLR is positively regulated by sterol regulatory element binding protein (SREBP). On the other hand, the activity of SREBP is repressed when the intracellular cholesterol concentration is high. Answer the name of the latter gene regulatory mechanism, and briefly explain the biological merit of the gene regulatory mechanism.

QUESTION 8 (Subject: Life Science)

Read the following sentences on cell metabolism and answer the questions.

To maintain cellular functions, cells possess mechanisms to harvest energy by stepwise oxidation of carbohydrates. As a part of the process, glycolysis and the (A) cycle are shown in the figure.

In glycolysis, glucose is converted into pyruvate, yielding (B) and ATP. Under aerobic conditions, pyruvate is decarboxylated to form (B) and (C) . Transferring the acetyl group of (C) to (D) produces (A) , starting the (A) cycle. (B) and (E) function as electron donors that carry high-energy electrons.
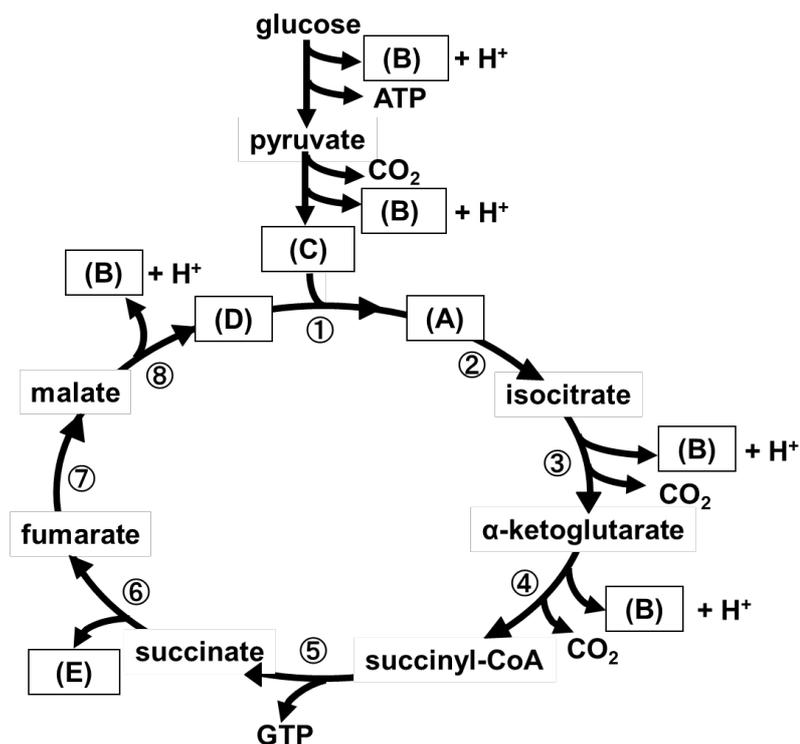
Question 8-1. When ATP (molecular weight: 507) was measured in the extract of animal cells, ATP concentration was found to be 1.521 g/L. Calculate the molar concentration (mol/L) of ATP in this cell extract. Answer the molar concentration with the unit.

Question 8-2. Fill the blankets (A) to (E) with appropriate compounds.

Question 8-3. In yeast under anaerobic conditions, pyruvate produced by glycolysis is converted into ethanol.
(1) Answer the name of the process.
(2) Ethanol cannot be used as energy for yeast. Explain why yeast produces ethanol under anaerobic conditions.

Question 8-4. Which organisms perform glycolysis? Describe the presence or absence of glycolysis in bacteria, archaea, animals and plants, respectively.

Question 8-5. Explain the roles of the (A) cycle in metabolism other than harvesting energy.

Question 8-6. Most of biological reactions are catalyzed by enzymes. In the reaction ⑥ in the (A) cycle, succinate is converted into fumarate, which is catalyzed by succinate dehydrogenase.

(1) When it is assumed that this enzymatic reaction follows the Michaelis-Menten equation, explain an experiment to estimate K_m and V_{max}. You can include a figure to explain.
   The Michaelis-Menten equation is presented as follows (v_0: initial velocity of the reaction, V_{max}: maximum velocity of the reaction, [S]: substrate concentration, K_m: Michaelis constant).

$$v_0 = \frac{V_{max}[S]}{[S] + K_m}$$

(2) Enzymatic activity of succinate dehydrogenase is inhibited by addition of malonate, which is structurally similar to succinate. Write the name of this type of enzyme inhibition, and explain how K_m and V_{max} will be changed when malonate is added to the reaction system described in (1) above. You can include a figure to explain.

QUESTION 9 (Subject: Aquatic and Marine Science)

Question 9-1. The three fundamental strategies for the sustainable use of fisheries resources are as follows: a) constant escapement strategy (CES), b) constant harvest rate strategy (CHR), and c) constant catch strategy (CCS). Select two the above three strategies and briefly explain each strategy along with its advantages/disadvantages (about 100 words per strategy).

Question 9-2. Explain the methods for conducting the basic measures of fishery resource management using all of the following terms (about 150 words in total).

Input control, Output control, Technical control, TAC (Total Allowable Catch), MPA (Marine Protected Area)

QUESTION 10 (Subject: Aquatic and Marine Science)

Read the following sentences, and answer the questions.

In recent years, the decline and disappearance of seaweed communities due to a lack of nutrients is becoming more serious. On the other hand, eutrophication of coastal areas is also seen due to landfill, construction of shore protection-works, living drainage and industrial drainage, and (a) the large-scale propagation of algae that absorb excess nutrients has been reported in various regions. Therefore, it is considered (b) to restore the environment by growing seaweeds that are resistant to eutrophication against environmental deterioration such as the load of nutrients in the sea. In addition, in fish and shellfish aquaculture grounds, attempts are being made to improve the marine environment by combined aquaculture in which useful seaweeds are also grown.

Question 10-1. List one of the visible changes that occur in the body of seaweeds due to a lack of nutrients.

Question 10-2. Explain the underlined part (a) in about 8 lines by giving examples that include both micro-algae and macro-algae.

Question 10-3. Regarding the underlined part (b), seaweeds such as *Ulva*, *Gracilaria* and coralline algae are said to be useful bio-filters for seawater purification. Explain one of these three seaweeds (*Ulva*, *Gracilaria*, coralline algae) in about 6 lines.

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Question 10-4. Explain the merits of "combined aquaculture" in about 6 lines.

QUESTION 11 (Subject: Aquatic and Marine Science)

Read the following text and answer each question below.

Marine organisms are classified according to their lifestyle into the following three groups; plankton (organisms drifting in the water column), nekton (organisms swimming in the water column) and benthos (organisms living on the sea floor). Benthos consists of various types of organisms, such as marine plants, invertebrates, fishes and many microbial species. Among these, (a) many invertebrate and fish species have characteristics of plankton or nekton during a part of their life cycles.

Benthic ecosystems are diverse, affected by various factors such as depth, bottom type, geography and the input from terrestrial ecosystems such as rivers. Among these, several conspicuous habitats in the near shore, such as tidal flats, seagrass/seaweed beds, mangroves and coral reefs are known to have high productivity and biodiversity. Generally, the productivity of benthic ecosystems decreases with depth, but some deep-sea ecosystems are known to have higher biomass and biodiversity than their surrounding habitats.

Question 11-1. List up two invertebrate taxa belonging to benthos, and describe the characteristics of each taxon in about 30-50 words.

Question 11-2. List up an animal species which has the characteristics written in the underlined part (a), and explain its life history in about 80-100 words.

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Question 11-3. Explain why coral reefs, seagrass beds and mangroves in the tropics have high productivity and biodiversity in about 80-100 words.

Question 11-4. Name a deep sea habitat which has high biomass and biodiversity and explain the reason in about 40-60 words.

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QUESTION 12 (Subject: Aquatic and Marine Science)

Answer the following two questions.

Question 12-1. Explain the mechanisms of Ocean Acidification and the specific issues on marine organisms and ecosystems caused by Ocean Acidification in total ca. 200 words.

Question 12-2. Phytoplankton absorb carbon and nutrients during photosynthesis in the sea, but carbon is not a limiting factor for photosynthesis even in phytoplankton blooms. Considering the chemical equilibrium of carbon, explain why carbon is not a limiting factor for photosynthesis in ca. 200 words.