

Entrance Examination

For October 2018 and April 2019 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 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
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QUESTION 1 (Subject on Field Science)

The following sentences mention interactions between plants and microorganisms. Read the text and answer each question.

The type of relationship where an organism coexists with another is called (1). In (1), the relationships between the host and the other (microorganism) species may be classified into three distinct types. In the first type, the host is attacked by the microorganism; this is termed (2). In the second type of relationship, called (3), the host is generally unaffected by the microorganism. The third relationship where both species benefit from each other is referred to as (4).

Moreover, the relationship between legume plants and Rhizobia is an example of (4). In this case, Rhizobia transforms gaseous nitrogen into (5), which is then converted to (6) by the plant and taken to each of its organs. In return, the plant supplies carbohydrates to Rhizobia.

Question 1-1. Fill in the correct words from (1) to (6).

Question 1-2. Explain the pathway from root nodule formation to nitrogen fixation in *Rhizobium*, using every term below:
flavonoid, nod factors, bacteroid, nitrogenase, and leghemoglobin.

Question 1-3. Nitrogen fixation by Rhizobia plays a key role in the nitrogen cycle in natural ecosystems. Explain the other three processes affecting the nitrogen cycle that involve soil microorganisms as well as their impact on natural ecosystems.

QUESTION 2 (Subject on Field Science)

Question 2-1. Answer each question about plant propagation.

- (1) Explain “propagation by apomixis” and describe its genetic characters.
- (2) Excluding apomixis, explain three types of vegetative propagation, naming specific plant species.
- (3) Some seeds are suitable for dispersal and may thrive in new habitats. Explain two ways seeds may disperse, referring to specific plant species.

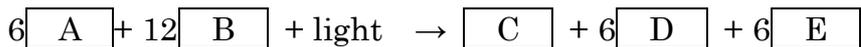
Question 2-2. Explain the following terms:

- (1) Parasitic plant
- (2) Carnivorous plant
- (3) Mycorrhizal fungus
- (4) Aggregate fruit
- (5) Drupe
- (6) True berry

QUESTION 3 (Subject on Field Science)

Read the following sentences relating to photosynthesis and answer each question.

The energy supporting life on Earth is produced by the photosynthesis of organisms capturing sunlight. Photosynthesis occurs in photosynthetic bacteria, algae, green plant tissue, etc. The cells of plant leaves contain organelles called (①) that play a significant role in photosynthesis. Inside (①), flattened saclike structures called (②) are stacked to form layers known as (③). Furthermore, there is a semiliquid substance called stroma surrounding the (②). The (②) membrane contains photosynthetic pigments that capture light and molecular machinery that synthesize (④). The stroma contains enzymes that use (④) and (⑤) to synthesize organic molecules from carbon dioxide. Photosynthesis is conducted in the following three steps: (1) light energy capture, (2) (④) and (⑤) production, and (3) use of (④) and (⑤) to synthesize organic molecules from carbon dioxide (this last step is termed (⑥) fixation). Additionally, the complete photosynthetic reaction may be expressed as the following formula:



Question 3-1. Fill in the correct words from (①) to (⑥) .

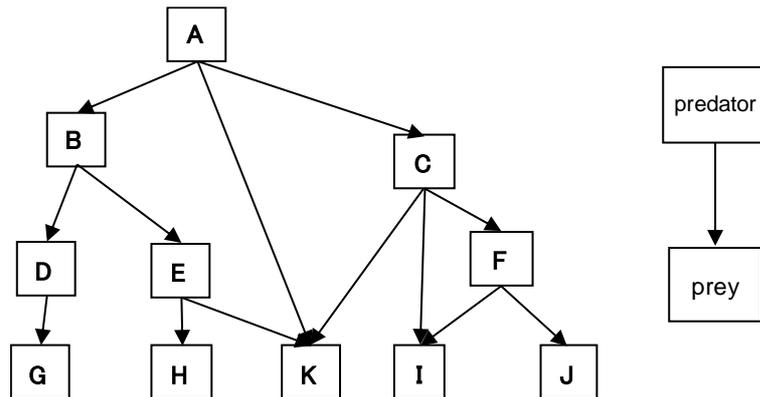
Question 3-2. Fill in the appropriate chemical formulae from (A) to (B) .

Question 3-3. Describe the differences between C₃ and C₄ plants.

Question 3-4. Plants utilizing crassulacean acid metabolism are generally called CAM plants. Describe the particular characteristics of photosynthesis in CAM plants, referring to differences between daytime and nighttime.

QUESTION 4 (Subject on Field Science)

Question 4-1. The following figure represents all predator-prey interactions in a hypothetical community. The arrows in the figure indicate combinations of predators and prey. Each square containing a letter represents an individual species. Answer the questions below.



- (1) With reference to the figure, what is the collection of all predator-prey interactions in a community called?
- (2) What is a species in the place of C called?
- (3) Determine the trophic level of species B.
- (4) Assuming the effects of all species are negligible except for species A, B, D, and G, how would you expect the removal of species A to change the abundance of species D and G? Please explain the basis of your predictions.

Question 4-2. The following descriptions explain predator-prey interactions. Select all the correct sentences and enter the corresponding numbers on the answer sheet.

1. In both natural habitats and laboratory experiments, predator and prey population dynamics sometimes exhibit oscillation.
2. In general, the effects of predation on a prey population intensify with increased prey density.
3. In laboratory experiments, predators often exterminate their prey.
4. Predation arising from biological invasion is an important cause of endemic species extinction.
5. A prey species is usually better dispersed than its predator.
6. In the coevolution of a one-to-one predator-prey system, an arms race generally continues indefinitely.
7. A predator may have a positive influence on a prey's population growth, if it consumes competitors of the prey species.
8. A generalist predator usually decreases prey species diversity, because it reduces the density of prey.
9. The prey choice of a generalist predator is affected by both nutritional quality and relative abundance of the prey.
10. On a global scale, predation often limits prey species distribution.

Question 4-3. The following descriptions explain circumstantial evidence of competition between two species in natural habitats. Select all the correct sentences and arrange their corresponding numbers on the answer sheet from the weakest to the strongest evidence.

1. Both species are observed in the same habitat.
2. Both species reproduce in the same season.
3. Resources use by one species reduces resource availability to another species.
4. Both are closely related species (e.g. congeneric species).
5. Body size and morphology are similar between the two species.
6. Both species consume the same prey species.
7. The population of one species increases if that of another species decreases.
8. Both species are included in the same trophic level.
9. Both species share the same predators.
10. The fundamental niches of both species overlap; in addition, intraspecific competition is detected for both species.

QUESTION 5 (Subject on Life Science)

Question 5-1. Read the following sentences about the body structure of mollusks and fill in the blanks.

Mollusks (phylum Mollusca) are bilaterally symmetrical, but this symmetry is modified in some groups. The digestive, excretory, and reproductive organs form the visceral mass. The muscular (①) is adapted for various functions, such as locomotion, attachment, digging, or food capture. A thick epidermal sheet, called the (②), covers the dorsal side of the body. The (②) forms a cavity between itself and the visceral mass. This cavity functions as a lung in some groups, whereas in other groups, it contains respiratory structures called (③), which are specialized parts of the (②) and consist of filaments with well-developed blood vessels. These structures increase the surface area for gas exchange and the efficiency of respiration.

Many marine mollusks have a free-swimming larval form, called the (④). They resemble the typical larval stage of marine annelids. The (④) swims by moving cilia that surround the middle of the body.

Question 5-2. Answer the following questions.

- (1) Terrestrial arthropods (such as insects) have a unique respiratory system of branched, cuticle-lined ducts. What is the name of this respiratory system?
- (2) Contrast the features of this respiratory system with those of the vertebrate respiratory system in about 30 words using the keyword “circulatory system”.
- (3) The limited oxygen supply due to the above-mentioned feature of the respiratory system is considered to be one factor limiting the maximum size of terrestrial arthropods. What is another possible major factor limiting the maximum size of terrestrial arthropods? Answer in about 10 words.

Question 5-3. Answer the following questions.

- (1) The human eye has the typical structure of the terrestrial vertebrate eye. In about 80 words, describe how the human eye focuses.
- (2) Compared with the mechanism in humans, amphibians and fish have a different mechanism of focusing. Briefly (about 10 words), describe the focusing mechanism of amphibians and fish.
- (3) There are two types of photoreceptors (cells) in the human retina. What are the names of these two types of cell?
- (4) Using the following keywords, describe the features of these two types of cell in about 20 words: dim, black-and-white vision, visual acuity, color vision

QUESTION 6 (Subject on Life Science)

Read the sentences and answer the following questions.

All living organisms are composed of one or more cells enclosed by a membrane. The basic structure of cell membranes is a lipid bilayer⁽¹⁾. In eukaryotes, endomembrane systems are highly developed for compartmentation in cells.

The flow of gene expression “DNA → (transcription) mRNA⁽²⁾ → (translation) protein” is common in prokaryotes and eukaryotes. Prokaryotes mainly regulate gene expression by controlling transcription⁽³⁾. In eukaryotes, post-transcriptional regulation, such as alternative splicing⁽⁴⁾, is found in addition to transcriptional regulation. This difference may be attributable to spatial and temporal differences between prokaryotes and eukaryotes in the processes from transcription to translation⁽⁵⁾.

Question 6-1.

Explain the structure of the lipid bilayer⁽¹⁾ in approximately 30 words.

Question 6-2.

RNA is subdivided into mRNA⁽²⁾, which encodes proteins, and non-coding RNAs that do not encode proteins. List three examples of non-coding RNAs and explain their respective functions.

Question 6-3.

Transcription of the tryptophan operon is downregulated when the tryptophan concentration is high in cells. Explain the molecular mechanisms⁽³⁾ underlying this downregulation in approximately 30 words.

Question 6-4.

Design and explain an experiment to examine whether alternative splicing⁽⁴⁾ is induced in gene *X* regulation (or expression of gene *X*) in response to a stimulus under the condition that gene *X* is a single-copy gene and the DNA sequence of gene *X* is available.

Question 6-5.

Explain the spatial and temporal differences between prokaryotes and eukaryotes in the processes from transcription to translation⁽⁵⁾ in approximately 40 words.

QUESTION 7 (Subject on Life Science)

Answer the following questions.

Question 7-1.

Read the sentences and answer the following questions.

Lederberg and Tatum conducted an experiment in which a new nutrient-requiring strain arose when two auxotrophs of *Escherichia coli* were mixed and co-cultured. They proved that genetic recombination occurs between prokaryotes. It is gene exchange by conjugation.

< Lederberg and Tatum' Experiment >

Mutant 1 does not grow unless methionine and biotin are added to the minimal nutrient medium, but it can synthesize threonine and leucine on its own. The phenotype can be described as $met^- bio^- thr^+ leu^+$.

Mutant 2 does not grow unless threonine and leucine are added to the minimal nutrient medium, but it can synthesize methionine and biotin on its own. Its phenotype is $met^+ bio^+ thr^- leu^-$.

The two mutant strains were mixed and inoculated on minimum nutrient liquid medium supplemented with methionine, biotin, threonine, and leucine so that both strains could grow, and they were cultured for several hours. The medium was centrifuged to precipitate the bacteria, which were again plated in minimal nutrient solid medium with no supplements. Bacterial colonies formed after cultivation.

Conclusion: Genetic recombination occurred between the two different mutant strains, and a new-type nutrient-requiring strain (prototrophic strain) was born.

Before reaching this conclusion, three hypotheses were considered:

Hypothesis #1: A reverse mutation (e.g. *met⁻ bio⁻ thr⁺ leu⁺* to *met⁺ bio⁺ thr⁺ leu⁺*) returning to the wild-type occurred.

Hypothesis #2: Natural transformation resulted in the occurrence of the prototrophic strain.

Hypothesis #3: Physical contact between the cells of different mutants resulted in the occurrence of the prototrophic strain.

What kind of experiments should be performed to rule out hypotheses #1 and #2? Explain each in about 100 words.

Question 7-2.

The replication of *E. coli* DNA proceeds in both directions from the origin of replication. In this process, two replication forks are typically formed. Explain the molecular mechanisms of DNA replication in about 200 words.

Question 7-3. Answer the following questions.

- (1) Carbohydrates are not the only energy source. Proteins and fats are also metabolized and used as energy sources. The amino acids of protein are first deaminated, fatty acids are subjected to β -oxidation, and energy is eventually produced. Explain the processes after the aforementioned deamination (A) and β -oxidation (B) in about 100 words each.

- (2) Prokaryotic cells vary in size from smaller than 0.2 μm in diameter to greater than 50 μm in diameter. For comparison, eukaryotic cells range from 2 to more than 200 μm in diameter. In general, prokaryotes have very small cells compared with eukaryotes, and this determines their biological characteristics. In about 150 words, explain the benefits that likely accrue to prokaryotes because they are formed of very small cells.

QUESTION 8 (Subject on Life Science)

Read the following sentences and answer the questions.

Proteins are very long polypeptide chains of 100 to several thousand amino acid residues. Some naturally occurring peptides have only a few amino acid residues. Differences in protein and peptide function result from differences in the number and sequence of amino acids. Amino acid sequences are useful information for studying protein structure and function relationships, as well as for discussing the evolution of life on this planet.^(a) The protein secondary structure is the spatial arrangement of atoms in the main chain of a polypeptide in which each amino acid residue interacts spatially with its neighbors. The most common secondary structures are the α helix and β sheet.^(b) Proteins fold further into tertiary structure via the interaction and combination of their secondary structures. The quaternary structure results from interactions between the subunits^(c) of multi-subunit proteins or large protein assemblies. Proteins may undergo conformational changes upon the binding of ligand or substrate molecules; in a multi-subunit protein, its binding to one subunit may affect the ligand binding to other subunits.^(d)

Glycoproteins contain oligosaccharides covalently linked to an asparagine^(e) residue or serine/threonine residues. The covalently attached oligosaccharides influence the folding, function, and stability of the proteins and may be involved in specific molecular recognition by other proteins.

Question 8-1.

For the underlined sentence (a), describe an outline of bioinformatics methods in about 100 words.

Question 8-2.

Explain the underlined structures (b) in about 70 words each.

Question 8-3.

Regarding the underlined terms (c), explain the four kind of forces that function between the protein subunits (about 100 words).

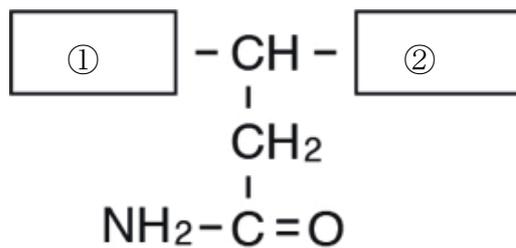
Question 8-4.

The underlined sentence (d) is called cooperative ligand binding. Provide a specific example of ligand binding.

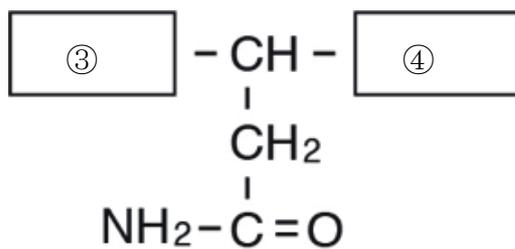
Question 8-5.

Regarding the structure of the underlined amino acid (e) under acidic (pH 1.0) and neutral pH conditions, fill the blanks (① ~ ④) in the figures shown below; consider the predominant ionization state.

(1) Acidic pH



(2) Neutral pH



Question 9 (Subject on Aquatic and Marine Science)

Question 9-1. This table summarizes the production sites and actions of hormones in teleost fishes. Select the most appropriate word or phrase from the list below to fill in the blanks with numbers.

Production site	Hormone name	Action
Anterior pituitary	(1)	Transfer of amino acids and promotion of protein synthesis
	(2)	Prevention of sodium ion loss
	Gonadotropic (follicle stimulating) hormone	(3)
	(4)	Production of glucocorticoids
Pineal	Melatonin	(5)
Thyroid gland	(6)	Increases metabolism
Head kidney (pronephros)	Cortisol	(7)
Gonads	(8)	Synthesis of the precursor to egg yolk protein
	(9)	Promotion of spermatogenesis
Islets of Langerhans	Insulin	(10)

Lists of words or phrases

- a) Prolactin, b) Triiodothyronin, c) Estradiol-17 β , d) 11-Ketotestosterone, e) Vitellogenin, f) Growth hormone, g) Glucagon, h) Thyroglobulin, i) Somatolactin, j) Insulin-like growth factor, k) Adrenalin,

- l) Adenocorticotrophic hormone, m) Thyroid stimulating hormone,
- n) Aldosterone, o) Sensing of water temperature, p) Regulation of glucose and minerals, q) Storage of glucose and lipids, r) Maintenance of blood glucose level, s) Related to diurnal rhythm, t) Maintenance of placenta,
- u) Induction of ovulation, v) Production of sex steroid hormones,
- w) Regulation of calcium

Question 9-2. There are two major ways to promote the production of aquatic resources: resource enhancement by hatchery release and aquaculture. Although closely related, producers, managers, researchers and administrators need to recognize certain differences between them. Describe or/and compare their characteristics by using all the keywords listed below each question.

- (1) Compare hatchery release and aquaculture in terms of ways to produce and harvest.
Keywords: Release, Owner, Open-system, Catch, Harvest
- (2) Describe the desired characteristics of “fish health” and “fish quality” needed for hatchery release and aquaculture.
Keywords: Disease, Disease resistance, High growth, Morphological abnormalities, Ability to escape
- (3) Describe possible influences of farmed fish and hatchery fish on wild fish.
Keywords: Escape, Numbers released, Cross-breed, Selective breeding, Compete

QUESTION 10 (Subject on Aquatic and Marine Science)

The incident light penetrating into water attenuates exponentially. The light intensity I_z ($\mu\text{mol}/\text{m}^2/\text{s}$) at a water depth z (m) can be shown as:

$I_z = I_0 \exp(-kz)$ where k represents the light attenuation coefficient.

Question 10-1. Here we assume 1 % light depth to be 100 m at a site in the open ocean. Calculate the light attenuation coefficient in the water column at the site. Note that you can use 2.3 for $\ln 10$.

Question 10-2. What is the term representing the layer of seawater that receives more than 1 % of photosynthetic available radiation at the surface?

Question 10-3. Explain the term “daily compensation depth”. In addition, explain the relationship between the daily compensation depth and the layer that you examined in Question 10-2.

Question 10-4. In general, how does the light attenuation coefficient change from open ocean waters to coastal waters? In addition, explain why such changes occur.

Question 10-5. In tropical, subtropical, and temperate regions, the maximum concentrations of chlorophyll a , an indicator of phytoplankton biomass, may be observed in subsurface layers, not in surface layers with a high light availability. Explain the reason(s) why the subsurface chlorophyll maximum is formed.

QUESTION 11 (Subject on Aquatic and Marine Science)

Question. The following sentences describe the principles and procedures of chromosome set manipulation in teleost fishes. Choose the appropriate word from those in the lower part and write down the corresponding letter of the alphabet. Words may be used multiple times.

We can obtain individuals with appropriate genomic combinations by using chromosome set manipulation methods, combining the genomic inactivation of gametes before fertilization and the duplication of chromosome sets after fertilization.

1) Artificial gynogenesis is induced by fertilization between genetically inactivated (①) and normal (②) , and artificial androgenesis is induced by fertilization between normal (③) and genetically inactivated (④). Resultants from gynogenetic and androgenetic fertilization are usually lethal, because of (⑤) genome.

2) (⑥) irradiation is available for genetic inactivation of gametes. (⑦) ray is weaker energy for penetration than that of (⑧) ray, but inactivate the DNA by inducing (⑨).

3) Generally speaking, artificial duplication of chromosome sets are induced by disruption of the mitotic spindle at the second polar body release just after fertilization, or during the first cleavage. In both cases, spindle fibers are disrupted by thermal treatments, such as cold or heat shocks, or hydraulic pressure. Spindle fibers, tubulin, changes their form (⑩) by these treatment.

4) Chiasma is formed during meiosis. Therefore, gynogenetic individuals resultant from inhibition of second polar body release have (⑪) allele, but those from inhibition of the first cleavage have not.

(Continued to next page)

5) Genetically (12) population are theoretically induced in the second gynogenetic generation from a female individual, which originated from gynogenesis by the first cleavage inhibition. When sex-reversal male from this second gynogenetic generation is mated with the first gynogenetic female or from normal wild female, genetically (13) or (14) population are induced, respectively.

6) Mono-sex population (15) induced in androgenetic diploid in the species with XY sex-determination system. Mono-sex population (16) induced in androgenetic diploid in the species with ZW sex-determination system.

7) Hybrid with AB genomic combination is induced by fertilization between egg from A species and sperm from B species. In this case, inhibition of the second polar body release induces (17) individuals with AAB genomic combination, and inhibition of the first cleavage does (18), or (19) individuals with AABB genomic combination. When the hybrid with AB are sterile, recovery of fertility can be expected in the individual with AABB. This law is called the (20) .

Words

a) haploid, b) auto-diploid, c) allo-diploid, d) auto-triploid,
e) allo-triploid, f) auto-tetraploid, g) allo-tetraploid, h) polyploid,
i) amphidiploid, j) egg, k) sperm, l) homo-zygotic, m) hetero-zygotic,
n) are, o) aren't, p) homo-clonal, q) hemi-clonal, r) hetero-clonal,
s) from monomer to polymer, t) from polymer to monomer,
u) Winge's law, v) Mendel's law, w) ultraviolet, x) gamma,
y) thymine dimer, z) methylation.

QUESTION 12 (Subject on Aquatic and Marine Science)

Question. Read the following sentences about marine pollution and answer the questions below.

Municipal and industrial effluents include sewage (human waste), heavy metals (lead, mercury), and persistent organic pollutants (DDT, PCBs). Many of these effluents are toxic and can be devastating to the biota of a local habitat if occurring as a persistent influx.

Coastal water bodies, if suffused with massive dosages of nutrients through sewage, respond by supporting dense, long-lasting plankton (①), a biological process that saturates the water with algal cells. These large quantities of algae eventually die and decompose.

Among the heavy metals, mercury, particularly in the form of (②) , is deadly poisonous. The ingestion of mercury-tainted shellfish and finfish causes (③) dysfunctions and kidney malfunctions in humans. For example, mercury poisoning afflicted over two thousand people who had unknowingly consumed (②) -laced shellfish from (④) Bay, Japan.

DDT, which is the abbreviation for dichloro-diphenyl-trichloro-ethane, was used extensively by farmers and forestry personnel as a (⑤). One of the characteristics of DDT is the rapid dispersal rate. It has been detected in mud samples taken from the deep sea and in the snow and ice of Antarctica, thousands of kilometers from where it was applied to land. Known toxic effects include incomplete development of copepods and oysters, and the toxic death of fish, sea birds and sea animals.

Question 12-1. Fill in the blanks from (①) to (⑤) with appropriate words.

Question 12-2. How does the death and decomposition of large quantities of algae in coastal waters affect coastal ecosystem? Explain in 60 words or less.

Question 12-3. By what biological process can even low-level concentrations of persistent organic pollutants dissolved in seawater affect an ecosystem? Explain in 70 words or less.

Question 12-4. What does PCB stand for? Also, why have lots of PCBs been released into the environment? Explain in 70 words or less.