

Entrance Examination
For October 2014 and April 2015 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 subject.
- One sheet should be used for each selected QUESTION. The reverse side could be used, if you need.
- Name and ID should be written on each answer sheet.
- QUESTION No. should also be written on each answer sheet.

Division of Biosphere Science
Graduate School of Environmental Science
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QUESTION 1 (Field Science)

Question 1-1. Select three of the following five terms and explain the meaning.

- (1) Leaf area index
- (2) Warmth index
- (3) Effective accumulated temperature
- (4) Qualitative and quantitative defensive substances of plants
- (5) Niche partitioning
- (6) The law of constant final yield

Question 1-2. Explain the morphological and physiological differences of leaves between plants inhabiting sun and shade environments using all of the following key terms: maximum photosynthetic rate, light compensation point, dark respiration, leaf thickness, leaf size.

Question 1-3. Dioecy is a characteristic common in many species of animals where reproductive organs occur separately in males and females. However, hermaphroditism, where male (stamen) and female (stigma) reproductive organs occur in a single flower, is common among angiosperm plant species. Propose a hypothesis for the advantage of hermaphroditism in plants and describe a possible experiment to test the hypothesis.

QUESTION 2 (Field Science)

Table 1 shows the distribution of three species of insects (two herbivores sharing a single host plant and their common parasitoid) on the North Imaginary Archipelago (Fig.1).

Table 1 Presence (+) and absence (-) of three species of insects in North Imaginary Archipelago

Island	Species 1 (herbivore)	Species 2 (herbivore)	Species 3 (parasitoid)
A	+	+	+
B	+	+	-
C	+	+	-
D	+	+	+
E	+	+	+
F	+	+	+
G	+	-	-
H	-	+	-
I	+	-	-
J	-	+	-
K	?	+	+

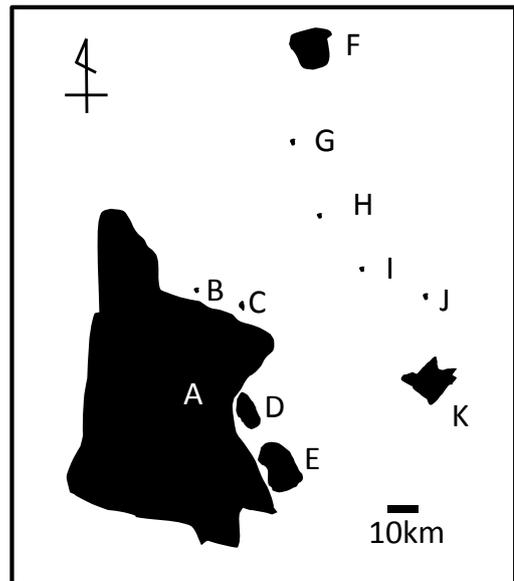


Fig. 1 North Imaginary Archipelago

Question 2-1. Explain the distribution pattern of species 1 and propose a hypothesis that could explain this pattern.

Question 2-2. Would you predict species 1 is present on Island K? Explain your prediction based on ecological knowledge of species interaction and species distribution.

Question 2-3. More than thirty species of insects are distributed in the North Imaginary Archipelago. Arrange islands A, B, E, G and K in order of insect species richness based on theory of island biogeography.

QUESTION 3 (Field Science)

Question 3-1. Habitat fragmentation is a process known to increase the extinction risk of a species. Explain its ecological processes using the following key terms: demographic stochasticity, inbreeding, genetic drift, positive feedback.

Question 3-2. Answer the following questions regarding “umbrella species”, which is used in the context of biodiversity conservation.

- (1) Define “umbrella species” and indicate typical umbrella species
- (2) Assume you are tasked with determining whether or not a species, for which available ecological information is limited, can be regarded as an umbrella species of an ecosystem. Describe what kind of characteristics of this species must be identified and described in the field research.

Question 3-3. Fill the blankets (1)-(4) in the following sentence.

Ecosystem services are the benefits people can obtain from ecosystems. These include 【 (1) 】 services such as food, timber, and fuel; 【 (2) 】 services such as flood and disease control; 【 (3) 】 services such as spiritual and recreational benefits; and 【 (4) 】 services such as nutrient cycling that maintain the conditions for Life on Earth (Millennium Ecosystem Assessment).

QUESTION 4 (Field Science)

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

A genome is the totality of genetic materials carried by an organism. Genome maps are useful tools for breeding programs and ecological genetics. There are two types of maps, “genetic” and “physical”, which are constructed based on different kinds of information.

- (1) What is the difference between a “genetic map” and a “physical map”?
- (2) Select two kinds of genetic markers for the construction of physical maps and indicate their characteristics.

Question 4-2. Plant hormones are produced in small (sometimes very small) amounts in specific part of a plant. They are then transferred to the point of action where they regulate plant growth.

- (1) Indicate 4 major plant hormones and explain their physiological role in plant growth.
- (2) Indicate 2 examples on the application of plant hormones in agriculture.

QUESTION 5 (Life Science)

Question 5-1. Read the following sentences about fertilization in angiosperms, and answer the questions from 5-1-1 to 5-1-3.

A pollen grain spread by wind etc. can adhere on the stigma covered by sticky and sugary substances. Then the pollen grain begins to grow a (1) on the stigma. The (1) grows until it reaches the embryo sac in the ovule. At the entry to the embryo sac, the (1) penetrates into the degenerated synergid. Then, the tip of the (1) bursts and releases the two (2). One of the (2) fertilizes with the egg cell, forming a (3). The other (2) fuses with the two polar nuclei located at the center of the embryo sac, and the products develops into the (4). This unique process concerning with two sperm cells is called (5) fertilization.

Question 5-1-1. Fill the blankets (1) ~ (5) with appropriate words.

Question 5-1-2. Estimate ploidy level of (4) tissues, when tetraploid plants are self-pollinated.

Question 5-1-3. Describe other agents which transfer a pollen in relation to the underlined part in the above explanation.

Question 5-2. Read the following sentences about patterns of inheritance proposed by Mendel, and answer the questions from 5-2-1 to 5-2-2.

Mendel conducted cross experiments by using the garden pea (*Pisum sativum*), and concluded that alternative alleles for a character segregate from each other. It is commonly referred to as Mendel's first law of heredity, "the Principle of (1)". Furthermore, he analyzed the behavior of two different traits in hybrids, and found Mendel's second law of heredity, "the Principle of (2) Assortment". These laws are recognized as allele (1) caused by the behavior of chromosomes during (3) in gamete development. Two alleles are segregated by the random alignment of different homologous chromosome pairs in metaphase plate during metaphase I of (3), and following (1) of

homologous chromosomes in anaphase I of (3). Therefore, the (2) behavior of different homologous chromosomes leads to the (2) (1) of the different alleles.

Question 5-2-1. Fill the blankets (1) ~ (3) with appropriate words.

Question 5-2-2. Describe differences between (3) and mitosis in relation to the underlined part in the above explanation.

QUESTION 6 (Life Science)

When the sucrose concentration in the cell's cytoplasm is higher than the one in the extracellular fluid, water diffuses into the cell from the extracellular fluid, causing the cell to swell. The pressure of the cytoplasm pushing out against the cell membrane, or [A], increases. On the other hand, [B], defined as the pressure that must be applied to stop the movement of water across a membrane, will also be at work.

Question 6-1. Answer appropriate words in [A] and [B].

Question 6-2. Let P [Pa] and π [Pa] be the pressure of the cytoplasm pushing out against the cell membrane, and the pressure that must be applied to stop the movement of water across a membrane, respectively. When water diffuses into the cell, the sucrose concentration decreases and converges to the equilibrium. Give the condition that should be satisfied at the equilibrium using P and π .

Question 6-3. When sucrose concentration in the cell's cytoplasm is high, what kind of difference is expected between animal and plant cells? Explain briefly.

Question 6-4. Phloem is the plant tissue that carries organic nutrients such as sucrose. In phloem, sucrose is transported from sources (mature leaves) where sucrose is produced by photosynthesis to sinks (roots and fruits) where sucrose is consumed. Explain how [A] and [B] in the above sentences are involved in the phloem transportation, assuming phloem as a tube of cylinder shape, and using the knowledge that pressure difference is what drives the solution flow in the tube.

QUESTION 7 (Life Science)

Question 7-1. Biological membranes allow some substances, but not others, to pass through them. This characteristic of membranes is called selective permeability. Selective permeability allows the membrane to determine what substances enter or leave a cell or organelle. Membrane transport system is shown in following Table.

Mechanism	ATP required?	Driving force	Membrane protein required?	Specificity
Simple Diffusion	No	Concentration gradient	No	No
Facilitated Diffusion	(a)	(b)	(c)	(d)
Active transport	(e)	(f)	(g)	(h)

Question 7-1-1. Fill the blankets from (a) to (h) with appropriate words.

Question 7-1-2. Active transport is directional, and there are three kinds of membrane proteins that carry out active transport. Explain the three kinds of membrane proteins with examples.

Question 7-2.

Question 7-2-1. Write the sequence of the mRNA molecule synthesized from a DNA template strand having the following sequence.

5'- ATCGTACCGTTA -3'

Question 7-2-2. What amino acid sequence is encoded by the following base sequence of an mRNA molecule? Assume that the reading frame starts at the 5' end.

5'- UUGCCUAGUGAUUGGAUG -3'

Question 7-2-3. What is the sequence of the polypeptide that is formed when poly(UUAC) is added to a cell-free protein-synthesizing system?

The genetic code

2nd → 1st ↓	U	C	A	G	3rd ↓
U	Phe Phe Leu Leu	Ser Ser Ser Ser	Tyr Tyr Stop Stop	Cys Cys Stop Trp	U C A G
C	Leu Leu Leu Leu	Pro Pro Pro Pro	His His Gln Gln	Arg Arg Arg Arg	U C A G
A	Ile Ile Ile Met	Thr Thr Thr Thr	Asn Asn Lys Lys	Ser Ser Arg Arg	U C A G
G	Val Val Val Val	Ala Ala Ala Ala	Asp Asp Glu Glu	Gly Gly Gly Gly	U C A G

Question 7-3. An operon, that is a unique gene structure in prokaryotes, typically consists of a promoter, an operator, and two or more structural genes. There are a number of mechanisms to control the transcription of operons in *Escherichia coli*. Among them, there are inducible and repressible mechanisms controlled by operator and repressor interaction. Explain each control system of lactose operon (*lac* operon) and tryptophan operon (*trp* operon) in the presence or absence of lactose and tryptophan, respectively.

QUESTION 8 (Life Science)

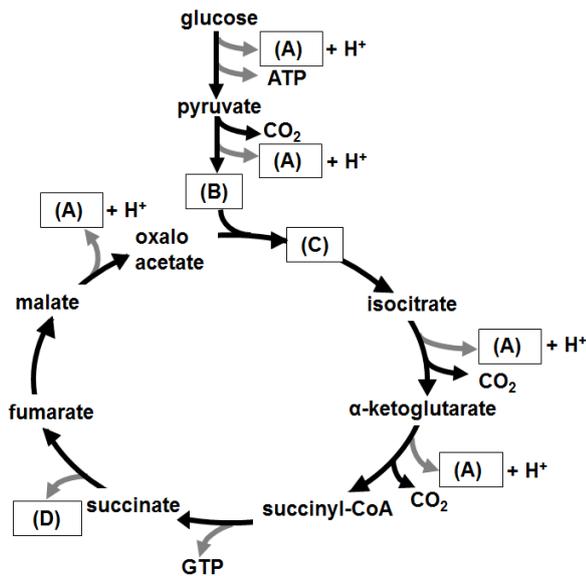
Read the following sentences about fertilization in angiosperms, and answer the questions from 8-1 to 8-4.

In order to maintain cellular functions, cells have evolved mechanisms to harvest energy. As a part of the process, glycolysis and Krebs cycle are shown in the figure.

In glycolysis, 1 mole of glucose is converted into 2 moles of pyruvate. This process has a net yield of 2 moles of ATP and 2 moles of (A).

Then, under aerobic conditions, 1 mole of pyruvate is

decarboxylated to form 1 mole of (A) and 1 mole of (B). Transferring the acetyl group of (B) to oxaloacetate produces (C), starting the Krebs cycle. In one round of Krebs cycle, 1 mole of (B) yields 3 moles of (A), 1 mole of (D) and 1 mole of GTP. (A) and (D) are electron carriers that supply high-energy electrons. High-energy electrons are passed along the electron transport chain and finally used to reduce oxygen, and water is formed. ATP is produced by proton gradient which is generated in the electron transport.



Question 8-1. Fill the blankets (A) to (D) with appropriate compounds.

Question 8-2. Yeast performs alcohol fermentation under anaerobic conditions.

In this process pyruvate produced by glycolysis is converted into ethanol, however, ethanol cannot be used as energy for yeast and high levels of ethanol accumulation is toxic to yeast cells. Explain why yeast produces ethanol under anaerobic conditions.

Question 8-3. Carbon compounds in the Krebs cycle are also used as substrates for synthesis of essential compounds including amino acids. Explain why a series of reactions in the Krebs cycle are not immediately arrested even if carbon compounds in the Krebs cycle are consumed in metabolic pathways other than the Krebs cycle.

Question 8-4. Most of reactions in organisms are regulated by enzymes. Enzyme “Z” catalyzes a reaction to convert a single substrate “X” into a single product “Y”, and follows Michaelis-Menten equation. 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).

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

Describe an experiment to estimate K_m and V_{max} of enzyme “Z”.

QUESTION 9 (Aquatic and Marine Science)

Read the following sentences, and answer the questions from 9-1 to 9-5.

Temperature and salinity in the ocean vary in time and space due to many factors e.g. solar radiation, evaporation, precipitation, advection and diffusion. Sea surface temperature is generally high at low latitudes and low at high latitudes. It also varies zonally; for example, (1) sea surface temperature in the subtropical North Pacific is high in the western part and low in the eastern part. (2) Sea surface salinity does not increase or decrease latitudinally, but is high in the subtropical regions and low in the subpolar regions. However, the relative proportions of (3) the major salt constituents (4) are almost constant in the global ocean. (5) Temperature and salinity determine density of seawater, the distribution of which leads to the estimation of the ocean current field as well as the sea surface height distribution.

Question 9-1. Explain the reason for underline (1) within 100 words.

Question 9-2. Explain the reason for underline (2) within 100 words in case of the North Pacific as an example.

Question 9-3. In regard to underline (3), provide the names or the chemical formulas of the five major salt ions in seawater.

Question 9-4. In regard to underline (4), explain the reason why the relative proportions of the major salt constituents are almost constant in the global ocean using the keyword “residence time” within 100 words.

Question 9-5. The ocean current in underline (5) is referring to the geostrophic current. In the Northern Hemisphere, the geostrophic current flows with the high sea surface to the right. Explain the mechanism using the key terms “Coriolis force” and “pressure gradient force” (no word limit).

QUESTION 10 (Aquatic and Marine Science)

There are three fundamental strategies for sustainable use of fisheries resources: (1) constant escapement strategy (CES), (2) constant harvest rate strategy (CHR), and (3) constant catch strategy (CCS). Explain these three strategies and their advantages/disadvantages briefly.

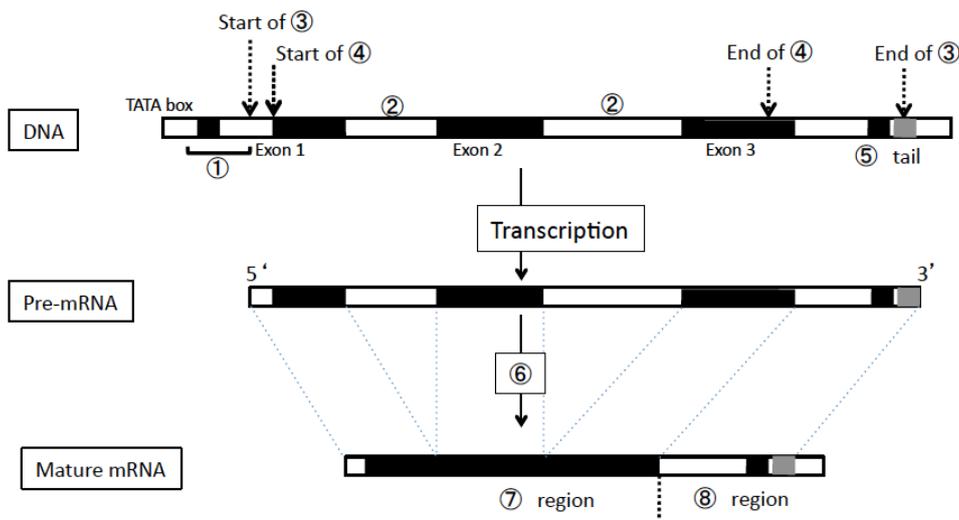
QUESTION 11 (Aquatic and Marine Science)

Question 11-1. The following text describes the genetic engineering technique. Insert appropriate word(s) within the parentheses (A) to (G).

The basic techniques of genetic engineering include “cut”, “combination”, “amplification”, and “sequencing”. (A), which can recognize specific base sequences, are used for cutting DNA into fragments. The enzyme that can combine DNA fragments is (B). DNA that is artificially combined with a DNA fragment cut by (A) is (C).

PCR is the acronym for (D). PCR is composed of three steps. First, the target DNA is separated into single stranded DNA by (E). Next, the (F) is united to the single stranded DNA, and then the amplification reaction progresses by (G), which has been extracted from heat-resistant bacterium. The target DNA can be exponentially amplified by repeating these three reactions.

Question 11-2. The figure shows the composition of a gene and the process of transcription to mRNA. Answer appropriate word(s) from ① to ⑧ You may use some of the following words: telomere, promoter, vector, poly C, translation, transcription, and codon.



QUESTION 12 (Aquatic and Marine Science)

Explain the differences between macro-nutrients and micro-nutrients in the ocean focusing on the following terms: definition, chemical forms, horizontal and vertical distributions, roles in the phytoplankton cell, and region and time limiting phytoplankton growth.