Division of Biosphere Science, Graduate School of Environmental Science, Hokkaido University, Entrance Examination for Admission in October 2026 and April 2027, Master's Course (Specialized Subjects), Intent of Questions and Sample Answers

QUESTION No. 1. (Subject on Field Science)

【Intent of the question】

To understand that there are various strategies involved in carbon fixation (photosynthesis) by plants, which forms the foundation of material cycles and food chains in terrestrial ecosystems.

【Sample answer】

Question 1-1.
Beech (*Fagus*), Oak (*Quercus*)

Question 1-2.
(A)

Question 1-3.
(C), (D), (E)

Question 1-4.
Within the forest, unfolding leaves during the bright periods before the canopy begins to leaf out is advantageous for photosynthesis. As canopy closure occurs in early summer, the leafing of *P. odoratum* is concentrated in May. Conversely, in environments that remain bright throughout the growth season, there is no such constraint, so the timing of leaf unfolding can be more flexible.

Question 1-5.
Sample answer 1

As it grows darker in the forest during the changing seasons, the rate of photosynthesis decreases. Plants must shed their leaves before the amount of carbon released through respiration exceeds that fixed through photosynthesis. Conversely, vigorous photosynthesis can continue for extended periods in consistently bright conditions, resulting in prolonged foliage.

Sample answer 2
Since the leaves of *Polygonatum odoratum* that unfurl all at once age simultaneously, leaf fall occurs in a concentrated burst at a specific time. In contrast, for *Polygonum sachalinensis* that unfurl sequentially, the timing of leaf aging varies depending on when each leaf unfolds, allowing individual plants to retain their leaves for a longer period.

Question 1-6.

Sample answer 1
If the lifespan of individual leaves is shorter than the growing season, those that unfurl early will fall off before the end of the season. Since new leaves are continuously produced, it is believed that the number of leaves a plant can maintain is around ten, due to the turnover of old and new leaves.

Sample answer 2
Within the plant, lower leaves are shaded by upper leaves, which hinders photosynthesis. Since *Polygonum sachalinensis* is a plant with sequential leaf production, there is no advantage to retaining older leaves once new leaves accumulate; therefore, it is believed that there is a limit to the number of leaves the plant can maintain.

QUESTION No. 2. (Subject on Field Science)

【Intent of the question】

In recent years, concern over the environmental burden arising from animal husbandry and agriculture has been growing. This question addresses matters that should be recognized in order to develop animal husbandry sustainably. It is intended to ask not only questions in animal science, but also to assess comprehensive knowledge of related fields.

【Sample answer】

Question 2-1.

They are called zoonoses (zoonotic diseases). The main routes of transmission from the farm environment can be organized as follows: via food such as meat; via environmental contamination through manure, compost, and water systems; through direct contact between livestock and workers or visitors; and via vector animals.

Question 2-2.

Antimicrobials do not create resistance itself; rather, they selectively allow bacteria that had already acquired resistance by chance (e.g., through mutation) to survive. In the presence of an antimicrobial, susceptible bacteria are eliminated, while resistant bacteria proliferate relatively and spread through the population.

Question 2-3.

1) C
2) B
3) A

Question 2-4.

(A) anaerobic
(B) eubacteria
(C) archaea
(D) nitrification
(E) ammonia

Question 2-5.

Nitrogen and phosphorus contained in manure and wastewater from the farm flowed into the lake and caused algae and phytoplankton to proliferate abnormally. When microorganisms decomposed the resulting dead biomass, dissolved oxygen was consumed, producing hypoxic conditions under which the fish are thought to have died. Possible measures include appropriate storage and treatment of manure, optimization of application rates, and the establishment of buffer zones between farmland and water bodies.

QUESTION No. 3. (Subject on Field Science)

【Intent of the question】

I. To assess fundamental knowledge in conservation ecology, as well as the ability to provide concise and logical explanations.
II. To assess fundamental knowledge and applied thinking skills in adaptive evolution, as well as the ability to explain concepts logically.

【Sample answer】

Question 3-1.
6 (sixth)

Question 3-2.
IUCN (International Union for Conservation of Nature and Natural Resources)

Question 3-3.
Vulnerable (VU)

Question 3-4.
(A)

Question 3-5.
When a population declines because of habitat degradation or the introduction of invasive species, a positive feedback process can accelerate its decline. This process, known as the extinction vortex, involves several factors. First, stochasticity (chance events) has a stronger effect on small populations, increasing the risk of sudden extinction. Second, genetic problems arise as genetic diversity decreases, reducing the population's ability to adapt to environmental change. Finally, inbreeding depression occurs as individuals are more likely to mate with close relatives, leading to reduced fitness, lower reproduction, and higher mortality. These factors further reduce population size, which strengthens the effects of stochasticity, genetics, and inbreeding depression, increasing the risk of extinction.

Question 3-6.

ⓐ (F)

ⓑ (B)

ⓒ (A)

Question 3-7.

A correct answer to any one of ⓐ, ⓑ, or ⓒ is sufficient.

ⓐ Bergmann's rule: In cold regions, animals must conserve body heat. Larger bodies have a lower surface area-to-volume ratio, which reduces heat loss. As a result, individuals living in colder environments tend to have larger body sizes than those living in warmer regions.

ⓑ Allen's rule: In cold regions, conserving body heat is important. Shorter appendages, such as ears, tails, and limbs, reduce surface area relative to body volume and minimize heat loss. Therefore, animals in colder climates tend to have smaller appendages than those in warmer climates.

ⓒ Gloger's rule: Tropical and low-latitude regions receive stronger sunlight and ultraviolet radiation. Darker pigmentation helps protect the skin, feathers, or fur from UV damage. Consequently, animals living in these regions often have darker coloration than those inhabiting higher latitudes. (protection against ultraviolet radiation)

Body coloration can help animals blend into their surroundings and avoid predators. Dense tropical forests are generally darker environments, where darker coloration provides better camouflage. Therefore, animals living in low-latitude regions often exhibit darker body colors. (camouflage)

Feather-degrading bacteria thrive in warm and humid environments. Dark pigments can strengthen feathers and improve their resistance to bacterial damage. As a result, darker coloration is often favored in tropical regions where such microorganisms are more abundant. (biological defense)

*Any one of the answers listed in the sample answer for ⓒ is acceptable.

Question 3-8.

Similar traits repeatedly appear in unrelated lineages exposed to similar environmental conditions. Such repeated patterns are unlikely to be explained by chance alone and

instead suggest that environmental pressures favor certain adaptations. Therefore, this phenomenon supports the idea that natural selection is a major mechanism driving evolutionary change.

QUESTION No. 4. (Subject on Field Science)

【Intent of the question】

To assess the ability to understand the fundamental concepts and major theories of ecology and to use them to logically explain and predict interspecific interactions, population and community dynamics, mechanisms maintaining biodiversity, and life-history evolution.

【Sample answer】

Question 4-1.

① d
② b
③ c
④ a

Question 4-2.

(1)
① Increase
② Decrease
③ Increase

(2)
① Remain largely unchanged
② Remain largely unchanged
③ Remain largely unchanged

Question 4-3.

In birds with iteroparity, individuals reproduce multiple times during their lifetime. Laying the maximum number of eggs in a single breeding attempt can reduce survival or

future reproductive success of the parents. Because there is a trade-off between current reproductive success and future survival and reproductive success, the number of eggs laid per breeding attempt has evolved to be smaller than the maximum number that the parents can successfully rear.

Question 4-4.

In environments where disturbance is rare, competitively superior species monopolize resources and exclude other species, reducing species diversity. In contrast, where disturbance is frequent, organisms are removed before they can establish and grow, limiting the number of species that can persist and thereby reducing species diversity.

Question 4-5.

A keystone species is a species that has a disproportionately large effect on community structure relative to its abundance or biomass. An ecosystem engineer is an organism that affects other species by modifying the physical structure of the environment. Therefore, an organism may be considered both a keystone species and an ecosystem engineer if it substantially alters the environment despite its relatively low abundance, and if this environmental modification has major effects on the habitat availability, species composition, or overall community structure of many other organisms.

QUESTION No. 5. (Subject on Life Science)

【Intent of the question】

To assess the examinee's specialized knowledge of molecular biology and ability to apply that knowledge to solve biological problems.

【Sample answer】

Question 5-1.

① Chromatin
② Nuclear pore (Nuclear pore complex is also acceptable)
③ Proteasome

Question 5-2.

DNA methylation of cytosine and modifications of histone tails, such as methylation and acetylation, alter chromatin structure and regulate gene expression. During cell division, enzymes such as maintenance DNA methyltransferases help maintain these modification patterns on newly synthesized DNA and histones. As a result, epigenetic states are transmitted to daughter cells and gene expression patterns are maintained as cellular memory.

Question 5-3.

Transcription factors bind to cis-regulatory sequences such as enhancers on DNA. Their binding induces chromatin remodeling, including changes in histone positioning, which exposes the promoter region. RNA polymerase II is then recruited to the promoter and transcription is initiated.

Question 5-4.

Addition of the 5′ cap structure
Addition of the poly(A) tail at the 3′ end

Question 5-5.

a) Correct
b) Correct
c) Incorrect
Ribosomes are complexes composed of both RNA and proteins.
d) Correct

Question 5-6.

miRNAs bind complementarily to target mRNAs and suppress gene expression by inducing RISC-mediated cleavage or translational repression. Even in the case of translational repression, the target mRNA is often destabilized and subsequently degraded.

Question 5-7.

Deletion of exon 50 alters the translational reading frame, resulting in the appearance of a premature stop codon and preventing the production of normal dystrophin protein. Treatment with the antisense oligonucleotide induces skipping of exon 51, thereby restoring the reading frame. As a consequence, the transcript can be translated into a shortened dystrophin protein. Although the resulting protein lacks part of its amino acid sequence, it retains some biological activity, leading to partial recovery of dystrophin

function.

QUESTION No. 6. (Subject on Life Science)

【Intent of the question】

This question was designed to verify the comprehension of the concept of enthalpy, entropy and free energy as well as the acquisition of knowledge regarding intermolecular interactions.

【Sample answer】

Question 6-1.

① Enthalpy
② Entropy
⑦ activation energy
⑧ hydrogen bonds

Question 6-2.

③ higher
④ higher

Question 6-3.

Proceeds spontaneously.
The standard free energy change for Eq. 3 is the sum of Eqs. 4 and 5. Because this value is negative, the reaction proceeds spontaneously under standard conditions.

Question 6-4.

is unchanged

Question 6-5.

Under the standard condition, the reaction/product concentrations are 1M for all solutes.

Question 6-6.

Eq.3: -34.5 (or -34.4)、Eq.4: 25.7、Eq.5: -60.2 (or -60.1)

First, determine the ΔG for Eq. 4

$\Delta G = 13.8\ (kJ/mol) + 8.31\ (J\ mol^{-1}\ K^{-1}) \times 310\ (K) \times \ln([G6P]/[glucose][Pi])$

Here, $(4 \times 10^{-4}/(2 \times 10^{-3} \times 2 \times 10^{-3}) = 10^2$

Referring to the hint, $\ln 10^2$ becomes $2.30 \times \log_{10}10^2$, which equals 4.60.

Calculating the equation above yield 25.7 (kJ/mol).

Next, regarding Eq. 5

$\Delta G = -30.5\ (kJ/mol) + 8.31\ (J\ mol^{-1}\ K^{-1}) \times 310\ (K) \times \ln([ADP][Pi]/[ATP])$

Since $\ln Q = \ln([ADP][Pi]/[ATP]) = \ln([2 \times 10^{-5}][2 \times 10^{-3}]/[4 \times 10^{-3}]) = 2.30 \times -5 = -11.5$, substituting this into the equation above yields:

$\Delta G = -60.2$ (kJ/mol) (depending on the order of calculation, -60.1 is also correct)

Therefore, the ΔG for Eq. 3 is 25.7 - 60.2 = -34.5 (kJ/mol) (-34.4 is also correct)

Question 6-7.

aspartate, glutamate

Question 6-8.

hydrophobic interactions

QUESTION No. 7. (Subject on Life Science)

【Intent of the question】

Signal transduction is extremely important in cellular responses; this question tests basic knowledge of signal transduction using the action of hormones as an example. It also assesses the ability to interpret and analyze the experimental results presented in graphs.

【Sample answer】

Question 7-1.

① islets of Langerhans (pancreatic islets)
② cAMP
③ calcium

④ exocytosis
⑤ second messengers
⑥ enzyme-coupled receptors (receptor tyrosine kinase)
⑦ ion-channel-coupled receptors

Question 7-2.

Peptide B　insulin
Peptide C　glucagon

Question 7-3.

Signal transduction pathways consist of multiple stages and function to amplify weak input signals into large physiological outputs. Furthermore, each stage incorporates regulatory mechanisms, such as feedback and feedforward control, that enable cellular responses to be precisely regulated. Additionally, by integrating information from different pathways or branching inputs from a single pathway, cells can process complex information and respond in diverse ways to their environment.

Question 7-4.

Although the effect of Peptide A is not as strong as that of Peptide D, it is thought to act on pancreatic islet β-cells and promote insulin secretion. Therefore, β-cells are inferred to possess receptors that recognize Peptide A. Furthermore, because the effects of Peptide A and Peptide D on β-cells are strongly inhibited by Peptide E, both peptides are likely to act via the same receptor. If Peptide E binds to this receptor and inhibits the actions of Peptides A and D, then Peptide E can bind the receptor but cannot activate it or induce signal transduction. Furthermore, since the action of Peptide D is concentration-dependently inhibited by Peptide E, this suggests that Peptide E functions as an antagonist, competitively inhibiting the action of Peptide D by occupying the receptor.

QUESTION No. 8. (Subject on Life Science)

【Intent of the question】

To assess students' understanding of the structure and function of cell membranes, and of the role of cell walls in osmotic responses and solute transport in plants.

【Sample answer】

Question 8-1.

Question 8-1-1.

A phospholipid is an amphipathic molecule, meaning it has both a hydrophilic region and hydrophobic region. A phospholipid bilayer can exist as a stable boundary between two aqueous compartments because the molecular arrangement shelters the hydrophobic tails of the phospholipids from water while exposing the hydrophilic heads to water.

Question 8-1-2.

Most membrane proteins reside in the phospholipid bilayer with their hydrophilic regions protruding. A continuous hydrophobic region composed of amino acids with hydrophobic side chains is embedded within the membrane.

Question 8-1-3.

Fluid mosaic model

Question 8-2.

a) incorrect, from where it is more concentrated to where it is less concentrated

b) incorrect, polar molecules, ions

c) incorrect, transporters, pumps

Question 8-3.

Question 8-3-1.

When red blood cells are transferred to a hypertonic solution, they lose water and shrivel. When they are transferred to a hypotonic solution, they uptake water and lyse.

Question 8-3-2.

When plant cells are immersed in a hypertonic environment, they lose water and shrink. As they shrivel, their plasma membranes pull away from the cell walls at multiple places (plasmolysis). When plant cells are immersed in a hypotonic environment, they uptake water and swell. However, the relatively inelastic cell walls expand only to a limited extent. As they do, the cell contents exert turgor pressure against the cell walls, thereby opposing further water uptake.

Question 8-4.

① apoplast

② symplast

③ Casparian

Question 8-5.

Question 8-5-1.

Growing roots, shoots, stems, fruits, unfolding leaves and leaves during the night act as sinks. Tubers and bulbs act as sinks when receiving photosynthetic products from the leaves. Under sufficient light during the day, mature leaves act as sources. Tubers and bulbs become sources when they supply sugars to the growing aboveground parts.

Question 8-5-2.

A sugar concentration gradient is formed as sugars are consumed by cell growth and metabolism in the sinks or converted into insoluble substances such as starch.

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

【Intent of the question】

The question is designed to assess students' fundamental understanding of cell biology, including flagellar diversity across taxonomic groups, organismal responses to environmental cues, and the life cycles of seaweeds.

【Sample answer】

Question 9-1.

① 9
② doublet
③ 2
④ 0
⑤ triplet

Question 9-2.

animal sperm (2)
stramenopiles (3)
dinoflagellates (1)

Question 9-3.

Bacterial flagella are not composed of microtubules but consist of protein fibers and are

not surrounded by cell membrane. At the base of the flagellum, a motor embedded in the cell membrane is connected to the fibrous flagellar body through a hook. The flagellum rotates to propel the cell.

Question 9-4.

Taxis is the property by which a cell or organism moves in a specific direction in response to external stimuli such as light, chemicals or gravity.

Question 9-5.

(1) The sporophyte is a macroscopic thallus, whereas the gametophyte is microscopic and filamentous, indicating a heteromorphic life cycle.
(2) Meiosis occurs during spore formation in the sporophyte.
(3) They are motile using two flagella.
(4) Female gametophytes release eggs, whereas male gametophytes release sperm with two flagella.

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

【Intent of the question】

The question is designed to assess students' basic understanding of reproductive physiology and the mechanisms by which genetic diversity in offspring is produced through oogenesis and meiosis in sexually reproducing animals.

【Sample answer】

Question 10-1.

① prophase
② I
③ metaphase
④ II

Question 10-2.

Genetic diversity in gametes arises from the independent segregation of chromosomes and chromosomal recombination that occur during meiosis. During meiosis I, the

maternal chromosomes and paternal chromosomes of each homologous chromosome pair are independently distributed to the daughter cells. Furthermore, during prophase I of meiosis, when homologous chromosome pairs form, crossing over occurs between non-sister chromatids, resulting in recombinant chromosomes. Consequently, individual chromosomes come to carry genes from both parents in a mosaic pattern. Sister chromatids are no longer equivalent, thereby increasing the number of genotypes in the daughter cells.

Question 10-3.

When puberty begins, the anterior lobe of the pituitary gland increases its secretion of follicle-stimulating hormone (FSH). FSH reaches the ovaries via the bloodstream, stimulating ovarian follicle development and promoting estradiol production by the follicular cells surrounding the oocyte. Once the ovarian follicle has grown sufficiently, the anterior lobe of the pituitary gland secretes a large amount of luteinizing hormone (LH). When LH reaches the ovaries, it stimulates the ovarian follicle and triggers ovulation.

Question 10-4.

Offspring produced through sexual reproduction possess diverse genotypes even among siblings born to the same parents, and no two individuals will have exactly the same genotype. The presence of diverse genotypes may enhance survival and reproductive success, even when encountering new pathogens or rapid changes in environmental conditions. Another potential benefit is that it makes it easier to eliminate deleterious gene combinations from the population.

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

【Intent of the question】

To assess whether examinees understand the derivation of the population growth equations underlying the exponential growth model under unlimited resources and the logistic growth model under resource limitation, as well as their biological significance.

【Sample answer】

Question 11-1.

Question 11-1-1.

$\Delta N / \Delta t = B - D$

Question 11-1-2.

$B = bN$、$D = mN$

Therefore,

$\Delta N / \Delta t = bN - mN$ or

$\Delta N / \Delta t = (b - m) N$

Question 11-1-3.

Since $r = b - m$,

$\Delta N / \Delta t = r N$

Question 11-1-4.

The population size N increases when $r > 0$.

Because $\Delta N / \Delta t = r N$,

the increase in population size per unit time becomes larger as the population size N increases.

or

Population size increases exponentially.

Question 11-2.

Question 11-2-1.

Number of additional individuals that can still be supported by the environment:

$K - N$

Proportion of the carrying capacity available for population growth:

$(K - N) / K$

or

$1 - N / K$

Question 11-2-2.

$\Delta N / \Delta t = r N (1 - N / K)$

or

$\Delta N / \Delta t = r N ((K - N) / K)$

Question 11-2-3.

When N=0.1K：$\Delta N / \Delta t = 0.09\ r K$

When N=0.5K：$\Delta N / \Delta t = 0.25\ r K$

When N=0.9K：$\Delta N / \Delta t = 0.09\ r K$

Therefore, the population growth rate is greatest when N=0.5K.

Question 11-2-4.

Population growth is greatest at N = 0.5 K because when the population size is small, there are relatively few reproducing individuals, whereas when the population size is large, resource limitation reduces the per capita rate of increase. Thus, population growth is maximized at an intermediate population size.

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

【Intent of the question】

To test the fundamental knowledge of food webs in aquatic environments, light and nutrients controlling aquatic primary production, and the relationship between phytoplankton blooms and fishery resources.

【Sample answer】

Question 12-1.

The microbial loop is a system in which microorganisms, such as bacterial and protist communities, cycle organic matter in aquatic environments, including freshwater and marine ecosystems. In the classical (grazing) food chain, phytoplankton assemblages, which produce organic matter through photosynthesis by absorbing carbon dioxide (CO_2), sunlight, and nutrients, are grazed by zooplankton communities, thereby facilitating the transfer of energy to higher trophic levels in aquatic environments. In the microbial loop,

bacterial communities take up dissolved organic matter (DOM) released into water or seawater by phytoplankton, zooplankton, other aquatic organisms, and the remains and excreta of organisms. Protist communities, such as flagellates and ciliates, prey on bacterial communities and are, in turn, consumed by zooplankton in the classical (grazing) food chain. In other words, the microbial loop serves to reincorporate organic matter and energy back into the original classical (grazing) food chain in aquatic environments. The microbial loop increases and enhances the efficiency of material (carbon and biogeochemical) cycling in aquatic ecosystems and contributes to nutrient regeneration, making it an important concept in aquatic environments in both freshwater and marine ecosystems.

Question 12-2.

Light in the water column is exponentially attenuated. This phenomenon is expressed by the following equation:

$I_z = I_0 \exp(-k \cdot z)$,

where I_z is the irradiance at a certain depth (μmol photons m^{-2} s^{-1}), I_0 is the irradiance at the surface of the sea or lake, k is the light attenuation coefficient (or extinction coefficient, m^{-1}), and z is the depth (m). The attenuation coefficient k varies depending on water molecules, the concentrations of phytoplankton, other suspended matter, and dissolved substances. Because these components are more abundant in coastal waters than in the open ocean, the k value increases, and the depth to which light penetrates decreases. For primary producers, the compensation depth is where sufficient PAR for photosynthesis is available, at approximately 0.1–1% of the surface level. At this depth, photosynthesis and respiration are balanced. Net photosynthesis occurs only in layers shallower than this, called the euphotic zone (or photic zone), which is shallower than 100 m in tropical and subtropical open oceans, but can be less than 10 m in coastal areas.

Question 12-3.

There are four types of HABs, as described below.

1. Biomass blooms (High phytoplankton counts): These are basically harmless, but their massive proliferation causes water quality to deteriorate, resulting in hypoxic water masses that cause mass mortality of fish and shellfish.

2. Toxic bloom: potent toxins causing a variety of gastrointestinal and neurological illnesses through the food chain to humans, including paralytic shellfish poisoning (PSP), diarrhetic shellfish poisoning (DSP), amnesic shellfish poisoning (ASP), neurotoxic shellfish poisoning (NSP), and ciguatera poisoning (Fish poisoning).

3. Noxious (Fish-kill forming) red tide: Nontoxic to humans, but primarily causes mass mortality of farmed aquatic organisms, especially in aquaculture. It has caused fishery damage amounting to billions of yen to a wide variety of middle- and high-value farmed species.
4. Diatom bloom: The species consume more nutrients during the seaweed cultivation season, causing a reduction in the quality of the seaweed and damage to the fishery.