

北海道大学大学院環境科学学院
環境起学専攻

Division of Environmental Science Development
Graduate School of Environmental Science, Hokkaido University
Course in Human and Ecological Systems, Course in Environmental Adaptation Science,
and Course in Global Environmental Management

令和 4 年度大学院修士課程入学試験問題 (秋季入試)

令和 3 年度 10 月入学大学院修士課程入学試験問題

Entrance Examination

専門科目

Specialized Subjects

[留学生用]

For international students

- **Nine questions are given in the subjects of Environmental Science (3 questions), Mathematics and Physics (2 questions), Ecology and Geography (2 questions), and Chemistry and Biology (2 questions). Candidates are required to answer 2 questions out of 9 questions.**
- **Use one answer sheet for each question.**
- **Backside of answer sheet can be used if necessary.**
- **Specify the subject name and the question number on each answer sheet.**

August 24, 2021

Environmental Science

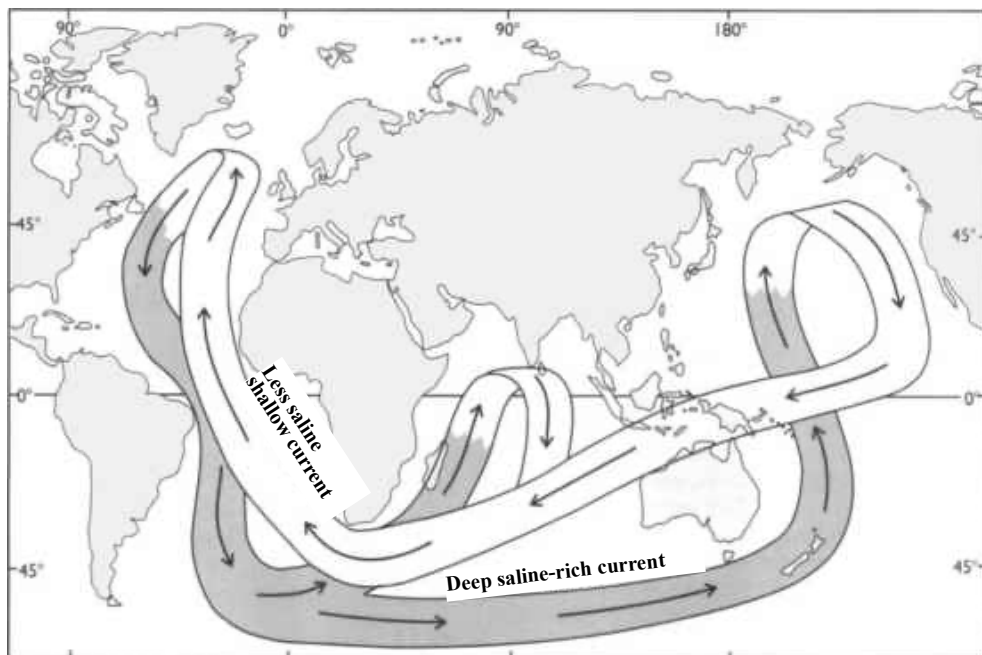
Question 1. Answer the questions (1) to (4).

- (1) One country decided not to chlorinate drinking water, since chlorination causes production of a carcinogen, trihalomethane. As a result, outbreak of cholera occurred. Explain a problem of this policy-making in 2-4 lines.
- (2) There are four types of recycling. 1) Primary recycling or closed-loop recycling. 2) Secondary recycling or conversion recycling. 3) Tertiary recycling or chemical recycling. 4) Quaternary recycling or thermal recycling. Tertiary recycling uses waste plastic as the feedstock in a process that generates chemicals and fuels. Quaternary recycling recovers energy from waste plastic by incineration. Explain examples of primary recycling and secondary recycling within five lines in total.
- (3) Chlorinated organic compounds such as dioxins and PCBs are persistent. Explain a problem caused by persistency of chlorinated organic compounds within four lines.
- (4) Explain environmental problems caused by sulfur dioxide released into the atmosphere within five lines.

Environmental Science

Question 2. Answer the questions (1) to (3).

- (1) Water exists as the form of solid, liquid and gas on the earth with the total amount of approximately 1.4 billion km³. How much percentage of this is occupied by fresh water? Describe what types of water resources are available for human use and the requisites for their exploitation, considering the global water cycle system in about 4 lines.
- (2) The red tides may occur when water contaminated by human activities is flowed into the rivers, lakes and oceans without proper treatment. Describe the mechanism causing the red tides in about 4 lines.
- (3) The following figure shows global ocean circulation called as the thermohaline circulation. Explain the mechanism driving this circulation in 4 lines. Furthermore, describe how this circulation affects local climate in about 4 lines.



Environmental Science

Question 3. Read following sentences and answer the questions (1) to (5).

In projected climate changes, some possible effects of a warmer atmosphere are predicted. For example, atmospheric warming will raise the number and intensity of extreme ⁽ⁱ⁾weather events in some areas. This in turn could affect ⁽ⁱⁱ⁾biological diversity, agriculture, and the health of people. Under such changing environments, appropriate dam operations may contribute to ⁽ⁱⁱⁱ⁾maintain stable supplies of water resources, conserve habitat of wildlife, and reduce the risk of flood disasters. In many cases, multi-purpose dams have a capacity of hydroelectric power generation and provide a source of ^(iv)renewable energy. In contrast, excessive controls of water in dams can have ^(v)harmful effects on downstream environments. Therefore, to adapt well to a changing environment, sustainable water resource management at the watershed scale by considering these factors will be needed.

- (1) For lined sentence (i), one example of weather events is floods. Write down another weather event concerned to increase in the future.
- (2) For lined sentence (ii), explain how atmospheric warming can affect each of biological diversity, agriculture, and the health of people. Three answers are needed each within five lines.
- (3) For lined sentence (iii), good management of forest is also important to maintain stable supplies of water resources. Explain the reason within five lines.
- (4) For lined sentence (iv), one example of renewable energy is hydroelectric power. Write down other three examples of energy sources.
- (5) For lined sentence (v), explain two examples of downstream effects by elaborating on how dams result in such consequences within five lines each.

Mathematics and Physics

Question 4 Answer the following questions (1) to (4).

(1) Obtain the following indefinite integrals.

(a) $\int x^2 e^{3x} dx$

(b) $\int \sin^2 x \cos x dx$

(2) Differentiate the following functions.

(a) $x^2 e^{-x} \cos x$

(b) 2^x

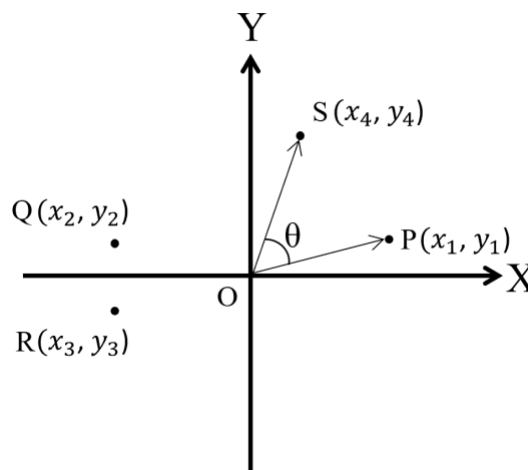
(3) Answer the following questions concerning the figure below.

(a) Obtain the matrix \mathbf{A} which satisfies $\begin{pmatrix} x_2 \\ y_2 \end{pmatrix} = \mathbf{A} \begin{pmatrix} x_1 \\ y_1 \end{pmatrix}$, where Q and P are symmetric about the Y-axis.

(b) Obtain the matrix \mathbf{B} which satisfies $\begin{pmatrix} x_3 \\ y_3 \end{pmatrix} = \mathbf{B} \begin{pmatrix} x_1 \\ y_1 \end{pmatrix}$, where R and P are symmetric about the origin point O.

(c) Obtain the matrix \mathbf{C} which satisfies $\begin{pmatrix} x_4 \\ y_4 \end{pmatrix} = \mathbf{C} \begin{pmatrix} x_1 \\ y_1 \end{pmatrix}$, where the counterclockwise rotation of the vector \overrightarrow{OP} by an angle θ about the origin point O gives the vector \overrightarrow{OS} .

(d) Prove $\mathbf{B} = \mathbf{C}\mathbf{C}$ when $\theta = 90^\circ$.



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(4) Answer the following questions on the function $f(x) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$.

(a) Obtain $\int_{-\infty}^{\infty} f(x)dx$ and $\int_{\mu}^{\infty} f(x)dx$ (no calculation required).

(b) Assuming $f(x)$ gives probability density of x , prove that the expected value of x , namely

$$\int_{-\infty}^{\infty} xf(x)dx, \text{ equals to } \mu. \text{ You must use Gaussian integral, } \int_{-\infty}^{\infty} e^{-ax^2} dx = \sqrt{\frac{\pi}{a}}.$$

(c) In a similar manner to (b), prove that the variance of x equals to σ^2 . You must use Gaussian integral,

$$\int_{-\infty}^{\infty} x^2 e^{-ax^2} dx = \frac{1}{2a} \sqrt{\frac{\pi}{a}}.$$

Mathematics and Physics

Question 5 Answer the following questions (1) and (2).

(1) Answer questions (a)-(e) concerning the energy budget of the Earth as summarized in Fig. 1.

(a) Explain the terms below in about two lines for each.

【Terms】 Sensible heat flux, Upward longwave radiation, Atmospheric window, Aerosol

(b) Solar radiation is an essential component of the renewable energy and photosynthesis of the plants. Find the magnitude of downward solar radiation energy at the Earth surface from Fig. 1, and answer it with unit.

(c) Calculate the total mass of water in kilogram evaporated per year from the Earth surface using the value in Fig. 1. Assume that the total area of the Earth surface is A (m^2), and the latent heat for vaporization is L (J/kg). All calculation steps should be written in the answer sheet.

(d) Describe the roles of clouds in Earth's climate from a viewpoint of energy budget in about four lines.

(e) A satellite measurement offers information of cloud distribution even during the nights. Explain the methodology how it becomes possible in about four lines using the Fig. 1.

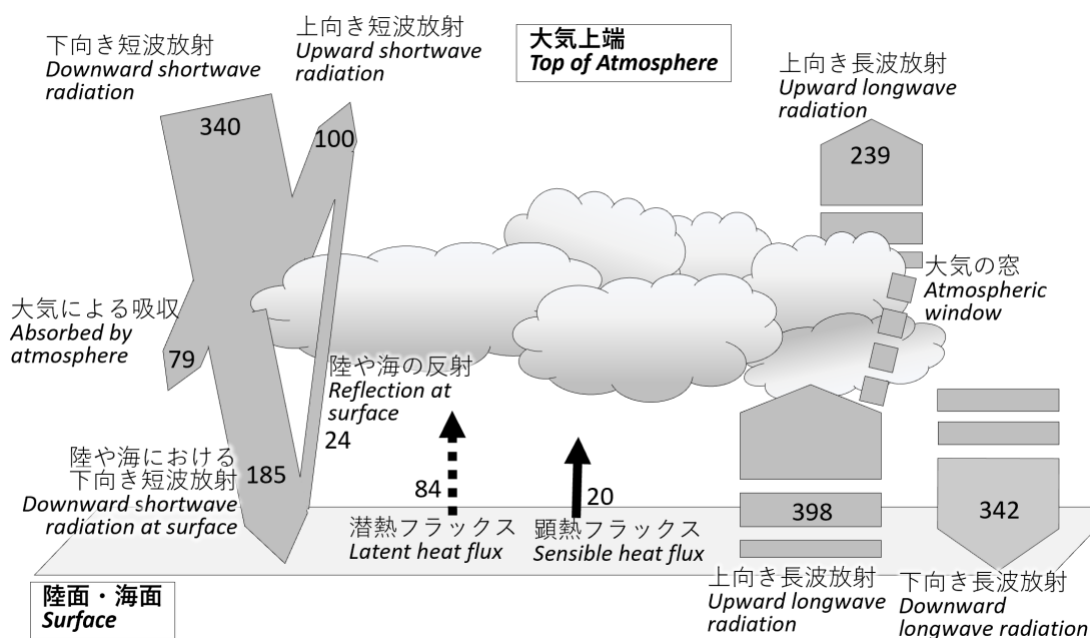


Figure 1: Global mean energy budget under present-day climate conditions. Numbers indicate magnitudes of the individual energy fluxes in W/m^2 . Modified after IPCC 5th assessment report.

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(2) Answer the following questions (a)-(d) concerning the air and ocean circulations.

(a) Explain the terms below in about two lines for each.

【Terms】 Trade wind, Hadley circulation, Thermocline

(b) Figure 2 illustrates the patterns of surface winds and sea water flows. Referring to Fig. 2, explain "Equatorial upwelling" and "Coastal upwelling" in about three lines for each.

(c) La Niña refers to the condition that sea surface temperature tends to be low in eastern equatorial Pacific. Explain the characteristics of surface winds and sea water flows during La Niña in about four lines.

(d) Explain the possible impacts of La Niña on marine ecosystems in about three lines using the keyword "phytoplankton".

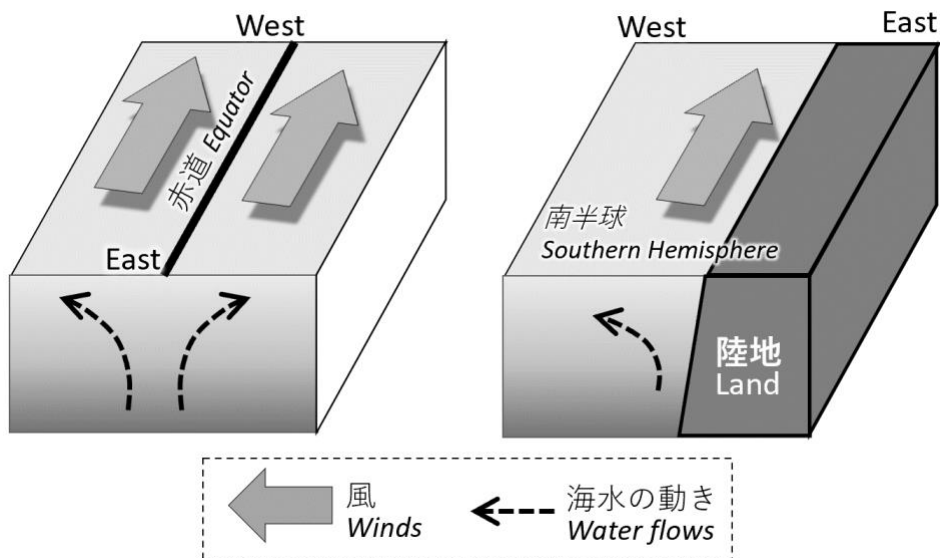


Figure 2: Surface winds and sea water flows.

Ecology and Geography

Question 6 Answer all the questions (1) to (3).

(1) Explain each of the five ecological terms (i) to (v).

- (i) life history (ii) net primary productivity (iii) food web
(iv) nitrogen fixation (v) greenhouse effect

(2) Answer the questions (a) to (c), based on the text.

(i)Sun tree forest develops in the late states of succession in regions where precipitation is plenty, and then the forest is replaced by (ii)shade tree forest in many cases. Shade tree forest is often fit into climax forest. (iii)Species diversity in climax forest is sometimes lower than that in seral communities.

(a) On the underlines (i) and (ii), show a representative tree species of each category.

(b) On the underlines (i) and (ii), explain why such succession occurs by using “light saturation”, “respiration rate”, and “photosynthetic active radiation”. Underline these three words in the answer.

(c) On the underline (iii), explain why such pattern occurs.

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(3) Examine the table and figure and answer the questions (a) to (d).

Table. Hypothetical experimental plots (25m²) containing different number of individuals in different species with the same total abundance (12 individuals). sp.1, sp.2, sp.3, and sp.4 represent four different species.

	sp.1	sp.2	sp.3	sp.4	Total abundance
Plot A	4	4	4	0	12
Plot B	3	3	3	3	12
Plot C	8	1	2	1	12

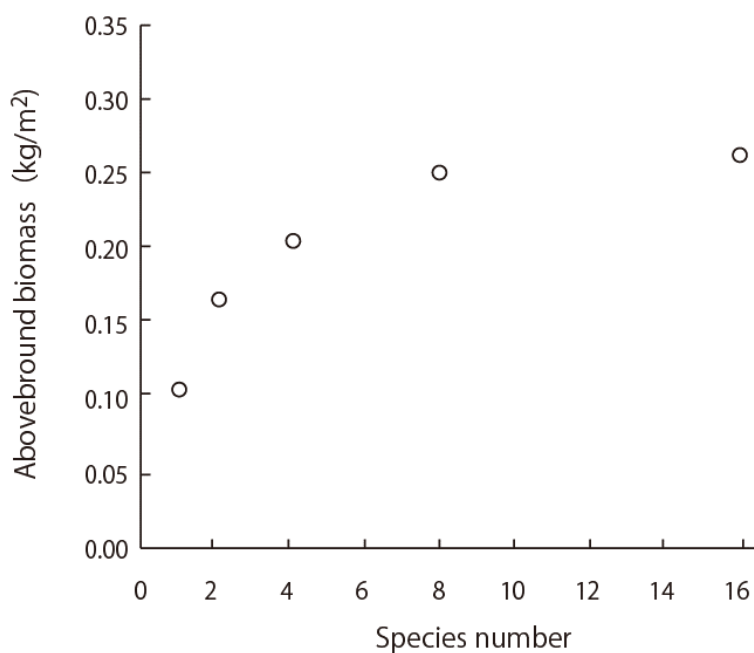


Figure. A biplot showing the mean species number of plant and their aboveground biomass within the experimental plots (81m²) in the prairie of Midwestern USA. Experimental plots were controlled to have the same plant density regardless of species number. (modified from Tilman et al., 2001)

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- (a) In the table, when both evenness and species number were considered, the plot B has the highest species diversity. Provide explanations why the plot B has a higher species diversity than the plot A, and why the plot B has a higher species diversity than the plot C within five lines each. In each answer, make sure to use both terms 'evenness' and 'species number'.
- (b) Concerning the figure, explain the trend in the relationship between species number and aboveground biomass and elaborate on the importance of this relationship for the conservation of species diversity within five lines. Make sure to use the term 'ecosystem function'.
- (c) Concerning the figure, provide one explanation of the mechanisms driving the trend within five lines.
- (d) At the plot scale similar to the table and figure, species diversity of many organisms is higher in areas near the equator than high-latitude areas. Provide an explanation of the mechanism behind this pattern within five lines. Make sure to use the terms 'net primary production' and 'climate'.

Ecology and Geography

Question 7 Provide answers to both questions (1) and (2).

(1) The following text and Figure 1 describe a meandering river. Read the text and answer questions (a) and (b).

The reasons for the development of meandering in straight river channels are not fully understood. It seems that meandering occurs once the flow begins to oscillate. Meanders do not develop in (A) where the channel morphology is constantly changing with the flow rate.

The characteristics of meandering zones are shown in Figure 1. As shown in this figure, at the meandering bend, (i) the channel cross-section is asymmetrical because of (B) occurring outside the bend and (C) inside. Pools are formed at the bends, and (D) are formed between the pools. As the meanders move, they leave (E) and depressions where meandering point-bars have already been formed.

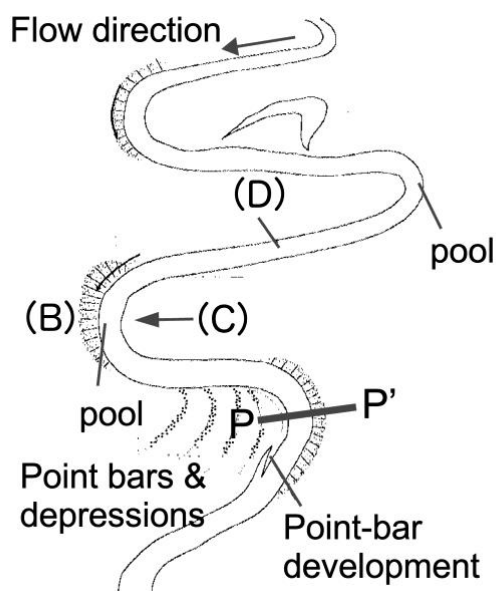


Figure 1: Landforms in a meandering zone.

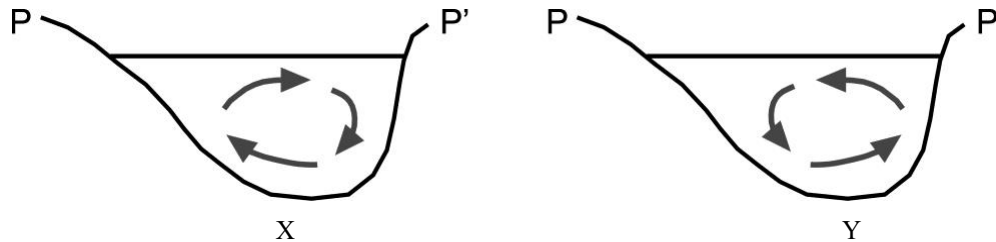
(Modified from "A Level Geography" (1996) Letts Educational)

(a) Select appropriate terms in (A) to (E) from the followings.

ablation, accumulation, erosion, land-tied islands, outwash plains,
 oxbow lakes, riffles, sandy area, sedimentation

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- (b) Regarding the underlined part of (i) in the text above, choose the correct diagram that shows the direction of water flow in the channel cross section at P-P' in Figure 1 from X and Y below, and explain the reason for your choice in about two lines.



- (2) Figures 2 and 3 are parts of old and new topographic maps of the same area. Look at these maps and answer (a) to (f) below.

(a) Are the river gradients in the channel B-B' sections in Figures 2 and 3 the same or different? Give the reason in about three lines.

(b) Find the difference in elevation between point C and point D in Figure 3.

(c) Write the topographic characteristics of landforms E and F in Figure 2 in about one line each.

(d) Which lake (Q or R) in Figure 3 is older in its formation? Provide the reason in about three lines.

(e) In about one line, provide one reason why channel T with developed meandering in Figure 2 was changed to the straight channel B-B' section in Figure 3.

(f) Comparing Figure 2 and Figure 3, the occurrence of some disasters has been decreased in this area. By the decrease, how had the land use changed in this area by the time of Figure 3? Describe the land use change in four lines.

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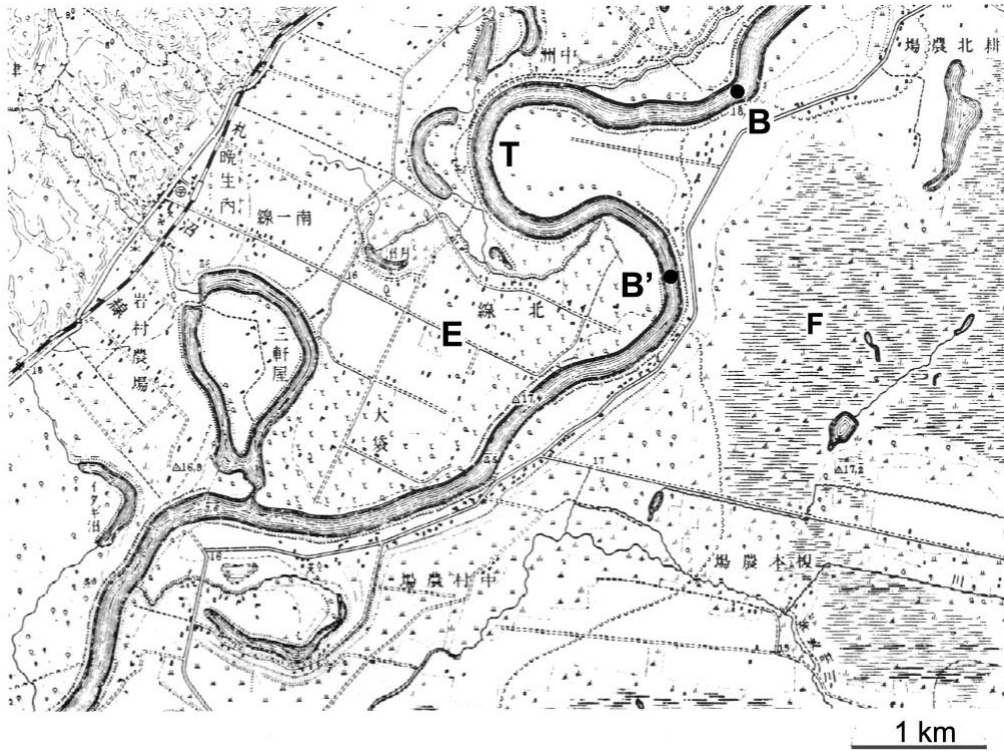


Figure 2: Topographic map in 1916 (original map: 1:50,000) in a part of Hokkaido

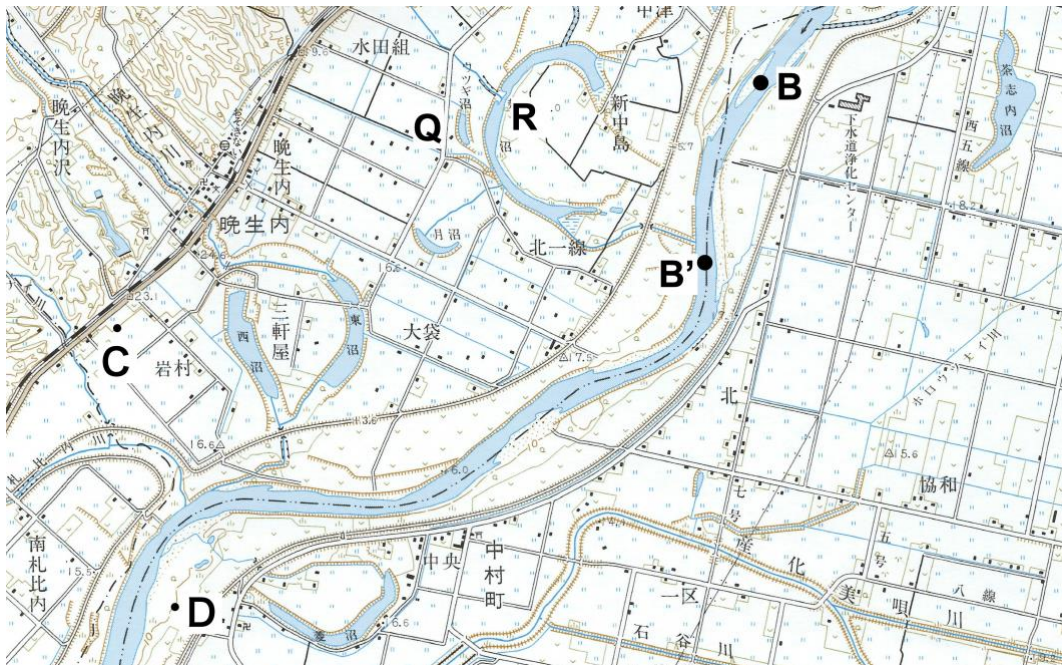


Figure 3: Topographic map in 1995 (original map: 1:50,000) in a part of Hokkaido

Chemistry and Biology

Question 8 Answer the following questions (1) to (4). In the case of numerical calculations, describe the calculation processes. If necessary, use the following atomic weights, C: 12, N: 14, O: 16, and Mg: 24.

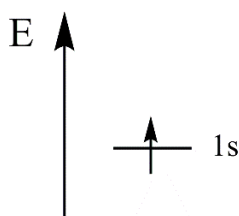
(1) Answer the following questions on an atomic structure.

(a) A wave function obtained by resolving the Schrödinger equation contains three kinds of quantum numbers. Write the names of these quantum numbers.

(b) Describe the shapes of $2p_z$ and $3d_{x^2-y^2}$ orbitals in terms of their phase (plus and minus of amplitude) and direction.

(c) Describe the electronic configuration of Si in the ground state as in the following example.

example: hydrogen H



(2) The boiling points of pentane isomers are as follows: *n*-pentane 36.1 °C, 2-methylbutane 27.9 °C and 2,2-dimethylpropane 9.5 °C. Explain the difference in boiling points in terms of molecular structures.

(3) When 0.300 g of Mg was strongly heated under N_2 atmosphere, a compound with Mg and N was obtained. The yield of the compound was 0.416 g. Calculate the composition formula of this compound.

(4) Nitrogen monoxide included in car exhaust reacts with oxygen in air to transform to nitrogen dioxide. Regarding this reaction, initial rates were measured by changing initial concentrations of nitrogen monoxide and oxygen and the results were as follows.

Experiment	Initial concentration (mol L ⁻¹)		Initial rate (mol(nitrogen monoxide) L ⁻¹ s ⁻¹)
	nitrogen monoxide	oxygen	
1	0.015	0.020	0.15
2	0.030	0.020	0.60
3	0.030	0.040	1.20

(a) Describe this reaction formula.

(b) What is the overall reaction order?

(c) Calculate the reaction rate constant. Answer with a unit and two significant digits.

Chemistry and Biology

Question 9 Answer the following questions (1) and (2).

(1) Explain the meaning and mutual relationship of the following two words in about six lines. Answer all four questions (a) to (d).

(a) transcription regulation, operon

(b) intron, cDNA

(c) active transport, cytosol

(d) histone, chromatin structure

(2) Indicate whether the following statements (a) to (h) are true or false. If a statement is false, explain why.

(a) When deprived of the appropriate set of signals for survival, a cell activates a suicide program and kill itself. It is called apoptosis.

(b) Animal cells store fuel in glucose and fatty acids to ensure a continuous supply of energy from oxidative metabolism.

(c) The most significant contribution of the citric acid cycle to metabolism is the generation of high-energy compounds during the oxidation of the two carbon atoms of acetyl-CoA to carbon dioxide.

(d) Lysosomes are organelles made of a sac-like membrane that is found in almost all nucleated eukaryotic cells.

(e) Animal and plant cells typically have a single Golgi apparatus.

(f) Phospholipids are added to the endoplasmic reticulum and subsequently transferred to mitochondria in the cell by transport vesicles.

(g) Because the outer mitochondrial membrane has large-scale pores, it does not present a permeability barrier to proteins.

(h) Membrane proteins exist as an extended monolayer on both surfaces of the lipid bilayer.