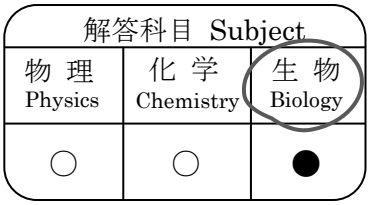
Biology

Marking Your Choice of Subject on the Answer Sheet

Choose two subjects from Physics, Chemistry, and Biology, and answer the questions for each. Use the front of the answer sheet for one subject and the back for the other.

As shown in the example on the right, if you answer the Biology questions, circle "Biology" and completely fill in the oval under the subject name.

＜解答用紙記入例＞



If you do not fill in the correct oval, your answers will not be graded.

Q1 Among the components that make up plant cells, excluding water, which substance has the greatest mass? Choose one from the following options ① to ⑤. 1

① Carbohydrates ② Proteins ③ Lipids
④ Inorganic salts ⑤ Nucleic acids

Q2 Read the following statements (A) to (C) about the genomic DNA of eukaryotic and prokaryotic cells, and select the option that includes only the correct statements from the choices ① to ⑦ below. If none of the statements are correct, choose option ⑧ "None of the above". 2

[Statements]
(A) The genomic DNA of eukaryotic cells is wrapped around proteins called histones.
(B) The genomic DNA of prokaryotic cells is circular and has multiple origins of replication.
(C) Both types of genomic DNA have a double-helix structure.

① (A), (B), (C) ② (A), (B) ③ (B), (C) ④ (A), (C)
⑤ (A) ⑥ (B) ⑦ (C) ⑧ None of the above

Q3 Choose the correct order from smallest to largest for the following: human red blood cells, E. coli, Paramecium, and coronaviruses, from the options ① to ⑥ below. 3

① Human red blood cells < E. coli < Paramecium < Coronavirus
② E. coli < Coronavirus < Paramecium < Human red blood cells
③ E. coli < Coronavirus < Human red blood cells < Paramecium
④ Coronavirus < E. coli < Paramecium < Human red blood cells
⑤ Coronavirus < E. coli < Human red blood cells < Paramecium
⑥ Paramecium < Coronavirus < E. coli < Human red blood cells

Q4 When observing a specimen with an optical microscope, first attach the [a] lens, then attach the [b] lens. Next, rotate the revolving nosepiece and set it to the [c] magnification, then adjust the diaphragm to control the brightness of the field of view. After that, place the prepared slide with the specimen on the stage, and while watching from the side of the microscope, turn the adjustment knob to bring the objective lens and the slide as [d] as possible. Finally, while looking through the eyepiece, turn the adjustment knob to bring the object into clear focus. Choose the appropriate combination of terms for [a] to [d] from the following options ① to ⑧: [4]

	[a]	[b]	[c]	[d]
①	Eyepiece	Objective	High	Closer
②	Eyepiece	Objective	High	Farther
③	Eyepiece	Objective	Low	Closer
④	Eyepiece	Objective	Low	Farther
⑤	Objective	Eyepiece	High	Closer
⑥	Objective	Eyepiece	High	Farther
⑦	Objective	Eyepiece	Low	Closer
⑧	Objective	Eyepiece	Low	Farther

Q5 Read the following statements (A) to (C) about the cell membrane, and select the option that includes only the correct statements from the choices ① to ⑦ below. If none of the statements are correct, choose option ⑧ "None of the above". [5]

[Statements]

(A) The cell membrane has a structure where many phospholipid molecules are strongly bonded and aligned.

(B) Various proteins involved in active transport and signal transduction are embedded in the cell membrane.

(C) The cell membrane allows the passage of small molecules such as oxygen and carbon dioxide.

① (A), (B), (C)	② (A), (B)	③ (B), (C)	④ (A), (C)
⑤ (A)	⑥ (B)	⑦ (C)	⑧ None of the above

Q6 Read the following statements (A) to (C) about human digestive enzymes, and select the option that includes only the correct statements from the choices ① to ⑦ below. If none of the statements are correct, choose option ⑧ "None of the above". 6

[Statements]

(A) Saliva and pancreatic juice contain amylase, which has the function of breaking down starch.

(B) Gastric juice contains pepsin, which has the function of breaking down proteins.

(C) Pancreatic juice contains trypsin, which has the function of breaking down fats.

① (A), (B), (C)	② (A), (B)	③ (B), (C)	④ (A), (C)
⑤ (A)	⑥ (B)	⑦ (C)	⑧ None of the above

Q7 The variable region of the immunoglobulin genes for the heavy chain (H chain) consists of three regions, and the variable region of the light chain (L chain) consists of two regions. Each region is composed of numerous smaller sub-regions. During the maturation process of B cells, one sub-region from each region is selected and linked together to create a new combination. If the three regions of the H chain have 50, 30, and 6 sub-regions respectively, and the two regions of the L chain have 50 and 6 sub-regions respectively, what is the approximate number of different antibodies that can be synthesized? Choose the appropriate option from ① to ⑧. 7

① 4.8×10^{3}	② 9.6×10^{3}	③ 2.7×10^{6}	④ 7.3×10^{6}
⑤ 2.3×10^{7}	⑥ 4.6×10^{7}	⑦ 5.4×10^{12}	⑧ 7.3×10^{12}

Q8 Read the following statements (A) to (C) about the electron transport chain in chloroplasts, and select the option that includes only the correct statements from the choices ① to ⑦ below. If none of the statements are correct, choose option ⑧ "None of the above". 8

[Statements]

(A) The flow of electrons causes the transport of hydrogen ions.

(B) The electrons are ultimately transferred to $NADP^{+}$.

(C) The electron transport chain is located in the outer membrane of the chloroplast.

① (A), (B), (C)	② (A), (B)	③ (B), (C)	④ (A), (C)
⑤ (A)	⑥ (B)	⑦ (C)	⑧ None of the above

Q9 Read the following statements (A) to (C) about the electron transport chain in mitochondria, and select the option that includes only the correct statements from the choices ① to ⑦ below. If none of the statements are correct, choose option ⑧ "None of the above". 9

[Statements]

(A) The flow of electrons results in the transport of hydrogen ions.

(B) The electrons are ultimately transferred to NAD^+

(C) It is located in the inner membrane of the mitochondria.

① (A), (B), (C)	② (A), (B)	③ (B), (C)	④ (A), (C)
⑤ (A)	⑥ (B)	⑦ (C)	⑧ None of the above

Q10 Read the following statements (A) to (C) about carbon assimilation in bacteria, and select the option that includes only the correct statements from the choices ① to ⑦ below. If none of the statements are correct, choose option ⑧ "None of the above". 10

[Statements]

(A) Cyanobacteria perform photosynthesis using water and carbon dioxide as raw materials.

(B) Green sulfur bacteria perform photosynthesis using water and sulfur as raw materials.

(C) Nitrifying bacteria perform chemosynthesis using water and nitrate ions as raw materials.

① (A), (B), (C)	② (A), (B)	③ (B), (C)	④ (A), (C)
⑤ (A)	⑥ (B)	⑦ (C)	⑧ None of the above

Q11 Consider a somatic cell before DNA replication as Cell A, a somatic cell after DNA replication as Cell B, and a somatic cell immediately after cell division as Cell C. Choose the appropriate combination of ploidy and DNA content for Cells B and C from the options ① to ⑧ below. Assume that Cell A has a ploidy of $2n$ and a DNA content of 1 (relative value). 11

	Cell B Ploidy	Cell B DNA Content	Cell C Ploidy	Cell C DNA Content
①	$2n$	2	$2n$	1
②	$2n$	2	$2n$	2
③	$2n$	4	n	2
④	$2n$	4	n	4
⑤	$4n$	2	$2n$	1
⑥	$4n$	2	$2n$	2
⑦	$4n$	4	n	2
⑧	$4n$	4	n	4

Q12 How many of the following materials are <u>inappropriate</u> for use in a PCR (Polymerase Chain Reaction) procedure? Select the correct number from the options ① to ⑧ below. 12

［Materials］ Template DNA, DNA primer, RNA primer, DNA polymerase, RNA polymerase, Deoxynucleotide, Dideoxynucleotide

① 1 ② 2 ③ 3 ④ 4
⑤ 5 ⑥ 6 ⑦ 7 ⑧ None of the above

Q13 Read the following statements (A) to (C) about the lactose operon in E. coli, and select the option that includes only the correct statements from the choices ① to ⑦ below. If none of the statements are correct, choose option ⑧ "None of the above". 13

[Statements]

(A) When lactose is absent, the repressor binds to the operator, and the expression of the genes involved in lactose metabolism is suppressed.

(B) When glucose is absent and lactose is present, a lactose metabolite binds to the repressor, preventing it from binding to the operator, and the genes involved in lactose metabolism are expressed.

(C) If a mutation prevents the repressor from binding to the lactose metabolite, the genes involved in lactose metabolism will always be expressed.

① (A), (B), (C)	② (A), (B)	③ (B), (C)	④ (A), (C)
⑤ (A)	⑥ (B)	⑦ (C)	⑧ None of the above

Q14 Consider a plant where the gene for seed shape is round (*A*) or wrinkled (*a*), and the gene for flower color is red (*B*) or purple (*b*). A plant (individual P) with round seeds and red flowers is test-crossed, and the phenotypic ratio in the next generation is round/red: round/purple: wrinkled/red: wrinkled/purple = 1 : 4 : 4 : 1. If individual P self-fertilizes and produces a large number of offspring, what percentage of the next generation will have the genotype *aabb*? Choose the appropriate percentage from the options ① to ⑧ below. 14

① 1%	② 4%	③ 8%	④ 10%
⑤ 16%	⑥ 20%	⑦ 24%	⑧ 30%

Q15 Read the following statements (A) to (C) about human meiosis and gametes, and select the option that includes only the correct statements from the choices ① to ⑦ below. If none of the statements are correct, choose option ⑧ "None of the above". 15

[Statements]

(A) Primary spermatocytes arise from a portion of spermatogonia, and four spermatids are produced from one primary spermatocyte through meiosis.

(B) Oogonia have a ploidy of *2n*, and secondary oocytes have a ploidy of *n*. The resulting egg also has a ploidy of *n*, and the side where the polar body is released is called the animal pole.

(C) The head of a sperm contains the nucleus, and the midpiece contains mitochondria that produce ATP to power the flagellum.

① (A), (B), (C)	② (A), (B)	③ (B), (C)	④ (A), (C)
⑤ (A)	⑥ (B)	⑦ (C)	⑧ None of the above

Q16 Select the appropriate combination of organs derived from each of the three germ layers in human development from the options ① to ⑧ below. 16

	Ectoderm	Mesoderm	Endoderm
①	Epidermis	Liver	Heart
②	Epidermis	Kidney	Skeletal muscle
③	Dermis	Liver	Lungs
④	Dermis	Kidney	Intestines
⑤	Spinal cord	Liver	Heart
⑥	Spinal cord	Kidney	Skeletal muscle
⑦	Lens	Liver	Lungs
⑧	Lens	Kidney	Intestines

Q17 Read the following statements (A) to (C) about the autonomic nervous system, and select the option that includes only the correct statements from the choices ① to ⑦ below. If none of the statements are correct, choose option ⑧ "None of the above". 17

[Statements]

(A) When the sympathetic nervous system is activated, the heart rate increases, and the peristaltic movements of the small intestine are also promoted.

(B) When the parasympathetic nervous system is activated, the pupils constrict, and urination is suppressed.

(C) The autonomic nerves originate in the diencephalon and are distributed throughout the body without passing through the spinal cord.

① (A), (B), (C)	② (A), (B)	③ (B), (C)	④ (A), (C)
⑤ (A)	⑥ (B)	⑦ (C)	⑧ None of the above

Q18 Read the following statements (A) to (C) about hormones, and select the option that includes only the correct statements from the choices ① to ⑦ below. If none of the statements are correct, choose option ⑧ "None of the above". 18

[Statements]

(A) Hormones secreted by the pituitary gland include growth hormone and vasopressin.

(B) When body temperature decreases, thyroxine is secreted from the thyroid gland, which promotes metabolism in body cells.

(C) The receptors for water-soluble hormones like insulin are located inside the nucleus of target cells.

① (A), (B), (C)	② (A), (B)	③ (B), (C)	④ (A), (C)
⑤ (A)	⑥ (B)	⑦ (C)	⑧ None of the above

Q19 How many of the following immune cells perform phagocytosis to break down foreign substances? Select the correct number from the options ① to ⑧ below. 19

［Cells］ Neutrophils, Helper T cells, Killer T cells, Antibody-producing cells, Macrophages, Dendritic cells, NK cells

① 1	② 2	③ 3	④ 4
⑤ 5	⑥ 6	⑦ 7	⑧ None of the above

Q20 When [e] acts on plant epidermal cells, cellulose fibers in the cell wall are formed in the [f] direction, and when [g] acts, the cells undergo lateral expansion as they absorb water. Choose the appropriate combination of terms for [e] to [g] from the options ① to ⑧ below. 20

	[e]	[f]	[g]
①	Abscisic acid	Vertical	Auxin
②	Abscisic acid	Horizontal	Auxin
③	Gibberellin	Vertical	Abscisic acid
④	Gibberellin	Horizontal	Abscisic acid
⑤	Auxin	Vertical	Gibberellin
⑥	Auxin	Horizontal	Gibberellin
⑦	Ethylene	Vertical	Auxin
⑧	Ethylene	Horizontal	Auxin

Q21 A skeletal muscle attached to a motor nerve was removed from an animal, and a contraction recording apparatus was set up. When the muscle was directly stimulated at the nerve-muscle junction using stimulating electrodes, a single contraction occurred, resulting in a myogram like Figure 1. Next, when the nerve was stimulated 15 cm away from the junction, a result like Figure 2 was obtained. When the nerve was stimulated 45 cm away from the junction, a result like Figure 3 was obtained. The horizontal axis of the graph represents time (×10 milliseconds).

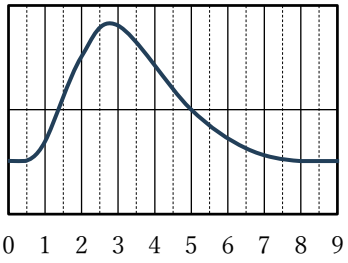


Figure 1

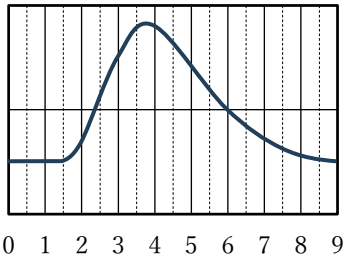


Figure 2

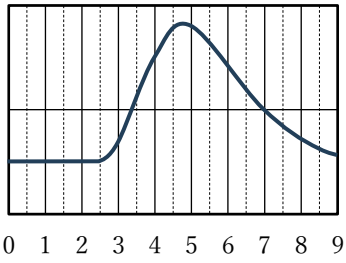


Figure 3

Based on these results, choose the appropriate combination of the nerve conduction speed (m/s) and the time required for the transmission of excitation from the nerve to the muscle (milliseconds) from the options ① to ⑧ below. 21

	Conduction Speed (m/s)	Transmission Time (ms)
①	15	5
②	30	5
③	45	5
④	60	5
⑤	15	10
⑥	30	10
⑦	45	10
⑧	60	10

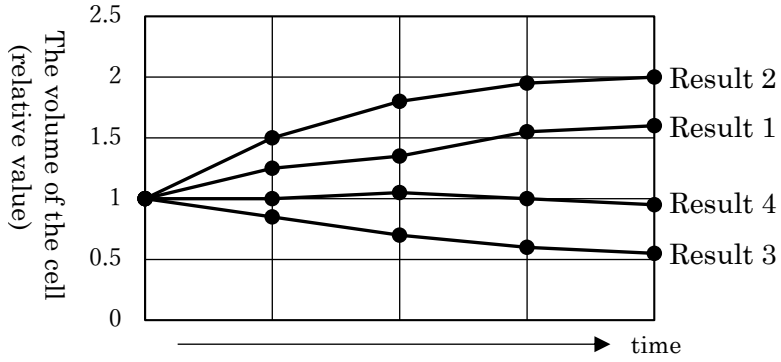
Q22 Aquaporin is a protein found in the cell membrane that is involved in the transport of water molecules. To investigate its function, the following experiments 1 to 4 were conducted using cultured animal cells, with the results shown in Figure 4.

Experiment 1: The cultured cells were immersed in a hypotonic solution (a solution with lower osmotic pressure than the cells), and the volume changes were measured (Result 1).

Experiment 2: Cells with artificially increased aquaporin expression were created and immersed in the same hypotonic solution used in Experiment 1, and the volume changes were measured (Result 2).

Experiment 3: The cultured cells were immersed in a hypertonic solution (a solution with higher osmotic pressure than the cells), and the volume changes were measured (Result 3).

Experiment 4: The cultured cells were immersed in a hypotonic solution containing silver chloride, which is known to inhibit the function of aquaporin, and the volume changes were measured (Result 4).



Changes in cell volume over time

Figure 4

Based on the results of these experiments, predict what would happen if the expression of aquaporin were reduced using RNA interference (RNAi) technology and the cultured cells were immersed in the same hypotonic solution as in Experiment 1. Choose the most appropriate outcome from the options ① to ⑨ below. 22

① Similar to Result 1 ② Similar to Result 2
③ Similar to Result 3 ④ Similar to Result 4
⑤ Between Result 2 and Result 1 ⑥ Between Result 1 and Result 4
⑦ Between Result 4 and Result 3 ⑧ Greater than Result 2
⑨ Less than Result 3

End of Biology questions. Leave the answer spaces 23 ～ 75 blank.

Please check once more that you have properly marked the name of your subject as “Biology” on your answer sheet.

Do not take this question booklet out of the room.