Biology and Biotechnology: Second-round sample tasks for the Open Doors undergraduate track

You will be asked to complete 35 tasks, including:

- 19 entry-level tasks, each correct answer worth 1 point;
- 13 intermediate-level tasks, each correctly answered task worth 3-4 points;
- 3 advanced tasks (constructed response), each correctly completed task valued at 12–13 points.

Evaluation criteria and standard answers are provided for the advanced tasks requiring constructed responses.

Scientific field 1: Biology

Task 1
Entry level (1 point)

Which plant division is defined by reproduction through spores and the lack of a root system?

a) Gymnosperms
b) Angiosperms
c) Mosses
d) Ferns
e) Brown algae

Answer: c.

Task 2
Entry level (1 point)

The excretory organs of the earthworm are:

a) Pelvic kidneys;
b) Protonephridia ;
c) Metanephridia;
d) Coxal glands
e) Malpighian vessels

Answer: c.

Task 3
Entry level (1 point)

Aldosterone is produced by the gland:

a) Hypothalamus
b) Pituitary
c) Adrenal
d) Renal
e) Pancreas

Answer: c.

Task 4
Intermediate level (4 points)

Haploid structures in gymnosperms are:
a) Female cone
b) Pollen
c) Sperm
d) Male cone
e) Seed germ
Answer: b, c.

Task 5
Intermediate level (4 points)

The following have a closed circulatory system:
a) Gastropod
b) Ringed worm
c) Fish
d) Fly
e) Snake
Answer: b, c, e.

Scientific field 2: Virology

Task 6
Entry level (1 point)

RNA viruses include:
a) Variola virus
b) Varicella zoster virus
c) Human papillomavirus
d) Human herpes simplex virus
e) Yellow fever virus
Answer: e.

Task 7
Entry level (1 point)

The first to use vaccination against viral infection:
a) E. Jenner
b) L. Pasteur
c) A. Flemming
d) R. Koch
e) I. Mechnikov
Answer: a.

Task 8
Intermediate level (3 points)

Viral diseases transmitted through blood include:
a) Hepatitis A
b) Hepatitis B
c) Hepatitis C
d) Dysentery
e) Typhoid fever
Answer: b, c.

Task 9
Intermediate level (3 points)

The influenza virus is characterized by the presence of:
a) DNA
b) RNA
c) Circular molecule
d) Linear single-chain (+)
e) Linear single-stranded (-)
Answer: b, e.

Scientific field 3: Genetics and Heredity

Task 10
Entry level (1 point)

What does crossing over refer to?
a) The process of packaging chromosomes
b) The transfer of a chromosome segment to a non-homologous chromosome
c) The **exchange of segments between homologous chromosomes during conjugation**
d) The rotation of a chromosome segment by 180°
e) The loss of a segment from a chromosome
Answer: c.

Task 11
Entry level (1 point)

How many different types of gametes can an organism with the genotype aaBbCcDDee produce?
a) 2
b) 4
c) 5
d) 8
e) 32
Answer: b.

Task 12
Entry level (1 point)

What might be the blood types of two children in a family where the mother is type I (0) and the father is type IV (AB)?:

a) I(0) and IV(AB)
b) I(0) and II(A)
c) I(0) and III(B)
d) II (A) and III (B)
e) II(A) and IV (AB)

Answer: d.

Task 13
Intermediate level (3 points)

Polyploidy is very common among cultivated plants. Let the allele A- be responsible for the absence of bitter substance in fruits, and the recessive allele a – for its presence. Two polyploids are crossed : ♂ AAaa ×♀AAaaaa . Check the correct statements

a) Ratio among gametes of the paternal plant: 1AA: 2Aa:1aa
b) Ratio among gametes of the mother plant: 1AAa: 3Aaa: 1aaa
c) Chance of getting a bitter fruit offspring: 1/32
d) The offspring of this cross are likely to be sterile
e) All fruits produced as a result of crossing will not be bitter

Answer: b, d, e.

Task 14
Advanced level (13 points)

The dominant allele of the R gene is responsible for the red color of corn grains, the recessive r - for yellow), the e allele leads to an increased amount of starch, E - is responsible for a reduced starch content. Pollen is transferred from a homozygous line with red grains with a high starch content (1) to the pistils of a homozygous line with yellow grains with a low starch content (2). In the next generation, F1 hybrids are crossed with each other.

1. Write down the crossing scheme, indicate the genotypes and phenotypes for the parents, gametes, genotypes and phenotypes of the offspring.
2. Indicate the genotypes for the grains and its color for F1
3. Specify the gametes of F1 hybrids
4. Indicate the genotypes for the grains and its color for F2

Note that the evaluation will consider how you solve the task; providing only the final answer is not sufficient.

Solution:

P: ♂ RRee (red, rich in starch) ×♀ rrEE (yellow, poor in starch)
G:Re rE
F 1: RrEe (red, low in starch)

1. Caryopsis F1 rrEE , caryopsis color – yellow
2. RE,Re ,rE , re
3. Caryopsis F2 RrEe , caryopsis color – red

Answer:
1. P: ♂ RRee (red, rich in starch) ×♀ rrEE (yellow, poor in starch)
G:Re rE
F 1: RrEe (red, low in starch)
2. Caryopsis F1 rrEE , caryopsis color – yellow
3. RE,Re ,rE , re
4. Caryopsis F2 RrEe , caryopsis color – red

Evaluation Criteria:
Criterion 1: The crossing scheme is documented, including:
1. Gender
2. Genotypes
3. Parental phenotypes
4. Gametes labeled
5. Genotype and phenotype of the offspring

(1 point each; total of 5 points)

Criterion 2: Correct responses to the following questions:
- Question 2: 2 points
- Question 3: 4 points

(Total of 6 points)

Criterion 3: Correct response to Question 4: 2 points

Scientific field 4: Microbiology

Task 15
Entry level (1 point)

Storage polysaccharides in bacteria are used as
a) Nitrogen source
b) Carbon source
c) Source of phosphorus
d) Sulfur source
e) Oxygen source
Answer: b.

Task 16
Entry level (1 point)

Microorganisms growing in the temperature range from 40 to 90°C and above belong to the group:
a) Mesophiles
b) Thermotolerants
c) Thermophiles
d) Psychrophiles
e) Extremophiles
Answer: c.

Task 17
Intermediate level (3 points)

What groups of microorganisms are the main producers of antibiotics?

a) Seaweed
b) Spore-forming bacteria
c) Actinomycetes
d) Molds
e) Protozoa

Answer: c, d.

Task 18
Advanced level (12 points)

An experiment was designed at the research institute to assess the effect of a biological product based on microorganisms on wheat yield. According to the experimental protocol, the experimental field had to be treated during the tillering phase with a working solution, so that at least 10,000 CFU of the target bacterial strain would fall per 1 cm^2 of the treated area. The area of the experimental field is 5 hectares. The control and experimental plots should be of equal size. Working fluid consumption – 150 l/ha.

How much of the drug should be used, provided that the manufacturer claims to contain at least 109 CFU/ml in the supplied drug?

After treatment, the soil of the control and experimental plots was sown. Three mixed soil samples were taken from each, after which surface inoculation of soil dilutions (applied in a volume of 50 µl per plate) was carried out on meat- peptone agar (from a soil dilution of 10-4), as well as on Czapek's medium with streptomycin (from a dilution soil 10-2). Soil moisture at the time of sowing was 15% in the control, and 21% in the experiment.

After counting the colonies, the following results were obtained:

Sample no.	repetition	Control		Experience	
		MPA environment	Wednesday Capek	MPA environment	Wednesday Capek
1	1	27	23	55	34
	2	32	24	57	21
	3	34	27	60	37
2	1	43	32	61	43
	2	45	30	63	45
	3	47	36	68	42
3	1	23	31	70	26
	2	22	29	67	32
	3	20	27	64	24

1. What microorganisms were taken into account in this experiment?
2. What is the significance of adding streptomycin to Czapek's medium?
3. What is the average number of each group of microorganisms present in 1 g of soil in the control and experiment?
4. Did the biological product affect the number of microorganisms in the soil during this experiment? Did it affect all studied groups of microorganisms?

Note that the evaluation will consider how you solve the task; providing only the final answer is not sufficient.

Solution:

1. The area of the experimental plot is half a field of 2.5 hectares, or 25,000 m2. This corresponds to 250 million cm2. To achieve a dose of 10,000 CFU/cm, 2.5 trillion must be applied to the field. CFU, which corresponds to 2.5 liters of the drug.
2. Heterotrophic (ammonifying) bacteria on MPA medium and soil fungi on Czapek medium with the addition of streptomycin were taken into account.
3. Streptomycin is a broad-spectrum antibiotic that inhibits the growth of bacteria without interfering with the growth of fungi.
4. It is necessary to calculate the number in each average soil sample for analytical replicates, and then for the entire variant by averaging the data for three mixed samples. It is necessary to take into account that when sowing on MPA, the soil was diluted 10,000 times, and when sowing mushrooms - 100 times. Since the inoculation was carried out in a volume of 50 µl, it is also necessary to take into account that 1/20 ml was added, that is, this must be taken into account. Finally, the samples varied in moisture content, which requires conversion to dry soil to obtain comparable results. Calculation example: 27 colonies * 20 (calculated per 1 ml of dilution) * 10000 (calculated per 1 g of soil) * 100/(100-15) (calculated per 1 g of dry soil) = 7294118 CFU/g 4 points
5. To do this, it is necessary to obtain the average number of microorganisms for each mixed sample, and then compare those obtained from three biological replicates in the control and experiment with each other using a statistical criterion for the significance of differences. 2 points

Answer:

1. 2.5 l
2. Heterotrophic (ammonifying) bacteria on MPA medium and soil fungi on Czapek medium with the addition of streptomycin were taken into account.
3. Streptomycin is a broad-spectrum antibiotic that inhibits the growth of bacteria without interfering with the growth of fungi.
4. 7294118 CFU/g
5. To do this, it is necessary to obtain the average number of microorganisms for each mixed sample, and then compare those obtained from three biological replicates in the control and experiment with each other using a statistical criterion for the significance of differences.

Evaluation Criteria:

Criterion 1: A thorough response to questions 1-3 is provided, with each question worth 2 points, totaling 6 points.
Criterion 2: Accurate calculations are presented, along with a response to question 4, worth 4 points.
Criterion 3: A comprehensive answer to question 5 is included, worth 2 points.

Scientific field 5: Cytology

Task 19
Entry level (1 point)

Plastids and mitochondria are similar in that they contain:

a) Centrioles
b) Vacuoles
c) Electron transport chain in the membrane

d) Smooth endoplasmic reticulum
e) Golgi complex
Answer: c.

Task 20
Entry level (1 point)

If a fluorescent dye binds to the protein tubulin, which of the structures in the cell will be most clearly visible under a light microscope?
a) Core
b) Mitochondria
c) Centriole or spindle
d) Vacuole
e) Nucleolus
Answer: c.

Task 21
Intermediate level (3 points)

Escherichia coli is characterized by:
a) Gram - staining
b) Absence of pili and flagella
c) Lack of dispute formation
d) Inability to grow under aerobic conditions
e) One membrane within the cell wall
Answer: a, c.

Task 22
Intermediate level (3 points)

What processes are characteristic of prophase 1 of meiosis?
a) Divergence of monochromatid chromosomes
b) Shortening the spindle filaments
c) Conjugation of homologous chromosomes
d) Chromatin compaction
e) Cell septum formation
Answer: c, d.

Scientific field 6: Ecology

Task 23
Entry level (1 point)

The genus *Nepenthes* comprises carnivorous plants that have evolved modified leaves designed to trap a variety of insects. These insects are then digested and absorbed by the plants. This adaptation developed with the goal of…
a) Obtaining energy
b) Obtaining organic carbon
c) Obtaining organic reducing agents

d) Obtainin water
e) Obtaining phosphorus and nitrogen
Answer: e.

Task 24
Entry level (1 point)

Select parasites whose intermediate host can be human:
a) Bull tapeworm
b) Cat fluke
c) Echinococcus
d) Schistosoma
e) Pinworm
Answer: c.

Task 25
Intermediate level (3 points)

It is understood that energy is lost at each transition to the next trophic level. Please select the accurate statements:
a) 90% of the energy goes to each next level
b) When moving to next level, about 90% of energy is lost
c) This statement applies only to forest communities
d) The biomass of producers in the ecosystem will be equal to the biomass of consumers of the 1st order
e) In an ecosystem, the biomass of 1st consumers will be less than that of producers
Answer: b, e.

Task 26
Intermediate level (3 points)

Examples of mutualism include interactions:
a) Shark and sticky fish
b) Sea anemones and hermit crab
c) Man and cockroach
d) Penguin and polar bear
e) Phycobiont and mycobiont of lichen
Answer: b, e

Scientific field 7: Biochemistry and Molecular Biology

Task 27
Entry level (1 point)

At a substrate concentration of 3 Km (Michaelis constant), what is the rate of the enzyme reaction?
a) 33% max speed
b) 66% maximum speed
c) 75% maximum speed
d) 90% maximum speed
e) 133% maximum speed

Answer: c.

Task 28
Entry level (1 point)

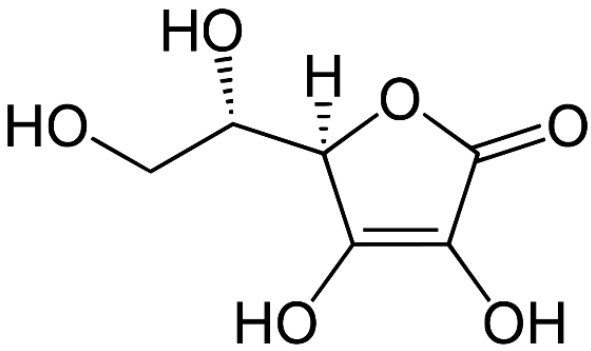
The tertiary structure of a protein is:
a) α-helix held together by hydrogen bonds
b) Sequence of amino acid residues in a polypeptide chain
c) Mutual arrangement of several protein chains
d) Spatial configuration of an α-helix formed by covalent polar, nonpolar, and ionic bonds
e) β-sheets
Answer: d.

Task 29
Entry level (1 point)

The purine base is:
a) Cytosine
b) Cytidine
c) Thymine
d) Thymidine
e) Adenine
Answer: e.

Task 30
Intermediate level (4 points)

Analyze the picture and choose the correct statements:



a) Contains conjugated aliphatic double bonds in the hydrocarbon skeleton
b) Contains aromatic structures
c) Synthesized from hexoses
d) Is a good reducing agent
e) Contains centers of optical isomerism
Answer: c, d, e.

Task 31
Advanced level (12 points)

Restriction enzymes, also known as restriction endonucleases, are a class of enzymes that facilitate the hydrolysis of phosphodiester bonds within nucleic acid molecules. Today, these enzymes are essential tools for molecular biologists, enabling them to map genomes, construct vectors for bacterial transformation, produce proteins in vitro, and perform various other applications.
1) The average size of the bacterial genome of Escherichia coli is 6.72 Mb ($6.72 \cdot 10^6$ bp). It is understood that the length per nucleotide pair is 0.34 nanometers. Calculate the diameter of circular bacterial DNA in E. coli in mm, taking the approximate value $\pi = 3.14$. Give the answer in mm, rounded to two decimal places.
2) Let the AAGCTT restriction site be known for restriction enzyme A, and the AGCT restriction site for restriction enzyme B. Calculate how many restriction sites can be expected for restriction enzymes A and B, assuming a GC composition of 60%. Answer round to whole numbers.
Note that the evaluation will consider how you solve the task; providing only the final answer is not sufficient.

Solution:
1) Let's get the length of the nucleotide chain; to do this, multiply the size of the genome by the length of the nucleotide pair: $6.72 \cdot 10^6$ bp .·0.34 nm/ bp . =2.29 mm . To estimate the diameter, divide the circumference by π: 2.29 / (3.14) = 0.72 mm .
2) GC composition -60%, this means that the probability is p(G)=p(C)=0.3, p(A)=p(T)=0.2 . Number of restriction enzyme A sites: 6.72·106 bp . ·(0.2)4·(0.3)2= 968
3) Number of restriction enzyme B sites: 6.72·106 bp . ·(0.2)2·(0.3)2=24192

Answer:
1. 0.72 mm
2. 968
3. 24192

Evaluation Criteria:
Criterion 1: The correct answer to one question is provided. Length (3 points) and diameter (3 points) – total of 6 points.

Criterion 2: The number of restriction enzyme A sites is calculated – 3 points.

Criterion 3: The number of restriction enzyme B sites is calculated – 3 points.

Scientific field 8: Biotechnology and Applied Microbiology

Task 32
Entry level (1 point)

As a selective marker indicating the presence of the vector in the genome, the following is introduced into the construct:
a) Antibiotic resistance gene
b) Inducible transcription promoter
c) Origin of replication
d) mRNA polyadenylation signal
e) Polylinker
Answer: a.

Task 33

Entry level (1 point)

Identify the polymerase chain reaction (PCR) component responsible for synthesizing new nucleotide chains

a) Magnesium salts
b) Polymerase
c) Deoxynucleoside triphosphates
d) Buffer
e) DNA matrix

Answer: c.

Task 34
Intermediate level (4 points)

The lactose operon of a prokaryotic cell includes:

a) Cistrons
b) Promoter
c) Terminator
d) Enhancer
e) Silencer

Answer: a, b, c.

Task 35
Intermediate level (4 points)

Shuttle plasmid vectors used for protein expression must contain:

a) Origins of replication
b) Recombination sites
c) Polylinker
d) Marker genes
e) Promoter

Answer: a, c, d, e.