Biology and Biotechnology: Second-round Sample Tasks for the Open Doors Bachelor's Track

This sample test comprises tasks, including 19 entry-level tasks with a single correct answer (each correct answer is assigned 1 point), 13 intermediate-level tasks with multiple correct answers (the correct answer is assigned 3-4 points), and 3 advanced-level tasks requiring a detailed answer (the correct answer is assigned 12-13 points depending on its correctness and completeness).
For advanced-level tasks requiring a detailed answer, assessment criteria and a standard answer are provided.

Field of Science 1. Biology

Task 1
Entry level (1 point)

Which plant division is characterized by reproduction through spores and the absence of a root system?

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

Answer: c

Task 2
Entry level (1 point)

What type of excretory organs does the earthworm have?

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

Answer: c

Task 3
Entry level (1 point)

Which gland produces aldosterone?

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

Answer: c

Task 4
Intermediate level (4 points)

Which of the following structures in gymnosperms are haploid? Select all that apply.

a) Female cone
b) Pollen
c) Sperm
d) Male cone
e) Seed germ

Answer: b, c

Task 5
Intermediate level (4 points)

Which of the following organisms have a closed circulatory system? Select all that apply.

a) Gastropod
b) Ringed worm
c) Fish
d) Fly
e) Snake

Answer: b, c, e

Field of Science 2. Virology

Task 6
Entry level (1 point)

Which of the following is an RNA virus?
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)

Who was the first to use vaccination against a viral infection?

a) Edward Jenner
b) Luis Pasteur
c) Alexander Flemming
d) Robert Koch
e) Ilya Mechnikov

Answer: a

Task 8
Intermediate level (3 points)

Which of the following viral diseases are transmitted through blood? Select all that apply.

a) Hepatitis A
b) Hepatitis B
c) Hepatitis C
d) Dysentery
e) Typhoid fever

Answer: b, c

Task 9
Intermediate level (3 points)

Which of the following characterize the influenza virus? Select all that apply.

a) DNA
b) RNA
c) Circular molecule
d) Linear single-chain (+)
e) Linear single-stranded (-)

Answer: b, e

Field of Science 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 the blood types of two children be 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.

Which statements are correct? Select all that apply.

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, and 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: A complete solution must include both your method and the reasoning behind it. Providing the final answer alone will not suffice.

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

Assessment 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 - 5 points)

Criterion 2: Correct answers to the following questions:
Question 2: 2 points
Question 3: 4 points
(Total - 6 points)

Criterion 3: Correct answer to Question 4: 2 points

Field of Science 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? Select all that apply.
a) Seaweed
b) Spore-forming bacteria
c) Actinomycetes
d) Molds
e) Protozoa

Answer: c, d

Task 18
Advanced level (12 points)

An experiment was conducted at the research institute to assess the effect of a microbial-based biological product on wheat yield. According to the experimental protocol, the field was to be treated during the tillering phase with a working solution, ensuring that at least 10,000 CFU of the target bacterial strain were applied per 1 cm^2 of the treated area. The total area of the experimental field was 5 hectares, with control and experimental plots of equal size. The working solution consumption rate was 150 L/ha.
How much of the biological product should be used, given that the manufacturer states the concentration of the supplied preparation is at least 10^9 CFU/mL?

Following treatment, both the control and experimental plots were sown. Three composite soil samples were collected from each plot. Surface inoculation of soil dilutions (50 µL per plate) was performed on meat-peptone agar (from a 10^{-4} soil dilution) and on Czapek medium supplemented with streptomycin (from a 10^{-2} soil dilution). At the time of sowing, soil moisture was 15% in the control plot and 21% in the experimental plot.

After counting the colonies, the following results were obtained:

Sample no.	Repetition	Control		Experience	
		MPA environment	Wednesday Czapek	MPA environment	Wednesday Czapek
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 medium?
3. What is the average number of each group of microorganisms present in 1g of soil in the control and the 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: A complete solution must include both your method and the reasoning behind it. Providing the final answer alone will not suffice.

Solution

The area of the experimental plot is half the total field, i.e., 2.5 hectares or 25,000 m^2, which corresponds to 250 million cm^2. To achieve the required dose of 10,000 CFU per cm^2, a total of 2.5×10^{12} CFU must be applied. Given that the manufacturer's product contains at least 10^9 CFU/mL, this corresponds to 2.5 liters of the biological preparation.

Quantification was performed for heterotrophic (ammonifying) bacteria on meat-peptone agar (MPA) and for soil fungi on Czapek medium supplemented with streptomycin.

Streptomycin is a broad-spectrum antibiotic that suppresses bacterial growth without inhibiting fungal development, thereby allowing for the selective isolation of fungi.

To determine microbial abundance, it is necessary to calculate the number of colony-forming units (CFU) per gram of dry soil for each composite soil sample, using the data from analytical replicates. It is important to consider the dilution factors: 10^{-4} for bacteria (MPA) and 10^{-2} for fungi (Czapek medium), as well as the inoculation volume of 50 µL (i.e., 1/20 of a milliliter). Additionally, variations in soil moisture must be accounted for by converting values to dry weight.
Example calculation:
27 colonies × 20 (to scale to 1 mL of dilution) × 10,000 (dilution factor for MPA) × 100 / (100 − 15) (moisture correction) = 7,294,118 CFU/g dry soil.
(4 points)

The final step involves calculating the average number of microorganisms for each composite sample and then comparing the means of the three biological replicates for the control and experimental variants. This comparison should be conducted using an appropriate statistical test to assess the significance of the observed differences.
(2 points)

Answers

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.

Assessment criteria
Criterion 1: A detailed and accurate answer is provided for questions 1–3; each question is assigned 2 points, totaling 6 points.
Criterion 2: A detailed and accurate answer is provided for question 4, with correct calculations; 4 points are assigned.
Criterion 3: A detailed and accurate answer is provided for question 5, including appropriate statistical interpretation; 2 points are assigned.

Field of Science 5. Cytology

Task 19
Entry level (1 point)

A common feature of plastids and mitochondria is the presence of:
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)

What is escherichia coli characterized by? Select all that apply.
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? Select all that apply.

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

Field of Science 6. Ecology

Task 23
Entry level (1 point)

The genus *Nepenthes* comprises carnivorous plants that have evolved modified leaves adapted to trap a variety of insects. These captured insects are subsequently digested and absorbed by the plant. This adaptation evolved primarily in response to:
a) Obtaining energy
b) Obtaining organic carbon
c) Obtaining organic reducing agents
d) Obtaining water
e) Obtaining phosphorus and nitrogen

Answer: e

Task 24
Entry level (1 point)

Select the parasite for which a human can be an intermediate host.
a) Bull tapeworm
b) Cat fluke
c) Echinococcus
d) Schistosoma
e) Pinworm

Answer: c

Task 25
Intermediate level (3 points)

Energy is progressively lost at each successive trophic level.

Select all correct statements.
a) 90% of the energy goes to each next level
b) When moving to the 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)

Which of the following interactions are examples of mutualism? Select all that apply.

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

Field of Science 7. Biochemistry and Molecular Biology

Task 27
Entry level (1 point)

At a substrate concentration equal to 3 times the Michaelis constant (3 Km), what is the rate of the enzyme-catalyzed reaction relative to Vmax?

a) 33% of Vmax
b) 66% of Vmax
c) 75% of Vmax
d) 90% of Vmax
e) 133% of Vmax

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

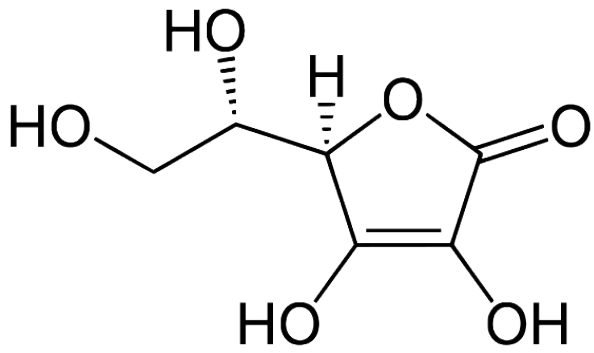
Answer: d

Task 29
Entry level (1 point)

Which of the following is a purine base?
a) Cytosine
b) Cytidine
c) Thymine
d) Thymidine
e) Adenine
Answer: e

Task 30
Intermediate level (4 points)

Analyze the molecular structure below. Select all correct statements.



a) It contains conjugated aliphatic double bonds in the hydrocarbon skeleton.
b) It contains aromatic structures.
c) It was synthesized from hexoses.
d) It is a good reducing agent.
e) It contains centers of optical isomerism.

Answer: c, d, e

Task 31
Advanced level (12 points)

Restriction enzymes, also termed restriction endonucleases, constitute a class of enzymes that catalyze the cleavage of phosphodiester bonds within nucleic acid molecules. These enzymes are indispensable tools in molecular biology, facilitating genome mapping, construction of vectors for bacterial transformation, in vitro protein synthesis, and numerous 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 $\pi = 3.14$. Provide the answer in millimeters, 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%.
Provide the answer rounded to whole numbers.

Note: A complete solution must include both your method and the reasoning behind it.
Providing the final answer alone will not suffice.

Solution

1) To calculate the length of the nucleotide chain, multiply the genome size by the length of a nucleotide pair: $6.72 \cdot 10^6$ bp .·0.34 nm/ bp =2.29 mm.
   To estimate the diameter, divide the circumference by π\piπ: 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

Assessment criteria
Criterion 1: Correct calculation of the nucleotide chain length (3 points) and diameter (3 points), for a total of 6 points.
Criterion 2: Correct calculation of the number of restriction enzyme A sites – 3 points.
Criterion 3: Correct calculation of the number of restriction enzyme B sites – 3 points.

Field of Science 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)

What polymerase chain reaction (PCR) component is 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)

What does the lactose operon of a prokaryotic cell include? Select all that apply.
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