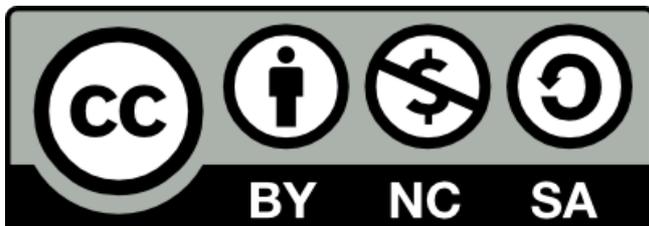




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14-th International Biology Olympiad
Minsk - Belarus,
8th-16th July, 2003

THEORETICAL TEST

Dear competitors!

You will have 4.5 hours for answering all the tasks of parts A and B. Tasks for **part A** have **only one** correct answer. You have to mark it by filling in the circle opposite the test number on the **answer sheet**. Answers written in the question paper will not be taken into account.

Tasks for **part B** may have **several (more than one)** correct answers. You must fill them in the **answer sheet part B**. The marks for the questions of **part B** depend on the number and complexity of the questions.. The marks are shown in the text.

Be attentive while filling in the answer sheet. Make sure the correct circle corresponding to the appropriate question is filled in. Any corrections in **answer sheet** should be avoided!

Note there are some questions which are marked SKIPPED. **Do Not** answer these.

Please read all possible answers before attempting the question, as many questions continue over from one page to the next page.

PART A

Cell Biology (14 questions, 20 points).

A1. (1 point). List the following proteins in the order of decreasing evolutionary conservativeness of their primary structure:

1. Somatotropin.
2. Catalytic subunit of a DNA – polymerase.
3. Histone H1.
4. Prolamines (storage proteins of cereals).

- A. 1, 4, 3, 2.
- B. 2, 3, 1, 4.
- C. 3, 2, 1, 4.
- D. 4, 1, 2, 3.
- E. 1, 2, 3, 4.

A2. (1 point). What is the common feature of amino acids encoded by codons XUX, where X is any base, U is uracil?

- A. Hydrophobicity.
- B. Positive charge.
- C. Negative charge.
- D. Sulfur in the side chain.
- E. No common feature.

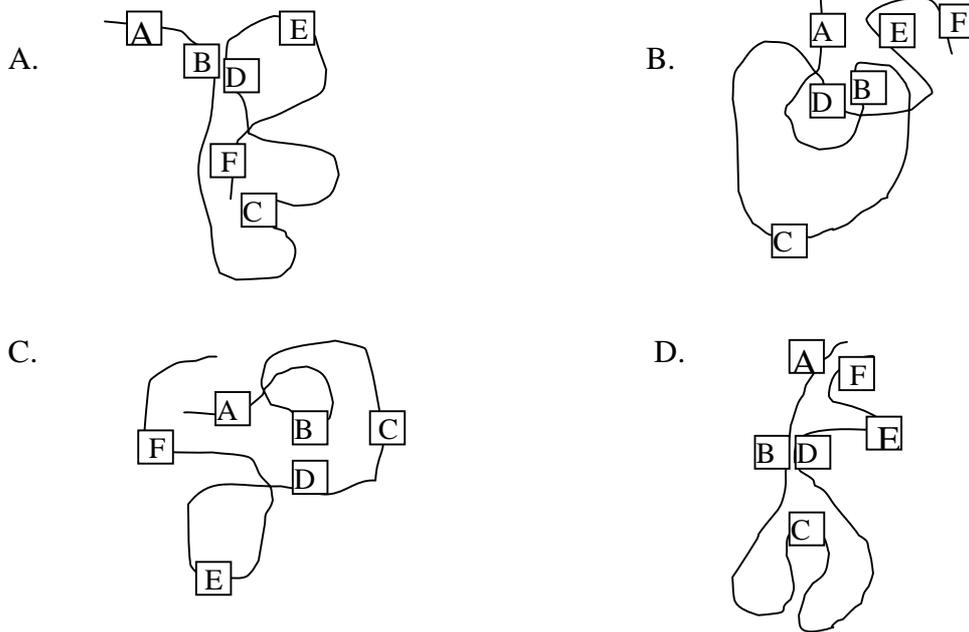
A3. (1 point). A denatured polypeptide chain containing amino acids of different chemical properties is shown in the figure.



Amino acid properties:

A and E: Have negatively charged side groups.	B: With many electropositive atoms.
C and F: Have hydrophobic side groups.	D: With many electronegative atoms.

If renatured, the most stable configuration of the above polypeptide in the cytoplasmic environment will be:



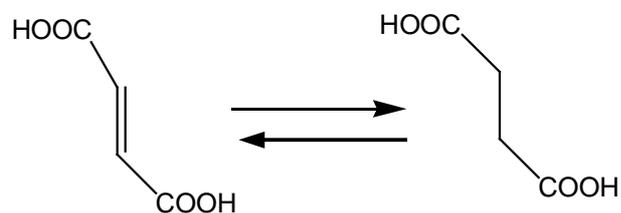
A4. (1 point). Nucleoside phosphates can be interphosphorylated enzymatically. Which one of the following reactions is impossible?

- A. $\text{ADP} + \text{ADP} = \text{AMP} + \text{ATP}$.
- B. $\text{AMP} + \text{GTP} = \text{ADP} + \text{GDP}$.
- C. $\text{ATP} + \text{GDP} = \text{ADP} + \text{GTP}$.
- D. $\text{ATP} + \text{UMP} = \text{ADP} + \text{UDP}$.
- E. $\text{ADP} + \text{AMP} = \text{ATP} + \text{adenosine}$.

A5. (1 point). Which nucleotides predominate in the genome of extremely thermophilic bacteria *Thermus aquaticus* in comparison to *E.coli*?

- A. A-T.
- B. C-T.
- C. G-A.
- D. G-C.
- E. T-G.

A6. (2 points). Define from reaction written below:



A6.1. (1 point). To which class does the enzyme catalyzing the reaction of formation of succinic acid (Succinate) from fumaric acid (Fumarate) belong?

- A. Isomerase.
- B. Dehydrogenase.(Oxidoreductases)
- C. Hydrolase.
- D. Synthase.
- E. Transferase.

A6. 2. (1 point). The coenzyme of this reaction is the derivative of which vitamin?

- A. B₁ - thiamine
- B. B₂. - riboflavin
- C. B₆. - pyridoxalphosphate
- D. B₁₂. - cyancobalamine
- E. B_c. – folic acid

A7. (1 point). It is known that cyanides (CN⁻) and carbon monoxide bind specifically to the reduced and oxidized form of cytochrome a₃ (cyt a₃) (part of complex IV of electron transport chain), respectively, in mitochondria. Which of the following statements are correct:

1. Cyanides and carbon monoxide are equally toxic to mitochondria.
2. Cyanides are far more toxic for mitochondria than carbon monoxide.
3. Carbon monoxide is more toxic for animals since it is capable of binding other iron-containing substances, e.g. hemoglobin.
4. Carbon monoxide is less toxic for animals since it is capable of binding other iron-containing substances, e.g. hemoglobin.
5. Cyanides are more toxic for animals since they are only capable of binding to cytochrome a₃.

- A. 1, 2, 4.
- B. 2, 3, 5.
- C. 1, 4, 5.
- D. Only 4.
- E. Only 1.

SKIPPED

A8. (1 point). *Lactobacilli* lack electron transport chain. However, under special circumstances, up to 50% of ATP is synthesized by membrane-linked H^+ - ATPase. What are the circumstances to generate a proton gradient to drive ATP formation mechanism.?

1. If the concentration of lactic acid is higher in the cell than it is in the medium.
2. If the concentration of lactic acid is lower in the cell than it is in the medium.
3. Uniport (unidirectional) of lactic acid.
4. Symport (both in or both out) of lactic acid with H^+ .
5. Antiport (one in and one out) of lactic acid with H^+ .

- A. 1, 3.
- B. 1, 4.
- C. 1, 5.
- D. 2, 5
- E. 2, 4.

A9. (3 points). The lactose operon of *E.coli* consists of three genes:

lacZ encodes β -galactosidase,

lacY encodes galactoside permease which carries out lactose transport to the cell,

lacA encodes galactoside-transacetylase.

Lac operon is under the control of LacI (repressor), which is inactive in the presence of lactose (inductor). There is a wide diversity of the chemical lactose analogs, for example:

Orthonitrophenyl- β -D-galactoside (ONPG) – is a substrate for β -galactosidase but not an inductor. The product of this reaction orthonitrophenol is toxic for a cell.

Isopropyl- β -D-thiogalactoside (IPTG) - is an inductor but not a substrate for β -galactosidase.

Phenyl- β -D-galactoside (PG) - is a substrate for β -galactosidase but not an inducer. The products of its hydrolysis are nontoxic for a cell.

A9.1. (1 point). Which cells will grow in the medium with PG as the only source of carbon and energy?

- A. $lacI^-$.
- B. $lacZ^-$.
- C. $lacy^-$.
- D. $lacZ^- lacy^-$.
- E. $lacI^- lacZ^-$.

A9.2. (1 point). Will these cells grow in the medium with ONPG?

- A. Yes.
- B. No.

A9.3. (1 point). Galactose is a toxic compound for the cells which have $galE^-$ mutation.

Which cells with this mutation will grow in the IPTG+PG medium (with arabinose as an additional source of carbon and energy available)?

- A. $lacI^-$.
- B. $lacZ^-$.
- C. $lacA^-$.
- D. $lacI^- lacA^-$.

A10. (2 points). A protein synthesis assay was carried out *in vitro*. A polyribonucleotide containing U and C in proportion 1:5 (positions of U and C are random) was used as a template. Which amino acids and in what proportions will be incorporated into the synthesized polypeptide molecules?

- A. $1Phe : 5Pro : 3Leu$.
- B. $1Leu : 1Pro : 1Ser : 1Phe$.
- C. $1Phe : 5Ser : 5Pro : 5Leu$.
- D. $1Phe : 25Pro : 5Ser : 5Leu$.
- E. $5Leu : 5Pro$.

For questions 11 and 12 use the table of genetic code at the beginning of the question paper.

A11. (3 points). The strand of DNA molecule isolated from *E. coli* bacteria has sequence: 5' – GTAGCCTACCCATAGG – 3'. Assume that an mRNA is transcribed from the corresponding double-stranded DNA, the template strand being complementary to the strand isolated.

A11.1. (1 point). What is the sequence of this mRNA?

- A. 3' – CAUCGGAUGGGUAUCC – 5'.
- B. 5' – GUAGCCUACCCAUAGG – 3'.
- C. 5' – GGAUACCCAUCCGAUG – 3'.
- D. 5' – CACAGAUACCCAGAUG – 3'.

A11.2. (1 point). Which peptide will be synthesized if its translation begins precisely at 5'– end of this mRNA? (Assume that start codon is not required).

- A. - Gly - Tyr - Pro - Ala – Asp.
- B. - His - Arg - Met - Gly – Ile.
- C. - Val - Ala - Tyr – Pro.
- D. - His - Arg - Tyr - Pro – Ala.

A11.3. (1 point). When tRNA^{Ala} separates from ribosome, which tRNA will bind next?

- A. tRNA^{Tyr}.
- B. tRNA^{Pro}.
- C. tRNA^{Val}.
- D. tRNA^{Arg}.
- E. tRNA^{His}.

A12. (1 point). The transcriptional activity of which kind of RNA polymerase in eukaryotes can be seen by using a light microscope (without any methods of colouration)?

- A. RNA-polymerase I.
- B. RNA-polymerase II.
- C. RNA-polymerase III.
- D. Primase.
- E. Impossible to determine.

A13. (1 point). Phalloidin, a very toxic compound isolated from the mushroom *Amanita phalloides*, has a very high affinity for actin polymers. Phalloidin can be marked by covalently linking it to a fluorescent molecule, like fluorescein, without affecting its affinity properties.

If a microscopic slide with methanol-fixed sperm is stained with a reagent containing fluorescein-marked phalloidin (excess reagent being washed away), which part of the

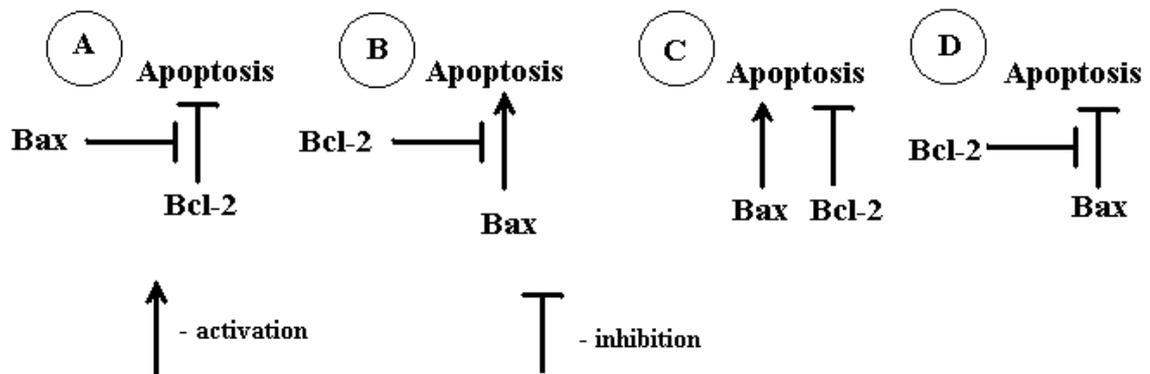
spermatozooids will be glowing under a fluorescence microscope?

- A. Acrosome.
- B. Flagellum.
- C. Head.
- D. Mitochondria.
- E. Whole spermatozoid.

A14. (2 points). On the basis of the following experimental facts, decide which of the four models (A, B, C or D) of Bax and Bcl-2 proteins' action in regulation of programmed cell death (apoptosis) is correct.

Experimental facts:

- Mice with inactivated bcl-2 gene had a high rate of apoptosis in various tissues, which could be corrected by the absence of Bax protein.
- Bax gene in a single genome copy was able to promote apoptosis in the absence of Bcl-2 protein.
- However, bcl-2 gene suppressed apoptosis in the absence of Bax protein.



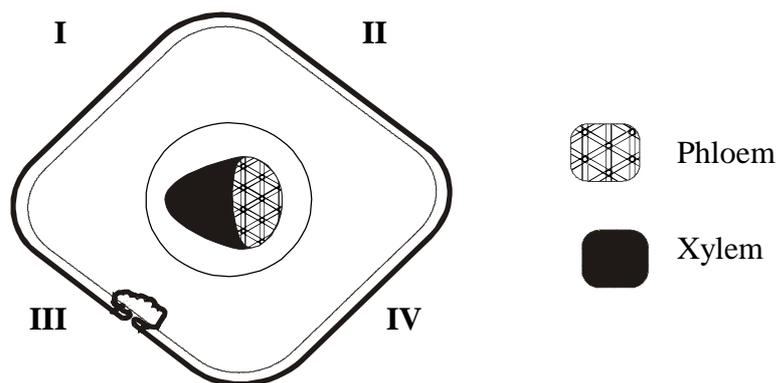
- A. Bax protein inhibits the action of Bcl-2 protein, which blocks apoptosis (look at A in the figure).
- B. Bcl-2 protein is an inhibitor of Bax protein, which promotes apoptosis (look at B in the figure).
- C. Bcl-2 and Bax proteins act independently, resulting in either survival or death, (look at C in the figure).
- D. Bcl-2 protein blocks inhibitory action of Bax protein on apoptosis (look at D in the figure).

Plant anatomy and physiology (10 questions, 12 points).

A15. (1 point). If the vascular system of a plant tendril is represented by the only one closed collateral (xylem & phloem are touching) bundle, the tendril is formed by the metamorphosis of which organ?

- A. Shoot.
- B. Leaf.
- C. Stem.
- D. Root.
- E. Impossible to determine.

A16. (1 point). A transverse microscopic section of a spruce needle leaf is shown in the diagram below. Which roman numerals indicates the upper surface of the leaf?



- A. I and II.
- B. II and IV.
- C. I and III.
- D. III and IV.
- E. II and III.

A17. (1 point). The endosperm in conifers develops from:

- A. The central nucleus resulting from double fertilization.
- B. The ovule after fertilization.
- C. The megaspore before fertilization.
- D. The megaspore after fertilization.
- E. The megasporangium cells before fertilization.

A18. (1 point). Which compounds are the main substrates for growth of xylophilous fungi (accomplishing decomposition of wood), which elicit white (1) and brown (2) rot?

1. 2.
A. Cellulose. Suberin.

B. Cellulose. Lignin.
C. Lignin. Cellulose.

D. Suberin. Cellulose.

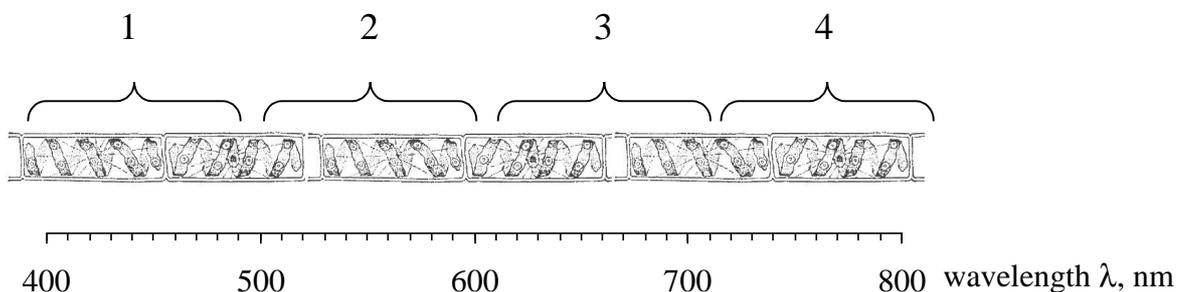
E. Pectin. Hemicellulose.

SKIPPED

A19. (1 point). Which is the correct rank order of the pH value in cytosol (1), chloroplast stroma (2) the inside of thylakoids (3) in plant cells exposed to light:

- A. 1>2>3.
- B. 1>3>2.
- C. 2>1>3.
- D. 2>3>1.
- E. 3>1>2.

A20. (1 point). Spirogyra filaments were placed in a medium, in which strict (obligate) aerobic bacteria were incubated without access to oxygen for some time. Then part of the spirogyra filament was illuminated with a narrow beam, which passed through a prism to obtain a spectrum (see figure below).



In which parts of the filament will the greatest concentration of bacteria be observed?

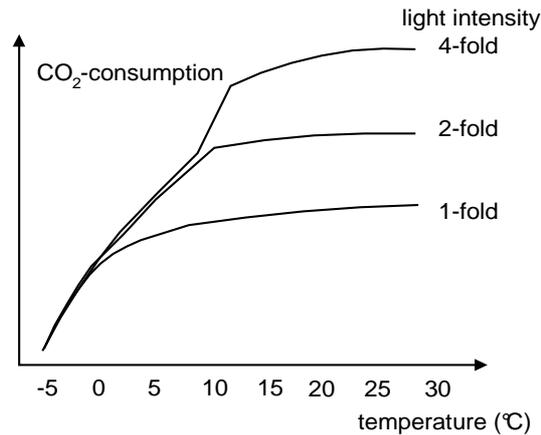
- A. 1,3.
- B. 1,4.
- C. 2,3.
- D. 2,4.
- E. 3,4.

A21. (2 points). Plants of wild type corn whose Rubisco function was normal were compared with a mutant corn variety whose Rubisco is not able to catalyze an oxygenation reaction. Which of the following statements regarding the photosynthetic capacity of this mutant corn and the wild type is correct and why would it be correct?

Assume the same temperature conditions.

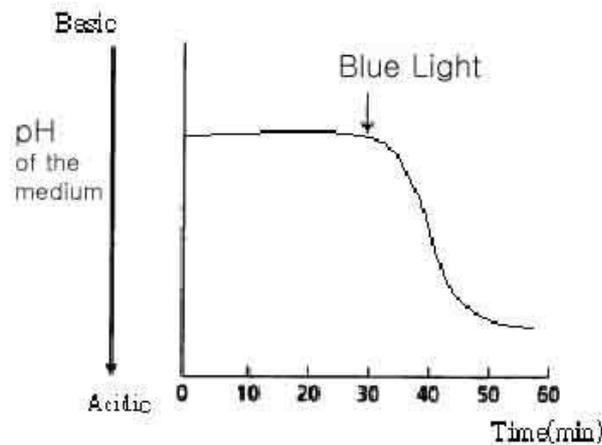
	Photosynthetic capacity of the mutant	Reason
A.	It would show much lower capacity compared to the wild type.	Rubisco in the bundle sheath cell loses its oxygen fixation capacity.
B.	It would show much lower capacity compared to the wild type.	Rubisco in the bundle sheath cell loses its carbon dioxide fixation capacity.
C.	It would show much higher capacity compared to the wild type.	Since mesophyll cells photorespire, photosynthetic capacity of the mutant would not be affected by this mutation.
D.	It would show the same capacity as the wild type.	Since mesophyll cells photorespire, photosynthetic capacity of the mutant would not be affected by this mutation.
E.	It would show the same capacity as the wild type.	Since CO ₂ concentration in the bundle sheath cells is high enough, both wild type and mutant corn do not photorespire.

A22. (2 points). Photosynthesis in plants is dependent on temperature (T) and light intensity (L). The following graphs show the results of measurements of CO₂ consumption for three plants of the same species under different light intensities. Which combination of statements concerning limiting factors in the temperature ranges (I) -5°C to 0°C and (II) $+20^{\circ}\text{C}$ to $+30^{\circ}\text{C}$ is correct under the light intensity used?



	Temperature range from -5 to 0°C (I)	Temperature range from $+20$ to $+30^{\circ}\text{C}$ (II)
A.	T and L limiting factor.	T and L not limiting factor.
B.	T limiting, L not limiting.	T not limiting, L limiting.
C.	T limiting, L not limiting.	T limiting, L not limiting.
D.	T not limiting, L limiting.	T limiting, L not limiting.
E.	None of the above combinations is correct	

A23. (1 point). The result of an experiment which uses guard cell protoplasts of *Vicia faba* is given below. Protoplasts were incubated in a suspension medium with isotonic osmotic pressure. After 30 min under saturating red light they were irradiated with blue light for 30 sec. During the experiment in which the protoplasts were cultured the pH of the medium was monitored.



What would be the most plausible conclusion based on the above results?

- A. Blue light may help guard cells to take up protons from outside into the cell.
- B. Blue light may enhance the ability of guard cells to pump protons out of the cell.
- C. Blue light may be a very effective wavelength of light for the respiration of the guard cells.
- D. Blue light may activate all of the protoplasts to give away their energy.
- E. Not only blue light but also other wavelengths of light may help guard cells to transfer protons.

A24. (1 point). If an oat coleoptile deprived of its epidermis is placed in a physiological solution with pH = 5.0, relatively fast lengthening of the coleoptile occurs. The action of which hormone does this experiment imitate?

- A. Auxin.
- B. Gibberellic Acid
- C. Cytokinins.
- D. Ethylene.
- E. Abscisic Acid

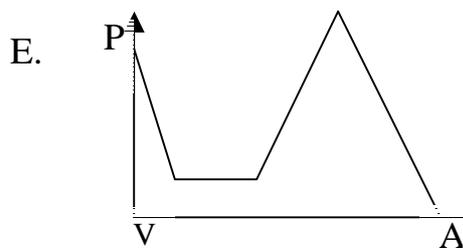
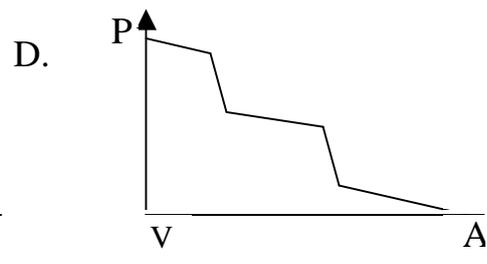
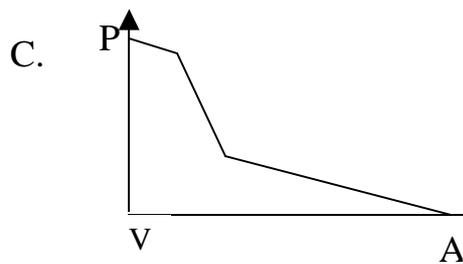
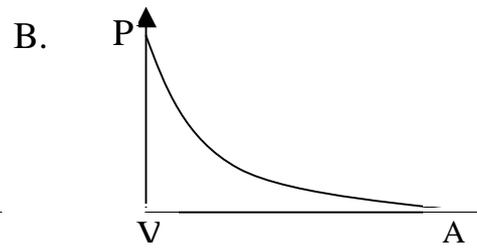
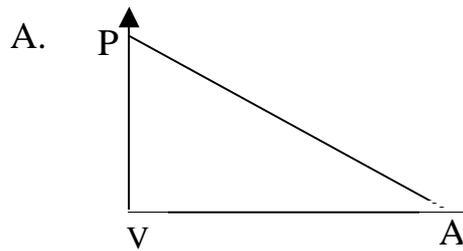
Animal Anatomy & Physiology (10 questions, 12 points).

A25. (1 point). In which animals is the volume of the lungs relatively constant during all the stages of ventilation (breathing)?

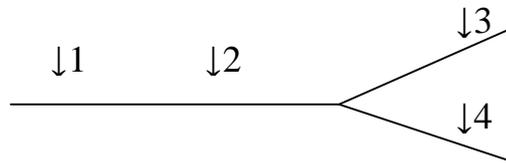
- A. In insects.
- B. In birds.
- C. In mammals.
- D. In reptiles.

A26. (1 point). During the blood flow from the ventricle to atrium in fishes, how does the pressure change?

- A - Atrium.
- V - Ventricle.
- P - Pressure.

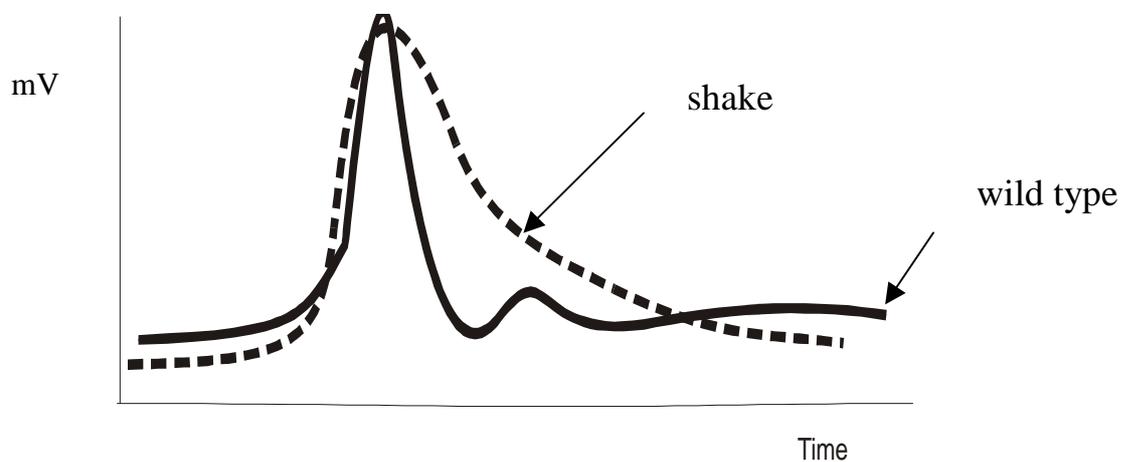


A27. (1 point). A branched axon is stimulated at the site '1' (see figure below). The excitation is transferred from site '1' to '2' and then to '3' and '4'. The excitation is measured at these sites. Which statement of impulse frequencies (I) measured at these sites is correct?



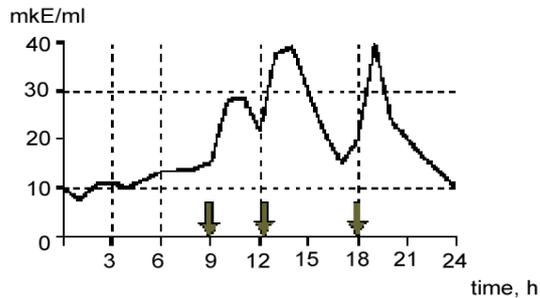
- A. $I(1) > I(2) > I(3)$, $I(3) = I(4)$, $I(3) + I(4) = I(2)$.
- B. $I(1) > I(2) > I(3)$, $I(3) = I(4)$, $I(3) \times I(4) = I(2)$.
- C. $I(1) < I(2) < I(3)$, $I(3) = I(4)$.
- D. $I(1) = I(2) > I(3)$, $I(3) = I(4)$, $I(3) + I(4) = I(2)$.
- E. $I(1) = I(2) = I(3) = I(4)$.

A28. (1 point). *Drosophila* flies homozygous for the *shake* mutation are extremely sensitive to diethyl ether that causes convulsions in homozygous individuals. Convulsions are caused by abnormalities in nerve impulse conduction. (see graph below). The function of which structures is impaired in the *shake* mutations?



- A. Na^+ -channels.
- B. K^+ -channels.
- C. Ca^{2+} -channels.
- D. K^+/Na^+ -ATPase.
- E. H^+ -pump.

A29. (1 point). Daily changes in the concentration of which hormone are represented by the following graph?



Arrows indicate the time of food consumption.

- A. Thyroxine
- B. Glucagon.
- C. Insulin.
- D. Cortisol.
- E. Parathormone.

A30. (1 point). Thyroiditis is an autoimmune disease, which is caused by the hyperactivity of the thyroid gland. In this disease the TSH (thyroid stimulation hormone) concentration in the blood is below normal. Antibody binding to hormone receptor sites may activate or block the receptor.

The cause of this disease is the binding of autoimmune antibodies to:

- A. Thyroxin receptors.
- B. Thyroxin.
- C. TSH receptors.
- D. TSH.
- E. Thyreoliberin receptors.

A31. (3 points). There are two recessive mutations ob^- and db^- in mice. These mutations cause the same phenotype: obesity, adipose tissue hypertrophy and predisposition to obesity related diseases (hypertension, physiological *diabetes insipidus* and so on). The mutations are not linked. Three experiments of parabiosis (surgically joining blood circulation systems of two mice with different genotypes) were carried out to define the roles of the products of these genes in weight regulation. Two weeks after the parabiosis, the weight of each mouse was determined (see table).

	ob^-/ob^- + wt^+		db^-/db^- + wt^+		ob^-/ob^- + db^-/db^-	
Weight	Loss of weight	Without changes	Without changes	Loss of weight	Loss of weight	Without changes

A31.1. (1 point). What is the consequence of the ob gene:

- A. Peptide hormone favouring obesity.
- B. Peptide hormone favouring loss of weight.
- C. Hormone receptor favouring obesity.
- D. Hormone receptor favouring loss of weight.
- E. Nonpeptide hormone favouring obesity.

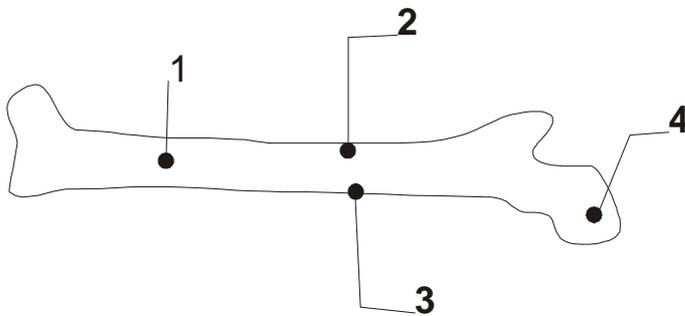
A31.2. (1 point). What is the consequence of the db gene:

- A. Peptide hormone favouring obesity.
- B. Peptide hormone favouring loss of weight.
- C. Hormone receptor favouring obesity.
- D. Hormone receptor favouring loss of weight.
- E. Nonpeptide hormone favouring obesity.

A31.3. (1 point). What segregation by phenotype will be seen in F_2 after interbreeding of individuals with the genotypes ob^- / ob^- and db^- / db^- ?

- A. 9:3:3:1.
- B. 9 :7.
- C. 15:1.
- D. 1:2:1.
- E. 3:1.

A32. (1 point). If four gold rods are implanted into a tibia-bone of a newborn rat (as shown in the figure), the distances between which of these rods will be maximally altered with growth?



- A. 1 and 2.
- B. 2 and 3.
- C. 3 and 4.
- D. 3 and 1.

A33. (1 point). Quick movement of the individuals of genus *Dryocopus* (wood-pecker) on tree trunks is enabled thanks to the fact that:

- A. All its leg fingers are directed forward.
- B. Two its leg fingers are directed forward and two its fingers are directed to the back.
- C. Three its leg fingers are directed forward and one leg finger is directed to the back.
- D. One its leg finger is directed forward and three leg fingers are directed to the back.

SKIPPED

A34. (1 point). The major difference between humoral immunity and cellular immunity is that:

- A. Humoral immunity is non-specific, whereas cellular immunity is specific for a particular antigen.
- B. Only humoral immunity is a function of lymphocytes
- C. Humoral immunity cannot function independently; it is always activated by cellular immunity.
- D. Humoral immunity acts against free-floating antigens, whereas cellular immunity works predominantly against pathogens that have entered body cells.
- E. Only humoral immunity displays immunological memory.

Ethology (2 questions, 2 points).

A35. (1 point). Which of the following cases result in optimal conditioning (Pavlovian)?

- A. Unconditional stimulus is delivered before conditional stimulus and unconditional stimulus is stronger than conditional stimulus.
- B. Unconditional stimulus delivered before conditional stimulus and unconditional stimulus is weaker than conditional stimulus.
- C. Conditional stimulus starts delivered unconditional stimulus and conditional stimulus is stronger than unconditional stimulus.
- D. Conditional stimulus starts delivered unconditional stimulus and conditional stimulus weaker than unconditional stimulus.

A36. (1 point). The cuckoo (*Cuculus canorus*) and its hosts is a well studied system of co-evolution as a long never ending process. A cuckoo lays its eggs in the nest of small passerines (*Passeriformes*). The cuckoo and its hosts have adopted different behaviours that result from the co-evolution between them.

Which combination of the following statements (1 – 6) are true?

1. The hosts lay their eggs in the afternoon.
2. The cuckoo eats ant eggs.
3. The host is aggressive towards a cuckoo.
4. The cuckoo eggs do not mimic the host's eggs.
5. The cuckoo is aggressive towards a host.
6. The cuckoo tries to avoid being seen in the host nest.

- A. 3 and 6.
- B. 4 and 6.
- C. 2 and 3.
- D. 1 and 5.
- E. 4 and 2.

Genetics (10 questions, 12 points).

A37. (1 point). In birds, for instance chickens, sex is determined by a combination of sex chromosomes Z and W. At an early age it is difficult to determine their sex. However, it is commercially very important to distinguish males and females at this age. Using a genetic marker, it is possible to conduct such crosses so that sex will be determined by phenotypic expression of the marker gene. On which chromosome must the marker gene (I) be located and which crossing allows discrimination of the males from females (II)?

	Marker gene localization (I)	Crossing (II)
A.	On Z chromosome.	Female with recessive phenotype is crossed with a male homozygous for dominant allele.
B.	On W chromosome.	Female with recessive phenotype is crossed with a male homozygous for dominant allele.
C.	On Z chromosome.	Female with dominant phenotype is crossed with a male homozygous for recessive allele.
D.	On an autosome.	Female with recessive phenotype is crossed with a male heterozygote.
E.	On Y chromosome.	Female with dominant phenotype is crossed with a male heterozygote.

A38. (1 point). *abcde* genes are closely linked on the *E. coli* chromosome. Short deletions within this region lead to the loss of some genes. For example:

deletion 1 – *bde* genes

deletion 2 – *ac* genes

deletion 3 – *abd* genes

What is the gene order on the genetic map of the *E. coli* chromosome?

- A. b, c, d, e, a
- B. e, a, c, b, d
- C. a, b, c, d, e
- D. c, a, b, d, e
- E. a, b, c, d, e

A39. (2 points). According to the model proposed for floral organization, each whorl is determined by a unique combination of three genes, namely, A, B and C.

It has been shown that genes A and C mutually repress each other. The expression pattern of these genes in wild type flowers is shown below.

		S	P	St	C
gene activity	A	■	■	□	□
	B	□	■	■	□
	C	□	□	■	■
		1	2	3	4

whorls of flower

S: sepal formation
 P: petal formation
 St: stamen formation
 C: carpel formation

A39.1. (1 point). The morphology of flower that lacks the functional gene A will be:

- A. $\left[\begin{array}{cccc} - & - & \text{St} & \text{C} \\ 1 & 2 & 3 & 4 \end{array} \right]$
- B. $\left[\begin{array}{cccc} \text{C} & \text{St} & \text{St} & \text{C} \\ 1 & 2 & 3 & 4 \end{array} \right]$
- C. $\left[\begin{array}{cccc} \text{C} & \text{P} & \text{P} & \text{C} \\ 1 & 2 & 3 & 4 \end{array} \right]$
- D. $\left[\begin{array}{cccc} - & \text{P} & \text{St} & \text{C} \\ 1 & 2 & 3 & 4 \end{array} \right]$

A39.2. (1 point). The whorls of a flower that lacks the functional gene C will be:

A.
$$\begin{bmatrix} C & P & St & P \\ 1 & 2 & 3 & 4 \end{bmatrix}$$

B.
$$\begin{bmatrix} - & - & - & C \\ 1 & 2 & 3 & 4 \end{bmatrix}$$

C.
$$\begin{bmatrix} S & P & P & S \\ 1 & 2 & 3 & 4 \end{bmatrix}$$

D.
$$\begin{bmatrix} S & P & St & - \\ 1 & 2 & 3 & 4 \end{bmatrix}$$

A40. (2 points). Colour of the plant endosperm is determined by a single gene located in the centromere region. Expression of this gene takes place only in the cells of endosperm.

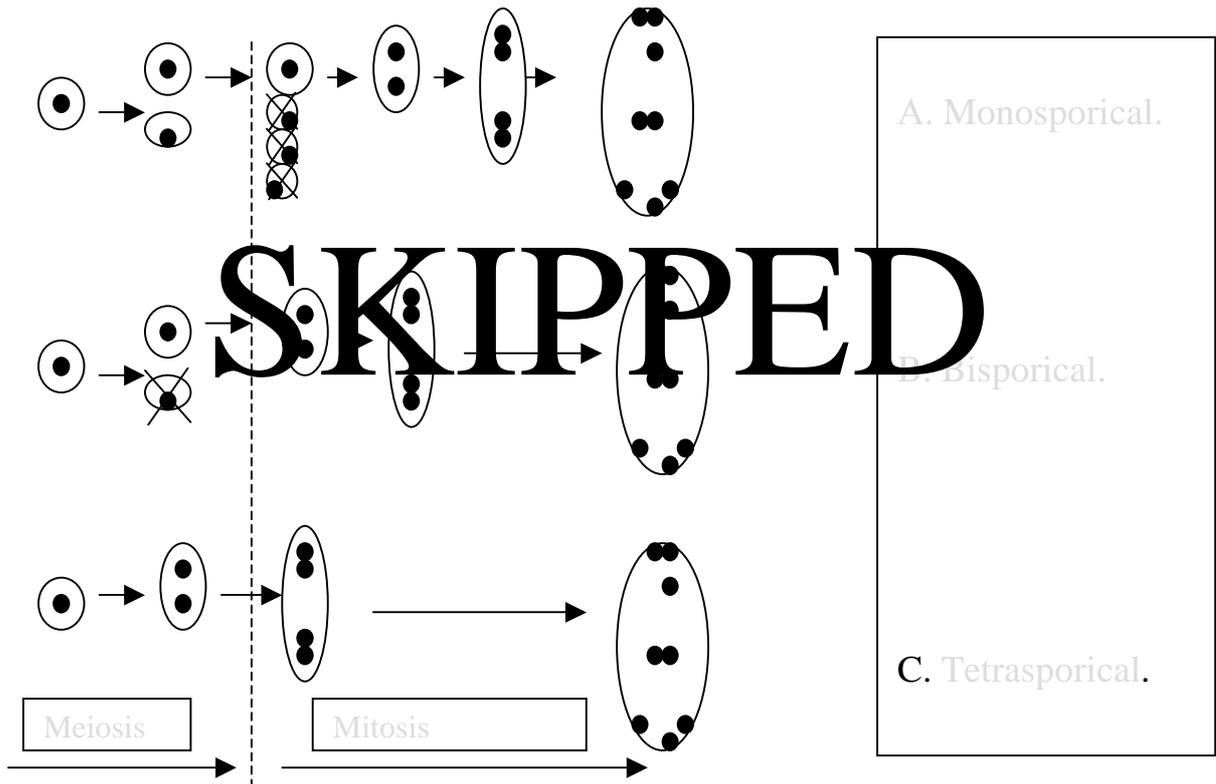
Experiment 1. Inbred plant line with coloured endosperm (CE) was pollinated by the pollen of inbred plant line with colourless endosperm (CLE). F₁ seeds were with coloured endosperm.

Experiment 2. After pollination of F₁ seeds with pollen of CLE line all F₂ seeds were with coloured endosperm as well.

Experiment 3. After pollination of F₂ plants with pollen of CLE line 50% of plant gave seeds were with coloured and 50% with colourless endosperm.

A40.1. (1 points). According to the results of three experiments, determine which type of embryo sack is typical for this plant species?

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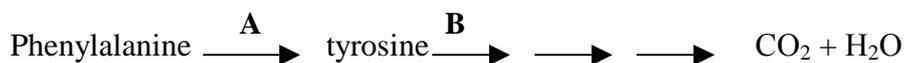


A40.2. (1 point). What ratio of seeds with coloured and colourless endosperm would be observed in experiment 2, if the gene of colouration of endosperm were located in >50 cM distance from centromere.

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- A. 3:1.
- B. 1:3.
- C. 7:1.
- D. All with coloured endosperm.
- E. All with colourless endosperm.

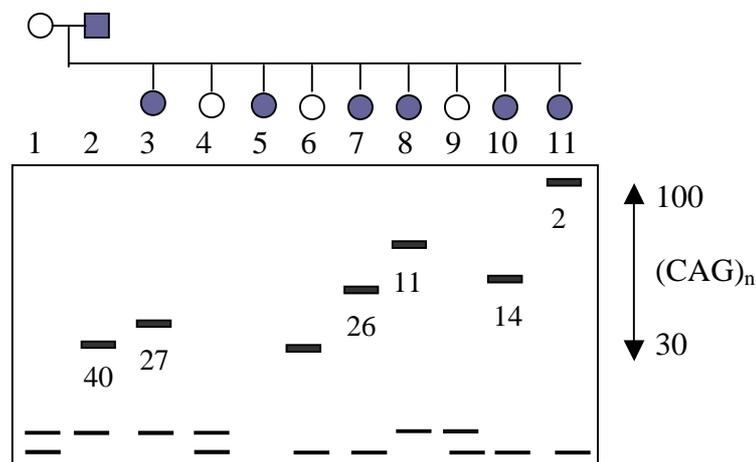
A41. (1 point). In humans PKU (phenylketonuria) is a disease caused by an enzyme dysfunction at step A in the following simplified reaction sequence, and AKU (alkaptonuria) is due to an enzyme inefficiency in one of the steps summarized as step B here:



A person with PKU marries a person with AKU. What are the expected phenotypes for their children? Note: both diseases (PKU and AKU) are not sex linked. Both parents are not heterozygous.

- A. All children will be ill.
- B. All children will be normal
- C. Half of their children will have PKU, but the other half will be normal.
- D. Half of their children will have AKU, but the other half will be normal.

A42. (1 point). The figure shows the results of electrophoresis of PCR-amplified DNA fragments obtained from members of a single family: mother (1), father (2) and 9 children. Father and 6 children (3, 5, 7, 8, 10, 11) in this family have symptoms of Huntington's disease (HD). Father first showed symptoms of the disease after he was 40 years old; the onset age of the disease in children is shown in the figure near corresponding DNA fragments. What is the probability of 4th, 6th and 9th child in this family falling ill with the disease?



- A. Child 4 and child 9 are healthy and will never develop Huntington's disease, whereas child 6 has high probability of developing the disease.
- B. Short PCR fragments correspond to appearance of HD at an early age.
- C. Child 4, child 6 and child 9 all have chances to develop HD at an older age.

D. There is no correlation between the age of children with disease symptoms and the rate of migration of PCR-amplified fragments.

E. Huntington disease is an infectious disease therefore most children of the family must be ill.

A43. (1 point). The long corolla of tobacco is inherited as a recessive monogenic characteristic.

If in a natural population 49% of plants have a long corolla, what is the probability that the result of test crossing plants with a short corolla from this population in F_1 will have uniformity of progeny?

- A. 82,4 %.
- B. 51 %.
- C. 30 %.
- D. 17,7 %.
- E. 42 %.

A44. (1 point). In a genetically balanced population involving alleles T and t. 51 % of the individuals show the dominant phenotype. Suddenly the living conditions change causing death of all recessive individuals before they reach maturity. After this, conditions return to normality. What will be the frequency of allele t after one generation?

- A. 0,41.
- B. 0,3.
- C. Impossible to determine.
- D. 0,7.
- E. 0,58.

A45. (1 point). On land the process of evolution proceeds faster than in the sea, because:

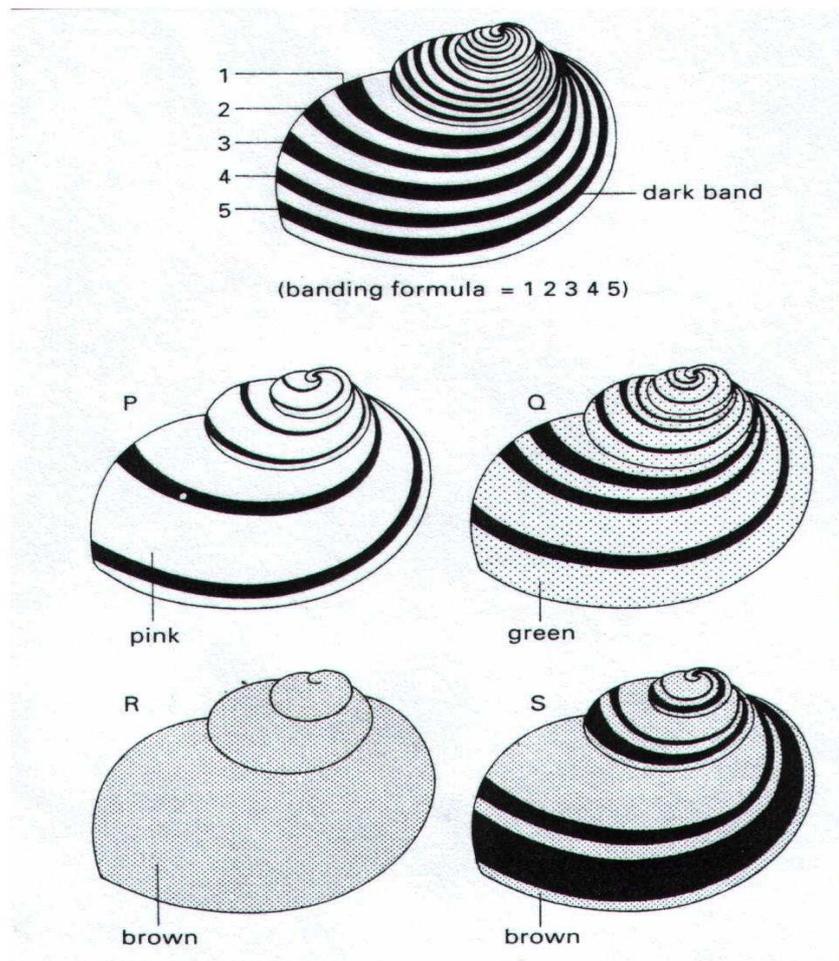
- A. Life started in the sea.
- B. Selection pressure is higher in the sea so surviving is more difficult.
- C. More fossils are found in depositions of the sea.
- D. Living conditions in the sea are more stable.

A46. (1 point). The phenomenon of reduction in organism complexity during the process of evolution is called:

- A. Ecological regress.
 - B. General degeneration.
 - C. Idioadaptation.
 - D. Aromorphosis.
 - E. Disjunction.
- # SKIPPED

Ecology (8 questions, 10 points).

A47. (3 points). The shell of the land snail shows variation in both colour and banding pattern. In order to construct a 5-figure banding formula, bands are numbered from the top of the largest whorl, as shown in the diagram. '0' is used to represent the absence of a band and square brackets indicate the fusion of two bands.



A47.1. (1 point). Using the appropriate letter, indicate the banding formula of shell S.

- A. 030[45].
- B. 03045.
- C. 02045.
- D. 003[45].

A47.2. (1 point). Thrushes (which have good colour vision) smash the shells of land snails against stones (anvils) in order to feed on the soft inner body. If snail types P, Q, R and S began in equal numbers in a habitat of grassland, which would be

the most popular among birds?

- A. P.
- B. Q.
- C. R.
- D. S.

A47.3. (1 point). A survey of broken shells collected from thrush anvils amongst dead beech leaves in a woodland area was carried out. Predict which of the following sets of results was obtained.

Options	Broken shells of each type (%)			
	P	Q	R	S
A.	13	33	1	5
B.	11	1	34	6
C.	5	1	14	32
D.	6	21	20	5

A48. (1 point). Which combination of the following statements, referring to the process of ecological succession, is correct?

1. Nutrient availability generally increases.
2. Species diversity decreases as the process proceeds.
3. A new group of plant species achieves dominance over time and ousts the previous species.
4. The height and biomass of the vegetation usually increases as the process proceeds.
5. Each group of species modifies the habitat making it more favourable for other species.

- A. 1, 2, 3.
- B. 2, 3, 4.
- C. 3, 4, 5.
- D. 1, 3, 4, 5.
- E. 1, 2, 4, 5.

A49. (1 point). Which matching of factors influencing the growth of a population is correct?

	Factors depending on the population's density.	Factors independent of the population's density.
A.	Development of territories, cannibalism.	Wind, parasites, light.
B.	Migration, amount of food.	Temperature, crowding factor.
C.	Development of territories, temperature.	Humidity, wind, light.
D.	Overcrowding factor, light.	Wind, quality of the soil.
E.	Parasites, predators.	Quality of the soil, humidity.

A50. (1 point). A typical feature of the climax stage of an ecological succession is:

- A. The ecosystem is very stable
- B. The increase of biomass is at its maximum.
- C. The number of plant and animal species continues to increase.
- D. The net production of the ecosystem has remarkable but regular differences from year to year.

A51. (1 point). In ecological pyramids, normally each higher trophic level is smaller. Possible exceptions leading to inverted pyramids are:

- I. A pyramid of numbers with one big producer.
- II. A pyramid of mass when producers have a very short life cycle.
- III. A pyramid of energy in extremely hot ecosystems.

Which combination is correct?

- A. Only I and II.
- B. Only II and III.

C. Only I and III.

D. I, II and III.

E. None of these.

A52. (1 point). You and your family are stranded on a remote island with one cow and a large stock of wheat for cow food. To obtain the highest amount of energy and survive for the longest period of time, you should:

A. Feed the wheat to the cow, then drink the milk.

B. Eat the cow, then eat the wheat.

C. Feed the wheat to the cow, drink the milk, then eat the cow.

D. Drink the milk, eat the cow when milk production ceases, then eat the wheat.

A53. (1 point). If an area has a total energy, K , in the sunlight available, the net energy productivity of the fourth trophic level in the area is roughly:

A. $10^{-3} \times K$

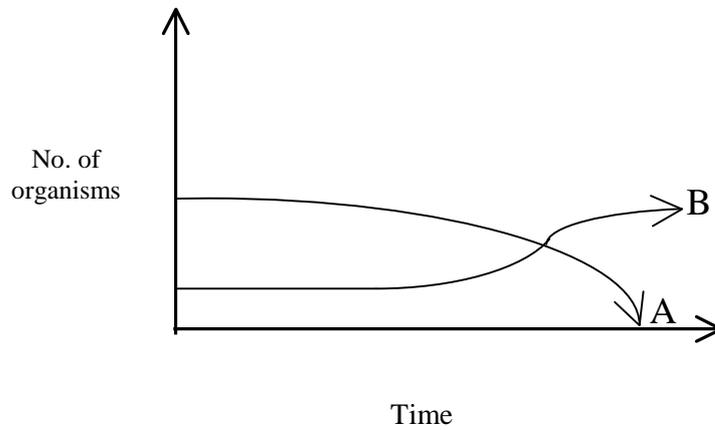
B. $10^{-5} \times K$

C. $10^{-7} \times K$

D. $10^{-4} \times K$

E. $10^{-6} \times K$

A54. (1 point). Assume first that the graph below shows the changes in two populations of herbivores in a grassy field. A possible reason for these changes is that:



- A. All of the plant population in this habitat decreased.
- B. Population B competed more successfully for food than did population A.
- C. Population A produced more offspring than population B did.
- D. Population A consumed the members of population B.
- E. Over time, both populations will have the same average number.

Biosystematics (6 questions, 6 points).

A55. (1 point). To assign ascidia to subphylum *Urochordata* it is necessary to

know the features of the larval stage of ascidia. Which is the correct combination of statements I-IV ?

- I. They possess a notochord in the larval stage.
- II. They are highly specialised.
- III. They possess a hollow dorsal neural tube, which in metamorphosis is reduced.
- IV. They possess a propulsive tail, pharynx and branchial slits

- A. I.
- B. II.
- C. I and II.
- D. I, III and IV.
- E. I and III.

A56. (1 point). Which are the characteristics of *Cnidaria* ?

- A. Oceanic/marine or freshwater, mainly predators.
- B. Only oceanic/marine, mainly predators.
- C. Oceanic/marine or freshwater, filter feeding.
- D. Only oceanic/marine, always filter feeding.
- E. Only freshwater, predators or parasites.

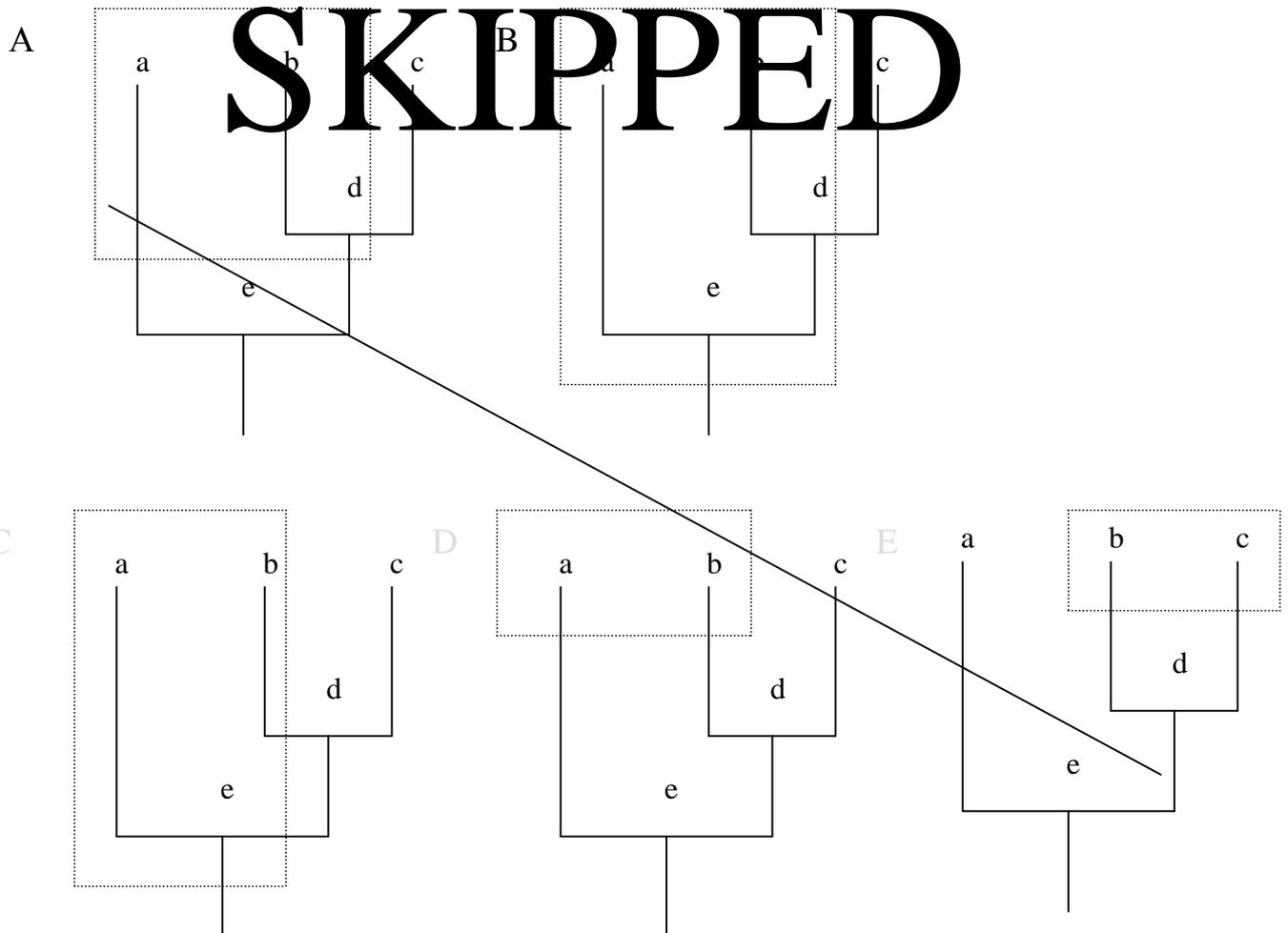
A57. (1 point). Which of the following statements can be used as evidence to prove the close evolutionary relationship between Phylum *Annelida* and Phylum *Mollusca*?

- A. Both of them have bodies with bilateral symmetry.
- B. Their digestive systems have similar parts.
- C. Their bodies consist of similar tegmata (segments).
- D. Both of them have a closed circulatory system.
- E. Many molluscs and marine annelids have a trochophore larva in their life cycle.

A58. (1 point). Zoologists place chordates and echinoderms on one major branch of the animal phylogenetic tree, and molluscs, annelids, and arthropods on another major branch. Which of the following is a basis for this separation?

- A. Whether or not the animals have skeletons.
- B. What type of symmetry they exhibit.
- C. Whether or not the animals have a body cavity.
- D. How the body cavity is formed.
- E. Whether or not the animals are segmented.

A59. (1 point). Phylogenetic connections between three extant (a, b, c) and two extinct (d, e) taxonomic groups are shown below in the cladogram. What kind of their association into a taxon of the highest rank (encircled with dotted line) would be in concord with principles of natural systematics (monophyletic or paraphyletic groups)?



A60. (1 point). There are five species (K, L, M, N, O) in a single family. They belong to the same genus. The table lists data concerning the presence or absence of six features in these species:

Species	Features					
	1	2	3	4	5	6
K.	+	-	+	+	+	-
L.	-	-	-	-	+	-
M.	+	-	-	-	-	-
N.	-	+	-	-	-	-
O.	+	-	+	+	-	-

Based on the assumption that the most probable scheme of phylogenetic development is that which required the least number of evolutionary changes, indicate the species that is the most probable ancestor of species O.

- A. K
- B. L
- C. M
- D. N

PART B

Cell biology (10 questions, 51 points).

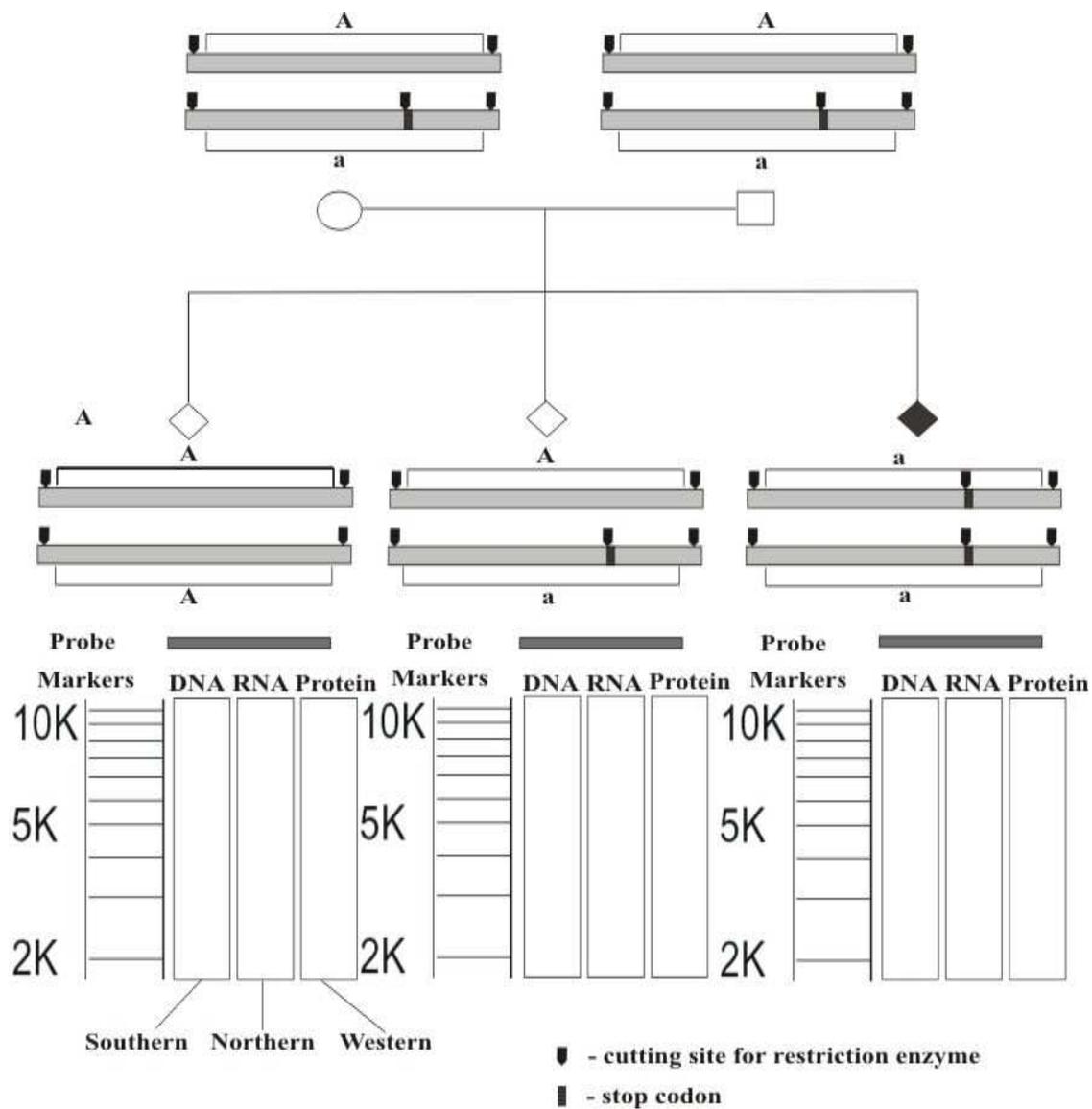
B1. (6 points). It is known that ribosomes of cytoplasm, ribosomes of endoplasmic reticulum (ER) and mitochondrial ribosomes take part in protein biosynthesis. Write the numbers of the proteins in the list below in the correct box, according to the site of their synthesis.

- | | | |
|-----------------|---------------------------|---------------------------|
| 1. Elastin | 5. Glycogen synthase | 9. Prothrombin |
| 2. Collagen | 6. Receptors for glucagon | 10. Keratin |
| 3. Somatotropin | 7. Casein | 11. Lactate dehydrogenase |
| 4. Actin | 8. Phosphofructokinase | 12. Tubulin |

Answers:

ER-bounded ribosomes	
Cytoplasmic ribosomes	
Mitochondrial ribosomes	

B2. (9 points). The Human condition albinism is inherited in the autosomal recessive manner (see figure). The cause of this condition is a mutation from wild type allele *A* to recessive allele *a*, which introduces a stop codon into the middle of the gene, resulting in a shortened polypeptide. The mutation also introduces a new target site for a restriction enzyme, which makes it possible to detect mutated genes by restriction mapping.

**Task:**

Depict the expected results of Southern-, Northern-, Western-blot hybridization analyses of all genotypes (*aa*, *Aa*, *AA*). Results of Southern-blot hybridization should be depicted according to the length of the largest restriction fragment (11 kb) and length markers shown to the left of each Southern-blot hybridization lane. Markers have to do only with the length of DNA fragments. Results of Northern- and Western-blot hybridization should be depicted without scale, but taking into account the respective positions of different restriction fragments for different genotypes.

B3. (3 points). Three human-mouse hybrid cell lines have been created (X, Y and Z). The table below summarizes their characteristics. Each cell line has several human chromosomes carrying genes coding for particular enzymes.

Human chromosome or enzyme	Line X	Line Y	Line Z
Chromosome 3	–	+	–
Chromosome 7	–	+	+
Chromosome 9	–	–	+
Chromosome 11	+	+	–
Chromosome 15	+	–	–
Chromosome 18	+	+	+
Chromosome 20	+	–	+
Glutathione reductase	+	+	–
Malate dehydrogenase	+	–	–
Galactokinase	–	+	+

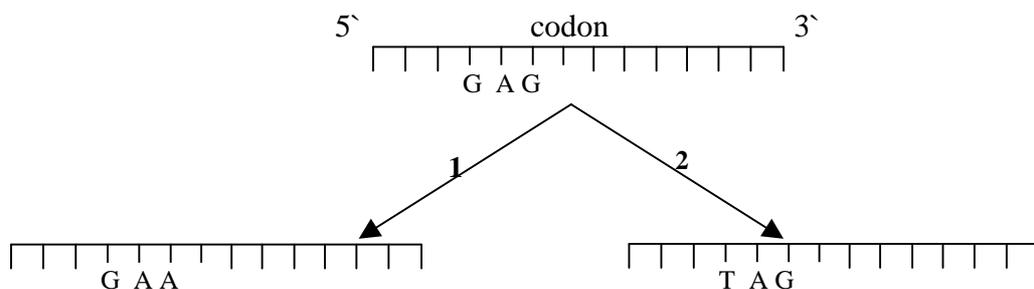
Identify by giving the number, the human chromosome that carries the gene of each enzyme.

Answers:

Gene of Enzyme	A. Chromosome number
Glutathione reductase	
Malate dehydrogenase	
Galactokinase	

B4. (3 points). Two independent mutations event of a DNA segment lead to the following results. Mark the type(s) of mutations observed.

(See Genetic Codes in the front of Part A)



- A. Point mutation.
- B. Transition.
- C. Silent mutation.
- D. Transversion.

- E. Neutral mutation.
- F. Missense mutation.
- G. Nonsense mutation.

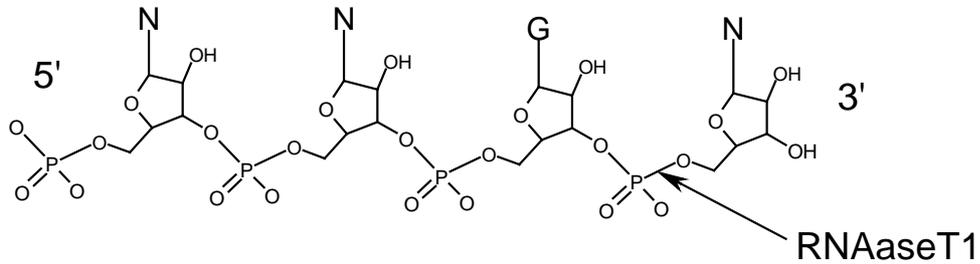
Answer

<p>1:</p> <p>2:</p>

B5. (3 points). Mark the correct statements by ‘+’ and the incorrect ones by ‘-’ in the appropriate box.

- A. In any region of the DNA double helix only one chain of DNA that is usually used as a template for transcription.
- B. In bacteria the transcription of all classes of RNA is carried out by RNA polymerase of a single type, whereas in eukaryotic cells three types of RNA polymerase are used.
- C. Formation of the peptide bond is carried out by enzyme peptidyl transferase, which binds to large subunit of ribosome after the initiation of translation.
- D. Since the start codon for protein synthesis is AUG, methionine is only found in N termini of polypeptide chains.
- E. Many antibiotics used in medicine today selectively inhibit protein synthesis only in prokaryotes because of structural and functional differences between ribosomes of prokaryotes and eukaryotes.
- F. Modified nucleotides, which are in the composition of tRNA molecule, form as a result of covalent modification of standard nucleotides after their incorporation into RNA-transcripts.

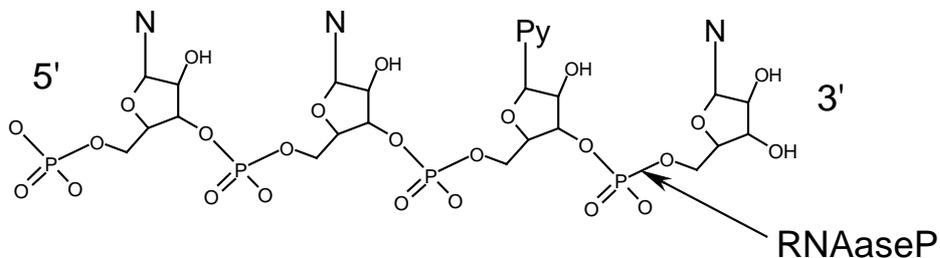
B6. (5 points). Oligoribonucleotide X was treated with phosphatase (for removal of 3' and 5' - terminal phosphates), then with RNAase T1, which cleaves all phosphodiester bonds located in a 3' position of guanosine in a 5'-specific manner.



As a result, oligonucleotides L, M and N were generated in equal amounts. Each of them was further treated with phosphatase and subjected to alkaline hydrolysis. Results are listed in the table below.

Oligoribonucleotide	Content, mole/mole of oligoribonucleotide
L	UMP (1), AMP (1), CMP (1), Guanosine (1)
M	AMP (1), Cytidine (1)
N	CMP (2) , Guanosine (1)

Then experiment was modified: oligoribonucleotide X after treatment with phosphatase was hydrolyzed with RNAaseP, which cleaves all phosphodiester bonds in a 3'-position of pyrimidines in a 5' - specific manner.



This hydrolysis yielded five products in approximately equimolar concentrations: uridine monophosphate, cytidine monophosphate and oligonucleotides P, Q and R. After resolution of

the mixture and alkaline hydrolysis of these oligonucleotides data listed in the table below were obtained.

Oligoribonucleotide	Content, mole/mole of oligoribonucleotide
P	CMP (1), GMP (1)
Q	GMP (1), AMP (1), Cytidine (1)
R	AMP (1), CMP (1)

Using the results given above, deduce the nucleotide sequence of oligoribonucleotide X.

Answer: _____

B7. (5 points). The amino acid cysteine (Cys) has three ionizable groups:

- α -amino group
- α -carboxyl group
- a side chain that can be negatively charged.

The pK values are 8.18, 1.71 and 10.28, respectively. In the answer table, enter the ionic charge of cysteine at pH 1, 5, 9 and 12.

Using an appropriate letter for each direction, show migration of cysteine in an electric field at different pH values.

- A. To cathode (-)
- B. To anode (+)
- C. Does not migrate

Also in the table, circle the pH value nearest to the pI (isoelectric point) of this amino acid.

Answer:

pH	Ionic charge	Migrates toward
1		
5		
9		

12		
----	--	--

B8. (8 points). Listed in the two tables below are vitamins (A-K) and functions (1-12).

Designation	Vitamin
A.	B ₁ (thiamine)
B.	B ₂ (riboflavin)
C.	B ₆ (pyridoxine)
D.	Folic acid
E.	A (retinol)
F.	D (calciferol)
G.	E (tocoferol)
H.	K (menaquinone)
I.	C (ascorbic acid)
J.	B ₁₂ (cobalamin)
K.	PP (nicotinic acid / niacin)

Number	Functions of vitamins or consequences of deficiency
1.	Antioxidant
2.	Regulation of calcium and phosphate metabolism
3.	Group transfer to or from amino acids
4.	Precursor of light absorbing group in visual pigments
5.	Blood coagulation
6.	Scurvy
7.	Beri beri
8.	Pellagra

9.	Anaemia
10.	-----leave this part blank-----
11.	Co-Enzymes of dehydrogenases
12.	Rickets

Match each of the vitamins with its appropriate biological functions and/or lack of deficiency of this vitamin or its derivatives. There may be more than one answer per question.

Answers:

Vitamin	Function
A.	
B.	
C.	
D.	
E.	
F.	

Vitamin	Function
G.	
H.	
I.	
J.	
K.	

B9. (4 points). The table below shows haploid or partial diploid *lac* operon of *E.coli*, where:

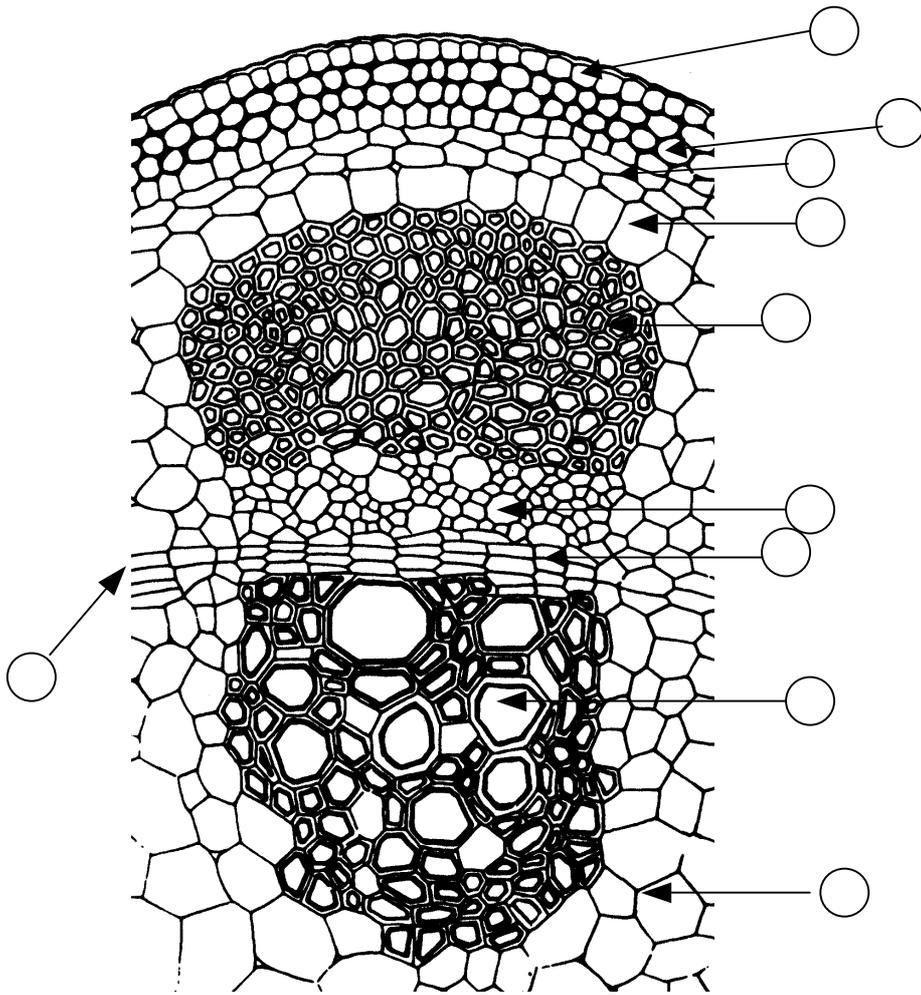
- Gene *lacI* codes for repressor.
- P and O are promoter and operator, respectively.
- *LacZ* and *lacY* represent genes encoding for β -galactosidase and β -galactoside permease, respectively.
- O^c is a constitutive mutation in the operator.
- I^s represents a mutation in the *lacI* gene, which causes mutant repressor protein not to be separated from the operator once it binds to it.

Assume that there is no glucose in the bacterial culture medium. In the following table write 'O' if β -galactosidase is synthesized, and 'X' if it is not.

Strain	Genotype	Lactose absent	Lactose present
1	$I^- O^c Z^+ Y^-$		
2	$I^+ O^c Z^- / I^+ O^+ Z^+$		
3	$I^- P^+ O^c Z^+ Y^+ / I^+ P^- O^+ Z^+ Y^-$		

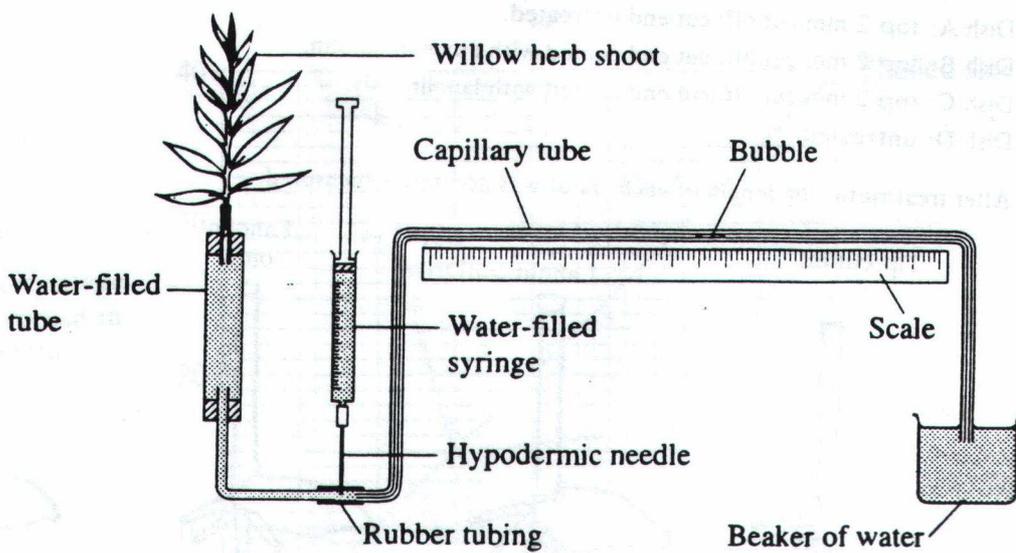
4	$I^s P^+ O^+ Z^+ Y^- / I^- P^+ O^c Z^- Y^+$		
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B12. (5 points). Label the plant structures in the following diagram, by inserting the number in the appropriate circle on the answer sheet.



1. Phloem.
2. Xylem.
3. Endodermis.
4. Fascicular cambium.
5. Epidermis.
6. Parenchyma.
7. Cortex parenchyma.
8. Sclerenchyma.
9. Interfascicular cambium.
10. Collenchyma.

B13. (5 points). The potometer can be used to measure transpiration in a cut shoot such as rose-bay willow plant, by measuring water uptake.



Indicate which of the following statements are true (+) and which are false (-).

- A. The potometer is usually assembled under water
- B. The water-filled syringe is used to suck water out of the apparatus when air bubbles appear.
- C. The shoot must be sealed over the cut point with vaseline immediately after it is cut from the plant.
- D. The hypodermic needle is used to introduce the air bubble into the potometer.
- E. Enclosing the shoot in a black plastic bag will reduce the transpiration
- F. The rate of transpiration will be high in still, humid air.
- G. The rate of transpiration will be highest in warm, dry moving air.
- H. The rate of water uptake and the rate of transpiration are not always equal.
- I. Low cohesive properties between the water molecules create problems for potometer experiments.
- J. Results from potometer experiments can never be quantitative.

B14. (2,5 points). For a short-day plant, indicate which treatments, as listed below, would inhibit flowering. All the treatments were conducted at night. Mark correct statements with “+”, incorrect statements with “-”.

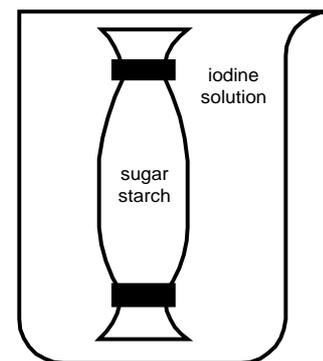
- A. Exposure to red light and far-red light, consecutively.
- B. Exposure to red light, far-red light, and red light, consecutively.
- C. Exposure to red light, far-red light, and white light, consecutively.
-

- D. Exposure to white light and far-red light, consecutively.
- E. Exposure to red light, far-red light, white light, red light, and white light, consecutively.

B15. (6,5 points). Diffusion and osmosis are important for the passive transport of molecules in the cell.

01. (2,0 points). The figure shows an experiment with a dialysis (visking) membrane filled with sugar and starch (colorless) suspended in a beaker with diluted iodine solution (orange – brown). Use ‘+’ to indicate which colour you would expect in the beaker and in the tube after several hours of dialysis.

	Solution in the beaker.	Solution in the dialysis tube.
Colorless		
Orange-brown		
Pink-red		
Greenish-yellow		
Blue-black		



02. (2.5 points). In a similar experiment, dialysis membranes are filled with solutions with different concentrations of molecules and left in beakers with solutions with different molecule concentrations. The dialysis tubes all have the same mass at the beginning of the experiment. The size of the molecules is bigger than the pore size of the membrane. Mark with “+” the experimental settings in which the beaker contains a hypotonic solution compared to the dialysis tube, and mark with “-” the ones which do not.

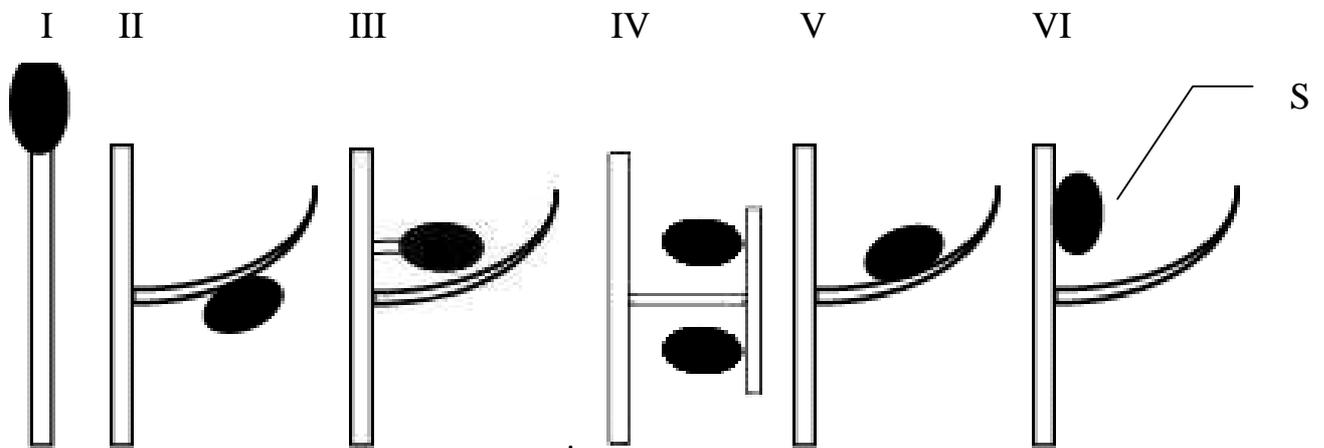
Experiment	A	B	C	D	E
Concentration in the dialysis tube (M).	0.1	0.8	0.4	0.2	0.4
Concentration in the beaker (M).	0.8	0.1	0.2	0.4	0.4
Hypotonic solution.					

03. (2 points). The tubes are weighed after several hours of dialysis. Their mass is compared to that before the dialysis. Write the letters of the experiments in the order of the final mass of the dialysis tube, beginning with the tube having the lowest mass.

Order of the tubes with regard to their mass:

Answers: _____

B16. (5 points). Which position of sporangia is characteristic of present day representatives of the higher plants phyla listed below?

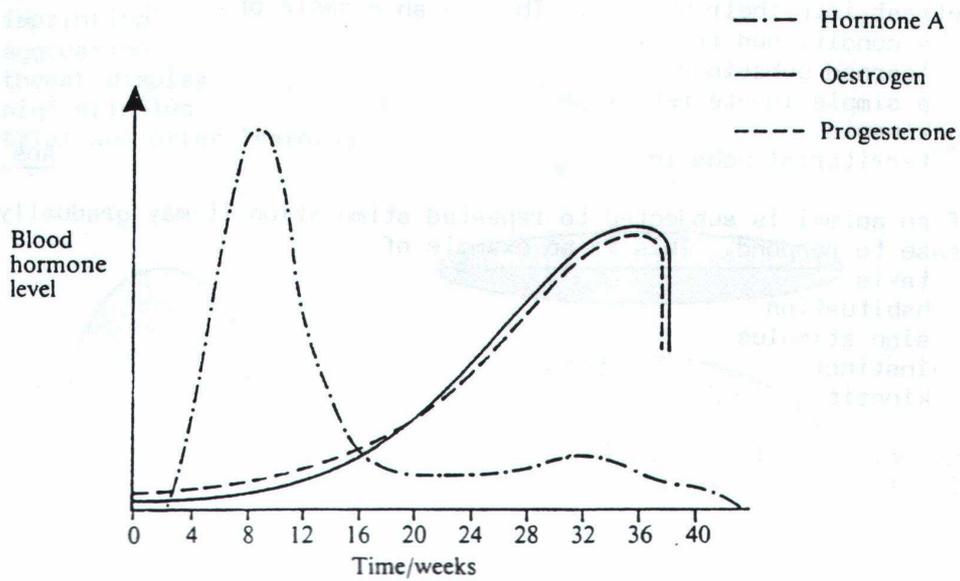


B. S- sporangium

Phylum	Plant number
<i>Bryophyta</i> (Liverworts and mosses)	
<i>Lycopodiophyta</i> (Club moss)	
<i>Equisetophyta</i> (Horse-tails)	
<i>Pterophyta</i> (<i>Polypodiophyta</i>) (Ferns)	

Animal Anatomy & Physiology (6 questions, 26 points).

B17. (5 points). The graph indicates the blood levels of three hormones produced in a pregnant woman.



01. (2 points). Using + (true) and – (false), indicate whether each of the following is true or false.

- A. Hormone A is produced by the ovary
- B. Hormone A is human chorionic gonadotrophin.
- C. Hormone A is prolactin.
- D. Hormone A is made by the chorion.

02. (1 point). Which hormone keeps the smooth muscle of the uterus relaxed during pregnancy? (mark with '+').

- A. Progesterone.
- B. Prolactin.
- C. Oxytocin.
- D. FSH.
- E. LH.

03. (2 points). Two other hormones, not shown on the graph, are also produced during pregnancy. These are prostaglandins and oxytocin. Indicate whether the following statements are true (+) or false (-).

- A. These two hormones are produced by the ovaries.
- B. These two hormones are responsible for milk formation.
- C. These two hormones are responsible for contractions of the uterine wall.
- D. These two hormones are made by the endometrium and pituitary gland, respectively.

B18. (3 point). Name the germ layers of a metazoan embryo from which the following systems or organs developed:

- A. Brain.
- B. Hair.
- C. Autonomic ganglia.
- D. Lungs.
- E. Cardiac muscle.
- F. Cartilage.

- 1. Ectoderm.**
- 2. Endoderm.**
- 3. Mesoderm.**

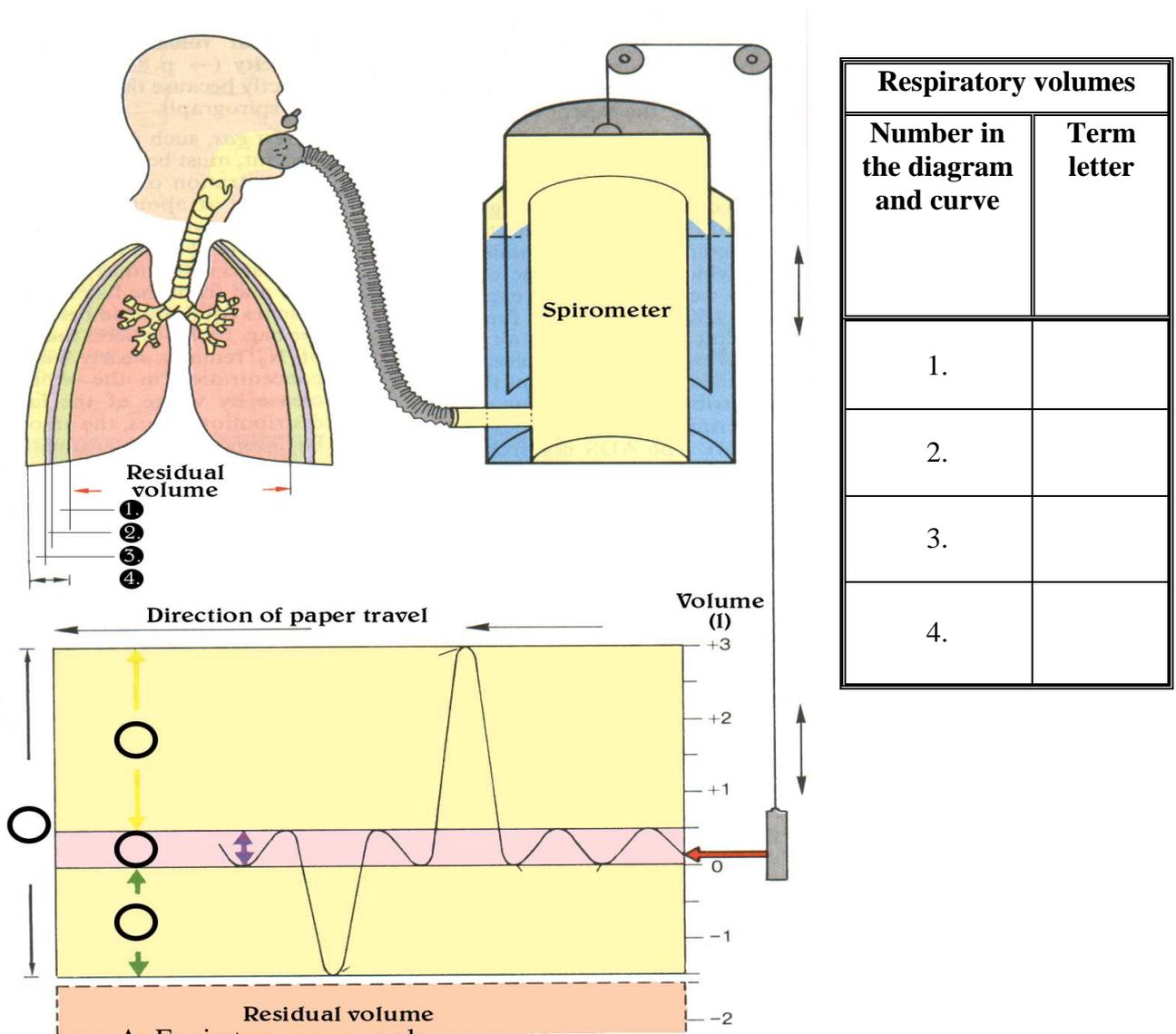
B19. (3 points). Match the protein (1 to 6) with its function (A to F):

- | | |
|-----------------|---|
| 1. Myoglobin. | A. Blood clotting. |
| 2. Prothrombin. | B. Regulation of water excretion. |
| 3. Ferritin. | C. Light-sensitive pigment of rod cells. |
| 4. Vasopressin. | D. Oxygen-storage in skeletal muscles. |
| 5. Collagen. | E. Iron storage in spleen, liver and bone marrow. |
| 6. Rhodopsin. | F. Major fibrous protein of connective tissue. |

Answers:

1	2	3	4	5	6

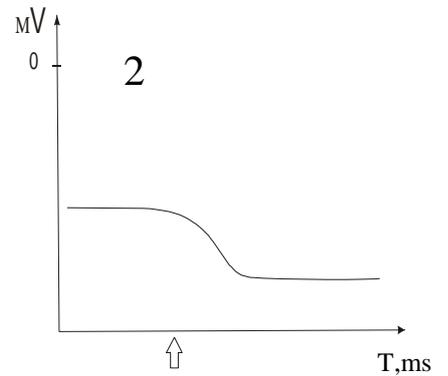
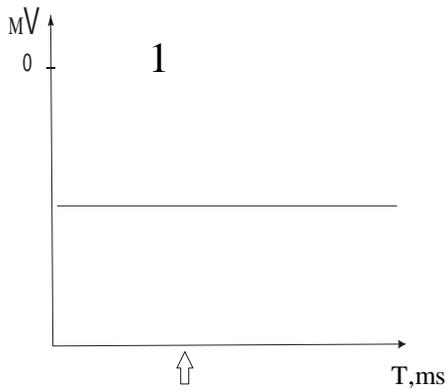
B20. (4 points). For the curve below, fill in the circles on the answer sheet using appropriate numbers from the upper figure. In the table, for every number put a correct letter corresponding to a term given below.



B21. (7 points). How can the resting potential of a cell change after addition of the biologically active compounds listed below (compound addition is marked by an arrow \uparrow)?

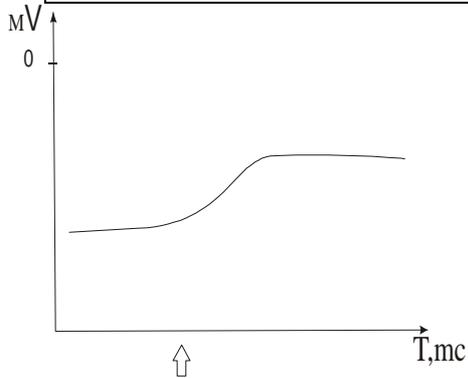
01. (5 points). Determine which graph reflects the addition of which compound.

Fill the results in the table.



3

Nistatin (Na⁺ - ionophor	T,ms	_____
Tetrodotoxin (inhibitor of Na⁺-channels):		_____
Valinomycin (K⁺ - ionophore):		_____



02. (2 points). What is the change of transmembrane potential, in graphs 2 and 3 called?

- A. Hyperpolarisation.
- B. Depolarisation.
- C. Repolarisation.
- D. Action potential.
- E. Overshoot.

Answers:

2 – _____

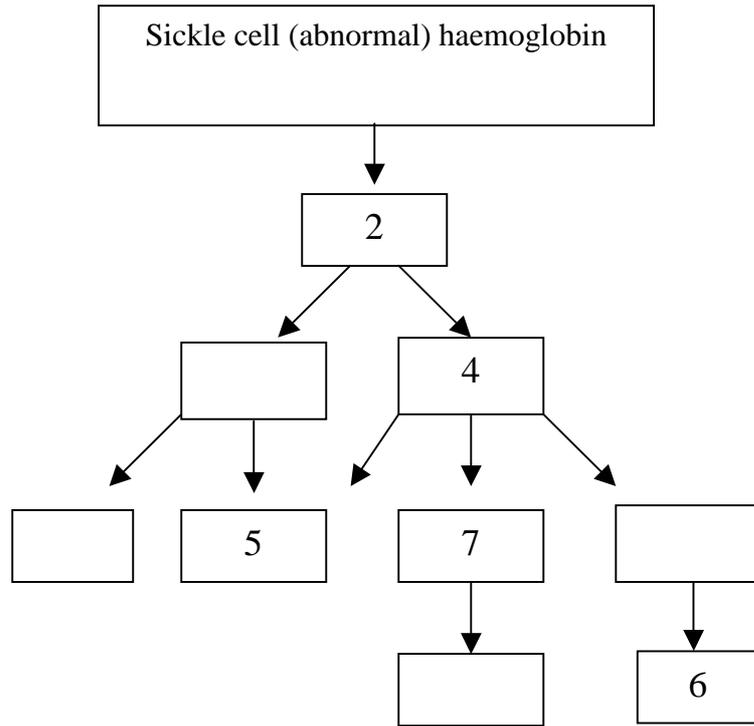
3 – _____

B22. (4 points). A mutation in the haemoglobin gene (*HbS*) causes sickle cell disease that produces a cascade of symptoms such as:

1. Anaemia.
2. Sickle shaped red blood cells.
3. Breakdown of red blood cells.
4. Clumping of cells and clogging of small blood vessels.
5. Heart failure.
6. Kidney failure.
7. Brain damage.
8. Damage to other organ.
9. Paralysis.

In the following diagram, the symptom in the box on top of the arrow causes the symptom in

the box below the arrow. Fill the empty boxes with the number of the appropriate symptoms.



Ethology (2 questions, 12 points).

B23. (3 points). Guppies are often called ‘millionaire fishes’ because of their abundant progeny.

In 1960, Professor C.M. Breder, then director of the New York aquarium, decided to perform an experiment, in order to learn more about fish reproduction. He put pair of

Guppies (one adult male and one adult female) into a small aquarium, with 27.5 liters of water capacity supplied with enough food and oxygen to maintain up to 300 fish. During

the 6 following months and with an interval of 4 weeks between each breeding (these

fishes are ovoviviparous), the female produced 102, 87, 94, 51 and 89 offspring, it means a

total of 443 guppies. A later recount showed that only 9 were alive: 6 females and 3 males.

The rest had been eaten by their own mothers.

In another aquarium with the same size and conditions, the researcher placed 8 adult males, 8 adult females and 8 young fishes, a total of 24 guppies. Females got abundant progeny, too. Data of proliferation during the course of the following 6 months from the introduction of the original group of 24 guppies in the aquarium, are shown in the following tables.

		FEMALE 1				
		Week 4	Week 8	Week 12	Week 16	Week 20
Number of offspring after each hatching	Males	29	24	31	30	33
	Females	58	48	64	58	68

	Total	87	72	95	88	101
Number of offspring counted some hours after hatching	Males	0	0	0	0	0
	Females	0	0	0	0	0
	Total	0	0	0	0	0
Observation: The just hatched guppies were devoured by their own mother						

FEMALE 2						
		Week 4	Week 8	Week 12	Week 16	Week 20
Number of offspring after each hatching	Males	32	26	33	28	29
	Females	65	50	66	56	58
	Total	97	76	99	84	87
Number of offspring counted some hours after hatching	Males	0	0	0	0	0
	Females	0	0	0	0	0
	Total	0	0	0	0	0
Observation: The just hatched guppies were devoured by their own mother						

FEMALE 3						
		Week 4	Week 8	Week 12	Week 16	Week 20
Number of offspring after each hatching	Males	32	29	25	34	28
	Females	64	56	51	69	55
	Total	96	85	76	103	83
Number of offspring counted some hours after hatching	Males	0	0	0	0	0
	Females	0	0	0	0	0

SKIPPED

	Total	0	0	0	0	0
Observation: The just hatched guppies were devoured by their own mother						

FEMALE 4						
		Week 4	Week 8	Week 12	Week 16	Week 20
Number of offspring after each hatching	Males	28	25	35	30	29
	Females	57	49	69	61	60
	Total	85	74	104	91	89
Number of offspring counted some hours after hatching	Males	0	0	0	0	0
	Females	0	0	0	0	0
	Total	0	0	0	0	0
Observation: The just hatched guppies were devoured by their own mother						

SKIPPED

FEMALE 5						
		Week 4	Week 8	Week 12	Week 16	Week 20
Number of offspring after each hatching	Males	33	30	30	23	30
	Females	67	59	64	47	60
	Total	100	89	94	70	90

Number of offspring counted some hours after hatching	Males	0	0	0	0	0
	Females	0	0	0	0	0
	Total	0	0	0	0	0

Observation: The just hatched guppies were devoured by their own mother

FEMALE 6

		Week 4	Week 8	Week 12	Week 16	Week 20
Number of offspring after each hatching	Males	30	29	26	35	25
	Females	62	57	53	70	52
	Total	92	86	79	105	77

Number of offspring counted some hours after hatching	Males	0	0	0	0	0
	Females	0	0	0	0	0
	Total	0	0	0	0	0

SKIPPED

Observation: The just hatched guppies were devoured by their own mother

FEMALE 7

		Week 4	Week 8	Week 12	Week 16	Week 20
Number of offspring after each hatching	Males	29	24	33	28	29
	Females	60	50	71	57	62
	Total	89	74	104	85	91

Number of offspring counted some hours after	Males	0	0	0	0	0
--	-------	---	---	---	---	---

counted some hours after hatching	Females	0	0	0	0	0
	Total	0	0	0	0	0
Observation: The just hatched guppies were devoured by their own mother						

FEMALE 8						
		Week 4	Week 8	Week 12	Week 16	Week 20
Number of offspring after each hatching	Males	26	32	33	28	28
	Females	52	65	64	58	57
	Total	78	97	97	86	85
Number of offspring counted some hours after hatching	Males	0	0	0	0	0
	Females	0	0	0	0	0
	Total	0	0	0	0	0
Observation: The just hatched guppies were devoured by their own mother						

SKIPPED

ORIGINAL NUMBER OF FISH			
	ADULTS		YOUNGS
	Males	Females	

Initial number of guppies in the aquarium	8	8	8
N° of guppies recounted one year later	3	6	0
Observations: The young of the original establishment were devoured by the adults. Some adults of the original establishment died by unknown causes.			

Which of the following statements arise from the analysis of the previous data? Mark with 'X' correct statements.

- I. Guppies eat their own offspring ('infanticide' behaviour).
- II. Guppies show 'indiscriminate' cannibalism, eating all individuals belonging to its species.
- III. Guppies show 'selective cannibalism', eating the individuals belonging to species which are shorter than threshold level.
- IV. Guppies show 'selective' cannibalism eating only foreign progeny.

SKIPPED

B24. (8 points). Two young men (Hans and Henri), behaviour researchers of more or less the same age and appearance, are going to do some investigations about sexual preferences of human females. For this purpose they select six nice outdoor cafés popular with young women and hire two similar bikes of which one is provided with an extra child saddle (see diagram).



Hans and Henri expect that a man having a bike with a child's saddle is more attractive to young women. This is checked on a sunny afternoon in July. Hans and Henri make a tour along the six outdoor cafés, indicated A to F. At every café they halt for 15 minutes. While standing in front of the café with their bikes and pretending they are having a talk together, they both try individually to make eye contact with as many as possible of the females sitting outside. The numbers are recorded and after each café Hans and Henri change bikes. The results of this experiment are shown in the table.

	Number of hits (eye contacts) at café A to F						
	A	B	C	D	E	F	Total
Hans	<u>12</u>	10	<u>14</u>	7	<u>17</u>	12	72
Henri	9	<u>17</u>	10	<u>10</u>	12	<u>20</u>	78
Total	21	27	24	17	29	32	150

Remark: underlined are the hits obtained by man (Hans or Henri)+bike with child saddle.

Hans and Henri expect that the man with a bike having an extra child saddle will be more attractive to females than the man with the bike without a child saddle. Possible arguments supporting this idea are based on the hypothesis that female organisms often show behaviour focusing on objects related to survival of species.

01. (1 point). Which of the following statements is a correct Null Hypothesis for the experiment of Hans and Henri?

1. Hans and Henri do have the same attractiveness for females.
2. The attractiveness of a man + bike with child's saddle is the same as man + bike without child's saddle.
3. The six cafés do not differ in the character of the visiting females.
4. Having eye contact between a male and a female is not an indicator of attraction.
5. The attractiveness of a man+bike with child's saddle is greater than that of a man+bike without child's saddle.

02. (1 point). Hans and Henri do some calculations with their results.

	Number of hits per café	
	Mean (average)	Standard deviation
Hans	12	3.4
Henri	13	4.5
Hans+Henri	25	5.5
<u>Situation A:</u> Man + bike with child's saddle	15 (n_A)	3.7 (S_A)
<u>Situation B:</u> Man + bike without child's saddle	10 (n_B)	1.9 (S_B)

You have to check the significance of the differences between situation A and B using the t-test. The following table should be used.

Level of significance	Critical t-value
10.0 %	2.02
5.0 %	2.57
2.5 %	3.37
1.0 %	4.03
0.5 %	6.86

Calculate the standard deviation of the difference between the means of the two situations A and B in using the formula:

$$s = \sqrt{\{ (s_A^2/n_A) + (s_B^2/n_B) \}}$$

S =

03. (1 point). Calculate t, using the formula:

$$t = d/s$$

t =

d – difference between means (situation A and situation B).

04. (1 point). How sure can we be about rejecting the Null hypothesis (i.e. the difference between situation A and B is significant)

1. Less than 75.0 %
2. In between 75.0 % and 90.0 %
3. In between 90.0 % and 95.0 %
4. In between 95.0 % and 97.5 %
5. In between 97.5 % and 99.0 %
6. In between 99.0 % and 99.5 %
7. Over 99.5 %

05. (1 point). Hans and Henri show their results to Paula, their boss. Paula claims that Hans and Henri made a big mistake looking at the total number of hits per café since the six cafés differ too much as a spread of 17 up to 32 is too much. Hans and Henri do not agree with Paula and want to prove their point of view using the χ^2 test. Determine the χ^2 using the following formula.

$$\chi^2 = \sum \frac{(O - E)^2}{E}$$

$\chi^2 =$

06. (1 point). Indicate the degree of freedom (df) for this test:

07. (1 point). Determine the probability (P) for this χ^2 test, using the following table. Estimate the answer in %.

(df)	Probability of random deviation (P)									
	0.995	0.975	0.9	0.5	0.3	0.25	0.1	0.05	0.025	0.01
1	0.00	0.00	0.02	0.46	1.07	1.32	2.71	3.84	5.02	6.64
2	0.01	0.05	0.21	1.39	2.41	2.77	4.61	5.99	7.38	9.214
3	0.07	0.22	0.58	2.37	3.67	4.11	6.25	7.82	9.35	11.35
4	0.21	0.48	1.06	3.36	4.88	5.39	7.78	9.49	11.14	13.28
5	0.41	0.83	1.61	4.35	6.06	6.63	9.24	11.07	12.83	15.09
6	0.68	1.24	2.20	5.35	7.23	7.84	10.65	12.59	14.45	16.81
7	0.99	1.69	2.83	6.35	8.383	9.04	12.02	14.07	16.0	18.48

08. (1 point). Which of the following conclusions based upon this χ^2 test is correct? Look at the total number of hits per cafe

1. The café's are different, but the differences are not significant
2. The differences between the cafés are significant
3. The results are dubious or questionable, something must be wrong in the design of this experiment
4. The cafés are not different, but this is not significant
5. The cafés are not different and this is significant

B26. (5 points). The birth records for 4 children were lost at a hospital. The ABO blood groups of the four babies are known to be A, B, AB, and O. To determine parentage all of their parents were tested for blood group. (The father of third child wasn't found). The results are shown in the following table.

01. (4 points). Match the babies with their parents by marking the right blood types in the table .

Families		Blood group of each parent	Blood group of a baby
Parents 1	Father	AB	
	Mother	O	
Parents 2	Father	A	
	Mother	O	
Parents 3	Father	Unknown	
	Mother	A	
Parents 4	Father	O	
	Mother	O	

02. (1 points). What is/are the possible blood group(s) the unknown father could have?

B27. (3 points). Connect the terms widely used in population genetics in the left column with the correct statement in the right column.

	Term
1	Inbreeding depression.
2	Gene flow.

	Statement
A	Fixes advantageous alleles and removes disadvantageous alleles.
B	Increases genetic diversity within and between sub-populations, but occurs rarely.

3	Selection.	C	Increases variation between sub-populations and decreases variations within sub-populations.
4	Outbreeding depression.	D	Fitness reduces due to increase in homozygosity, expression of deleterious alleles increases as a consequence of mating between closely related individuals.
5	Genetic drift.	E	Reduction of fitness due to mating of genetically divergent individuals.
6	Mutation.	F	Decreases variation between sub-populations and increases variation within sub-populations.

Term	1	2	3	4	5	6
Answers:	An					

B28. (4 points). In an isolated human population of 8400 persons, the frequency of allele I^A is 30% and allele I^B is 10%.

What is the number and % of people with each blood group?

Group	People number	%
O		
A		
B		
AB		

B29. (4 points). Suppose that the difference between 10 cm high maize and 26 cm high maize is due to four pairs of additive genes. The individuals with 10 cm have the aabbccdd genotype and the 26 cm - AABBCDD.

01. (1 point). Determine the phenotype of F1 if it is known that the parental plants are 10 cm and 26 cm of high.

Answer:

F1:

02. (1 point). How many phenotypes classes would be in F2?

Answer:

F2:

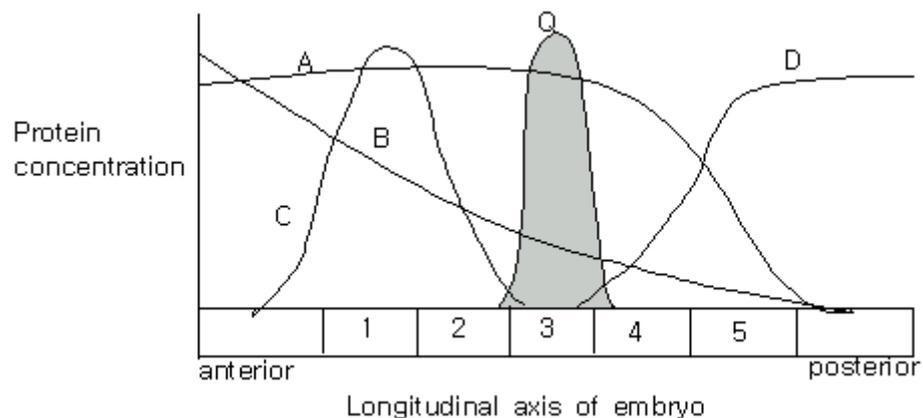
03. (1 point). Determine the phenotypes of F2 if it is known, that the parental plants are 10 cm and 26 cm high.

Answers:

04. (1 point). What fraction of the total number of plants in F2 will be 18 cm high ?

Answer:

B30. (4 points). The following figure shows the distribution of the concentrations of five hypothetical proteins in a *Drosophila* embryo. The anterior end is on the left and the posterior end is on the right. A and B gene products activate the expression of Q gene, and C and D gene products repress the expression of Q gene.



If one of the A, B, C and D genes is mutated, where would the protein Q be found? Choose the number of the correct answer.

	Expression pattern of Q gene
Mutant A	
Mutant B	
Mutant C	
Mutant D	
I. Would be found in the anterior end of the embryo body.	
II. Would be found in the posterior end of the embryo body.	
III. No significant change	
IV. Expression of Q gene would decrease significantly.	

B31. (2 points). It is known that in some dioecious plants sex can be determined genetically as in animals. Examine the results of analysis of different types of polyploids and ascertain the type (mechanism) of sex determination in the given plant species.

Choose the correct statement and put its number in the appropriate box.

<i>Rumex acetosa</i>		<i>Silene latifolia</i>	
Genotype	Sex	Genotype	Sex
2A+2X	♀	2A+2X	♀
2A+X+Y	♂	2A+X+Y	♂
2A+X+2Y	♂	2A+X+2Y	♂
2A+X+3Y	♂		
2A+2X+Y	♀	2A+2X+Y	♂
2A+2X+2Y	♀		
3A+X+2Y	♂		
3A+X+3Y	♂		
3A+X+4Y	♂		
3A+2X	♀	3A+2X	♀
3A+2X+Y	♂	3A+2X+Y	♂
3A+2X+2Y	♀		
3A+2X+3Y	♀		
3A+3X	♀	3A+3X	♀
3A+3X+Y	♂	3A+3X+Y	♂
3A+3X+2Y	♂	4A+X+Y	♂
4A+2X+2Y	♂	4A+2X	♀
4A+2X+3Y	♂	4A+2X+Y	♂
4A+2X+4Y	♂	4A+2X+2Y	♂
4A+3X	♀	4A+3X	♀
4A+3X+Y	♂	4A+3X+Y	♂
4A+3X+4Y	♂	4A+3X+2Y	♂
4A+4X	♀	4A+4X	♀
4A+4X+Y	♂	4A+4X+Y	♂
4A+4X+2Y	♂	4A+4X+2Y	♂
5A+5X	♀		
6A+4X+4Y	♂		

A – haploid number of autosomes.

1. Sex determination as in human.
2. Sex determination as in *Drosophila*.
3. Sex determination as in birds.
4. Sex determination as in bees.

5. In given plants X-chromosome determines maleness and Y-chromosome determines femaleness.

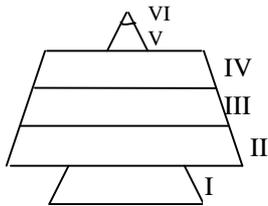
6. The presence of the Y-chromosome is a necessary and sufficient condition for the formation of male flowers.
7. Y-chromosome doesn't take part in sex determination.
8. X-chromosome doesn't take part in sex determination.

01. *Rumex acetosa*

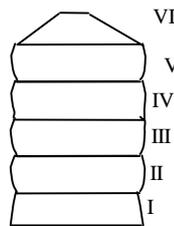
02. *Silene latifolia*

Ecology (5 questions, 19 points).

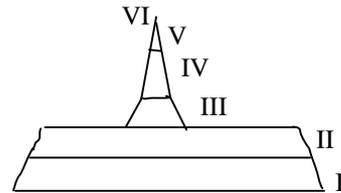
B32. (3 point). Three pond ecosystems (1, 2 and 3) were used for fish production. When the total number of fish in each pond was measured, the following pyramids were obtained. (Age of the fish is divided into six class intervals).



1.



2.



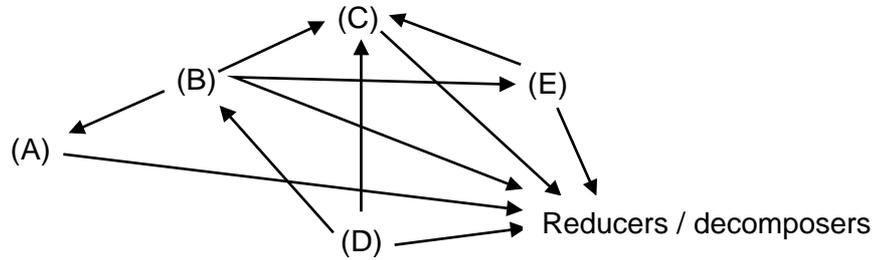
3.

Assign to these pyramids the appropriate features from the list below. Using letters indicate the answer(s) in the table.

- A. Pond with very intensive fish cropping.
- B. Pond with selective cropping of baby fish.
- C. Pond with limited fish cropping.
- D. Eutrophic pond.
- E. Pond cropped regularly.
- F. Pond with excessive turbidity and excessive phytoplankton.
- G. Pond with optimal age structure.

Pond	Statement
1	
2	
3	

B33. (2.5 points). The following figure shows the food web of a certain ecosystem with five species (A-E). Arrows indicate the flow of energy. Match the letters to the descriptions of the species:



Producer	
Herbivore	
Omnivore	
Carnivore	

B34. (8.5 points). Fresh water bodies can be subdivided into still-water systems (lentic waterbodies = ponds and lakes) and moving water systems (lotic waterbodies = creeks and rivers). Both groups differ in the abiotic factors and in their flora and fauna.

01. (2,5 points). Indicate with a '+' which characteristics are typical of the lentic and lotic systems.

Water system characteristic	Water system type	
	lotic	lentic
Rapid decrease of the light density with the depth		
Normally staggered water temperature		
Occurrence of long-lasting plankton communities		
Streamlined animal bodies		
Animals with suction cups (suckers)		

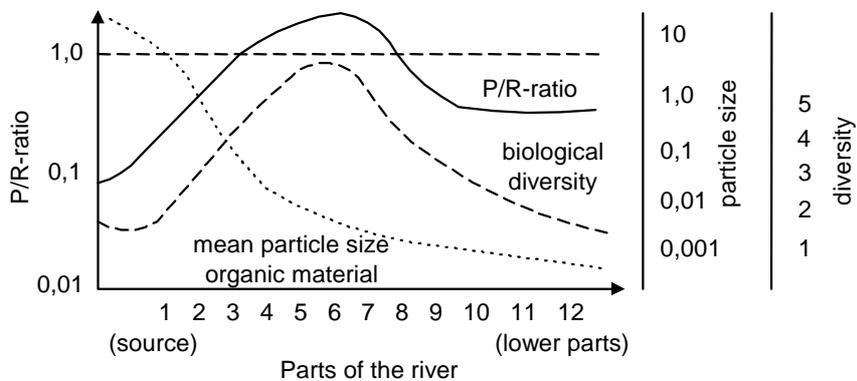
02. (3 points). Rivers show a marked profile of various water quality parameters along their length. Samples taken near the source of the river show different values for various parameters compared to samples from down stream parts of the river.

Mark the expected tendency of this difference using the symbols ‘+’ for increase, ‘-’ for decrease or ‘=’ for no change.

From near the river’s source \longrightarrow To lower part of the river.

- A. Water temperature.
- B. Oxygen content.
- C. Turbidity.
- D. Amount of sediments.
- E. Amount of nutrient minerals.
- F. Velocity of the flow.

03. (3 points). The graph shows values measured along a river (river continuum). The P/R ratio represents the ratio of production to respiration in the given part of the river. From the graph choose the correct parts of the river for the questions below.



Answer the three questions. Write the numbers of river parts in the boxes.

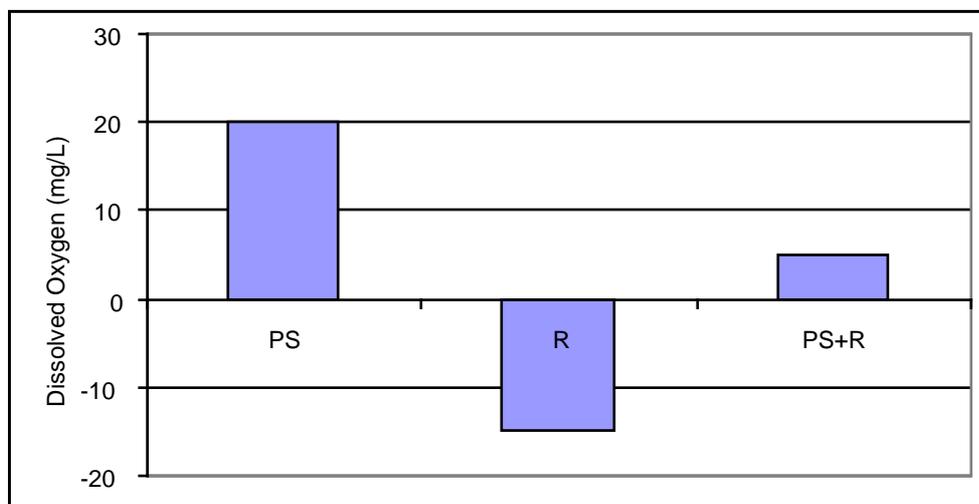
A. Which parts of the river are autotrophic?

B. In which parts is organic material (such as tree leaves) essential for the consumers?

C. In which parts can predators be found?

B35. (1 point). A student wished to estimate the size of a population of an endangered water beetle species in a small pond. He captured 30 individuals, marked and then released them back in the pond. After 24 hours, once again he captured 30 individuals. Of the newly captured individuals, only 14 were marked. Assume that no individuals were born, died, immigrated to or emigrated from the population during the experiment. What would be the student's estimation of the endangered water beetle population in the pond? Estimated population size of endangered water beetle in the pond is:

B36. (4 points). The graph shows the productivity of an aquatic ecosystem measured in terms of dissolved oxygen produced and consumed by green plants and photosynthetic algae where PS = photosynthesis and R = respiration.



Study the graph and answer the following questions, writing your answers in the box.

01. (1 points). Which bar represents net primary productivity?

02. (3 points). An algal bloom occurs until nutrient levels are exhausted. Then the algae die off and microbial decomposition begins. How will this affect the graph parameters PS and R?

02.1. (1 point). What will happen during the algal bloom?

1. PS will be increased, R will be decreased.
2. PS will be decreased, R will be increased.
3. PS and R will not change.
4. PS + R will increase.
5. PS + R will decrease.
6. PS + R will remain unchanged.

02.2. (1 point). What will happen after decomposition has begun?

1. PS will be increased.
2. PS will be decreased.
3. R will be increased.
4. R will be decreased.
5. PS + R will be increased.
6. PS + R will be decrease.
7. PS + R remain unchanged.

SKIPPED

02.3. (1 point). How would the graphs (parameters PS, R and PS+R) change if the net community productivity per dissolved oxygen levels was measured?

1. PS will be increased, R will be decreased.

2. PS will be decreased, R will be increased.

3. PS and R will not change.

4. PS + R will increase.

5. PS + R will decrease.

6. PS + R will remain unchanged.

SKIPPED



Biosystematics (4 questions, 16 points).

B37. (3 points). Below is a list of extant (living) mammalian genera. Assign them to the continents and subcontinents where they live and indicate the Order to which they belong.

Insert the number of the animal into the correct boxes of tables **01** and **02**.

<i>GENUS</i>	
1.	<i>Ursus</i> (Bears)
2.	<i>Cebus</i> (New world monkeys)
3.	<i>Pan</i> (Chimpanzees)
4.	<i>Pongo</i> (Orangutans)
5.	<i>Elephas</i> (Elephants)
6.	<i>Macropus</i> (Kangaroos)

01. (1.8 points). Continents & subcontinents.

Australia	
North America	
India	
Africa	
Europe	
Asia	
South America	

02. (1,2 points). Order

Marsupialia	
Proboscidea	
Carnivora	
Primates	

B38. (3 points). Match the terms in the left column (1 to 6) with the names of organisms in the right column (A to F).

- 1. Polyembryony. A. Fasciola
- 2. Heterogony. B. *Helix*.
- 3. Metagenesis C. Apis
- 4. Hermaphroditicity. D. *Ichneumon*
- 5. Parthenogenesis. E. *A. heli*
- 6. Parthenocarpy. F. Axolotl (*Ambystoma*).

SKIPPED

Answer:

1	2	3	4	5	6

B39. (3 points). The cladogram shows the phylogenetic relationships among seven hypothetical species.

01. (2 points). Which of the following is a paraphyletic group (A) and which is a polyphyletic group (B)?

- 1. E + F + G.
- 2. E + F.
- 3. E + F + C + H.
- 4. C + E.
- 5. B + C.

SKIPPED

Answer:

A. _____

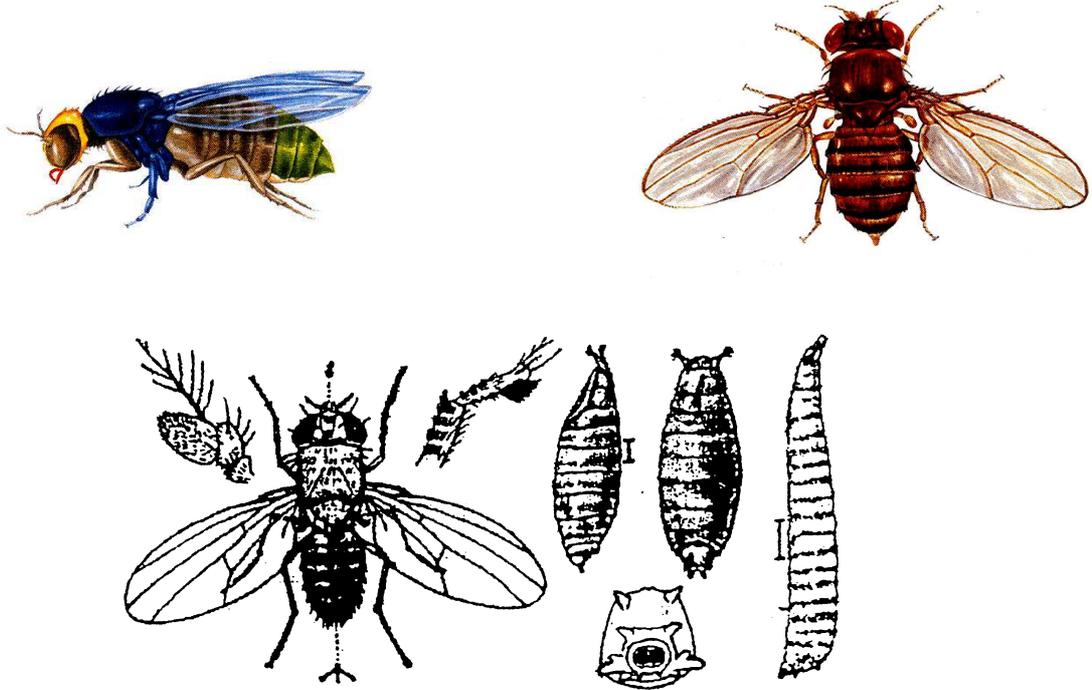
B. _____

02. (1 point). Which species are most closely related?

- 1. G and H.
- 2. G and F.
- 3. H and F.
- 4. Evolutionary closeness is equal for all species.

B40. In the figure is shown a well known organism.

01. (1,2 points). Give its systematic position by choosing suitable numbers from the list below.



- | | | |
|--------------------|------------------|--------------------|
| 1 – Animalia; | 11 – Gastropoda; | 21 – Drosophila; |
| 2 – Arthropoda; | 12 – Annelida; | 22 – Aphis; |
| 3 – Echinodermata; | 13 – Protozoa; | 23 – Leptinotarsa; |
| 4 – Mollusca; | 14 – Viviparus | 24 – Coleoptera; |
| 5 – Fungi; | 15 – Hymenoptera | 25 |
| 6 – Chilopoda; | 16 | 26 – Oligochaeta; |
| 7 – Insecta; | 17 – Arachnida; | 27 – Lepidoptera; |
| 8 | 18 – Cnidaria; | 28 – Anopheles; |
| 9 – Plantae; | 19 – Diptera; | 29 – Locusta; |
| 10 – Apis; | 20 | 30. |

Kingdom	
Phylum:	
Class:	
Order:	
Genus:	

02. (1 point). Choose the number corresponding to the type of the insect's leg.

1. Leaping.
2. Burrowing.
3. Swimming.
4. Gathering.
5. Walking.
6. Prehensile.

03. (1 point). Using the letters, list the leg structural elements this insect possesses in sequence (beginning with those closest to the body).

- A. Femur.
- B. Tibia.
- C. Trochanter.
- D. Coxa.
- E. Tarsus.

04. (1 point). Give the number corresponding to the type of insect mouthpart.

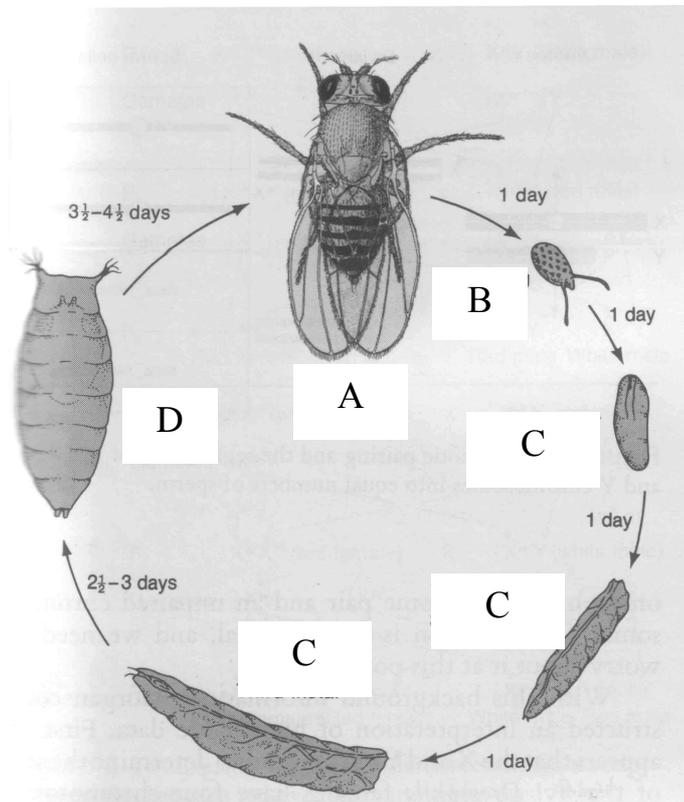
- 1. Piercing-suctorial.
- 2. Licking.
- 3. Biting.
- 4. Suctorial.

05. (1 point). Select the numbers of organs of other organisms, which are homologous to the wings of the insect concerned.

- 1. Sparrow wing.
- 2. Crayfish gills.
- 3. Bat wings.
- 4. Fish dorsal fin.
- 5. Fish pectoral fin.
- 6. Potato beetle elytrum.
- 7. Frog legs.

06. (0,8 point). In the answer table assign the developmental stages of this insect according to the letters in the figure.

- | | |
|-------------------|------------------|
| 1. Sporocyst. | 5. Imago. |
| 2. Egg. | 6. Redia. |
| 3. Graaf vesicle. | 7. Pupa. |
| 4. Larva. | 8. Hydatid cyst. |



Answer:

A	B	C	D

07. (1 point). What is the significance of the species for humans?

1. Animal and human parasite.
2. Crop pest.
3. Object of genetic investigation.
4. Entomophagous.
5. Vector of sleeping sickness agent.

