Part B

Please read carefully all the instructions!

For questions with multiple correct answers, you will be penalised for additional incorrect responses.

Only the calculators which were provided with the Olympiad materials are permitted.

Mark all the correct answers in the answer sheet! **The jury will check only the answer sheet!**

Cell Biology

B 1. The dependence of the initial reaction rate on substrate concentration for 3 different enzymes (**X, Y and Z**) is given in the table:

Substrate concentration (arbitrary units)	**Initial rate (arbitrary units)**		
	X	**Y**	**Z**
1	0.92	0.91	0.032
2	1.67	1.67	0.176
4	2. 85	2.86	0.919
6	3.75	3.75	2.180
8	4.40	4.44	3.640
10	4.90	5.00	5.000
15	5.80	6.00	7.337
20	6.23	6.67	8.498
30	6.80	7.50	9.397
50	6.00	8.33	9.824
100	4.20	9.09	9.968

1. Plot the initial rates versus substrate concentrations on the answer sheet! ***(1 point)***

2. Which enzyme (X, Y or Z) is a regulatory enzyme with a co-operative behaviour? ***(1 point)***

3. Which of the enzymes (X, Y or Z) is inhibited by its own substrate? ***(1 point)***

B 2. For an exponentially growing culture of microorganisms the specific growth rate (μ) is a parameter, that gives the cell biomass (g) synthesized per gram of existing cell biomass per unit of time (usually, per hour). This rate (**μ)** is inversely related to the doubling time of the culture, t_d: $\mu = \ln 2/t_d \approx \mathbf{0.7/t_d}$. Hence, the shorter the doubling time of cells, the higher is the specific growth rate of the culture.

Two microorganisms, A and B, were inoculated each in a fresh growth medium with an initial optical density (OD) of 0.1. A lag phase of 1 hr duration was observed for both cultures. Three hours after inoculation, the OD of culture A was 0.4, while that of the culture B was 1.6.

1. Estimate the specific growth rate for culture A

2. Estimate the specific growth rate for culture B ***(2 points)***

B 3. Calculate the intracellular millimolar (mM) concentration of potassium in *Escherichia coli*, if the measured potassium content is 7.8 micrograms per milligram of dry cell mass. Assume all potassium ions are free in the cytosol (not bound to macromolecules), and that the intracellular volume is 2 microlitres per milligram of dry cell mass. The atomic weight of potassium is 39 Daltons. ***(1 point)***

B 4. A species of fungus can dissimilate glucose and produce ATP in two ways.

Aerobically: $C_6H_{12}O_6 + 6O_2 = 6\ CO_2 + 6\ H_2O$,

Anaerobically: $C_6H_{12}O_6 = 2\ C_2H_5OH + 2\ CO_2$

This fungus is cultivated in a glucose-containing medium. Half of the total ATP production is anaerobic.

1. What is the ratio between the rates of aerobic and anaerobic catabolism of glucose?

(*Continuation see on the next page*)

2. What is the expected oxygen consumption (moles per mole of consumed glucose)?

3. What is the expected CO_2 evolution (moles per mole of consumed glucose)?

For calculations, assume that glucose is fermented via the usual Embden-Meyerhof-Parnas glycolytic pathway, and that oxidative phosphorylation proceeds with maximum efficiency.

(3 points)

B 5. For the bacteria *Bacillus subtilis*, several auxotrophic mutants have been obtained which need addition of aspartate, threonine or methionine to the growth medium.

Mutant	Amino acid precursors that are not synthesized by the mutant	Amino acid needed for growth	Metabolite, accumulating in the medium
aspA		**4.** Aspartate	**7.** Fumarate
metA	**1.** Homocystein	**5.** Methionine	**3.** Homoserine
metH		**5.** Methionine	**1.** Homocystein
thrC		**6.** Threonine	**2.** Homoserinephosphate
thrB	**2.** Homoserinephosphate	**6.** Threonine	**3.** Homoserine
thrA	**3.** Homoserine	**6.** Threonine	**4.** Aspartate
	2. Homoserinephosphate	**5.** Methionine	
	1. Homocystein		

1. What is the biosynthetic pathway for methionine biosynthesis?

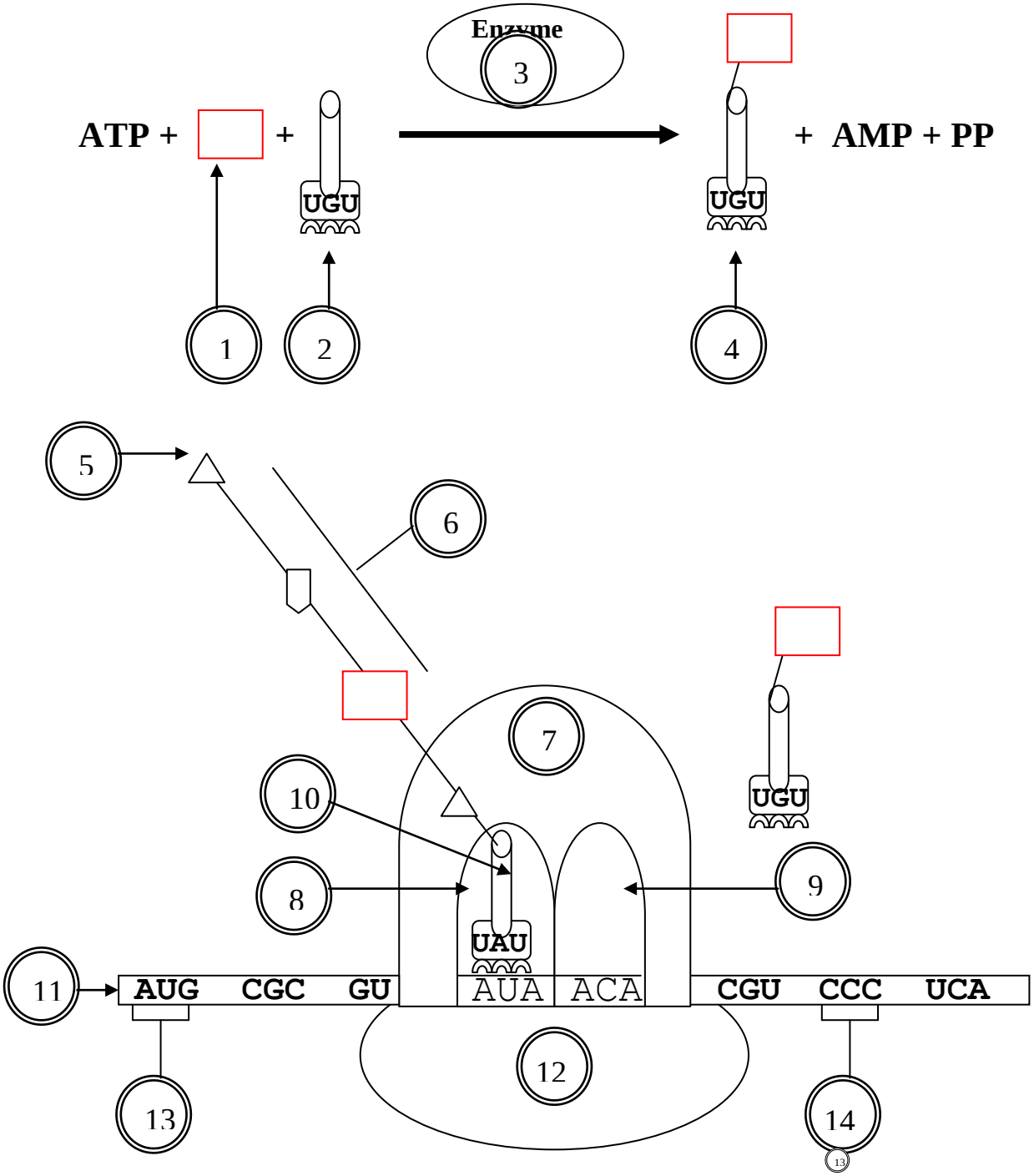
2. What is the biosynthetic pathway for aspartate biosynthesis?

3. What is the biosynthetic pathway for threonine biosynthesis?

Indicate the pathway with appropriate numbers from the table (1-7) and arrows in the answer sheet! ***(3 points)***

B6. Before a lecture, an assistant noticed that comments on an important diagram are lost. He found many of terms in a textbook, including some which were unrelated to this diagram.

1. Please help the assistant to locate the correct terms for this diagram and to place the appropriate numeric labels in the table in the answer sheet.



(*Continuation see on the next page*)

	Term	**Number**		**Term**	**Number**
A-1	Amino acid		**A-2**	Growing polypeptide	
B-1	Pentose		**B-2**	Growing DNA strand	
C-1	Fatty acid		**C-2**	Growing RNA strand	
D-1	Small ribosomal subunit		**D-2**	Alpha subunit of RNA polymerase	
E-1	tRNA		**E-2**	Nuclear pore	
F-1	IgG		**F-2**	P site	
G-1	Receptor		**G-2**	Centriole	
H-1	Aminoacyl-tRNA synthetase		**H-2**	Large ribosomal subunit	
I-1	Protein kinase		**I-2**	A-site	
J-1	Glucokinase		**J-2**	Z-site	
K-1	Aminoacyl-tRNA		**K-2**	Peptidyl-tRNA	
L-1	Inductor		**L-2**	DNA polymerase	
M-1	Operator		**M-2**	Spliceosome	
N-1	N - end		**N-2**	Adenylate cyclase	
O-1	C - end		**O-2**	Capsomer	
P-1	5` - end		**P-2**	Single stranded DNA	
R-1	3` - end		**R-2**	Codon	
S-1	Nucleotide		**S-2**	Initiation codon	
T-1	Lysosome		**T-2**	Gene	
U-1	Sigma subunit of RNA polymerase		**U-2**	Terminal transferase	

(*Continuation see on the next page*)

2. Which component of this diagram has (give the number) peptidyl transferase activity?

(5 points)

B 7. The growth of bacteria is studied. For a period of exactly one duplication, the sample is moved from an environment with a light nitrogen isotope (^{14}N) to an environment with heavy nitrogen isotope (^{15}N). After this the sample is again transferred to the environment with light nitrogen for a period of two duplications.

1. What is the composition of double-stranded DNA (in %) of light and heavy nitrogen isotopes after the experiment?

A. Only light	**B.** In between	**C.** Only heavy

From these cells two types of mRNA {mRNA (*A*) and mRNA (*B*), respectively, expressed from two different genes} were isolated. Both mRNAs were found to contain an identical number of nucleotides. The nucleotide composition of each mRNA was estimated as (see the table).

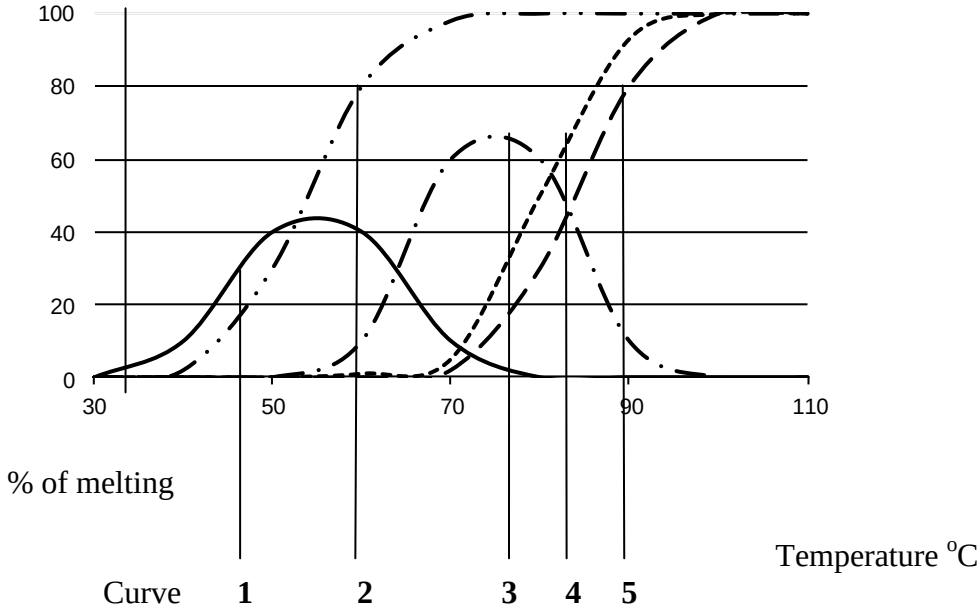
mRNA	**A %**	**C %**	**G %**	**T %**	**U %**
A	17	28	32	0	23
B	27	13	27	0	33

(*Continuation see on the next page*)

2. What is the nucleotide composition of double-stranded genomic DNA in the coding part of the genes A and B, respectively.

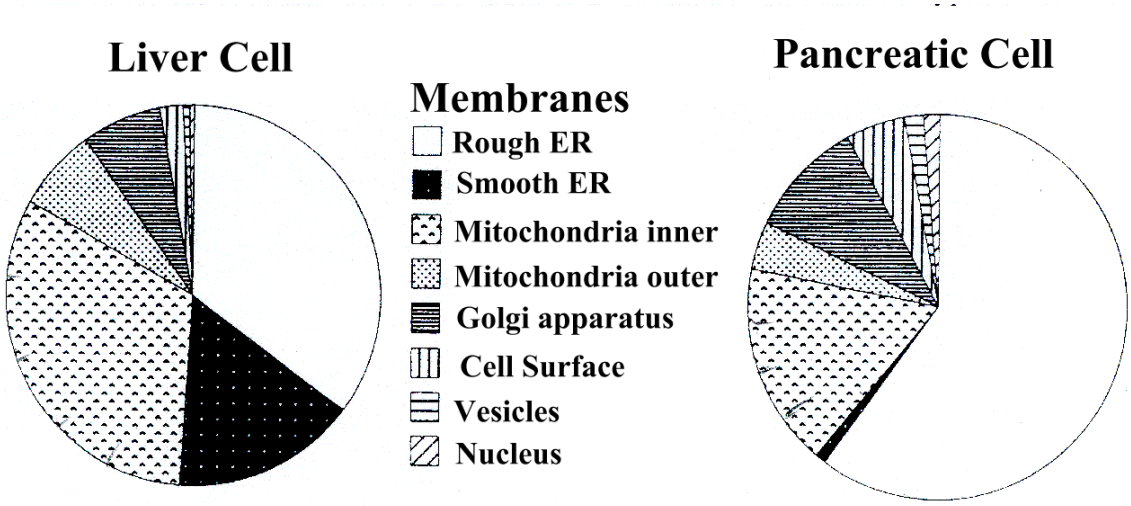
dsDNA	A %	C %	G %	T %	U %
A					
B					

3. What curve in the plot below represents the DNA melting profile of the coding part of genes A and B, respectively?



(3 points)

B 8.

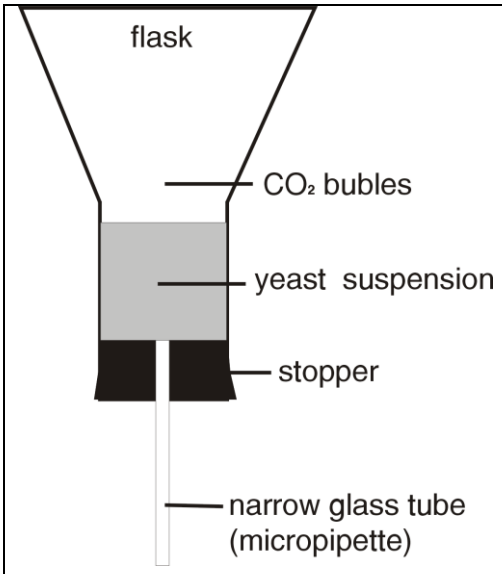


[Source: B. Alberts *et al, The Cell* (1989)]

The pie charts show the relative amounts of types of membrane found in two types of cells. Suggest, why liver cells (answer **1**) possess significantly more smooth ER, while pancreatic cells (answer **2**) have more rough ER. Chose the correct statements (**A to E**) from the left column and pair them with the appropriate numbers **(1 to 5)** from the right column.

	Process	**Structure**	**Number**
A.	Higher synthesis of lipids	In nuclear membrane of pancreatic cells	**1**
B.	Higher proteolytic activity	In glycogen particles of liver cells	**2**
C.	Higher lipolytic activity	In endoplasmic reticulum of pancreatic cells	**3**
D.	Higher protein-secretory activity	In mitochondria of liver cells	**4**
E.	Hihger ATP-synthesizing activity	In endoplasmic reticulum of liver cells	**5**

(2 points)



B9. The diagram shows an apparatus made by a student to investigate the effect of temperature on the activity of ethanol fermentation of yeast. The conical flask contains 2.5 g yeast suspended in 2% sucrose solution. The meniscus moves down the glass tube (5ml micropippete) during fermentation.

The table shows the amount of suspension (ml) pushed in the glass tube due to CO_2 accumulation at regular time intervals.

Time (min.)	**4^0 C**	**10^0 C**	**20^0 C**	**35^0 C**	**55^0 C**
1	0	0.2	0.4	0.7	0
2	0	1.0	1.3	1.2	0.1
3	0.1	1.9	2.2	2.8	0.2
4	0.2	3.1	3.3	4.4	0.3
5	0.3	4.0	NO RESULT	NO RESULT	0.4

1. Plot the data on CO_2 accumulation at different temperatures.

2. Estimate the average rate of CO_2 production (ml CO_2/min) for the yeast suspension at 20^0 C using the values obtained in the period between 2 and 4 minutes.

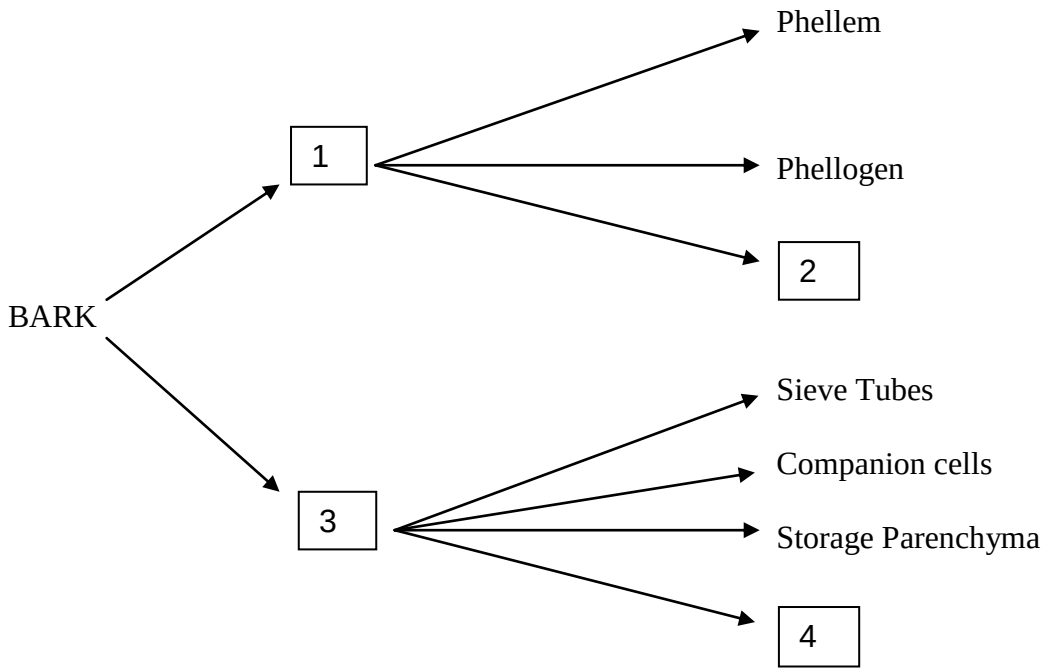
3. Estimate the specific rate of CO_2 generation (millimoles CO_2/(min g)) at 20^0 C.

4. What would be the specific rate of ethanol accumulation (millimoles ethanol /(min g)), if the fermentation follows the equation? $C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2\ CO_2$

(4 points)

Plant Anatomy and Physiology

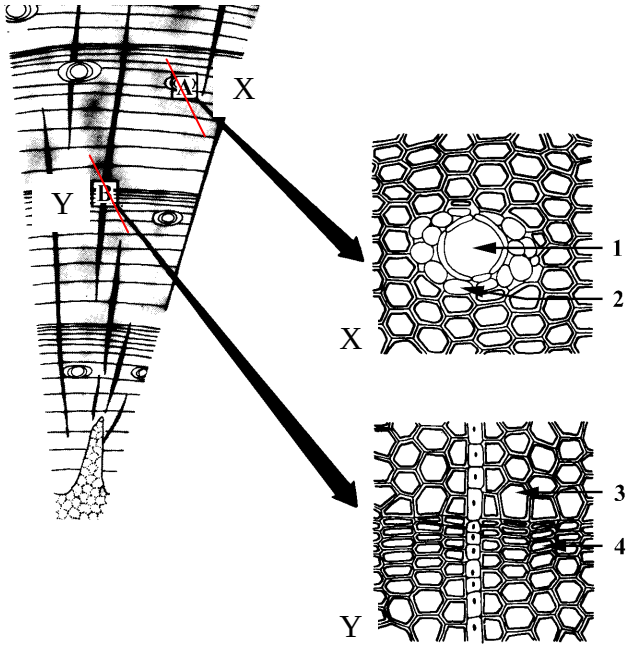
B 10. Write the numbers (each number can be used only once) of the unnamed structures in the appropriate boxes in the table in the answer sheet.



	Structures	Number
A.	Periderm	
B.	Primary phloem	
C.	Phloem fibers	
D.	Phelloblast	
E.	Phelloderm	
F.	Secondary phloem	
G.	Tracheids	

(2 points)

B 11. The figure shows a cross section of gymnosperm stem wood. Write in the table in the answer sheet the appropriate numbers (each number can be used only once) of corresponding plant structures.



	Plant structure	**Number**
A.	Early wood	3
B.	Sieve tube	
C.	Latewood	4
D.	Resin duct	1
E.	Companion cell	
F.	Xylem parenchyma	2

(2 points)

B 12. The following features pertain to specific structures and processes in plants. Write the number that corresponds to appropriate structure in the table in the answer sheet!

1. Regulates the inward flow of ions into the roots

2. A plastid which develops in a plant when it is kept in the dark

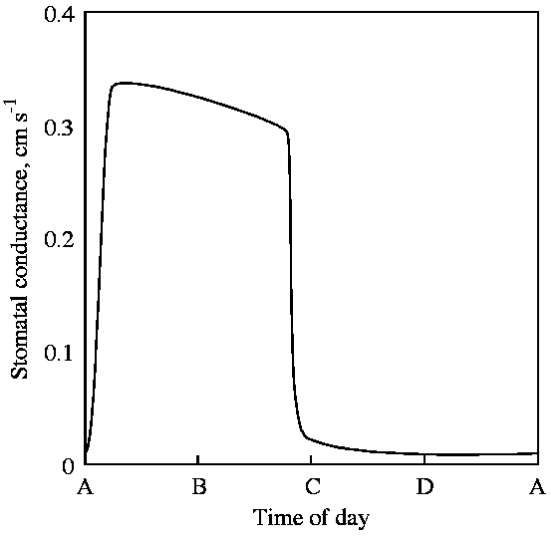
3. A cell type which provides the main support in gymnosperm wood

4. Provides water movement horizontally across the stem

	Plant structure	**Number**
A.	Tracheids	
B.	Epidermis	
C.	Endodermis	
D.	Resin duct	
E.	Rays	
F.	Leucoplast	
G.	Etioplast	

(2 points)

B 14. The diurnal curve indicates the stomatal opening for a typical C3 plant.

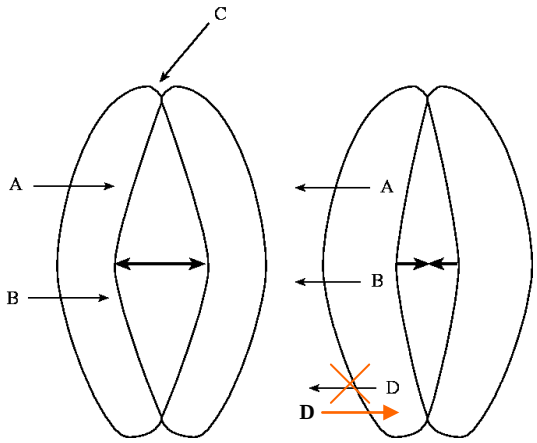


Stomatal conductance is an indication of the capacity for diffusion through stomata and an indirect measurement of stomatal opening. A stomatal conductance of zero indicates that stomata are closed (i.e., there is no transpiration).

1. Indicate the times of day in the diagram and mark them on the answer sheet, using the codes:.

1. Midnight **2.** Noon **3.** 6:00 a.m. **4.** 6:00 p.m

A	
B	
C	
D	



Stomatal opening vs. closure is regulated through several internal and external factors.

(*Continuation see on the next page*)

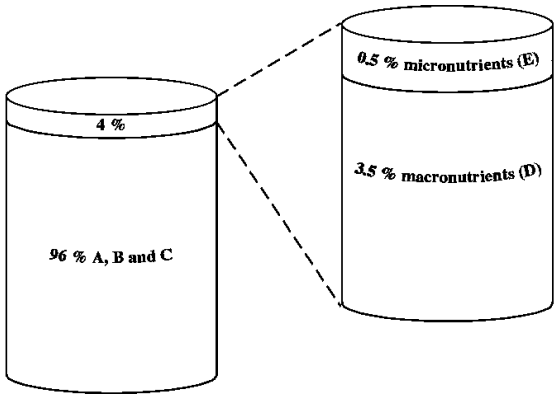
2. Indicate and mark in the answer sheet, which of the following corresponds to the factors depicted in the picture. Use the given code:

1. CO_2 **2.** Light **3.** Ca^{2+} **4.** Abscisic acid **5.** K^+ **6.** H_2O

A and B	
C	
D	

(4 points)

B 15. Plants require 16 essential elements - boron (**1**), calcium (**2**), carbon (**3**), chlorine (**4**), copper (**5**), hydrogen (**6**), iron (**7**), magnesium (**8**), manganese (**9**), molybdenum (**10**), nitrogen (**11**), oxygen (**12**), phosphorus (**13**), potassium (**14**), sulfur (**15**), zinc (**16**). The proportional masses of various elements in plants are shown.



1. Indicate the numbers in the answer sheet, corresponding to each element in the table.

A, B, C	
D	
E	

(3 points)

Animal Anatomy and Physiology

B 16. The Figure shows the overall fluid balance in the human gastrointestinal tract.

Calculate three volumes (**X, Y** and **Z**) and write them in the answer sheet.

Volume of fluids absorbed in the gastrointestinal tract or excreated during 24 hours.

.....

Small intestine absorbs **X ml**

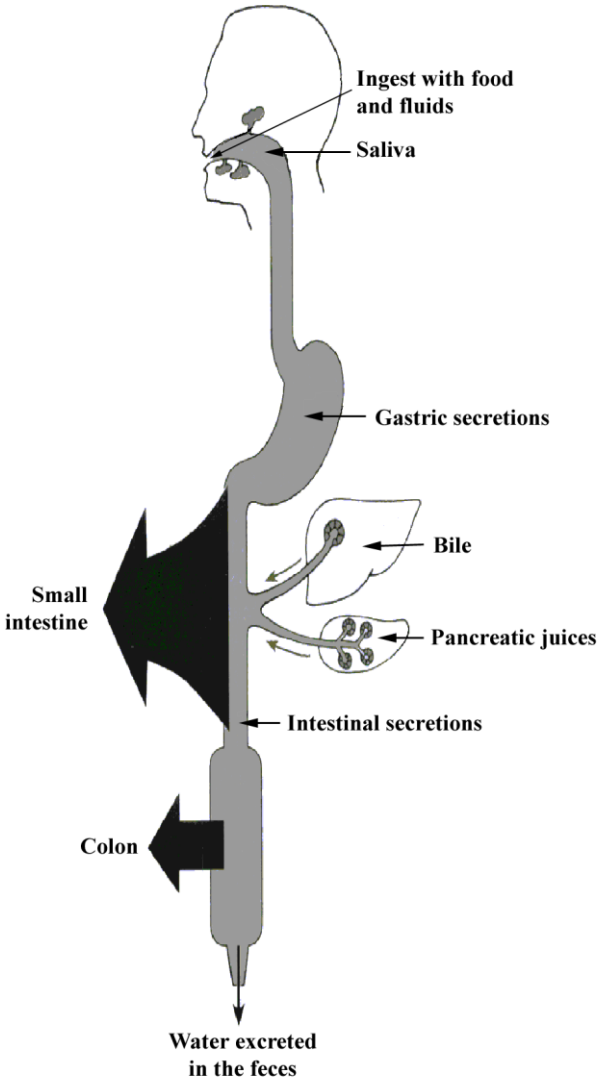
.....

Colon absorbs **1 000 ml**

.....

Water excreation in the faeces **100 ml**

Sum: **Y ml**



Volume of fluids entering the gastro-intestinal tract during 24 hours.

.....

Ingested with food and fluids **2 000 ml**

.....

Saliva **1 500 ml**

.....

Gastric secretion **2 000 ml**

.....

Bile **500 ml**

.....

Pancreatic juice **Z ml**

.....

Intestinal secretion **1 500 ml**

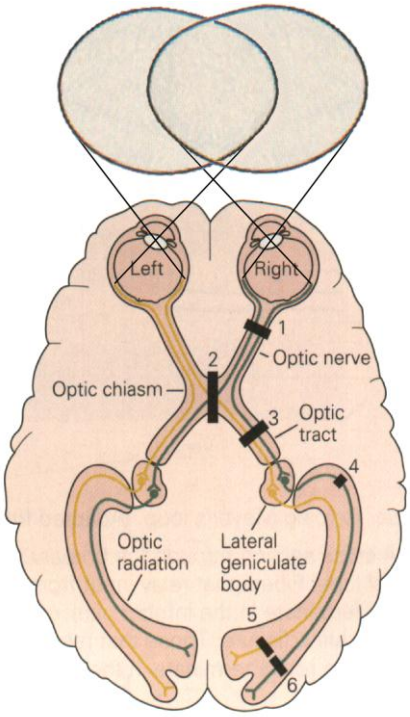
.....

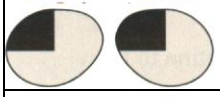
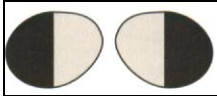
Sum: **9 000 ml**

(1 point)

B 17. Lesions in various points in the visual pathway produce deficitsat the visual field. The level of a lesion can be determined by the specific deficit in the visual field. In the diagram of the cortex the numbers along the visual pathway indicate the sites of lesions. The deficits that result from lesions are shown as black areas in the visual field maps on the right.

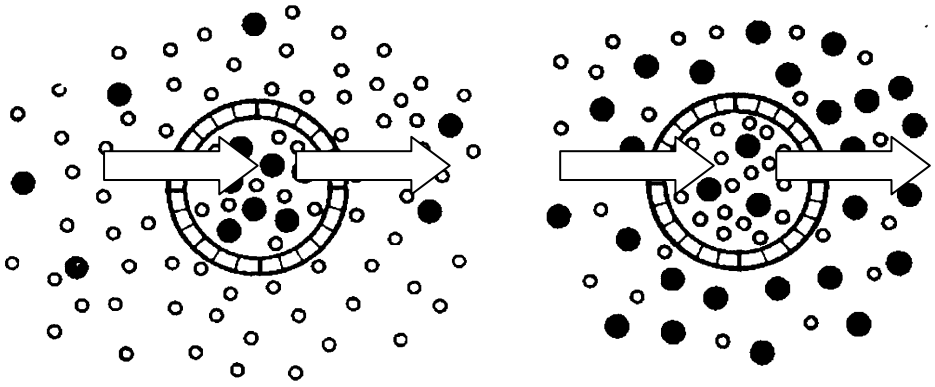
Choose the corresponding deficits that result from lesions at each site and write the numbers of the lesion sites in table in the answer sheet!



Defects in visual field of Left eye Right eye		**Number of lesion site**
	**A.**	
		
		
	**D.**	
	**E.**	
		

(3 points)

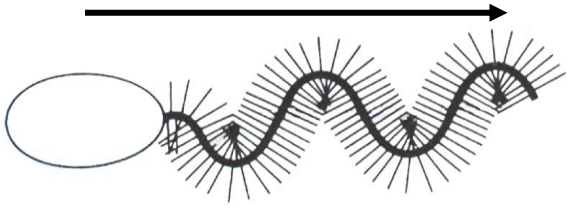
B 18. Please color the arrows in the answer sheet that indicate the direction of the water flow through the cell membrane of an erythrocyte. Light circles in the figure show the water molecules, dark circles show the molecules of the dissolved substances.



(1 point)

B 19. Please indicate the direction of the locomotion of protozoan (A) and (B) by arrows in the boxes in the answer sheet. Arrows in the figure indicate the direction of wave caused by ciliary's movement.

A.



B.

(1 point)

B 20. Please mark with crosses in the table in the answer sheet the locations where filtration, reabsorbtion and secretion take place in the mammal nephron (more than one correct answer per process possible)!

Process	1. Renal corpuscle	2. Proximal convoluted tubule	3. Henle loop	4. Distal convolu-ted tubule	5. Late distal tubule and collecting duct
A. Filtration of fluid that is isotonic to blood					
B. Reabsorption of water, Na^+, K^+, glucose, amino acids, Cl^-, HCO^-_3, urea					
C. Reabsorption of water, Na^+, K^+ and Cl^-					
D. Reabsorption of water, Na^+ and Cl^-					
E. Reabsorption of water, Na^+, HCO^-_3 and urea					

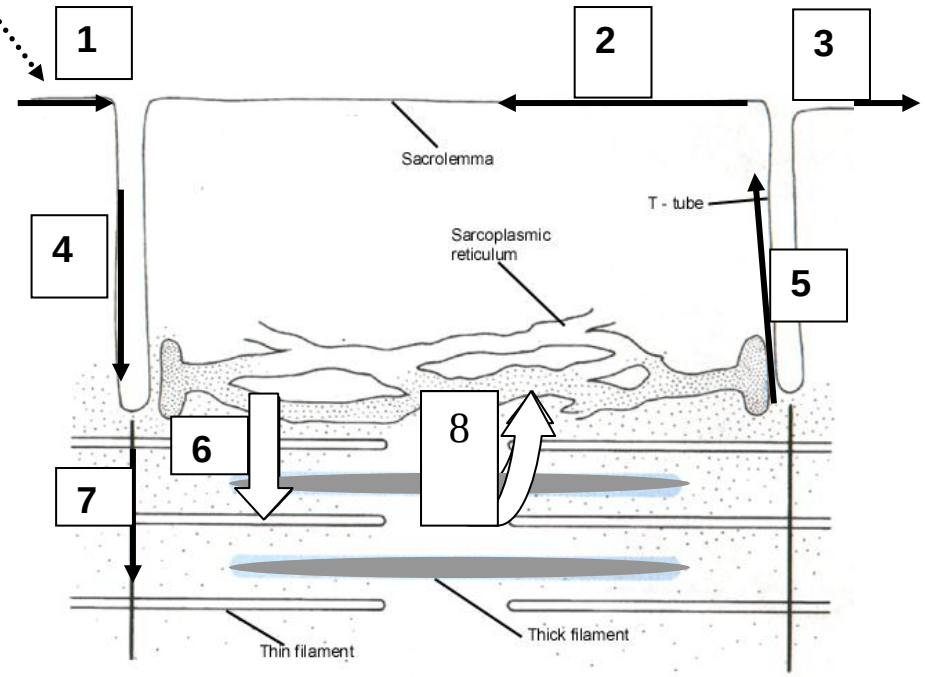
(*Continuation see on the next page*)

F. Secretion of H^+ and K^+					
G. Secretion of H^+, NH_4^+, urea, and creatinine					
H. Secretion of urea					

(5 points)

B 22. Arrange in the answer sheet in the correct sequence the arrows (choose from 1-8) that characterize the sequence of events in stimulation and contraction of muscle. The black arrows indicate propagation of excitation (action potential) in the membranes; the white arrows – depolarization - induced Ca^{2+} propagation in the sarcoplasma.

Stimulation



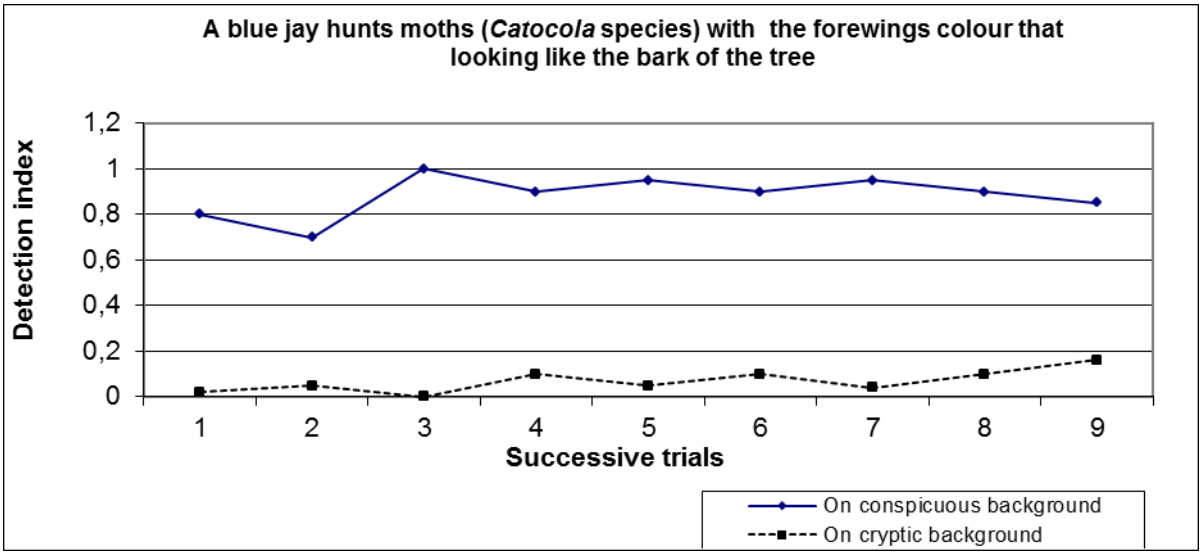
(1 point)

Ethology

B 25. A blue jay actively hunts on different moths (*Catocala*). The hindwings of the moths are often strikingly coloured yellow, orange, red or other color, but the forewings of the moths appear cryptic, looking very much like the bark of the trees on which the moths rest. In other words moths on a cryptic background appears like background. The forewings cover the hindwings, but when they are distrurbed, the hindwings are suddenly exposed. On a uniform background the moths are easily seen.

The detection index estimates the ability to spot a moth.

(*Continuation see on the next page*)



Which statements regarding wing coloration are true? Mark them with crosses in the answer sheet.

A. The forewings are coloured to decrease detection of moths by a predator

B. The hindwings are brightly coloured without any significance, it is a random feature

C. The hindwings' colour may have a "startle" effect on a bird, causing the bird to stop momentarily and thus giving the moth time to escape

D. The forewings' cryptic colour does not defend moths completely, because jays learn to see moths on a cryptic background

E. Brightly coloured hindwings promote sexual partner recognition

F. A predator does not discriminate colours

(3 points)

Genetics and evolution

B 26. In fruit fly *Drosophila melanogaster*, there is a dominant gene **(b+)** for grey body colour and another dominant gene **(c+)** for normal wings. The recessive alleles **(b, c)** of these two genes result in black body colour and curved wings respectively.

Two students Ada and Donald made crosses to determine the distance between these two genes. Flies with a grey body and normal wings were crossed with flies that had black bodies and curved wings. The results obtained in Ada's and Donald's experiments are shown in the table.

	Grey body, normal wings	**Black body, curved wings**	**Grey body, curved wings**	**Black body, normal wings**
Ada`s experiment	236	253	50	61
Donald's experiment	55	56	241	248

1. What is the distance (in map units) between these two loci? Mark in the answer sheet.

2. What was the genotype of flies with a dominant phenotype in Ada`s **(A.)** and Donald`s **(B.)** experiment? Give the genotypes and show the linkage phase of genes **b** and **c** in the answer sheet!

A. (Adas's flies)

B. (Donald's flies)

(3 points)

B 27. Several mutations (A, B, C, D) have been found in the coding sequence of a gene.

```
Codon  1   2   3   4   5   6   7   8   9   10  11  12
Wt    ATG TGC CCC CGA GTC GAG GAC CTG AGC CTG ACG AGC
A.    --- -C- --- --- --- --- --- --- --- --- --- ---
B.    --- --- --- A-- --- --- --- --- --- --- --- ---
C.    --- --- --- --- A-- --- --- --- --- --- --- ---
D.    --- --- --- --- --- --- --- *-- --- --- --- ---
```

***** Deletion of 1 nucleotide

1. Please translate codons of variants of the given sequence (Wt, A, B, C, D) in one letter codes of amino acids (use table of genetic codes) and place the answers in the table in the answer sheet. **Note:** write ST instead of STOP

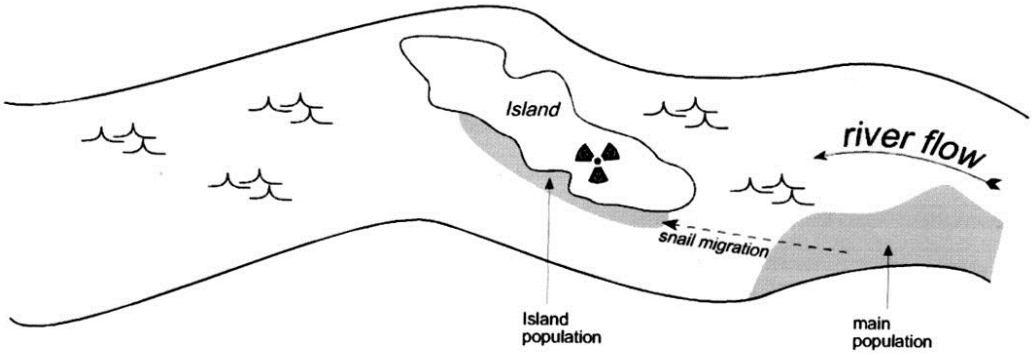
	Codon											
Wt	1	2	3	4	5	6	7	8	9	10	11	12
A.												
B.												
C.												
D.												

First base	**Second base**								**Third base**
	U		**C**		**A**		**G**		
U	**UUU**	F (Phe)	**UCU**	S (Ser)	**UAU**	Y (Tyr)	**UGU**	C (Cys)	**U**
	UUC	F (Phe)	**UCC**	S (Ser)	**UAC**	Y (Tyr)	**UGC**	C (Cys)	**C**
	UUA	L (Leu)	**UCA**	S (Ser)	**UAA**	STOP	**UGA**	STOP	**A**
	UUG	L (Leu)	**UCG**	S (Ser)	**UAG**	STOP	**UGG**	W (Trp)	**G**
C	**CUU**	L (Leu)	**CCU**	P (Pro)	**CAU**	H (His)	**CGU**	R (Arg)	**U**
	CUC	L (Leu)	**CCC**	P (Pro)	**CAC**	H (His)	**CGC**	R (Arg)	**C**
	CUA	L (Leu)	**CCA**	P (Pro)	**CAA**	Q (Gln)	**CGA**	R (Arg)	**A**
	CUG	L (Leu)	**CCG**	P (Pro)	**CAG**	Q (Gln)	**CGG**	R (Arg)	**G**
A	**AUU**	I (Ile)	**ACU**	T (Thr)	**AAU**	N (Asn)	**AGU**	S (Ser)	**U**
	AUC	I (Ile)	**ACC**	T (Thr)	**AAC**	N (Asn)	**AGC**	S (Ser)	**C**
	AUA	I (Ile)	**ACA**	T (Thr)	**AAA**	K (Lys)	**AGA**	R (Arg)	**A**
	AUG	M (Met)	**ACG**	T (Thr)	**AAG**	K (Lys)	**AGG**	R (Arg)	**G**
G	**GUU**	V (Val)	**GCU**	A (Ala)	**GAU**	D (asp)	**GGU**	G (Gly)	**U**
	GUC	V (Val)	**GCC**	A (Ala)	**GAC**	D (asp)	**GGC**	G (Gly)	**C**
	GUA	V (Val)	**GCA**	A (Ala)	**GAA**	E (Glu)	**GGA**	G (Gly)	**A**
	GUG	V (Val)	**GCG**	A (Ala)	**GAG**	E (Glu)	**GGG**	G (Gly)	**G**

2. Please arrange in the answer sheet the mutations (A-D) in an order, which shows their influence on protein functions starting from the most deleterious mutation.

(4 points)

B 28. A river has two populations of snails; a large population just off the left bank (main population), and a much smaller one downstream near an island (island population). Consider a locus that has two alleles, **G** ang **g**, in the island population, but is fixed for the **G** allele in the main population. Let *p* be the frequency of the **G** allele in the island population.



Because of river flow, migration occurs from the large population to the island, but not the reverse. Assume p= 0.6 before migration. After migration 12% of the islands snails originated from the main population.

1. Calculate p after the migration!

Following the wave of migration, the island snails reproduce. For some reason, the island snails, including the new immigrants, have a much higher mutation rate than the main population. The mutation rate of **G** $\rightarrow$ **g** in the island population is 0.003, and there is essentially no reverse mutation (mutation in the main population is rare, and can also be ignored).

2. Calculate p in the next generation of island snails?

(2 points)

B 29. In a specific population, genotype frequencies have been estimated before and after selection.

	a_1a_1	**a_1a_2**	**a_2a_2**
Frequency before selection (generation F_0)	0.25	0.50	0.25
Frequency after selection (generation F_1)	0.35	0.48	0.17

1. Calculate the selection coefficient of each genotype (a_1a_1, a_1a_2, a_2a_2) and write the answer in the answer sheet!

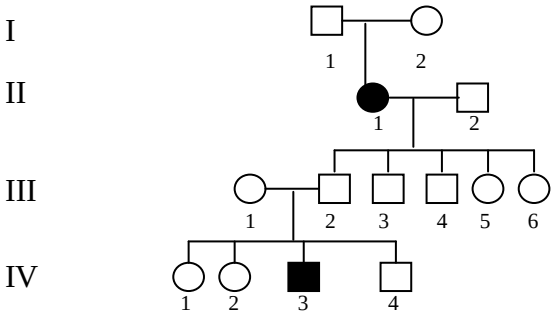
2. Against which genotype is selection the strongest? Write the answer in the answer sheet!

(2 points)

B 30. Expression of some autosomal genes depends on whether that gene came from male or female parent. These are so called imprinted genes (imprinted genes are expressed in a parent - specific manner). Imprinting of these genes happens during spermatogenesis or oogenesis, and may silence the allele coming from one parent.

(*Continuation see on the next page*)

Problem 1. Imprinted genes can account for many cases of incomplete penetrance. The pedigree shows the incomplete penetrance of an autosomal dominant gene resulting from imprinting during oogenesis. A woman II_1 is heterozygote for this gene. Analysis of DNA reveals that III_2 and III_5 have received the mutant gene from their mother.



1. What is the probability of II_1 and II_2 having an affected child? Mark the answer in the answer sheet!

2. What is the probability of III_1 and III_2 having an affected child? Mark the answer in the answer sheet!

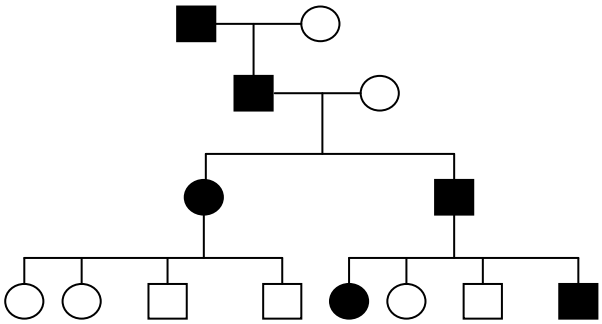
3. What is the probability of III_4 and III_5 having an affected child? Mark the answer in the answer sheet!

Problem 2. Parental imprinting gives a deviation from Mendelian patterns of inheritance, because the same allele may be differently expressed depending on whether it is inherited from the mother or the father.

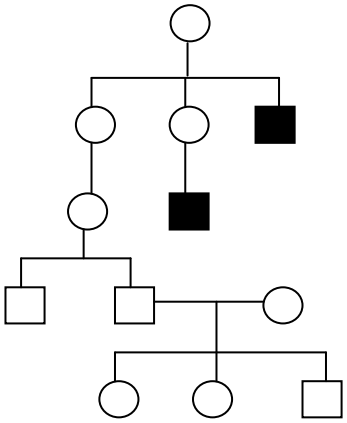
(*Continuation see on the next page*)

Determine which pedigree show maternal (**1**) and which paternal (**2**) imprinting (choose from pedigrees A,B,C,D).

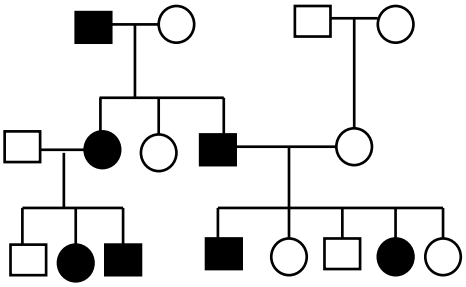
A



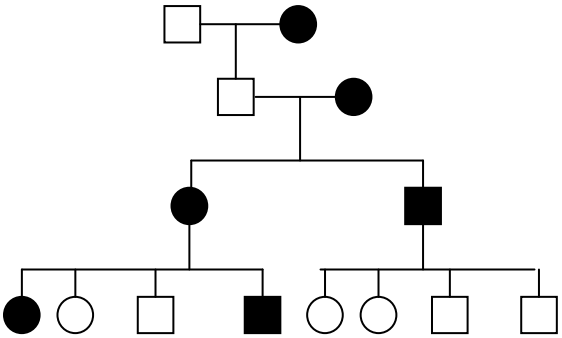
B



C



D

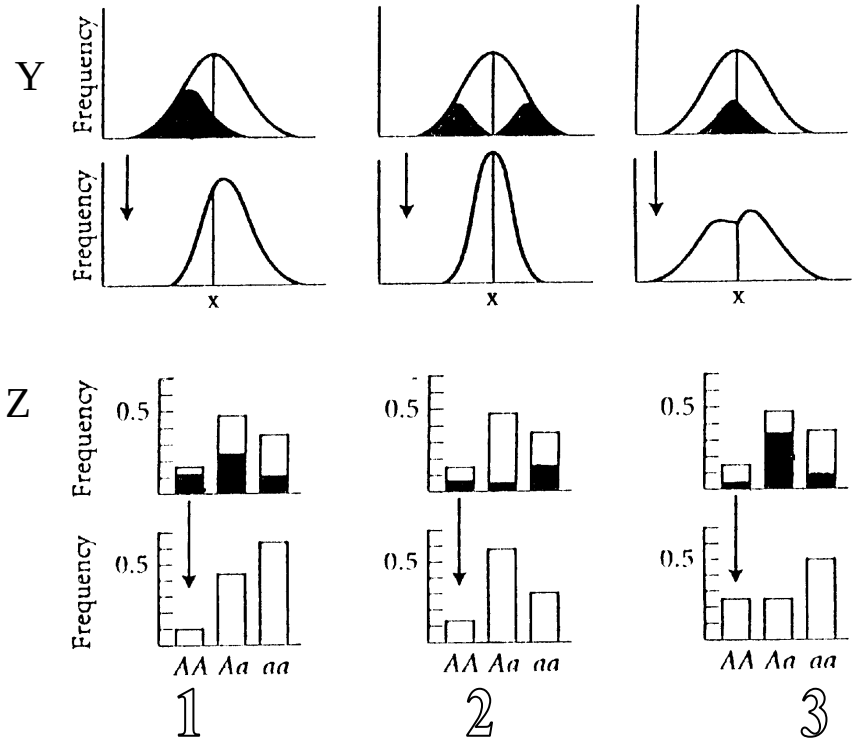


1. Maternal	**2.** Paternal

(5 points)

B 31. The figures show modes of selection on **(Y)** a heritable quantitative (continuous) trait and **(Z)** a polymorphism inherited as two alleles at one locus. In both cases, the phenotype was assumed to be inherited additively (i.e. heterozygote intermediate between homozygotes, there is no interaction among loci that contribute variation to the quantitative trait). The vertical axis is the proportion of the population with each phenotype. The upper rows of figures in both **Y** and **Z** show the distribution of phenotypes in one generation, before selection occurs. The shaded portions represent individuals with relative disadvantage (lower reproductive success). The lower rows of figures in both **Y** and **Z** show the distribution of phenotypes in the following generation, after selection among the parents has occurred. **X** marks the mean of the quantitative trait before selection.

(*Continuation see on the next page*)



A. Directional selection does not alter the means, but may reduce the variation

B. Disruptive or diversifying selection is unlikely to be exactly symmetrical, and thus usually shifts the means

C. Directional selection increases the proportion of genotypes with higher values of the trait

D. Stabilizing selection is unlikely to be exactly symmetrical, and thus usually shifts the means

E. Stabilizing selection does not alter the means, but may reduce the variation

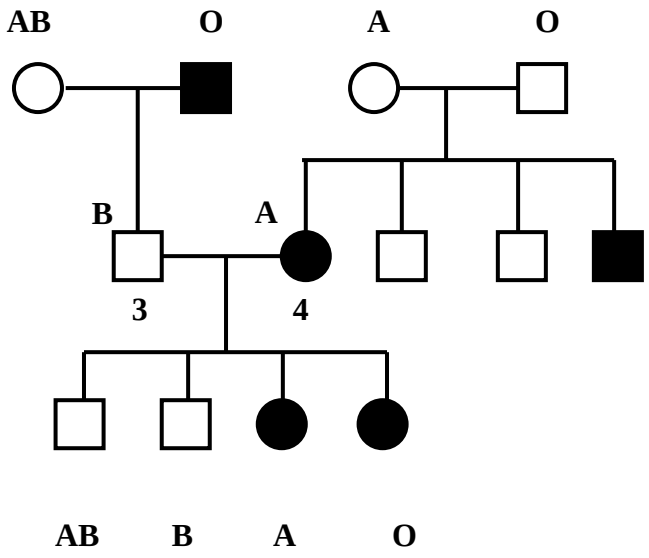
Match in the answer sheet the statements (A – E) with appropriate schemes (1 - 3)

Not all the rows in the table have to be filled.

Statements	Number of schemes
A	
B	
C	
D	
E	

(3 points)

B 32. Alkaptonuria is a rare genetic disease. The gene for alkaptonuria (**alk**) is recessive and has been located on chromosome 9. Gene **alk** is linked to the gene **I** encoding the ABO blood types. The distance between the **alk** gene and gene **I** is 11 map units. A pedigree of a family with the alkaptonuria is shown below. Affected individuals are indicated by shaded symbols. In addition, the blood type of family members is given.



1. What are the genotypes of individuals 3 and 4? Give the answer in the answer sheet

2. If individuals 3 and 4 are expecting their fifth child, what is the probability that the child will have alkaptonuria (a physician has determined that foetus has blood type B)? Give the answer in the answer sheet!

(2 points)

Ecology

B 33. The following table shows the commercial fishing catches of smelt and fishing intensity in the Riga Gulf between 1982 and 1985. The fishing intensity during those years was estimated by the total time spent by all fishing boats that were concentrated on this species. The fishing equipment did not change in the investigated time-period.

Year	Catch (tons)	Fishing intensity (relative units)
1982	100	2
1983	150	5
1984	100	5
1985	150	3

Estimate and write in the answer sheet the relative sizes of the smelt population, starting with a relative size of 10 units for the year 1982.

1982 = 10

1983= ……..

1984= ……

1985= ……..

(3 points)

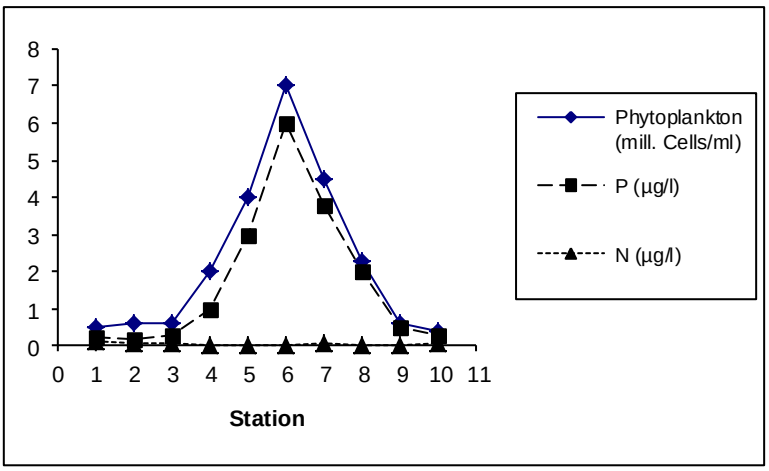
B 34. Figure 1 shows the number of phytoplankton cells, and P and N (inorganic) concentrations in water samples in a transect along the coast of the Atlantic Ocean around a fish processing factory.

The nitrogen concentrations in the water were very low and close to the detection limit. The closest station to the factory was Station 6. Figure 2 shows the results of a nutrient enrichment study. Water samples taken at the Stations were filtered to remove phytoplankton.

(*Continuation see on the next page*)

Then standard amounts of phytoplankton were added to the samples, and then they were enriched with only N, only P, or were unenriched, and the number of phytoplankton cells in these enriched or unenriched samples were counted at a later time.

Figure 1



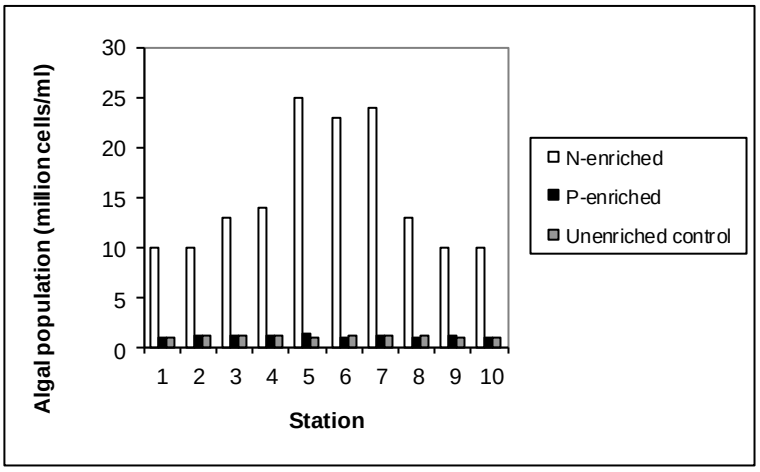


Figure 2

1. Which is pollutant or pollutants that factory is emitting? Give the answer in the answer sheet using the appropriate codes.

Codes: X. Phytoplankton **Y.** Zooplankton

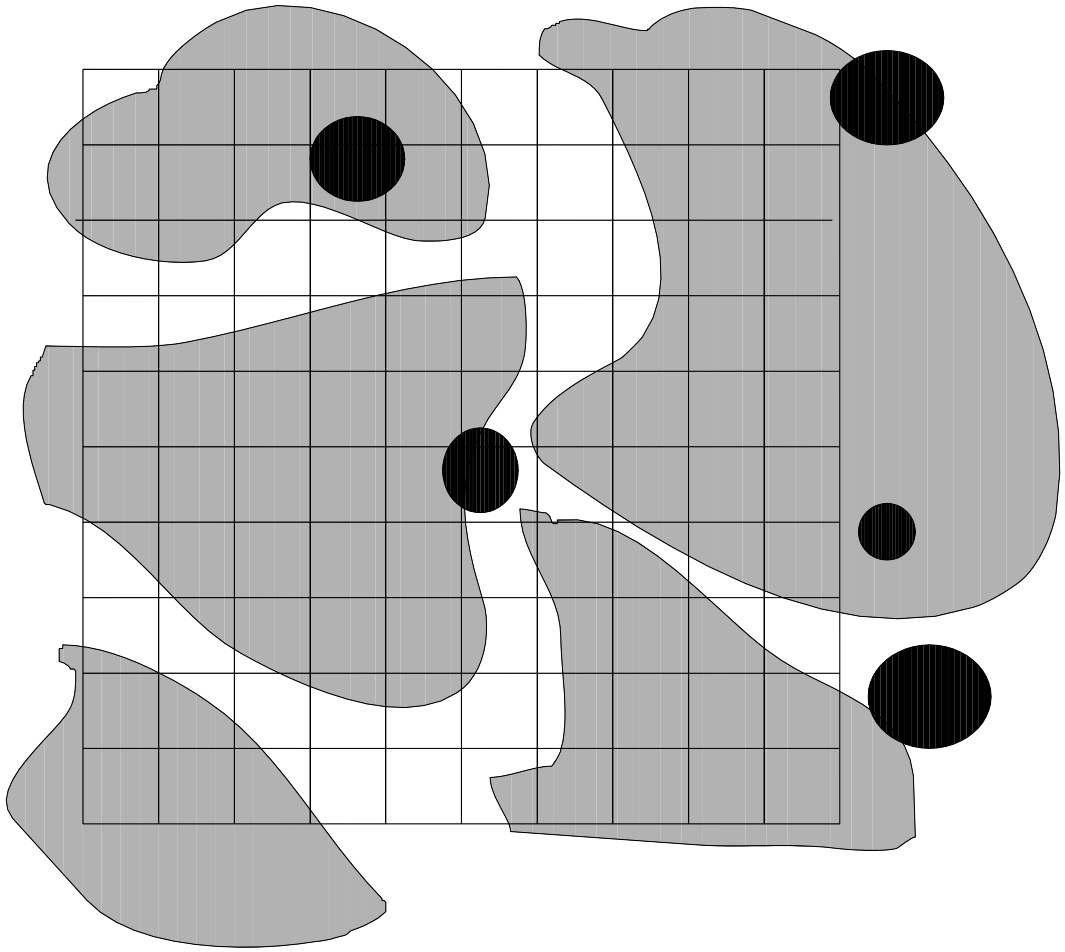
Z. Nitrogen **W.** Phosphorus **S.** Organic substances

2. Which is the main limiting nutrient (**A**) in this is case?

Which is the second limiting factor (**B**) in this case?

(3 points)

B 35.



The diagram shows a 10m x 10m plot located in a forest with two main tree species: Species X which is shaded grey, and Species Y which is shaded black. The plot is divided into a grid with step 1m.

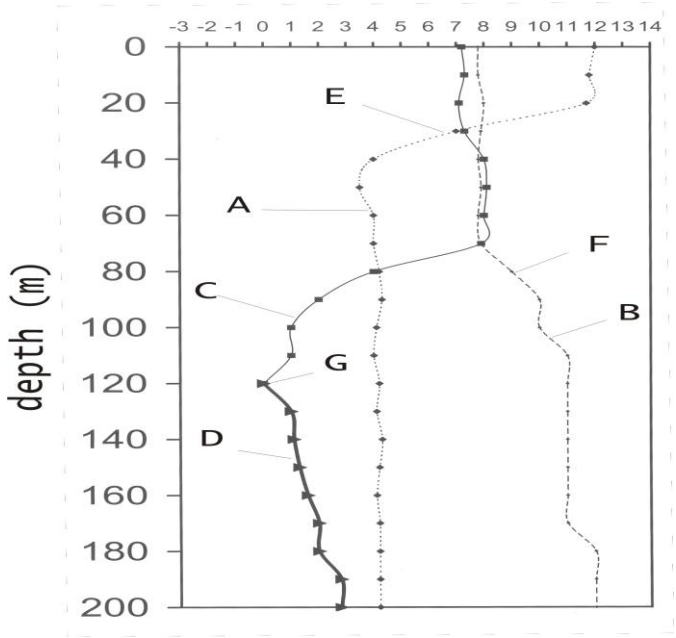
1. What are the percentage frequencies of Species X and Species Y using a quadrate size of 2 m x 2m?

2. What are the percentage frequencies of Species X and Species Y using a quadrate size of 5m x 5m. Write the correct answers in the answer sheet.

		1. Quadrate of size 2m x 2m	**2. Quadrate of size 5m x 5m**
A.	Species X		
B.	Species Y		

(4 points)

B 36. The Baltic Sea is brackish, receiving salt water from the North Sea, and fresh water from rivers. Turnover of water in deep layers is much slower than at surface layers. Stratification of the water column is common in summer. The following figure shows a depth profile (in July) for oxygen concentration (mg/l), hydrogen sulphide concentration (mg/l), salinity (PSU) and temperature (°C) in the water column.



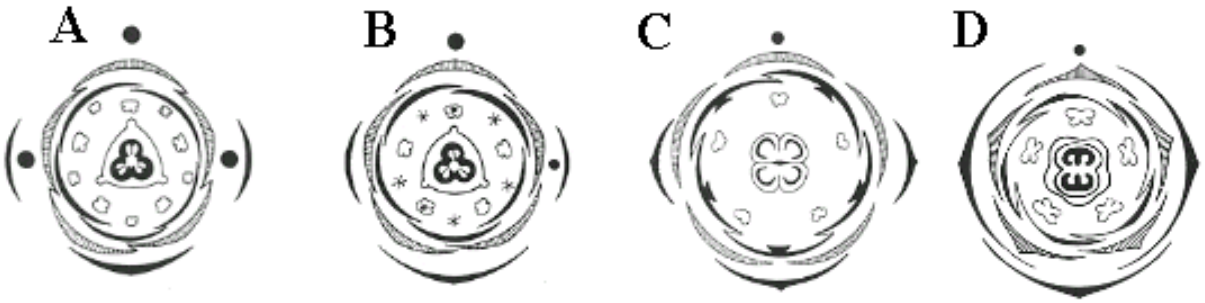
Match in the table in the answer sheet the labels A, B, C, and D with oxygen concentration, hydrogen sulphide concentration, salinity and temperature, and the labels E, F and G with parts of the curves – halocline, redoxycline and thermocline.

1	Oxygen concentration	
2	Hydrogen sulphide concentration	
3	Salinity	
4	Temperature	
5	Halocline	
6	Redoxycline	
7	Thermocline	

(7 points)

Biosystematics

B 37. There are 4 flower diagrams shown:



Write the appropriate label (**A-D**) of a diagram in the table in the answer sheet.

	Flower formulas	**Label**
1	!($Ca_{(5)}$ Co_5 A_{5+5} $G_{(3)}$	
2	!) $Ca_{(5)}$ $Co_{(5)}$ $A_{(5)}$	
3	!(Ca_5 Co_5 A_{0+5} $G_{(3)}$	
4	!(Ca_5 $Co_{(5)}$ A_5 $G_{(2)}$	
5	!(Ca_5 $Co_{(5)}$ A_5 $G_{(4)}$	

(2 points)

B 38. The pictures below show a seed **(1)** or a fruit **(2)**. Write the answers **(1 or 2)** in the table in the answer sheet.

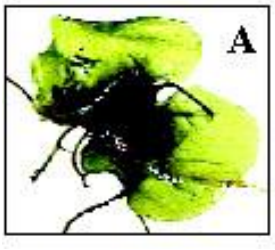
A. *Prunus*

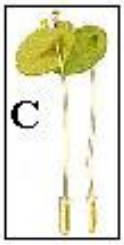
B. *Ginkgo*

C. *Taxus*

D. *Quercus*

(2 points)





(2 points)

B 41. The systematic, morphological, biological and ecological characters of two invertebrate species are presented. Write the appropriate number of an organism in the table in the answer sheet!

A. Protist

No flagellum, no cilia

Complex life cycle

Intracellular parasite

Intermediate host present

B. Arthropod

Secondarily reduced wings

Incomplete metamorphosis

Ectoparasite on mammals

Absence of intermediate host

……..	……..……

Code: **1** *Plasmodium* **2** Dysentery amoeba **3** *Paramaecium*

4 *Trypanosoma* **5** Tick **6** Flea **7**. Human louse **8** Spider

(2 points)

B 42. Most birds start to incubate when their clutch is full. There are species which start incubation after the first egg is laid. Their chicks hatch asynchronously, which is characteristic to birds of prey and owls (Falconiformes, Strigiformes).

Mark all the correct statements with crosses in the table in the answer sheet.

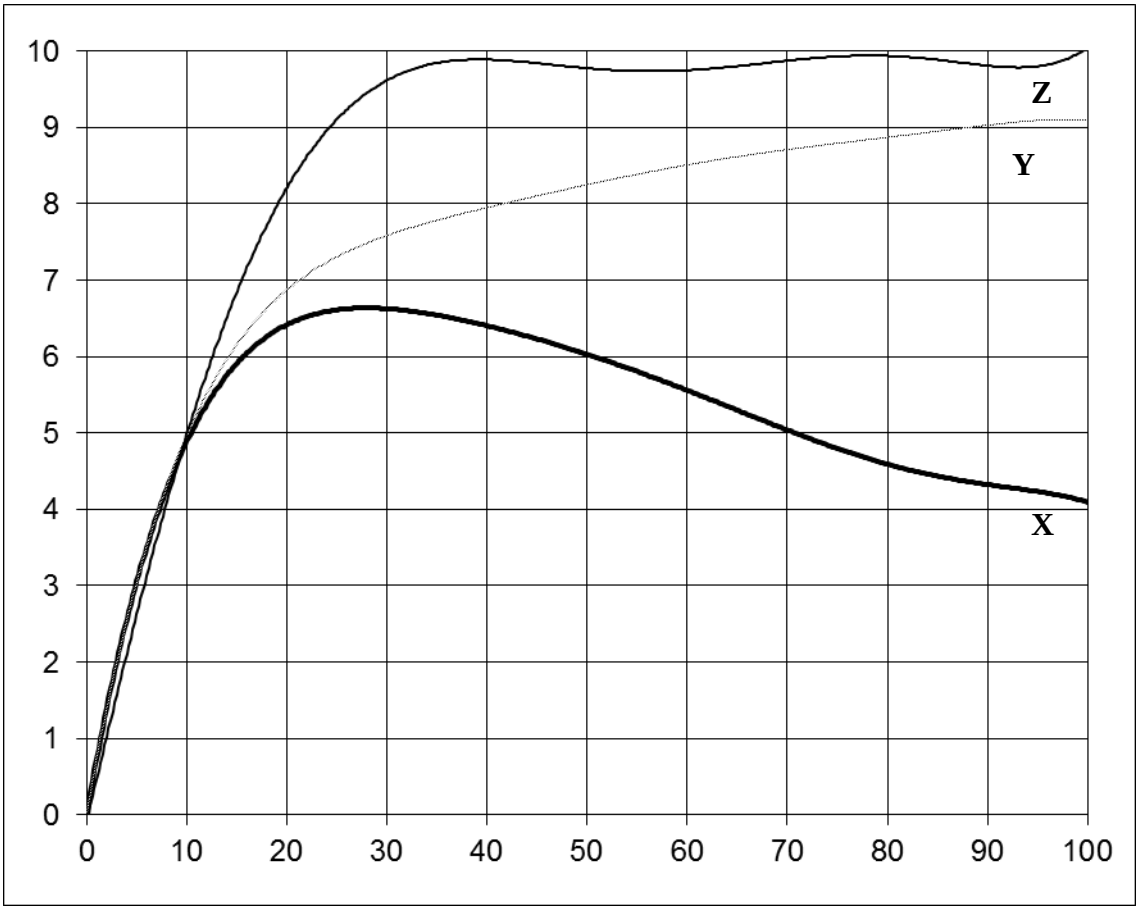
A.	Food resources for birds of prey, and therefore the number of chicks they can feed, differ between years significantly	
B.	Younger nestlings are fed more often and they catch up with older ones in the progress of their growth	
C.	Birds of prey feed as many chicks of the brood as the food resources allow in the given year	
D.	During years with scarce food resources, food is given mainly to the oldest nestlings, while the youngest ones starve to death	
E.	Older nestlings help to feed younger ones	
F.	Room in the nest is not sufficient for several big chicks simultaneously, therefore they grow up and fly out of the nest one at a time	
G.	One fledgling that can reach reproduction age is more important for species survival then several but not well developed fledglings	
H.	The number of fledglings and not their fitness is the most important for the species survival	

(2 points)

ANSWER KEY

B 1.

1.



2. Z (1 point)
3. X (1 point)

B 2. 1. μ_A = *0.7 g $g^{-1}h^{-1}$* [1 point] 2. μ_B = *1.4 g $g^{-1}h^{-1}$* [1 point]

B 3. 100 mM [1 point]

B 4. **1.** 1.16 or 1.18 or 1;19

2. 0.30 or 0.32 or 0.353

3. 2.2 or 2.21 or 2.24

B 5. **1.** 7 → 4 → 3 → 1 → 5 **2.** 7 → 4 **3.** 7 → 4 → 3 → 6

[1p x 3 = 3 points]

B 6.

1.	Number		Number
A-1	1	**A-2**	6
B-1		**B-2**	
C-1		**C-2**	
D-1	12	**D-2**	
E-1	2 or 10	**E-2**	
F-1		**F-2**	8
G-1		**G-2**	
H-1	3	**H-2**	7
I-1		**I-2**	9
J-1		**J-2**	
K-1	4	**K-2**	10
L-1		**L-2**	
M-1		**M-2**	
N-1	5	**N-2**	
O-1		**O-2**	
P-1	11	**P-2**	
R-1		**R-2**	13 or 14 or both
S-1		**S-2**	13
T-1		**T-2**	
U-1		**U-2**	

2. 17

3. skipped

[2 points per column]

[1 point if there are 1-3 mistakes]

B7.

1.

A.	B.	C.
75 %	25 %	0 %

[1 point]

2.

dsDNA	A %	C %	G %	T %	U %
A	20	30	30	20	0
B	30	20	20	30	0

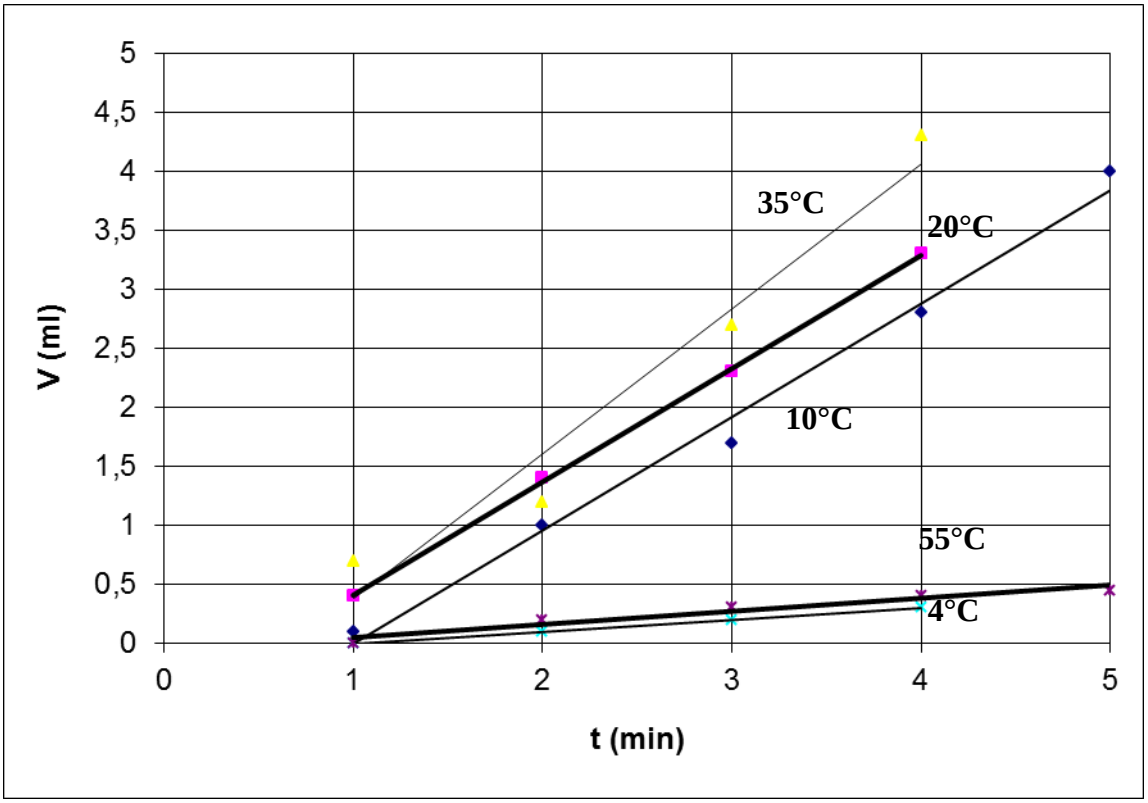
3.

A	5
B	4

B 8: skipped

B 9.

1.



[1 point for X axis]

[1 point for Y axis]

2. 1 ml/min [1 point]

3. 0.017 – 0.018 mmoles CO_2/g ·min [1 point]

4. 0.007 – 0.018 mmoles ethanol/ g ·min [1 point]

B 10.

	Number
A.	1
B.	
C.	4
D.	
E.	2
F.	3
G.	

B 11.

	Number
A.	3
B.	
C.	4
D.	1
E.	
F.	2

B 12.

	Number
A.	3
B.	
C.	1
D.	
E.	4
F.	
G.	2

B 13.

1.

A.	
B.	4

2.

A.	
B.	
C.	
D.	
E.	

B 14.

1.

A	3
B	2
C	4
D	1

2.

A and B	5,6
C	2
D	4

B 15.

1.

A, B, C	3,6,12
D	2,8,11,13,14, 15
E	1,5,4,7,9,10,1 6

2.

A.	
B.	
C.	
D.	
E.	
F.	

B 16.

X = 7900 ml

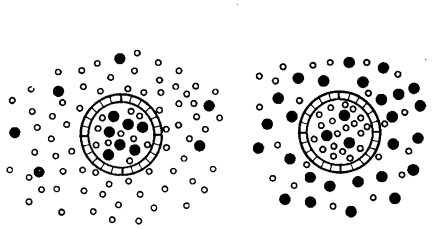
Y = 9000 ml

Z = 1500 ml

B 17.

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

B 18.



B. →

[0.5p x 2 = 1 point]

B 20.

	1.	2.	3.	4.	5.
A.	■				
B.		■			
C.			■		
D.				■	
E.					■
F.				■	
G.		■			
H.			■		

[5 points]
[1p per each column]

B 21: skipped

B 22.
1,4,6,8
[1 point]

B 23: skipped
B 24: skipped
B 25.

A.	**skipped**
B.	
C.	■
D.	■
E.	
F.	

[1p x 2 = 2 points]
[-1p per incorrect answer]

B. 26.
1. 18.5 units or 18.2 or 0.182 or 0.185 units

[0.5p x 2 = 1 point]

2. A. b + c / bc
B. b + c / bc$^+$
[1p x 3 = 3 points]

B 27.

B 19. **1.**

A. ←

	1	2	3	4	5	6	7	8	9	10	11	12
Wt	M	C	P	R	V	E	D	L	S	L	T	S
A	M	**S**	P	R	V	E	D	L	S	L	T	S
B	M	C	P	**R**	V	E	D	L	S	L	T	S
C	M	C	P	R	**I**	E	D	L	S	L	T	S
D	M	C	P	R	V	E	D	**Stop**				

[S,R,I, Stop = 1 point]
2. DACB [2 points]

B 28.

1. p = 0.648

2. p = 0.646

[1p x 2 = 2 points]

B 29.

1. a_1a_1= 0

a_1a_2= 0.3

a_2a_2= 0.6

2. a_2a_2

[1p x 2 = 2 points]

[1p for part 1 and 1p for part 2]

B 30.

1. 0 %

2. 50 %

3. 0 %

1.	2.
A	D .....

[1p x 5 = 5 points]

B 31.

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

[1p x 3 = 3 points]
[-1p per incorrect answer]

B 32.

1. 3 = $\underline{J^B \text{ alk}/J^C \text{ alk}}$

   4 = $\underline{J^A \text{ alk} /J^C \text{ alk}}$

2. 11 %

[0.5p x 2 = 1 point] +

[1p x 1 = 1 point] = 2 points

B 33.

1983 = 6

1984 = 4

1985 = 10

[1p x 3 = 3 points]

B 34.

1. .Z, W or Z, W, S

2. A. Z; **B (skipped)**

[1p x 2 = 2 points]

B 35.

	1.	2.
A.	100	100
B.	16	100

[1p x 4 = 4 points]

B 36.

1	C
2	D
3	B
4	A
5	F
6	G
7	E

[1p X 7 = 7 points]

B 37.

1	A
2	
3	B
4	D
5	C

[0.5p x 4 = 2.0 points]

B 38.

A	2
B	1
C	1
D	2

[0.5p x 4 = 2.0 poins]

B39 & B40 cancelled

B 41.

A.	B.
2	7

[1p x 2 = 2 points]

B 42.

A.	■
B.	
C.	■
D.	■
E.	
F.	
G.	■
H	

[0.5p x 4 = 2.0 points]
[- 0.5p per incorrect answer]