INTERNATIONAL BIOLOGY OLYMPIAD e. V. IBO

30th International Biology Olympiad
SZEGED, HUNGARY

Theoretical Exam 1

Morning

18th July 2019

COUNTRY
LANGUAGE

Theoretical Exam Morning

General instructions

This exam consists of 38 questions and lasts 180 minutes.

- Cell Biology (Q1-9)
- Animal Anatomy and Physiology (Q10-19)
- Plant Anatomy and Physiology (Q20-24)
- Genetics and Evolution (Q25-30)
- Ecology (Q31-33)
- Biosystematics (Q34-36)
- Ethology (Q37-38)

1. **Please remember to attach your BARCODE sticker to all pieces of paper on the answer sheet.**
2. Write your answers in the separate answer sheet provided. **Only answers given in the answer sheet will be considered.**
3. Stop answering and put down your pencil immediately when the bell rings signalling the end of the exam.
4. No paper, materials or equipment should be taken out of the exam room.

1.	2.				3.
	U	C	A	G	
U	F F L L	S S S S	Y Y STOP STOP	C C STOP W	U C A G
C	L L L L	P P P P	H H Q Q	R R R R	U C A G
A	I I I M	T T T T	N N K K	S S R R	U C A G
G	V V V V	A A A A	D D E E	G G G G	U C A G

Cell Biology

Q1

The effect of knocking out specific genes in worms on apoptosis (programmed cell death) was studied.

GENE	MANIPULATION	CELL DEATH
ced9	knock-out	increased
ced4	knock-out	reduced
ced3	knock-out	reduced
egl1	knock-out	reduced
ced4 & ced9	knock-out	reduced
ced9 & ced3	knock-out	reduced
ced9 & egl1	knock-out	increased

Q.1.1 Write the letters A-D corresponding to the genes into the correct rectangle in the model of the control of cell death (CD) on your answer sheet.
A. Ced3
B. Ced4
C. Ced9
D. Egl1

Q.1.2 Indicate whether an interaction is activating (+) or repressing (-) in the circles above the arrows.

Q2

Hall, Rosbash and Young were awarded the 2017 Nobel Prize for their discoveries of the molecular mechanisms that control circadian rhythms. 'Period' (*PER*) is a gene of the *Drosophila* that undergoes strict circadian oscillations. Mutations to *PER* alter or abolish the periodicity and phase of these rhythms. Another gene regulating the circadian rhythm is 'clock' (*CLK*). *Drosophila* with a certain mutation in the *CLK* gene sometimes have disrupted circadian rhythms as shown in Table 1.

Col 1	Col 2	Col 3	Col 4
Row 1	*CLK +/+*	24.3	0
	CLK +/-	24.3	36
	CLK -/-	24.2	86
Row 2	*CLK +/+*	24.3	1
	CLK +/-	24.8	47
	CLK -/-	*ARR*	100

Table 1. Col 1 = Condition. Col 2 = Genotype. Col 3 = Period of activity (h). Col 4 = % arrhythmic. Row 1 = 12 hr light:12 hr dark. Row 2 = Constant darkness. *ARR* = Arrhythmic

Cloning revealed that these identified *CLK* mutant flies have a premature stop codon that truncates the protein, making it non-functional. To determine the *in vivo* regulatory pattern of the PER gene, they generated transgenic *Drosophila* strains carrying a luciferase cDNA fused to the promoter region of the *PER* gene. Then they assayed the activity of luciferase (quantified in counts/s) in *Drosophila* of the various *CLK* genotypes. Results are shown in Figure 1. Note that the luciferase activity is proportional to the expression of the examined gene.

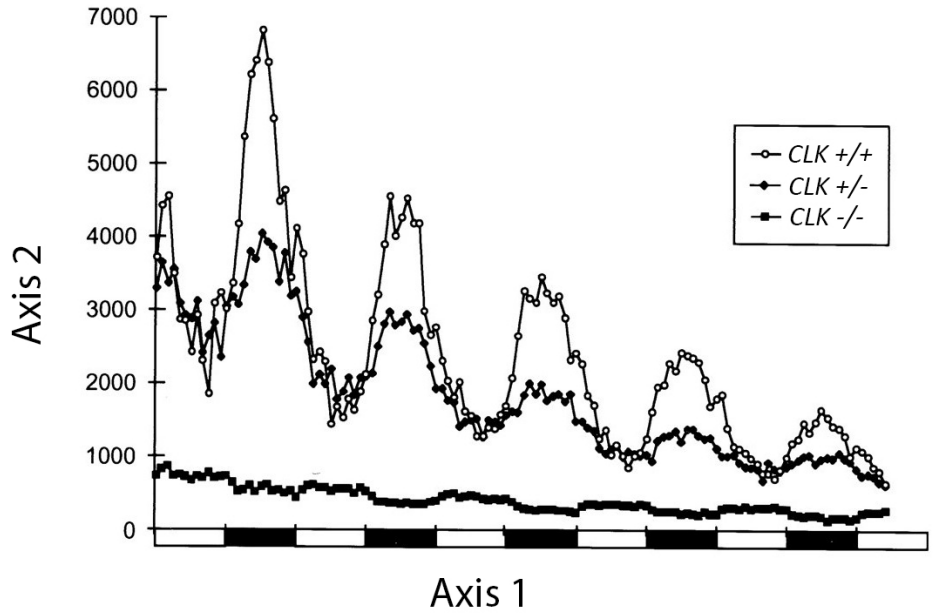


Fig.1. Axis 1 = Time (hours), white bars represent a 12 hour period of light, dark bars represent a 12 hour period of darkness. Axis 2 = Counts per Second

Indicate with an **X** if each the following statements are true (T) or false (F).

Q.2.1 Behavioural effects of *CLK* mutation are largely due to a defect in the degradation of circadian rhythm proteins, including *PER*.

Q.2.2 The main effects of *CLK* mutation are fully penetrant at the molecular level.

Q.2.3 The main effects of *CLK* mutation are fully penetrant at the behavioural level.

Q.2.4 *PER* promoter activity cycled with a reduced frequency in *CLK* +/- flies compared to *CLK* +/+ flies.

Q.2.5 The results shown could be explained by *CLK* acting as a transcription factor on *PER*.

Q.2.6 In constant dark, the circadian periodicity of wild-type *Drosophila* is approximately 24 hours.

Q3

G protein-coupled receptors (GPCRs) interact with G proteins that subsequently affect cell function through the generation of second messengers. Cyclic AMP (cAMP) generated by adenylyl cyclase controls cell functions via activation of protein kinases. GPCRs may either activate or inhibit the cyclase through the G proteins Gs and Gi, respectively. The difference between Gs and Gi resides in the α subunit, which binds and hydrolyses GTP. The Gs protein cycle is illustrated below.

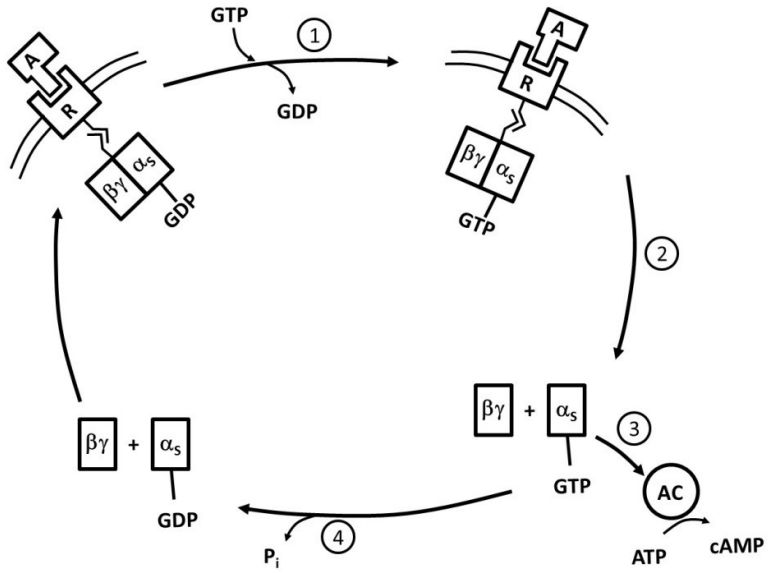


Fig.1

A lab is working on a pair of newly identified GPCRs, “GPCR-A” and “GPCR-B”. Each binds the same small ligand with the same affinity but activates different G-proteins that act on adenylyl cyclase. When activated, GPCR-A causes an increase in adenylyl cyclase activity, while GPCR-B causes a decrease in adenylyl cyclase activity. They have a cell line that expresses both GPCR-A, GPCR-B, the corresponding G-proteins, and adenylyl cyclase. There is a basal level of adenylyl cyclase activity that produces a baseline cAMP concentration.

A member of the lab studying a pathogenic bacterium has discovered that it secretes a toxin that interferes with the mentioned signalling pathway. To determine how this toxin acts, she did an experiment in which she looked at intracellular cAMP levels in untreated and toxin treated cells (the original ligand of the receptors was not added in either of the experiments).

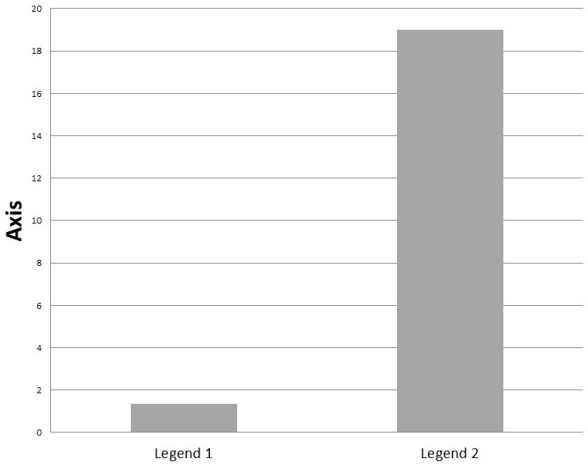


Fig.2. Axis = cAMP concentration (pmol/mL). Legend 1 = Toxin -. Legend 2 = Toxin +.

Indicate with an **X** whether each of the following mutations increase (A), not changed (B) or decrease (C) the intracellular levels of cAMP upon ligand addition in the absence of the toxin? **Remember, both GPCR-A and GPCR-B bind the same ligand!**

Q.3.1 A mutation in GPCR-A that prevents G protein activation

Q.3.2 A mutation in GPCR-B that prevents G protein activation

Q.3.3 A mutation in Gs that prevents release of bound GDP

Q.3.4 A mutation in Gi that prevents release of bound GDP

Q.3.5 A mutation in Gs that prevents GTP hydrolysis

Q.3.6 A mutation in Gi that prevents GTP hydrolysis

What is/are the **possible** explanation(s) for the mechanism in which the toxin in paragraph 3 affects adenylyl cyclase activity? Indicate with an X if each the following statements are true (T) or false (F)!

Q.3.7 The toxin inhibits activation of Gi in response to receptor stimulation.

Q.3.8 The toxin inhibits GTP hydrolysis in Gs.

Q.3.9 The toxin mimics GTP and causes persistent activation of all G proteins.

Q.3.10 The toxin is an inhibitor of GPCR-A receptor.

Q.3.11 The toxin is an activator of GPCR-B receptor.

Q4

CDK is a family of cyclin dependent kinases which drive the cell cycle. A portion of the liver was removed in WT mice, or in livers which had a particular *CDK* gene knocked-out. Mice were allowed to regenerate, then their regenerated livers were weighed, measured and stained. Individual liver cells were removed and stained for total DNA content, or for newly synthesised DNA (Figure 1).

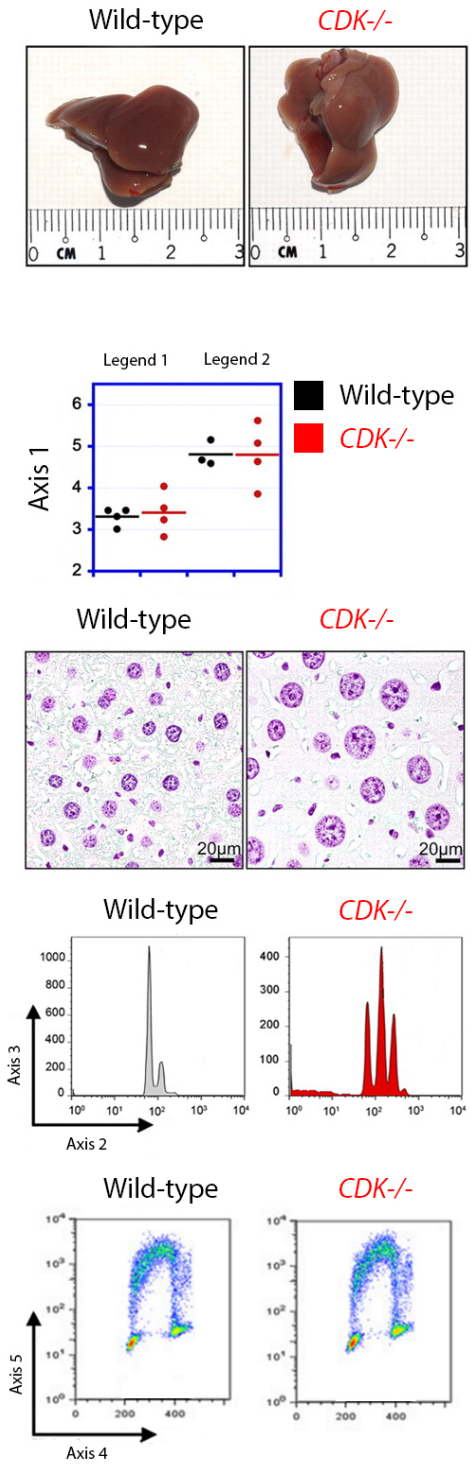


Fig.1. Axis 1 = Liver mass. Axis 2 = DNA content. Axis 3 = # of cells. Axis 4 = DNA content. Axis 5 = Newly synthesised DNA. Legend 1 = 4 days. Legend 2 = 21 days (left side = wild-type, right side = *CDK-/-*)

Indicate with an **X** whether you would expect number or amount increased (A), not changed (B) or decreased (C) of the following structures in *CDK* knock-out livers versus wild-type ones.

Q.4.1	Liver mass
Q.4.2	Hepatocyte number
Q.4.3	Average hepatocyte ploidy
Q.4.4	Number of mitotic spindles
Q.4.5	DNA synthesis

Q5

One way of heat production is non-shivering thermogenesis, mediated by norepinephrine via upregulation of mitochondrial uncoupling channel proteins (UCP) in brown adipose tissue (BAT). UCP increases the H^+ conductance of the inner mitochondrial membrane to dissipate the mitochondrial H^+ gradient and convert the energy of substrate oxidation into heat. To identify the member(s) of the UCP family responsible for the process, we carried out two experiments.

Figure 1. compares relative effects of acclimation to a cool environment for mice (from thermoneutrality at 30°C to the relative cold of 18°C) on the mRNA levels of different members of the uncoupling protein family in BAT.

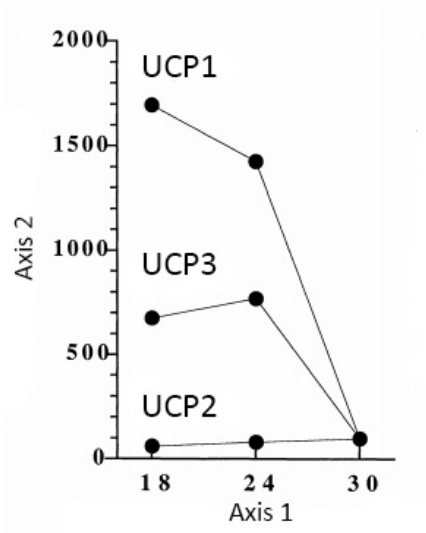


Fig.1. Axis 1 = Acclimation temperature (°C). Axis 2 = % of 30°C level

In a following experiment, three transgenic mouse strains were generated, bearing a single knock out mutation of either UCP1 or UPC3 and another bearing knock out mutations of both UCP1 and UCP3. We then measured metabolic rate in warm acclimated (30°C) and cool acclimated (18°C) conditions. In each case, besides the basal metabolic rate, we also measured metabolic rate following the injection of norepinephrine (NE).

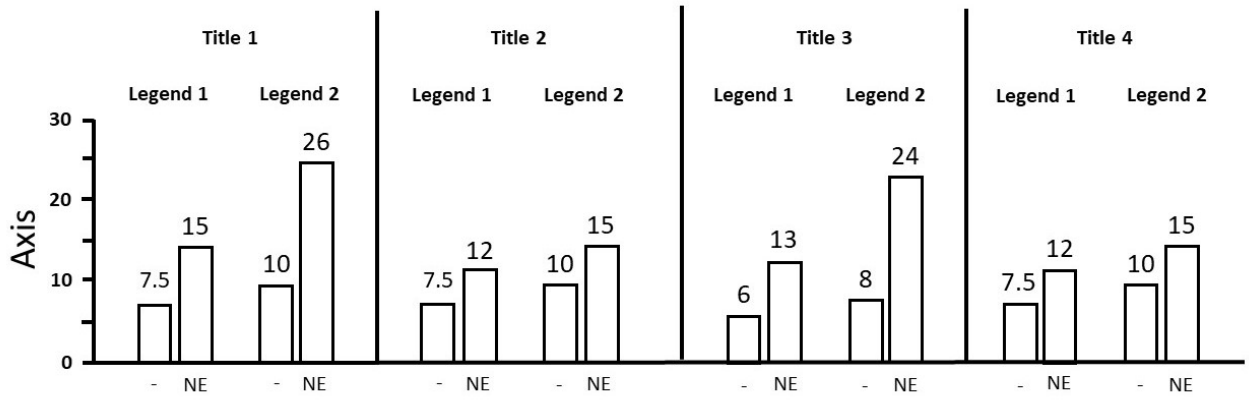


Fig.2. Axis = Metabolic rate ($mlO_2 \cdot min^{-1} \cdot kg^{-1}$). Title 1 = Normal mice. Title 2 = UCP1-knockout mice. Title 3 = UCP3-knockout mice. Title 4 = UCP3-UCP1-double knockout mice. Legend 1 = Warm-acclimated. Legend 2 = Cool-acclimated

Q.5.1 Estimate the increase in metabolic rate due to UCP1 dependent thermogenesis after NE stimulation in cool-acclimated mice. (in $mlO_2 \cdot \text{min}^{-1} \cdot kg^{-1}$)

Q.5.2 Calculate the increase of O_2 consumption in a 25-gram cool-acclimated mouse that is the result of NE stimulation but cannot be explained by UPC1 or UPC3 activity. ($ml \cdot \text{min}^{-1}$)

Indicate with an X if each the following statements are true (T) or false (F).

Q.5.3 UCP1 actively pumps H^+ ions across the inner mitochondrial membrane.

Q.5.4 The results from this experiment suggest that UCP1 is the most important UCP for non-shivering thermogenesis in response to cold.

2,4-Dinitrophenol (DNP) is an organic compound historically used as a weight loss drug. DNP allows protons to leak across the mitochondrial inner membrane making ATP production less efficient.

Indicate with an **X** if each the following statements are true (T) or false (F).

Q.5.5 Patients taking DNP experience hypothermia as their cells are not able to generate energy.

Q.5.6 A patient with mild DNP overdose can be treated by glucose administration.

Q.5.7 Mitochondrial uncoupling occurs under certain physiological conditions in animals.

Q.5.8 DNP reduces the oxygen consumption of cells.

Q.5.9 DNP increases the pH in the mitochondrial intermembrane space.

Q6

You are studying a small protein-coding locus the sequence of which is shown below. The sequence is shown from the 5' transcriptional START position to the 3' transcriptional STOP position. This part is responsible for coding of two different polypeptides. There is a short intron sequence which is shown with **BOLD** letters here.

```
          5.        10.       15.       20.       25.       30.       35.       40.       45.       50.       55.
5´ –CTACGTACTATGTATTCC GATCTATA CTCGATCTAGTCGCATTCCGATAAGATCGTAC– 3`
3´ –GATGCATGATACATAAGG CTAGATAT GAGCTAGATCAGCGTAAGGCTATTCTAGCATG– 5`
```

Q.6.1 How many nucleotides long would the final processed mRNA made from this gene be (not including the 5’ cap and the 3’ polyA tail)?

Q.6.2 Indicate with an **X** which strand is used as a template in transcription for the shorter polypeptide, the 5’-3’ strand or the 3’-5’ strand (read in a left $\rightarrow$ right direction)?

Q.6.3 What is the ratio of the numbers of amino acids in longer/shorter polypeptide (including the amino acid built in because of the START codon)? Give your answer to the nearest second decimal place!

Q.6.4 What is the third amino acid of the shorter polypeptide, if the Met is counted to be the first one? Add the one-letter code of amino acid based on the **codon table** in the beginning of your question sheet!

Q.6.5 Say that the C:G base pair that is underlined in the sequence above were changed to an A:T basepair to make a mutant form of this gene. Indicate with an **X** which kind of mutation would this be for the shorter polypeptide?

A. a frameshift mutation
B. a nonsense mutation
C. a silent mutation
D. a missense mutation

Q7

A microbiology lab studies the microbe *Thermus szegediensis*, which has recently been isolated from a thermal spring in Szeged. In a sequence of experiments (Exp), first, they grew *T. szegediensis* under different conditions to test its nutritional requirements. Conditions and results are in the table below.

Conditions	**Exp 1**	**Exp 2**	**Exp 3**	**Exp 4**
light	+	+	-	-
oxigen	+	+	+	+
nitrogen	+	+	+	+
phosphorus	+	+	+	+
thermal water salts	+	+	+	+
glucose	+	-	+	-
trace minerals	+	+	+	+
Growth?	**yes**	**yes**	**yes**	**yes**

Table 1

The lab was further interested in finding genes from *T. szegediensis* that are important for the microbe to exist at high temperatures. They isolated 6 mutants (M1-M6). Then, they performed a complementation test between each ("+" means growth, "-" means no growth) to see how they grow at high temperatures (T = 56°C).

	M1	M2	M3	M4	M5	M6	WT
M1	-	-	+	-	+	+	+
M2		-	-	-	-	-	-
M3			-	+	-	-	+
M4				-	+	+	+
M5					-	-	+
M6						-	+
WT							+

Table 2

Q.7.1 Which of the following best describes *T. szegediensis*? Indicate with an **X.**
A. Photoautotroph
B. Chemoautotroph
C. Photoheterotroph
D. Chemoheterotroph

Q.7.2 Which of the following does *T. szegediensis* most likely use as an energy source to produce complex organic compounds? Indicate with an **X.**
A. SO_4^{2-}
B. Light
C. H_2S
D. NO_3^-
E. H_2O
F. Chlorophyll
G. lactic acid

Q.7.3 Indicate the dominant and recessive mutations with an **X**.
A. Dominant
B. Recessive

Q.7.4 From the data in Table 2, at least how many different genes can you identify as being important for allowing *T. szegediensis* to exist at high temperatures?

Q.7.5 Indicate which mutants have mutations in the same genes. Indicate with an **X.** Incorrectly marked cells will incur a penalty.

Q8

Beadle and Tatum proposed that one gene produces one enzyme. They mutated mould and observed that different colonies required a different supplement to their normal media to survive (Figure 1).

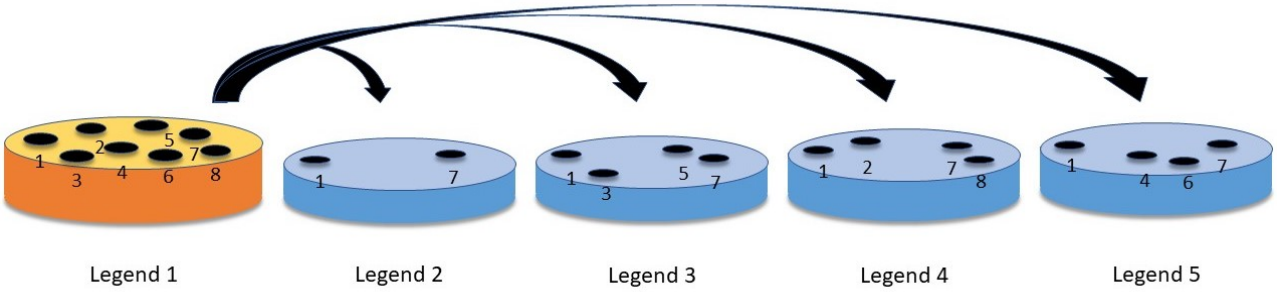


Fig.1. Legend 1 = Rich Medium. Legend 2 = Minimal Medium. Legend 3 = Minimal Medium + Phenylalanine. Legend 4 = Minimal Medium + Leucine. Legend 5 = Minimal Medium + Arginine

Indicate with an **X** which colonies (1-8) the statements are true for based on Figure 1. Mark all other cells with **O.**

Q.8.1	Which mutants have the same nutritional requirements as WT cells?

Q.8.2	Which colonies would you use to discover genes involved in the arginine synthesis pathway?

In another experiment you take a different set of mutants and plate them as seen in Figure 2.

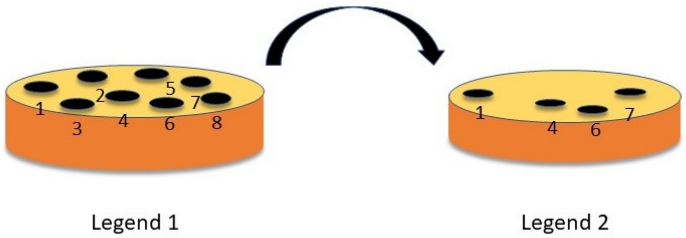


Fig.2. Legend 1 = Rich Medium. Legend 2 = Rich Medium without Arginine

Q.8.3	Which colonies (1-8) cannot produce arginine in Figure 2?

Q8.4 is concerned with a different set of arginine synthesis mutant strains. You identify 9 haploid yeast strains with single mutations in the amino acid production pathway. You perform complementation experiments, the crossing of different mutants to get a diploid progeny, and allow them to grow out in medium deficient in your amino acid of interest. (**-**) in the table below indicates where no growth occurs.

	1	2	3	4	5	6	7	8	9
1	–						–		
2		–		–		–		–	
3			–						–
4		–		–		–		–	
5					–				
6		–		–		–		–	
7	–						–		
8		–		–		–		–	
9			–						–

Table 1

Q.8.4 Based on these results how many at least genes are involved in the arginine synthesis pathway?

Q.8.5 QUESTION REDACTED

Q9

Bulb1 and Bulb2 are transcription factors involved in the survival response of plants exposed to UV radiation. Wild-type (wt) and homozygous mutant (*Bulb1-/-*) *Arabidopsis* plants were exposed to UV-B for various times and their RNA extracted. RNA was dissolved in 20 µl of buffer. A 2 µl aliquot was taken from one of the stock solutions and diluted to 1 ml. The absorbance of the solution at 260 nm was found to be 0.046.

Q.9.1 Given that a 40 µg/ml solution of RNA gives an absorbance of 1.0 at 260 nm, calculate the concentration of RNA in the stock solution in µg/ml.

Q.9.2 In each experiment the scientists carried out, they are required to use 2 µg of RNA. What volume of stock would they need to use? Give your answer in µl, rounded to two decimal places.

Q.9.3 How many experiments could the researchers conceivably carry out with the original stock of RNA?

The RNA samples were used for measurement of *bulb2* transcript levels by quantitative PCR (Figure 1A). In a different experiment Bulb1 and Bulb2 protein levels in wild-type *Arabidopsis*, exposed to UV-B radiation for various times were assessed (Figure 1B).

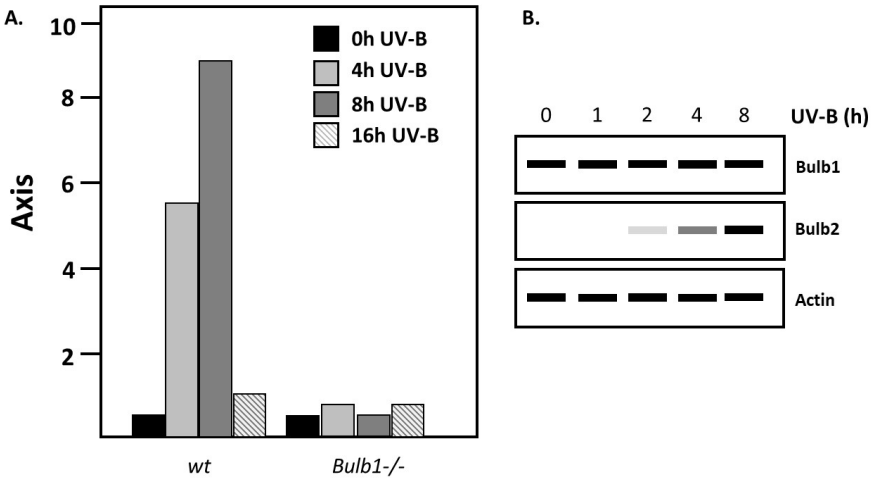
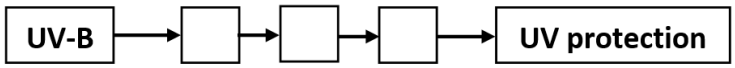


Fig.1. Axis = Fold change relative to control. *wt* = Wild-type

Q.9.4 Build a model of UV-B response in *Arabidopsis* based on the available information.

A. *Bulb1* transcription
B. *Bulb2* transcription
C. Bulb1 translation
D. Bulb2 translation
E. Bulb1 degradation
F. Bulb2 degradation
G. Bulb1 nuclear translocation
H. Bulb2 nuclear translocation



Animal Anatomy and Physiology

Q10

The graph below illustrates the pressure and volume changes during breathing.

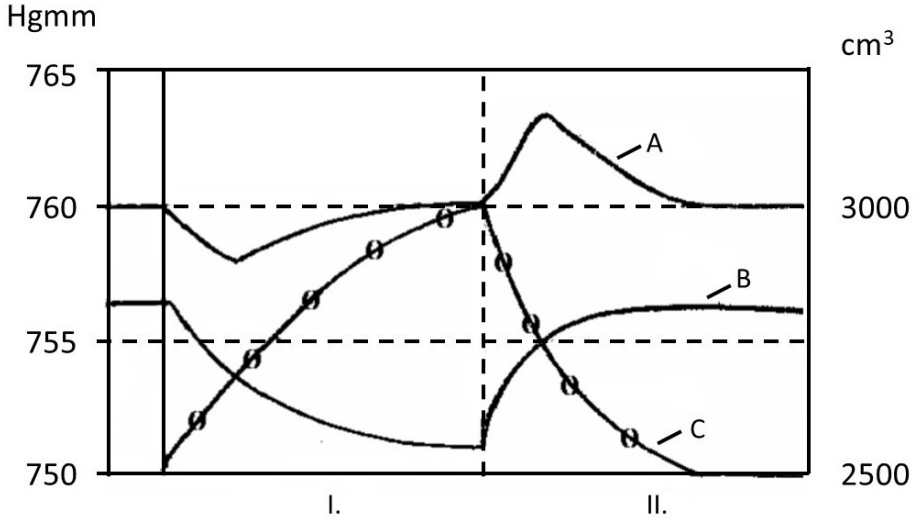


Fig.1

Identify what is represented by letters A, B and C, and the Roman numerals I. and II. Match these symbols (A-C and I-II) with the descriptions below (Q.10.1-8). Every symbol matches one description only, but there are descriptions that do not match any of those. Indicate correct answers by putting an X in the appropriate box on the answer sheet. **Match those that do not match any symbols with the "0" column on your answer sheet.**

Q.10.1 Volume changes of the intrapleural space during breathing
Q.10.2 Inhalation phase of breathing
Q.10.3 Pressure change in the lungs during breathing
Q.10.4 Pressure change in the left ventricle of the heart during breathing
Q.10.5 Pressure change of the intrapleural space during breathing
Q.10.6 Volume change of the lung during breathing
Q.10.7 Exhalation phase of breathing
Q.10.8 Volume change of abdominal cavity during breathing

Q11

The pH value of the human blood is kept in a strict range, in order to maintain the vital functions of the body. There are three main mechanisms which can help blunting acidic or alkaline shifts:

- Buffer systems, especially the bicarbonate system.
- Exhalation of carbon dioxide in the lungs.
- Excretion of protons and the reabsorption and production of bicarbonate-ions by the kidney.

These three regulatory systems usually operate simultaneously, compensating each other's malfunctions when needed. Conditions A to F are depicted in the Figure below.

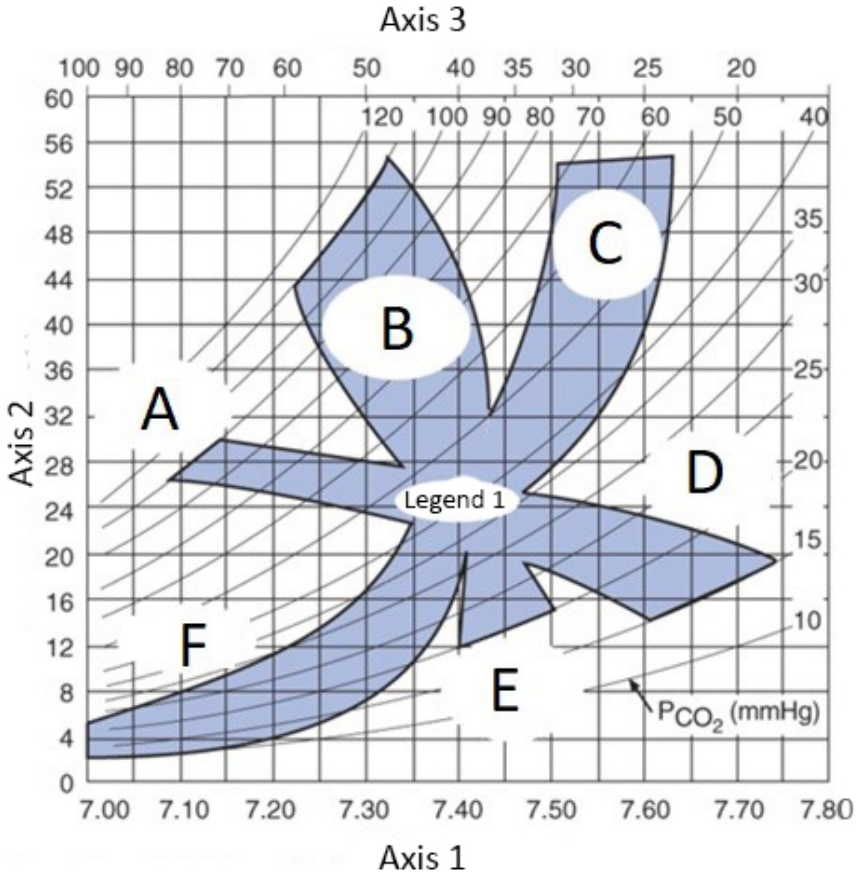


Fig.1. Axis 1 = Arterial blood pH. Axis 2 = Arterial plasma [HCO_3^-] (mmol/L). Axis 3 = Arterial blood [H^+] (nmol/L). Legend 1 = Normal.

Match the letters from the figure (from A to F) to the corresponding clinical conditions in the list below. Note that acute implies a sudden effect, while chronic conditions last for an extended period and involve compensatory mechanisms. Indicate your answer by putting an X in the appropriate box on the answer sheet. Note that not all the letters are used.

Q.11.1 Condition following vomiting

Q.11.2 Acute respiratory acidosis due to ineffective respiration caused by a stroke affecting the brainstem

Q.11.3 Acute respiratory alkalosis caused by hyperventilation

Q.11.4 Chronic respiratory acidosis associated with asthma

Q.11.5 Chronic respiratory alkalosis associated with anaemia

Q12

The Hungarian Grey is a rare breed of cow which was threatened by an epidemic caused by a new bacterial strain. An antibiotic was given to the cows to prevent infection. It has a half-life in cows of 6 hours, and at equilibrium, 25% of the antibiotic circulates in the blood, whilst 75% is found in interstitium.

A healthy cow received a single dose of 4400 mg intravenously at 11am. At 11pm, 10 ml of blood was withdrawn and 5 mg/l of antibiotic was present in this sample.

Q.12.1 Calculate the total blood volume of this cow in litres (L).

Q.12.2 Certain fruits (e.g., pomegranate) can inhibit metabolic enzymes in the liver. Using the equation below, calculate the concentration of the antibiotic in blood **at 5pm** ($N(t)$) after time (t) has passed, assuming the **half-life** ($t_{\frac{1}{2}}$) of the drug has **doubled** due to pomegranate consumption. N_0 is the starting concentration. Give your answer in milligrams/millilitres (mg/ml) to two decimal place accuracy.

$$t_{\frac{1}{2}} = \frac{t}{\log_{\frac{1}{2}}\left(\frac{N(t)}{N_0}\right)}$$

Consider the effects of a cow's treatment with strong oral antibiotics. Indicate with an X if each of the following statements is true (T) or false (F).

Q.12.3 The cow will eventually develop antibiotic resistance

Q.12.4 The cow will have increased blood clotting times

Q.12.5 The cow will have reduced nutrient absorption

Q.12.6 The cow will have elevated circulating insulin levels

Q13

The following graph shows how glucose handling in the kidney changes with plasma concentration.

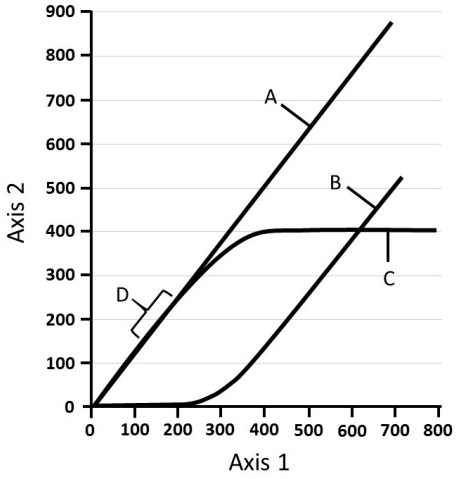


Fig.1. Axis 1 = Plasma glucose concentration (mg/100 ml). Axis 2 = Glucose filtered load, reabsorption or excretion (mg/min).

Q.13.1 Indicate with an X on your answer sheet if the following statement is true (T) or false (F).
Glucose is freely filtered in glomeruli.

Match the letters from the figure (A-D) to the correct parameter in the list below. Indicate your answer by putting an X in the appropriate box on the answer sheet.

Q.13.2 Glucose excreted

Q.13.3 Glucose filtered

Q.13.4 Glucose reabsorbed

Q.13.5 Normal levels

Q.13.6 What is the maximum rate of glucose reuptake? Round your answer to the nearest hundred and give your answer in milligram/minute (mg/min).

Q14

Answer the question using the letters from the figure.

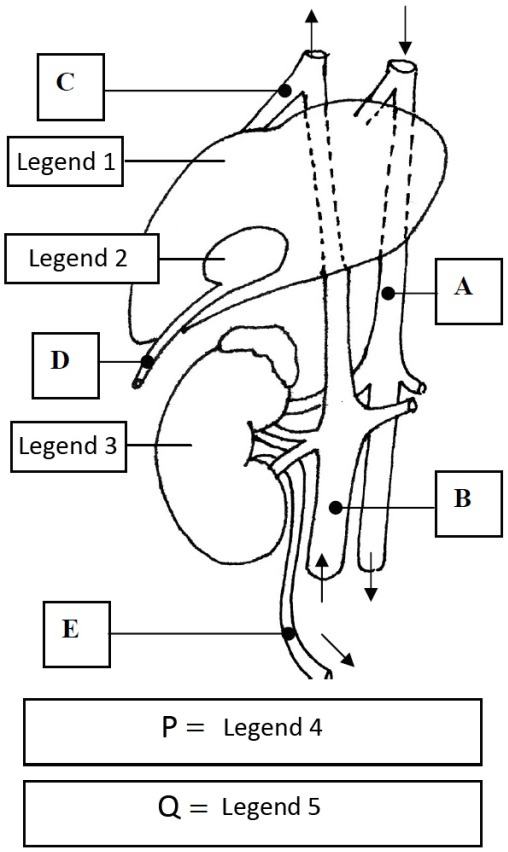


Fig.1. Legend 1 = Liver. Legend 2 = Gallbladder. Legend 3 = Kidney. Legend 4 = All of the above. Legend 5 = None of the above

Match the following statements with the letters in the figure above (A-E and P-Q). You may need to use the same letter more than once.

Q.14.1 Blood enters this vessel from the right ventricle

Q.14.2 The blood carried in the vessel will drain into the left atrium of the heart

Q.14.3 Carries urine

Q.14.4 Contains digestive enzymes

Q.14.5 Contains steroid salts

Q15

There are four different types of hypersensitivity reactions in the human body as it can be seen in the list below.

TYPE I:

Fast response which occurs in minutes, rather than multiple hours or days. Free antigens cross link the IgE on mast cells and basophils which causes a release of vasoactive biomolecules.

TYPE II:

IgG or IgM antibody binds to cellular antigen, leading to complement activation and cell lysis. IgG can also mediate Antibody Dependent Cell Cytotoxicity (ADCC) with cytotoxic T cells, natural killer cells, macrophages and neutrophils.

TYPE III:

Antigen-antibody complexes are deposited in tissues. Complement activation provides inflammatory mediators and recruits neutrophils. Enzymes released from neutrophils damage tissue.

TYPE IV:

Cell-mediated reactions are initiated by T-lymphocytes and mediated by effector T-cells and macrophages. This response involves the interaction of antigens with the surface of lymphocytes.

Match each of the following conditions (Q.15.1-6) with one of the hypersensitivities described above. Indicate your answer by putting an X in the appropriate box on the answer sheet.

Q.15.1 The type of reaction that occurs during a mismatched blood transfusion.

Q.15.2 This reaction occurs when one is exposed to poison ivy, which produces a toxin that binds to human proteins causing them to become self-antigens.

Q.15.3 Dermatologists make use of this reaction to identify specific allergens found in food to which patients are sensitive.

Q.15.4 This type of reaction occurs after certain pathogenic bacteria entering the body are destroyed by the immune system, but some of their macromolecules stay intact afterwards.

Q.15.5 This type of reaction cannot be transferred from one patient to another by serum.

Q.15.6 Hay fever is an example of this condition.

Q16

The Hungarian biophysicist, György Békésy was awarded the 1961 Nobel Prize for his research on the function of the mammalian cochlea. He showed that each frequency of sound causes a specific part of the basilar membrane to vibrate the most. This point is determined by the resonant properties of the membrane, with narrower parts vibrating more at higher frequencies.

Neurons sense this vibration and encode the sound with two different mechanisms:

1. **Place code:** Each neuron connects to the membrane in one place and signals the presence of the narrow frequency band that causes maximal vibration in that part of the membrane.
2. **Periodicity code:** If the frequency is below 4 kHz, the timing of action potentials in the cochlear nerve is synchronised with individual cycles of the stimulus *(this is called phase-locking).*

The intensities of audible sounds are expressed in **decibel sound pressure level** (dB SPL).

$$dB\ SPL = 20\ \log_{10} \frac{Pressure\ of sound\ in\ Pa}{2 \cdot 10^{-5}}$$

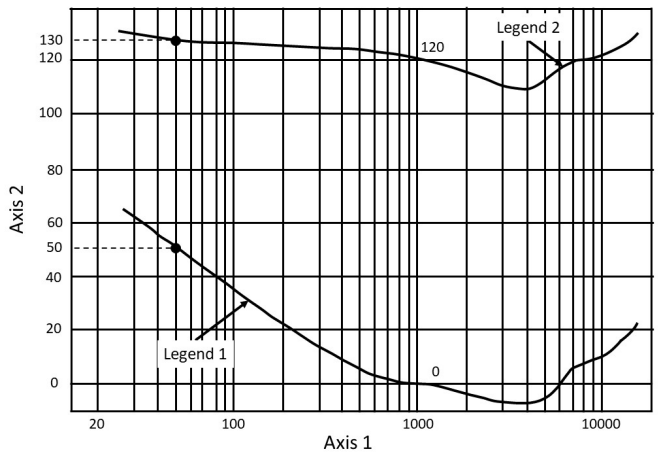


Fig.1. Axis 1 = Frequency (Hz). Axis 2 = Intensity (dB). Legend 1 = Threshold of audibility. Legend 2 = Threshold of pain

Based on the information above, indicate with an X if each of the following statements is true (T) or false (F).

Q.16.1 Sounds detected by hair cells towards the narrowest part of the cochlea are coded in a phase-locked manner.

Q.16.2 For sounds detected near the base of the membrane, the number of fibres firing is proportional to the amplitude of the displacement of the basilar membrane.

Q.16.3 What is the absolute refractory period of fibres in the cochlear nerve? Give your answer in milliseconds (ms) in the appropriate box on the answer sheet.

Q.16.4 At 50 Hz, how many times is the pressure of the sound that is painful greater than that of the sound that is just audible? Give your answer in the appropriate box on the answer sheet.

Q17

The impact of feeding on the central circadian clock of the brain, and the peripheral clocks of other cells was assessed. Mice were either fed only from 6.00-18.00 (daytime feeding) or only from 18.00-6.00 (night time feeding). The amount of Per1 and Per2 protein in liver is shown. The central brain clock was stained with labelled DNA complementary to the *per1* or *per2* sequences.

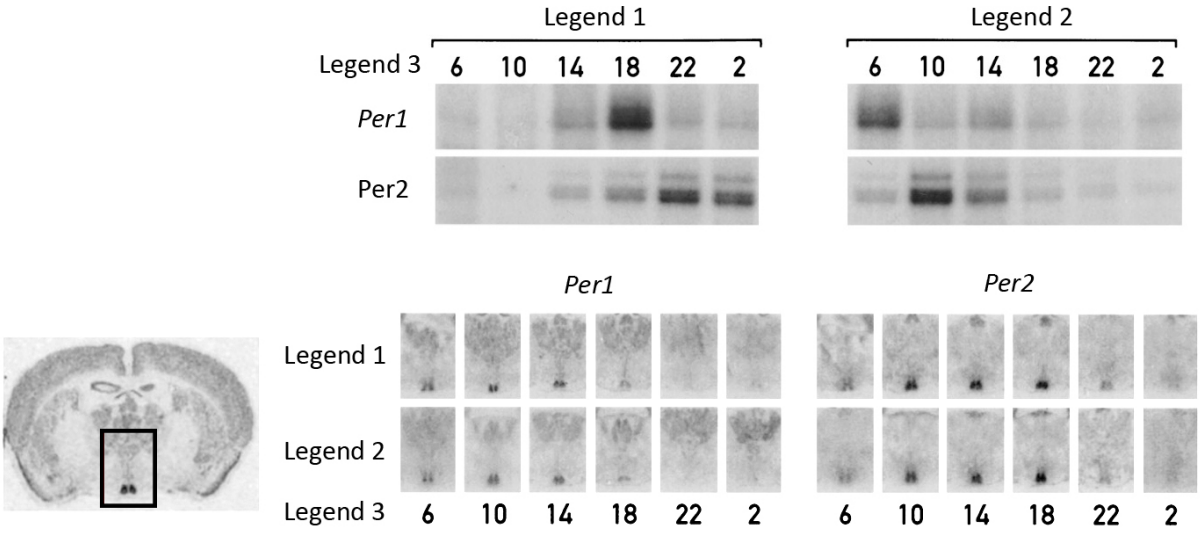


Fig.1. Legend 1 = Nighttime feeding. Legend 2 = Daytime feeding. Legend 3 = Time of the day (h)

For the following three questions, indicate your answer by putting an X in the appropriate cells of the table on the answer sheet.

Q.17.1 How many hours has peripheral circadian rhythm shifted by following a change in feeding time?

Q.17.2 How many hours has central circadian rhythm shifted by following a change in feeding time?

Q.17.3 How many hours do central Per1 peaks precede peripheral peaks during night feeding?

Q.17.4 What time would you expect peripheral Per1 peaks to occur if animals were fed between 14.00-2.00? Indicate your answer by putting an X in the appropriate box on the answer sheet.

A. 6
B. 10
C. 14
D. 18
E. 22
F. 2

Q18

Thyroid hormones (T3 and T4) regulate metabolism. Their release is controlled as shown in the figure. T4 can be metabolised to T3 in tissues.

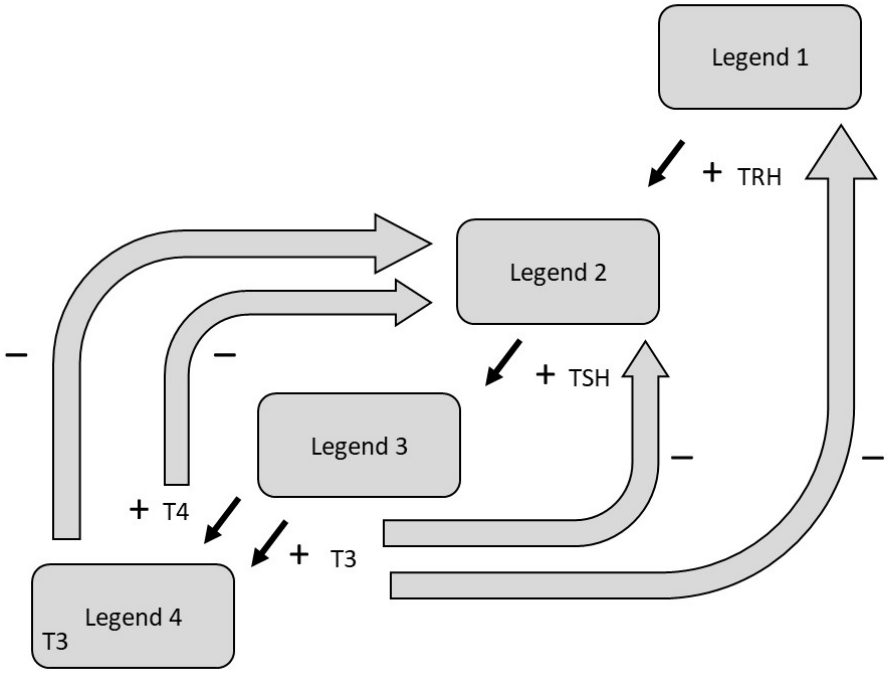


Fig.1. Legend 1 = Hypothalamus. Legend 2 = Anterior Pituitary. Legend 3 = Thyroid. Legend 4 = Peripheral body / blood. TRH = Thyrotropin-releasing hormone. TSH = Thyroid-stimulating hormone.

Which hormone's levels would you expect to be **increased** in patients with the following conditions relative to healthy individuals? Indicate your answer by putting an X in the appropriate box on the answer sheet.

Q.18.1 A patient with Hashimoto thyroiditis that causes the gradual immune destruction of thyroid tissue.

Q.18.2 A patient with Graves' disease, where the body produces antibodies against the TSH receptor (TSHR) that stimulate its activation.

Q.18.3 A patient abusing medication, taking T4 supplement pills hoping it would help them with weight loss.

Q.18.4 Patient with a very rare TSH-secreting anterior pituitary tumour.

Q.18.5 Patient with thyroid hormone resistance, a mutation of the thyroid hormone receptor.

Q19

Thyroid hormones play a crucial role in metabolism and the cardiovascular system. Too much or too little thyroid hormone can result in insufficient blood flow to the heart. Insufficient blood flow generates reactive oxygen species (ROS) which damage the heart further.

Methimazole prevents the production of thyroid hormones, whilst T4 is a thyroid hormone. Either was given to rats, and the expression of antioxidant enzymes in the heart was measured (Figure).

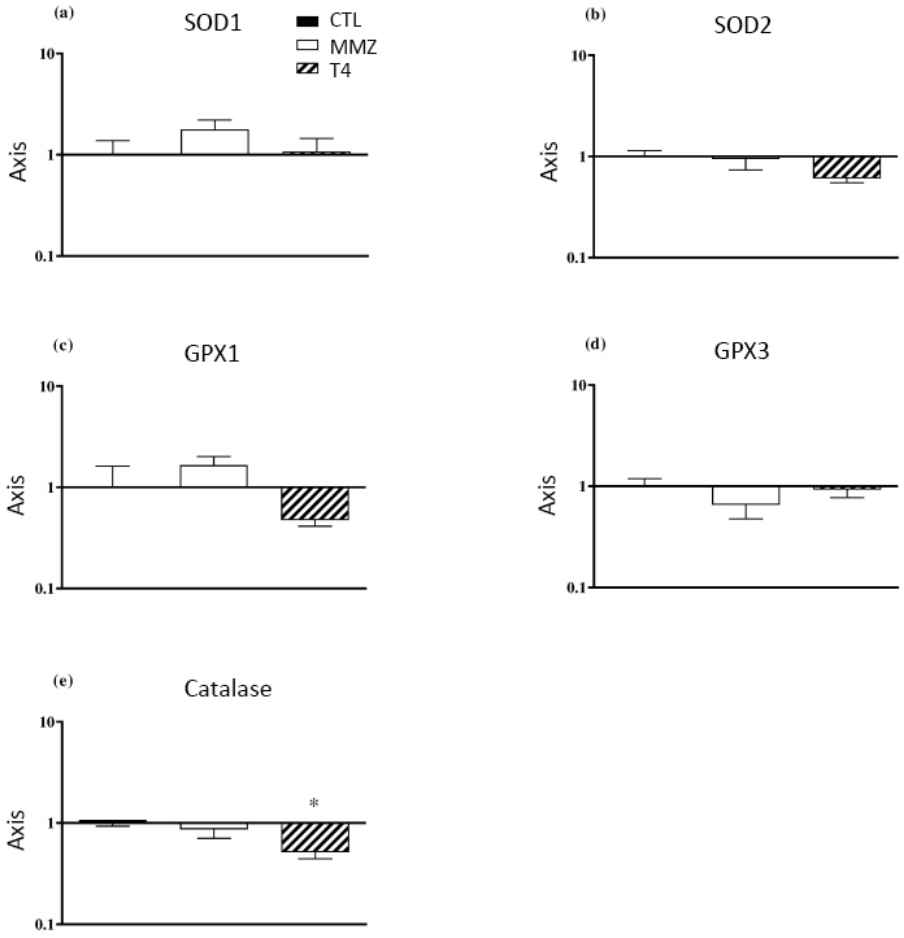


Fig.1. Axis = Fold change (Logarithmic scale). CTL = Untreated Control group. MMZ = Treated with Methimazole. T4 = Treated with thyroxine. SOD = Superoxide dismutase. GPX = Glutathione peroxidase.

Assess how the following variables change under the conditions described below using the symbols (A-C). Indicate your answer by putting an X in the appropriate box on the answer sheet.

A = increase

B = no change

C = decrease

Q.19.1 The expression of catalase enzyme on a thyroxine supplemented diet.

Q.19.2 Severity of ROS damage in patients treated with thyroid stimulating hormone.

Q.19.3 SOD1 expression of thyrotropin releasing hormone treated rats.

Q.19.4 Risk of heart failure in patients with Graves' disease, an autoimmune disease resulting in hyperthyroidism, treated with methimazole, as compared to untreated patients.

Q.19.5 Core temperature of animals on the T4 supplemented diet.

MOR2

Plant Anatomy and Physiology

Q20

Two families of transcription factors, GNC and GLK, have been implicated in regulating chloroplast development. The promoters which these transcription factors bind to were identified. These promoters were grouped according to whether the genes were upregulated, or downregulated when these transcription factors were overexpressed (colour of bar). The percentage of these promoters which contained certain hexamer or octamer sequences was plotted (height of bar). The asterisks indicate significant difference compared to the control.

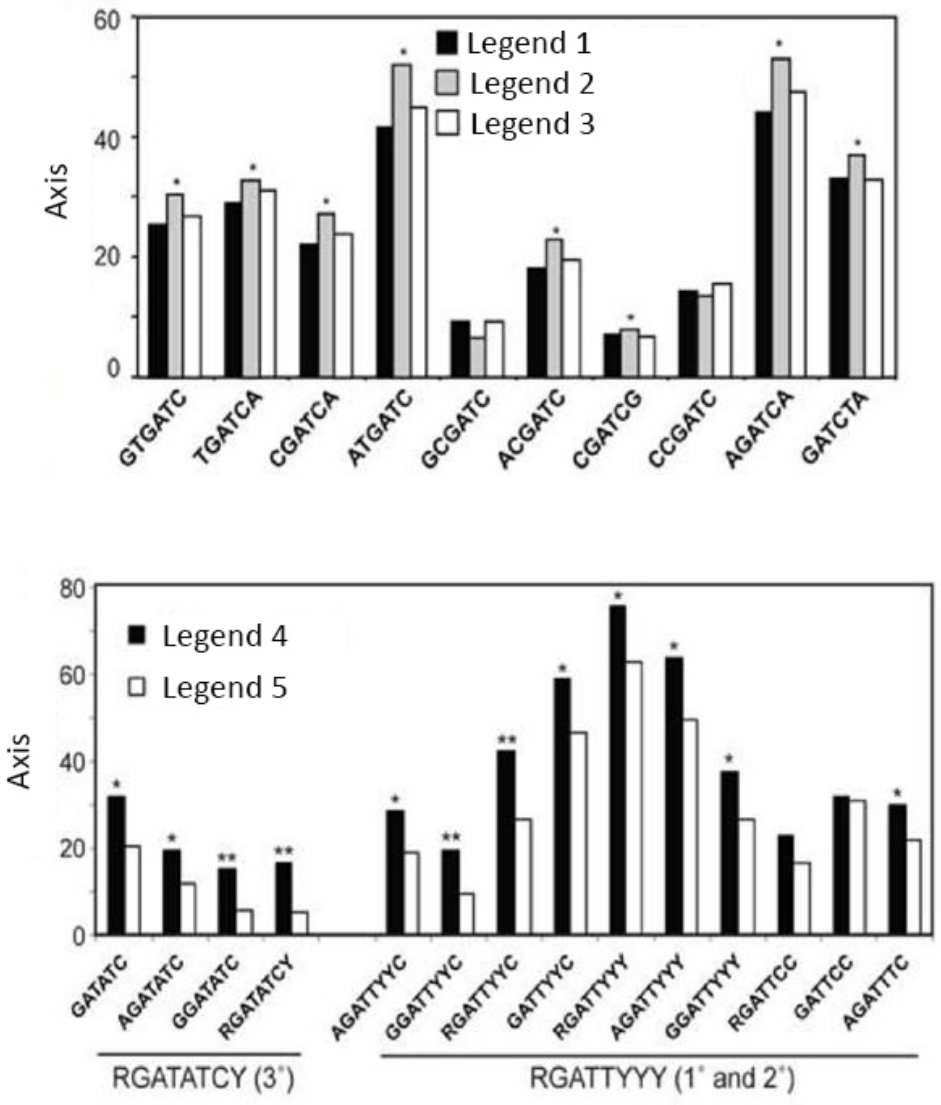


Fig.1. Axis = % of promoters. Legend 1 = Up-regulated by 35S:GNC. Legend 2 = Down-regulated by 35S:GNC. Legend 3 = Control. Legend 4 = Up-regulated by GLK. Legend 5 = Control

Q.20.1 The frequency of each nucleotide at each position of the nucleotide sequences which most strongly bound GNC were plotted. Deterimne the best estimate of the hexanucleotide sequence which GNC most prefers to bind ("consensus sequence"). Write your answer in the appropriate box on the answer sheet.

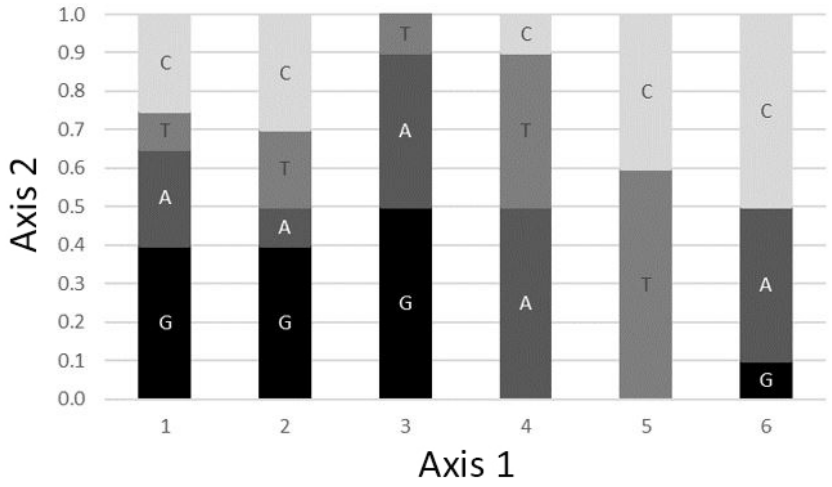


Fig.2. Axis 1 = Nucleotide position. Axis 2 = Nucleotide frequency

Q.20.2 Determine for both GNC and GLK transcription factors whether they are repressors or activators of the genes they control. Indicate your answer by putting an X in the appropriate box on the answer sheet **for both GNC and GLK.**
A = activator
R= repressor

Q.20.3 Which of the high-affinity binding sites are not specifically active (i.e. do not modulate gene expression) from those investigated above (see Figure 1)? Write the binding site sequences in the appropriate boxes on the answer sheet for both GNC and GLK.

Q21

The effect of drought on leaf anatomy was investigated in two types of Olive: Chemlali and Meski. Data is shown in the tables below.

	r (µm)							
Parameter	UE		SP		LE		TL	
CULT								
'Chemlali'								
WW	18.0	*	196.3	*	16.5	*	30.6	
UW	23.8		215.7		20.7		40.5	
'Meski'								
WW	26.8		224.9		16.3		37.9	
UW	20.1		234.8		16.4		47.9	

Parameter	LA (mm^2)		D($g\ kg^{-1}$)		S ($mg\ H_2O\ cm^{-2}$)	
CULT						
'Chemlali'						
WW	537.2	*	535.0	*	24.23	*
UW	405.0		485.5		30.45	
'Meski'						
WW	746.0	*	543.0	*	23.99	
UW	634.7		521.7		29.44	

Table 1. r = Thickness (µm), UE = Upper epidermis, SP = Spongy parenchyma, LE = Lower epidermis, TL = Trichome layer, WW = well-watered, UW = under-watered, LA = leaf area, D = density of leaf tissue, S = succulence, CULT = Cultivar x watering regime , asterisks * indicate significant differences

Q.21.1 Calculate "A" and "B" in the following table by quantifying the effect of under-watering (UW) relative to the well-watered (WW) condition on spongy parenchyma, as we have done for the effect on upper epidermis. Write your results as percentages in the appropriate box on the answer sheet.

	UE	SP
Chemlali	132	"A"
Meski	75	"B"

What are the consequences of the following changes? Assign the correct physiological consequence from the list below (A-F) to each of the anatomical changes listed (Q.21.2-7). In some of the boxes you may have to use more than one letter. You can use the same letter more than once.

A. Increase in CO_2 fixation rate

B. Decrease in CO_2 fixation rate

C. Increased transpiration rate

D. Decreased transpiration rate

E. Increased CO_2 conductance of leaves

F. Decreased CO_2 conductance of leaves

Q.21.2 Increased upper and lower epidermis thickness

Q.21.3 Increased upper palisade thickness

Q.21.4 Increased spongy parenchyma thickness

Q.21.5 Increased trichome density

Q.21.6 Increased leaf area

Q.21.7 Increased succulence

Q.21.8 Determine the difference in the degree of drought resistance for the two cultivars. Indicate your answer using the symbols, < or > or =.
A. Resistance of Chemlali
B. Resistance of Meski

Q22

To understand the relationship between different factors and tree height, *Sequoia sempervirens*, one of the tallest known tree species was studied. Multiple physiological parameters were determined at different heights of multiple individual trees as shown in Fig.1. A changing ratio of stable ^{13}C / ^{12}C isotopes in leaf tissues, $\delta^{13}C$, is a consequence of changing water stress (Fig.1c). For xylem pressure and $\delta^{13}C$, two sets of samples were taken: right before dawn (filled datapoints) and at midday (empty datapoints).

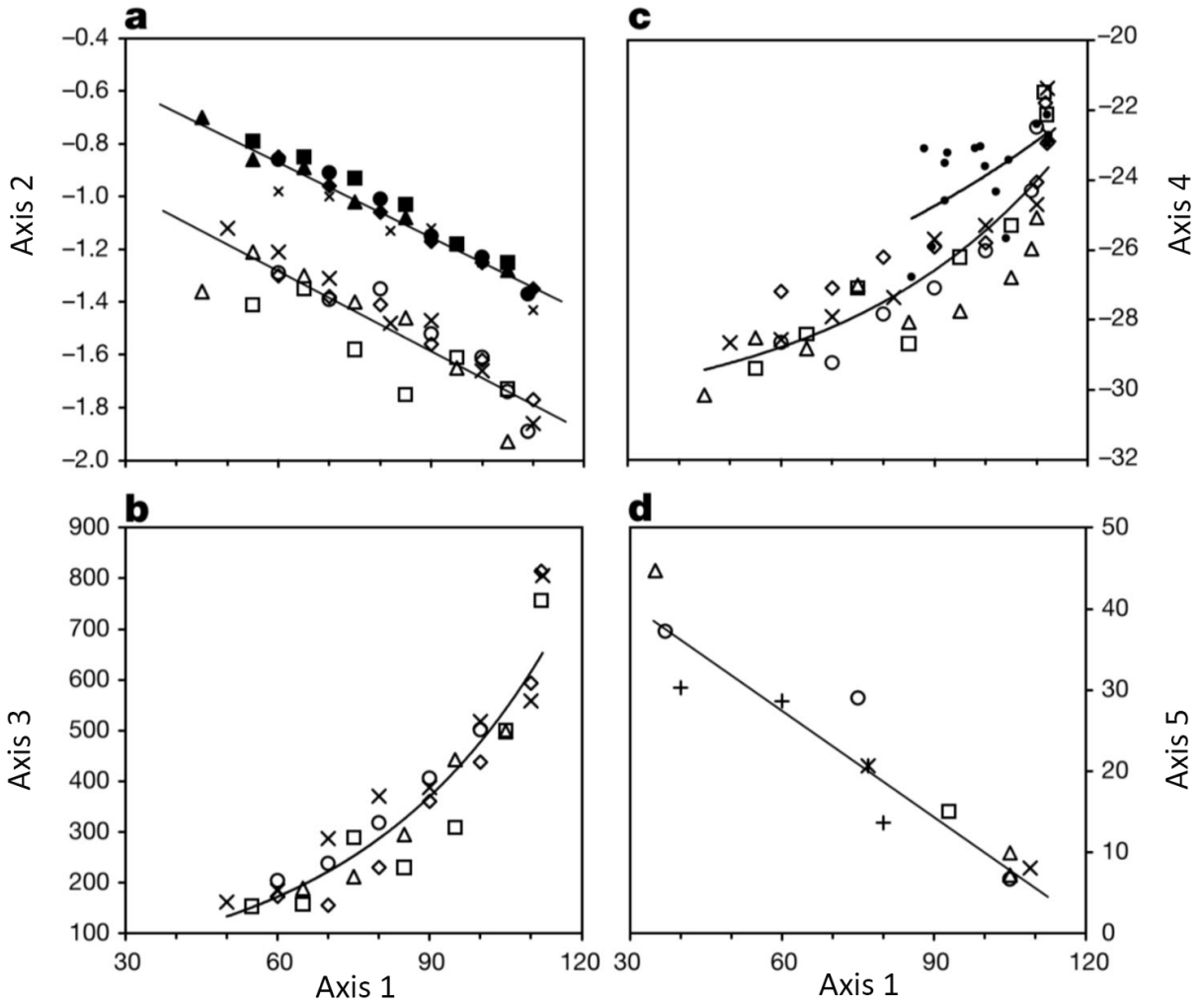
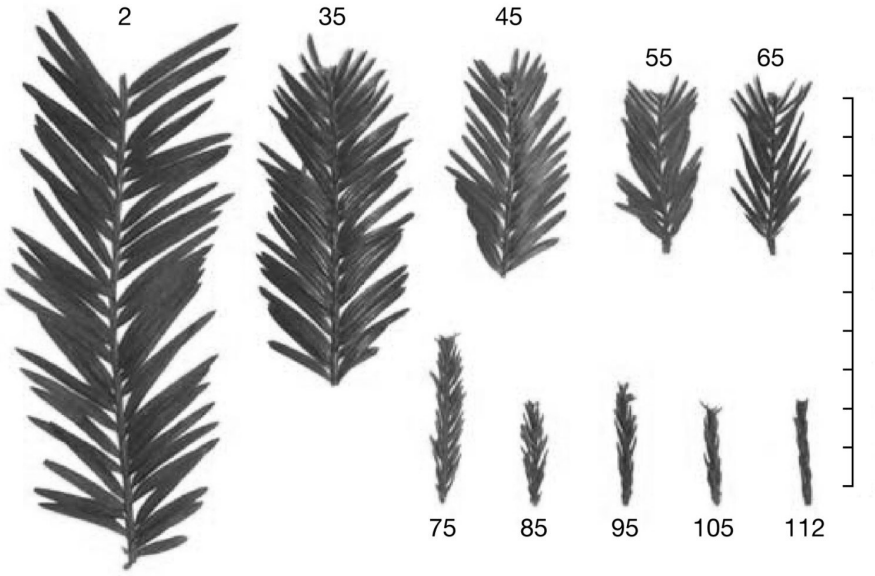


Fig.1. Axis 1 = Height above ground (m). Axis 2 = Xylem pressure (MPa). Axis 3 = Leaf mass:area ($g \cdot m^{-2}$). Axis 4 = Leaf $\delta^{13}C$ (‰). Axis 5 = "photosynthetic rate per unit mass" $P_{\text{max},m}$ ($nmolCO_2 \cdot g^{-1} \cdot s^{-1}$).

Pictures of leaves were taken at different heights (numbers are meters of height of sampling) as shown in Fig.2.



Additionally, model equations were constructed to predict how different variables influence the maximum height of trees (Ψ leaf water potential; LMA Leaf Mass : Area ratio; "Maximum height", h, in the equations, refers to the maximum height in meters predicted by the equations, values not shown).

Col 1	Col 2	Col 3
ψ, midday (MPa)	$\psi = -0.00973h - 0.712$	–1.9
LMA ($g \cdot m^{-2}$)	$LMA = 37.43 \cdot e^{0.0255h}$	833
$\delta^{13}C(‰)$	$\delta^{13}C = 0.559 \cdot e^{0.0229h} - 31$	–20
$P_{max,m}(nmol \cdot g^{-1} \cdot s^{-1})$	$P_{max,m} = -0.434h + 54.3$	0

Table 1. Col 1 = Dependent value. Col 2 = Equation of max height (h). Col 3 = Limit value of dependent variable.

Q.22.1 Select the single best statement from the options below that describes how xylem pressure changes with increasing height. Indicate your answer by putting an X in the appropriate box on the answer sheet.
A. Xylem pressure increases with increasing height at a significantly higher rate at night than during the day.
B. Xylem pressure increases with increasing height at a significantly higher rate during the day than at night.
C. Xylem pressure decreases with increasing height at a significantly higher rate at night than during the day.
D. Xylem pressure decreases with increasing height at a significantly higher rate during the day than at night.
E. Xylem pressure decreases with increasing height at a rate irrespective of the time of the day.

Q.22.2 Indicate the relationship between the values of xylem pressure in the following scenarios using the symbols > or < or = in the appropriate boxes on your answer sheet.
A. Xylem pressure in the topmost leaves of most studied trees **before dawn**
B. Xylem pressure in the topmost leaves of most studied trees **at midday.**

Q.22.3 Given the data above and that epiphytic saplings growing on branches at 95m show a similar leaf structure as leaves of non-epiphytes from 2m high, select the factor that is the most important in determining the leaf structure at a given height. Indicate your answer by putting an X in the appropriate box on the answer sheet.
A. Light intensity
B. Water availability
C. $\delta^{13}C$
D. Ambient relative humidity (that of surrounding air)
E. Ambient partial pressure of carbon dioxide (that of the surrounding air)

Calculate the maximum possible height predicted by each equation. Write your results, rounded to the nearest integer, in the appropriate boxes on the answer sheet.

Q.22.4 Maximum height as predicted by Ψ

Q.22.5 Maximum height as predicted by LMA

Q.22.6 Maximum height as predicted by $\delta^{13}C$

Q.22.7 Maximum height as predicted by $P_{\text{max},m}$

Q.22.8 Based on your calculations above, state which parameter(s) is/are the most limiting to tree height. Indicate your answer by putting an X in the appropriate box on the answer sheet.
A. Water potential (ψ)
B. Leaf Mass : Area ratio (LMA)
C. $\delta^{13}C$
D. $P_{\text{max},m}$

Q23

Statocytes are cells in the central root cap thought to be crucial in geotropism of the plant root. These cells possess starch-filled granules, statoliths, which have a higher density than the statocyte cytoplasm so their position in the statocyte depends on the root orientation relative to the direction of the gravitational force it experiences.

In order to determine the role of statoliths in geotropism and their mechanism of action, *Brassica napus* seeds were taken to and grown on the International Space Station. *Brassica* seedlings were grown either in a centrifuge that exerts 1g force on the seedlings (fig A) or in microgravity (experiencing negligibly small gravity, fig B). The root tissues were fixed after 40 hours of germination and the position of statoliths was determined. Results are represented in a unified coordinate system whose origin (0;0) is the centre of the statocyte.

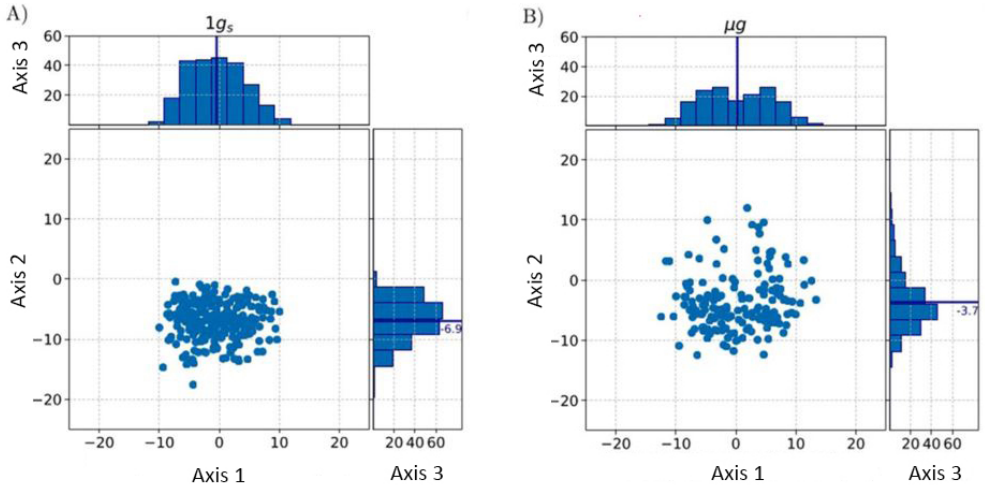


Fig.1. Axis 1 = Statocyte transverse position (μm). Axis 2 = Statocyte longitudinal position (μm). Axis 3 = Count

Each tile represents the final direction of a root tip of a seedling relative to direction of gravity (black arrow). Determine which of the following diagrams (A-G) depict the distribution of growing root tips in microgravity and in 1g gravitational force. There are two correct answers for both experimental conditions. Indicate your answer by putting **two Xs** in the appropriate boxes **in each line** on the answer sheet.

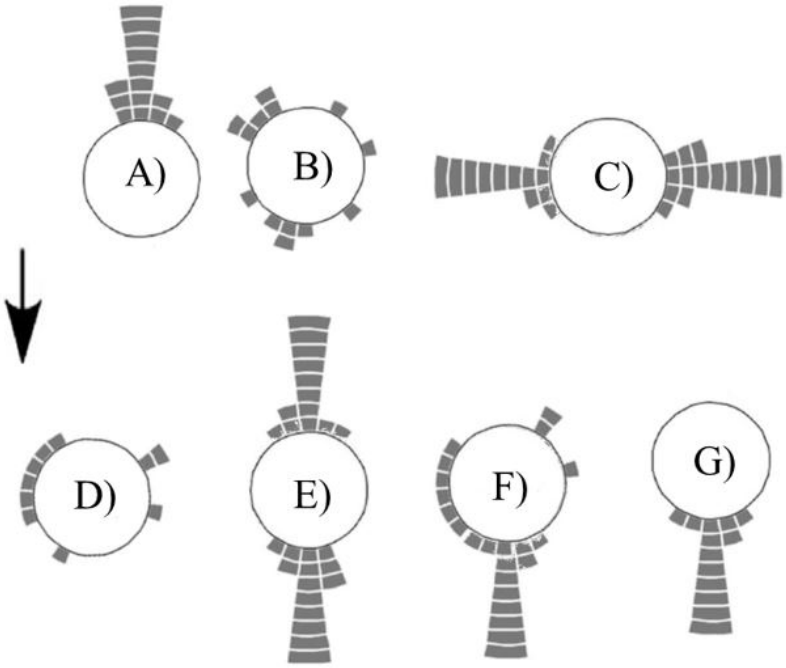


Fig.2

Q.23.1 In 1 g gravity

Q.23.2 In microgravity

Assume that statocytes are cylindrical. Statoliths can move freely across the diameter of the statocyte. Statoliths can move 40% of the length of the statocyte. Calculate the approximate diameter and length of a statocyte in μm. Write your results in the appropriate boxes on the answer sheet.

Q.23.3 Diameter

Q.23.4 Length

Q24

Electrophysiological measurements were carried out on bean guard cells to measure outwards K+ currents and how they are modified by various factors. Assume that the K^+ currents shown here are proportional to the net changes in the intracellular K^+ concentration.

Currents (I) across the plasma membrane at different voltages (V) were determined after each step of four different experiments.

Experiment 1
Step 1: Incubated in washing buffer.
Step 2: Exposed to exogenous nitric oxide (NO).
Step 3: Washed in washing buffer

Experiment 2
Step 1: Injected with buffer to set cytoplasmic pH to 7.4.
Step 2: Exposed to exogenous nitric oxide (NO).
Step 3: Washed in washing buffer.

Experiment 3
Step 1: Incubated in washing buffer.
Step 2: Exposed to exogenous nitric oxide (NO).
Step 3: Exposed to BAL, a reducing agent that is known to reduce disulphide bridges in proteins.
Step 4: Exposed to exogenous nitric oxide (NO).

Experiment 4
Step 1: Incubated in washing buffer.
Step 2: Exposed to PAO, an oxidising agent that localises to membranes within the cell.
Step 3: Washed in washing buffer containing 0.3mM BAL

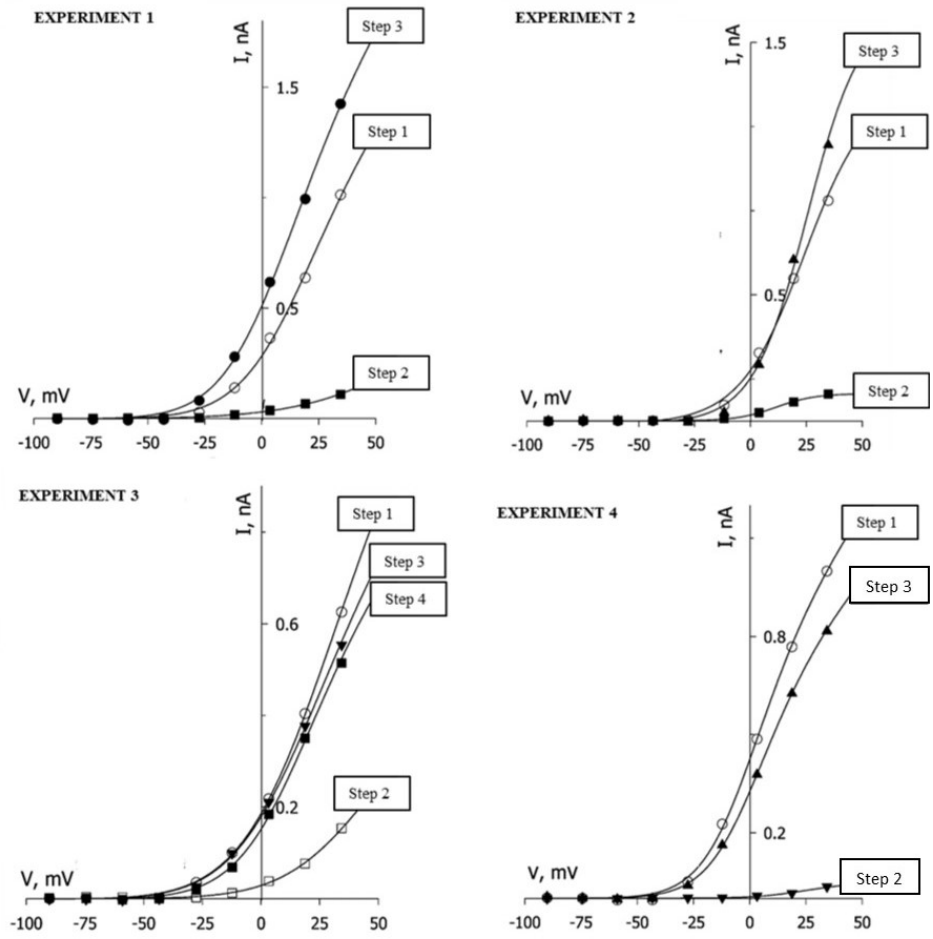


Fig.1

Based on the information above, indicate with an **X** if each of the following statements is true (T) or false (F).

Q.24.1	Guard cells treated in experiment 1 have a higher turgor and the stoma they form is more open when treated with NO compared to before the NO treatment.
Q.24.2	Intracellular pH significantly influences the NO-mediated reduction of K^+ efflux.
Q.24.3	BAL is a hydrophilic molecule.
Q.24.4	According to these data alone, infection of a bean leaf with a pathogen results in stomatal closure.

Genetics and Evolution

Q25

A test tube contains a suspension of bacteria that were never exposed to the antibiotic kanamycin. The bacteria were spread onto a so-called master plate, which contains nutrients for the bacteria and does not contain kanamycin. Millions of colonies (descendants of a single founder bacterium) developed on the master plate. Replicas (copies) of the master plate colonies were stamped - with a sterile velvet plate - onto three replica plates that contained growth medium supplemented with kanamycin (Figure 1).

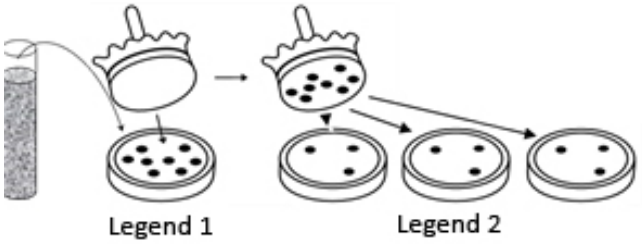


Fig.1. Legend 1 = Master plate. Legend 2 = Replica plates

Indicate with an **X** if each the following statements are true (T) or false (F).

Q.25.1 A spontaneous frameshift mutation caused the kanamycin resistance in bacteria which previously didn't contain the gene responsible for kanamycin degradation.

Q.25.2 The resistance of certain colonies is uncovered on the Replica plates.

Q.25.3 A mutation induced by the kanamycin caused the resistance.

Q.25.4 The kanamycin resistance occurred first on the 'Replica plates'.

Q.25.5 The best explanation is that kanamycin has a mild mutagenic effect on these bacteria.

Q.25.6 QUESTION REDACTED.

Q.25.7 There were no kanamycin resistant bacteria in the tube originally.

Q.25.8 The kanamycin resistance can spread on the Master Plate.

Q26

The pedigree shows inheritance of a trait in a model organism. The symbols are as follows: "empty circle" = healthy female; "empty square" = healthy male; "black circle" = sterile female, "black square" = sterile male.

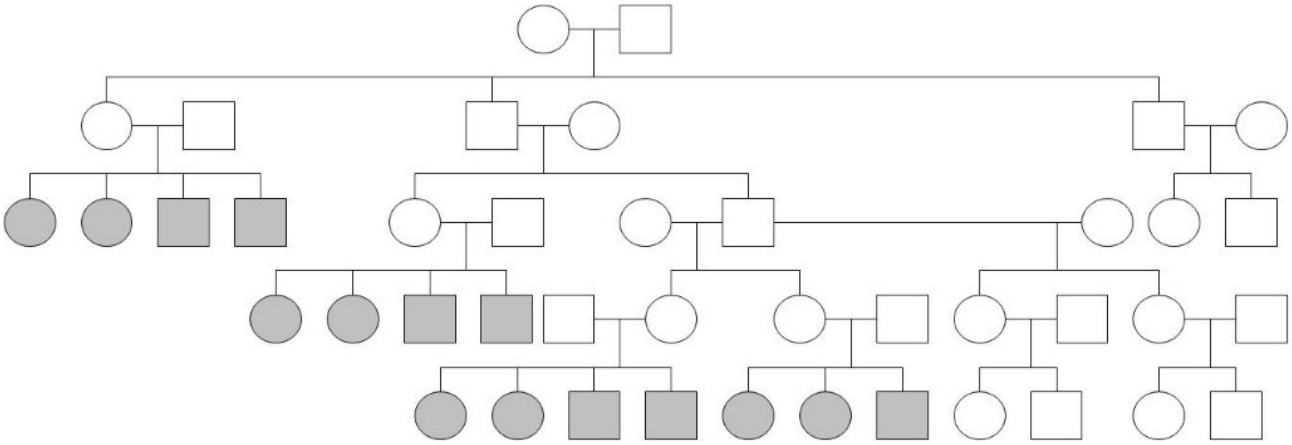


Fig.1

Q.26.1 Which ***one*** of the following options explains how sterility is inherited? Indicate your answer with an **X**.
A. Autosomal dominant
B. Autosomal recessive
C. X-chromosome linked dominant
D. X-chromosome linked recessive
E. Mitochondrial inheritance
F. Maternal effect

The change giving rise to sterility can be explained either through loss-of-function or gain-of-function mutation of the affected gene.

Q.26.2 Indicate individuals that are certainly heterozygous assuming a loss-of function change to the affected gene, by writing an **X** symbol into the appropriate empty circles and/or squares.

Q.26.3 Indicate individuals that are certainly heterozygous assuming a gain-of-function change to the affected gene, by writing an **O** symbol into the appropriate empty circles and/or squares.

Q27

Lily and Jacob visit a genetic counselling office where the doctor gathers the data summarized in the table below.

Person	Bald?	Rh
Lily	No	Rh^+
Lily's mother	Yes	Rh^+
Lily's father	No	Rh^-
Jacob	Yes	Rh^-
Jacob's mother	Yes	Rh^-
Jacob's father	No	Rh^+

Table 1

Please note the following facts:

1. Baldness is an example of the so-called sex-influenced traits. B/B women are bald, however B/b and b/b women are not. B/B and B/b men are bald, the b/b men are not.
2. Genotype of the Rh- people is r/r and that of Rh^+ people is R/R or R/r.
3. When the fetus of an Rh^- woman is Rh^+ the woman's immune system may produce antibodies against the Rh^+ fetus during a second pregnancywhich may result in the death of the fetus. This phenomenon is known as Rh incompatibility.
4. The B (b) and the R (r) genes are autosome linked and are 20 cM apart.

Q.27.1 Determine Lily's and Jacob's genotype. Indicate your answer with an **X** in the appropriate boxes.

Q.27.2 Determine what percentage of their children will be bald. Give your answer as a whole number.

Q.27.3 What percentage of their bald children will be female? Give your answer as a whole number.

Q.27.4 What percentage of their daughters may face the problem of Rh incompatibility once they will become pregnant? Give your answer as a whole number.

Q.27.5 What percentage of the daughters with the potential to develop Rh incompatibility would also be bald?

Q28

The human genome is composed from about $3 \cdot 10^9$ base pairs. Assume that the distribution of base pairs is random. How long should a random sequence be to appear once in the human genome, on average?

Q.28.1 Indicate your answer on the answer sheet, rounded to the nearest integer.

Q29

The genetic code can be used to reverse engineer the genetic information coding for peptides of a desired amino acid sequence. Your task is to design possible nucleotide substitution mutations that change the DNA coding for the peptide that comprises the M-A-R-C-E-L-L-A amino acid sequence to a peptide whose amino acid sequence is M-A-R-C-E-L.

Q.29.1 What are the potential numbers of substitutions you would have to make to achieve the goal set out in the question? Give your answer(s) as a number(s) on the answer sheet.

Q.29.2 Fill in the cells corresponding to codon 7 with the nucleotides that code for the new M-A-R-C-E-L peptide using the minimum possible number of substitutions. If there is more than one correct option, use only one.

Q.29.3 Circle the nucleotide base(s) that had to be changed in order to turn the original peptide into the new one.

Q30

Ec+ is an X-linked gene found in a newly discovered mammalian species. Females homozygous for the mutant allele (*Ec*) have green eyes, while a single copy of *Ec*+ is sufficient to result in the wild-type brown eyes.

Ec codes for an enzyme which catalyses the chemical reaction converting an inert substrate, commonly found throughout the body, into molecule X which diffuses freely in the animal and can be detected in bodily secretions. Molecule X is a very potent epigenetic regulator such that a few particles are sufficient to induce life-long effects on the eye phenotype.

Consider the following crossing experiments. What are the genotypes and the eye colors of the progeny of animals that descend from the following crosses, and what are the proportions of the various descendants?

1. *Ec*/*Ec* females and *Ec*+/Y males
2. *Ec*+/*Ec* females and *Ec*/Y males
3. *Ec*+/*Ec* females and *Ec*+/Y males

Use ***one*** letter of each group [(A-C), (D-H), (K-L)] in one of the four boxes to indicate the (i) proportions, (ii) genotype and (iii) phenotype of different groups progeny. There should be three letters in each cell that you fill in, but note that not all cells need to be filled in. If you think a cell should remain empty, please write an "X" in it.

A. 25%

B. 50%

C. 100%

D. *Ec*+/*Ec*+ female

E. *Ec*+/*Ec* female

F. *Ec*/*Ec* female

G. *Ec*+/Y male

H. *Ec*/Y male

K. brown eyed

L. green eyed

Ecology

Q31

The smallmouth bass (*Micropterus dolomieu*) is an introduced species in the area examined in the following experiment. To protect native fish species, a smallmouth bass removal program was initiated in Little Moose Lake in 2000 (indicated by the vertical line in Fig.1). It continued until 2007. A research group examined the effect of the removal on the smallmouth bass population. They found that while the total biomass of the population decreased during the program, the population size increased. To determine the cause of this phenomenon, they subdivided the population to three groups based on the size of individuals (Fig.1): yearlings (size <100 mm, Fig.1/a), juveniles (100-200 mm, Fig.1/b) and adults (>200 mm, Fig.1/c). They collected two samples in each year (spring and fall). Their results shown in Figure 1.

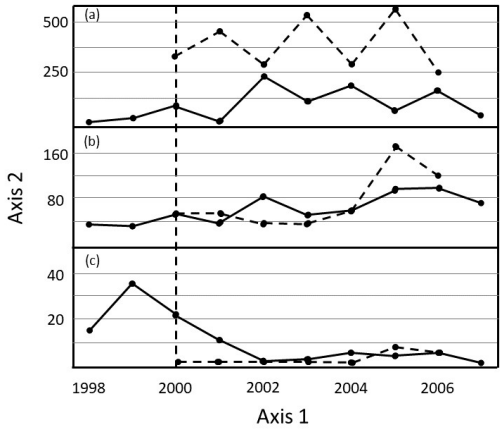


Fig.1. The change of the abundance of the subpopulations (y-axis) by time (x-axis). Solid lines = spring samplings, dashed lines = fall samplings. Axis 1 = Year. Axis 2 = Catch per unit effort (CPUE)

Which of the following models can possibly describe how the removal of individuals affected the population? Indicate with an **X** if each the following models can describe (T) or cannot describe (F) the changes.

Q.31.1 The percentage of removal was highest of adult fishes.

Q.31.2 The decrease in the abundance of the adults leads to higher per capita birth rate.

Q.31.3 The decrease in the abundance of the adults lowered the intraspecific competition, so more yearlings and juveniles could survive.

Q.31.4 The removal program was less effective at removing small fish than large fish.

Q.31.5 The size of breeding adults decreased over time due to this removal program.

Q32

The population dynamics of parasite species is complex, because the size of the parasite and the host population affect each other. One of the popular models for describing parasite population size is SIR model (Susceptible – Infected – Recovered model). The model is shown in Figure 1 with the description of the symbols below. You can get the changes in the host type numbers by multiplying the original host number with the factor above the arrow. For example, the number of hosts recovered in a given time is $\gamma \cdot I$.

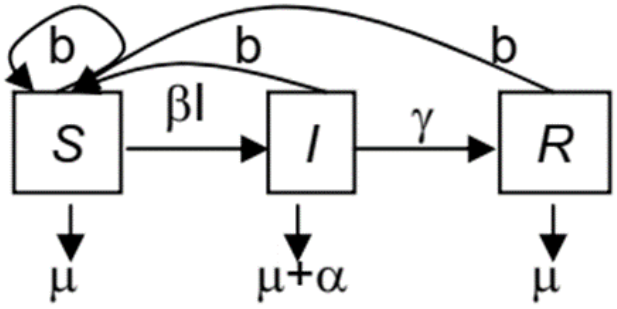


Fig. 1. The SIR model

Symbols:

S = susceptible hosts

I = infected and infectious hosts

R = recovered/immune hosts

N = total host population = S+I+R

b = per capita birth rate

β = transmission rate (contact rate*infectiousness)

μ = mortality rate without disease

α = mortality rate due to disease

γ = host recovery rate from infection

Indicate with an **X** if each the following statements are true (T) or false (F).

Q.32.1	The mortality rate of the infected hosts is higher than the others'.
Q.32.2	The average number of offspring of surviving individuals is higher for non-infected hosts than for infected ones.
Q.32.3	The parasite can be transmitted both vertically (from parent to offspring before birth) and horizontally (infection after the birth of organism).
Q.32.4	The individuals who recovered from the disease will be immune to it for the rest of their life.

Q.32.5 The number of new infections in a given time depends only on the number of susceptible hosts and is not affected by the number of infected and recovered hosts.

Q.32.6 Give the relationship between the ratio of infected (I) and the sum of susceptible (S) infected (I) individuals and the number of new infections in a given time! Draw the curve of the equation in the coordinate system in your answer sheet (Figure 2). The transmission rate (β) is constant.

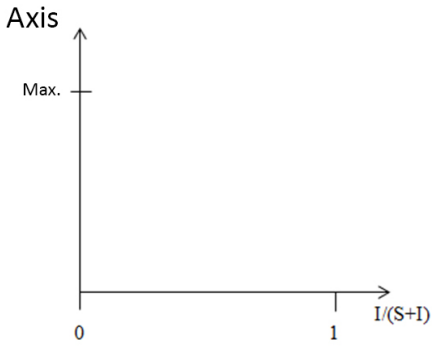


Fig. 2. The number of new infection in a given time in as the function of the ratio of infected hosts (I) to the sum of susceptible and infected hosts (S+I). Max. = the maximal value of the new infections. Axis = Number of new infections.

Many parasites cause diseases with high mortality rate (α) in spite of the death of the host being evidently disadvantageous for the parasite.

Indicate with an **X** if each the following statements are true (T) or false (F).

Q.32.7 Higher transmission rate (β) is advantageous for the parasite, but usually high infectiousness means the parasite causes more harm to the host.

Q.32.8 The bigger the mortality rate due to the disease, the bigger the ratio of the susceptible hosts in the population, which the parasites can infect, so the parasites spread easier.

Q.32.9 There may be a long incubation period after the infection, in which case the parasite has enough time to spread before the host die.

Q.32.10 The big mortality rate (α) doesn't mean problem for the parasite, if the transmission rate (β) is low.

Q.32.11 If the weakening of the host body results in a lower host recovery rate (γ), that will cause a higher mortality rate for the whole population.

Q33

The scheme below shows the model of interactions between the populations of an ecosystem. The capital letters indicate the populations. The two-ended arrows (⟷) indicate whether there are any direct interactions between the two populations. The interactions can be beneficial (+), harmful (-) or neutral (0) for each of the populations, which is indicated at the ends of the arrows.

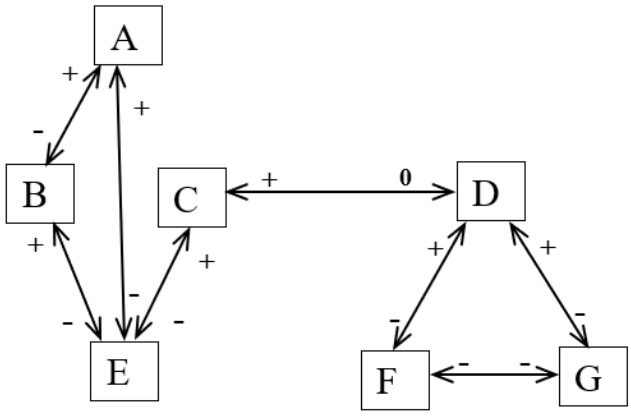


Fig.1

Determine, how the change of the size of one population affects (both directly and indirectly) the size of other populations in the ecosystem.

Indicate your answer by putting an **X** in the appropriate box on the answer sheet.

A: Increase

B: Not change

C: Decrease

D: Cannot be predicted (i.e. the change has both increasing and decreasing effect on the other population)

What will be the effect of the decrease in the size of population A on the other populations listed below?

Q.33.1 Population B

Q.33.2 Population D

Q.33.3 Population E

What will be the effect of the increase in the size of population D on the other populations listed below?

Q.33.4 Population G

Q.33.5 Population C

Q.33.6 Population A

Biosystematics

Q34

In this task you get a few parts of a phylogenetic tree of birds and you should assemble the full tree based on them.

The trees given:

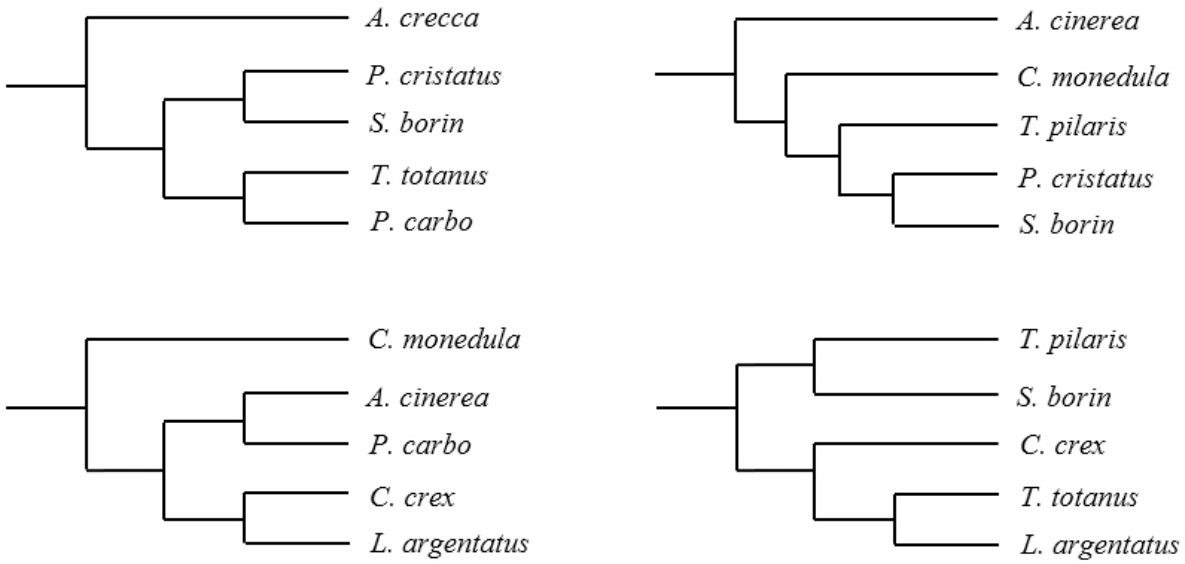


Fig.1

The species you should place in the full phylogenetic tree are indicated with letters:

A – *A. cinerea*

B – *A. crecca*

C – *C. crex*

D – *C. monedula*

E – *L. argentatus*

F – *P. carbo*

G – *P. cristatus*

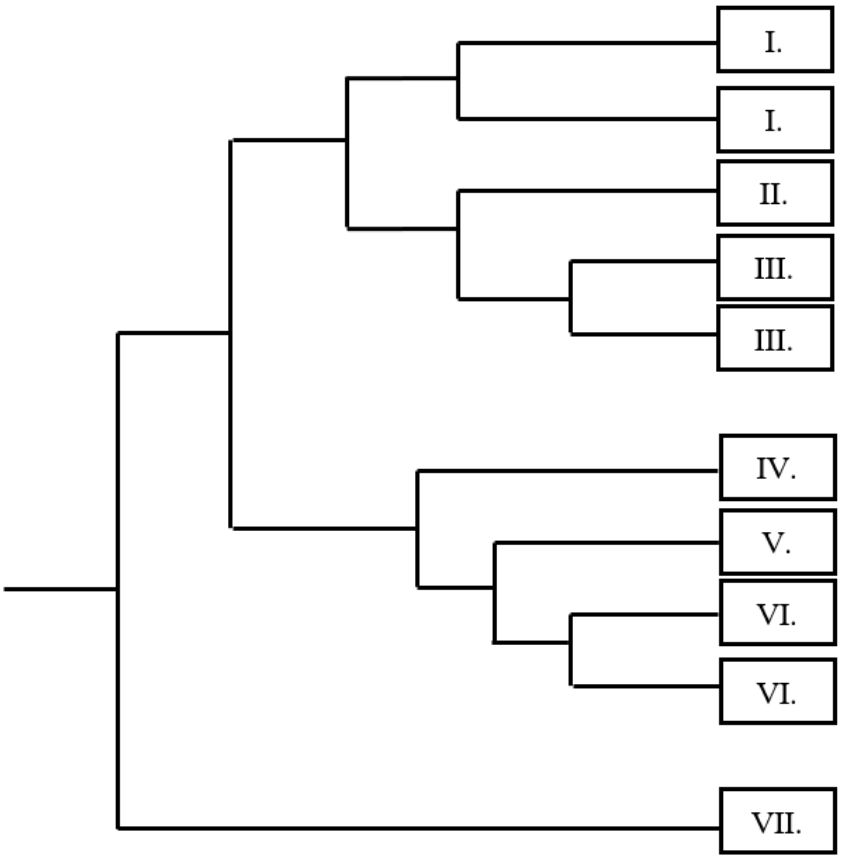
H – *S. borin*

I – *T. pilaris*

J – *T. totanus*

You should find the place of the species in the tree below. Match the letter of the species (A-J) with the roman numerals (I.-VII.) of the places in the tree. One numeral can belong to more letters.

Indicate your answer by putting an X in the appropriate box on the answer sheet.


I.
I.
II.
III.
III.
IV.
V.
VI.
VI.
VII.

Q35

A research group collected and examined gall wasp (*Cynipidae*) specimens. By examining their morphological traits they found a new genus (*Lithosaphonecrus*) with four species (*L. formosanus, L. huisuni, L. dakengi* and *L. yunnani*). To confirm these results, and determine their phylogenetic relationship to other closely related gall wasp species, they compared the sequence of two DNA fragment (COI and 28S D2) of each species. They calculated the pairwise distance (p-distance) between each species (Table 1.). The p-distance of two species is the number of nucleotide sites at which homologous sequences of the two species are different, divided by the total number of nucleotides compared.

	L. yunnani	*L. dakengi*	*L. formosanus*	*Sapho. shirakashii*	*Sapho. undulates*	*Sapho. gallaepo-miformis*	*Sapho. conatus*	*Ufo nipponicus*
COI								
L. huisuni	0.0770	0.1478	0.1289	0.1619	0.1588	0.1525	0.1619	0.1525
L. yunnani	0	0.1305	0.1085	0.1745	0.1572	0.1447	0.1541	0.1399
L. dakengi		0	0.1242	0.1950	0.1792	0.1855	0.1824	0.1777
L. formosanus			0	0.1792	0.1557	0.1588	0.1682	0.1557
28S D2								
L. huisuni	0.0041	0.0081	0.0183	0.0568	0.0487	0.0507	0.0507	0.0487
L. yunnani	0	0.0122	0.0223	0.0568	0.0527	0.0507	0.0507	0.0487
L. dakengi		0	0.0142	0.0629	0.0548	0.0527	0.0527	0.0548
L. formosanus			0	0.0669	0.0588	0.0568	0.0568	0.0588

Table 1. p-distances among the two sequence (COI and 28S D2) of the species.

Indicate with an **X** if each the following statements are true (T) or false (F).

Q.35.1 The *L. huisuni* and the *L. yunnani* are the two most closely related species in the genus.

Q.35.2 Phylogenetically *Ufo nipponicus* is more closely related to the *L. yunnani* than to the *L. dakengi.*

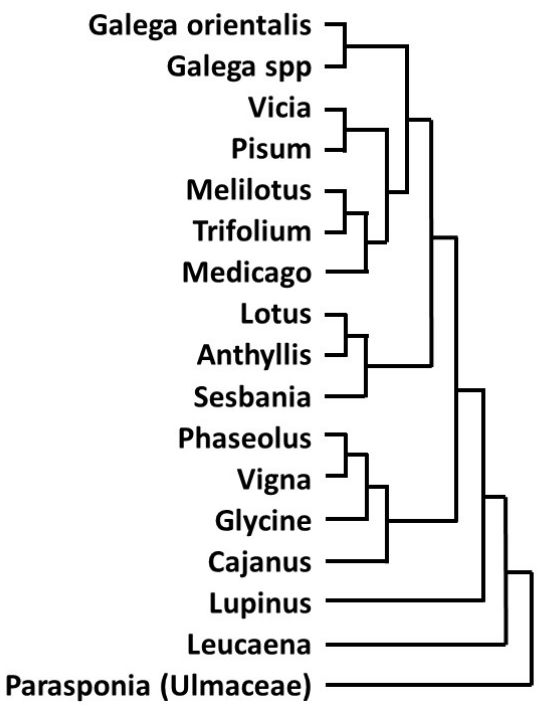
Q.35.3 The differences between the results obtained for the two sequences (COI and 28S D2) means an error has occurred during the sequencing of the DNAs.

Q.35.4 The COI region is more useful in research of phylogenetic relationship between more distantly related species, than 28S D2.

Q36

One of the main purposes of phylogenetics is to construct trees which represent the evolutionary relationship of the taxa. A major challenge is to combine the results from independent researchers in this field.

You can see two phylogenetic trees of legume genuses below from two independent research groups (Fig 1. and 2.).



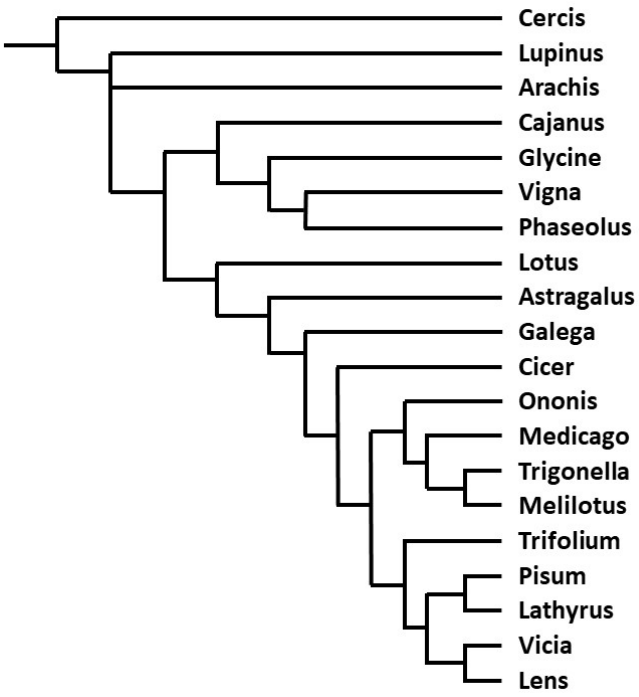


Fig 1. & Fig.2. Phylogenetic trees of legume genera.

Q.36.1 Is there any genus with conflicting results from the phylogenetic trees above?
Indicate the correct answer (A-E) with an **X** in your answer sheet.
A. No, there isn't.
B. Yes, the genus *Galega*.
C. Yes, the genus *Lotus*.
D. Yes, the genus *Trifolium*.
E. Yes, the genus *Vigna*.

Q.36.2 This is the combined tree from the two trees above. Some missing genera are indicated with letters (A, B, etc.). Your task is to find which genus belongs to which letter. Indicate the appropriate genus with an X in your answer sheet. It's possible that a letter can symbolize more than one genus. If a genus doesn't occur in the tree, you should indicate that by putting an **X** in column Q.

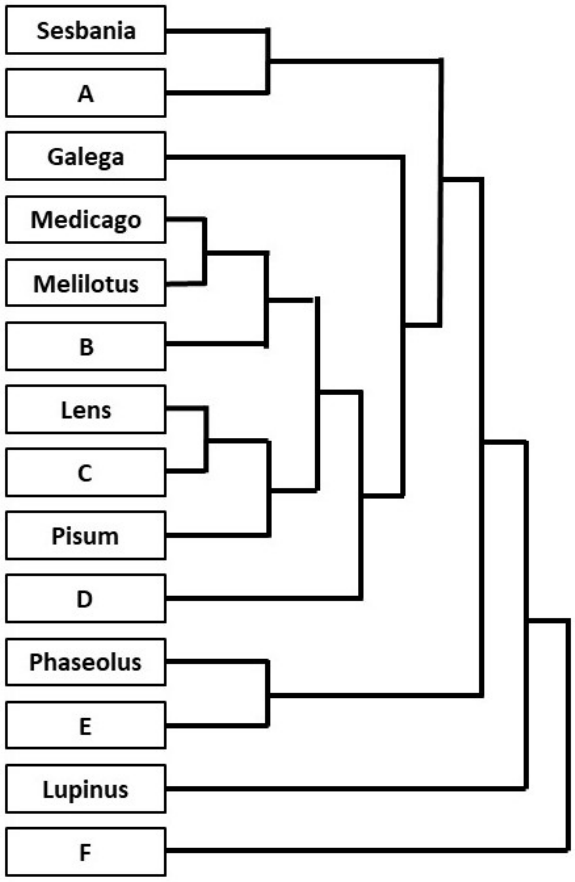


Fig.3

Ethology

Q37

Twenty-eight rare and protected species of bat live in Hungary. Bats sense their environments using echolocation, which is disrupted by different surfaces. A smooth metal plate was attached to the wall as shown in Figure 1. The bats were recorded attempting to drink from, or colliding with, the floor, walls or the plate on the wall.

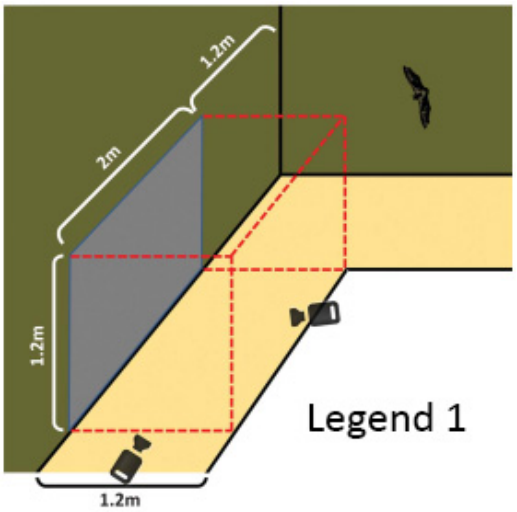


Fig.1. Legend 1 = High-speed cameras

In a second a experiment, the metal plate was instead placed on the floor, and the bats were recorded attempting to drink from, or colliding with the wall, floor or the plate on the floor.

The reaction of bats to different surfaces shown in Fig. 2.

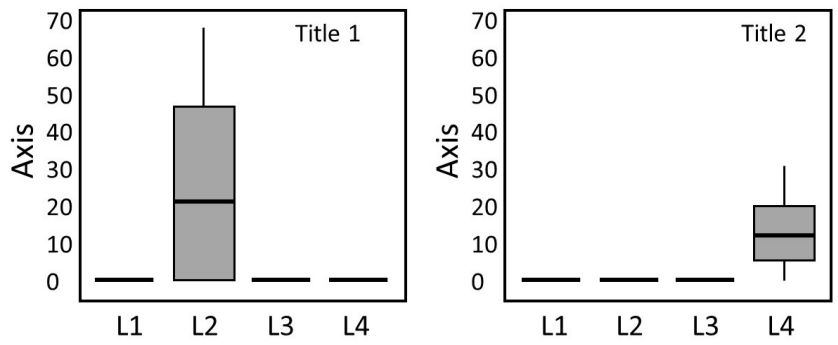


Fig. 2. Percentage of drinking attempts and collision events in box plots. Values were calculated per individual relative to its total number of passes through the corridor. Title 1 = Horizontally placed metal plate. Title 2 = Vertically placed metal plate. Axis = Percentage of occurrence. L1 = drink from ground. L2 = drink from plate. L3 = collision with wall. L4 = collision with plate

Why do bats react differently to smooth surfaces than to others? indicate with an X if each of the following statements is true (T) or false (F).

Q.37.1 The smooth metal plate/surface absorb more sound than the rough ones.

Q.37.2 The smooth metal plate/surface only reflect sound back to the bat if the sound reaches the surface perpendicularly.

Q.37.3 The vertical smooth metal plate/surface reflects sound in a way that attracts the bats.

Q.37.4 The bat can only detect a small part of a smooth surface.

Why do bats react differently to vertical and horizontal smooth surfaces? Indicate with an X if each of the following statements is true (T) or false (F).

Q.37.5 The sound reflected from a horizontal versus vertical smooth surface is different.

Q.37.6 The bats' reaction is different because in nature bats usually only meet with horizontal smooth surfaces.

Q.37.7 Bats use their sense of gravity to help them recognise water.

Q.37.8 The bats collided with vertical smooth surfaces because they sensed it as open space.

Q38

The following experiment was used to determine whether Pharaoh ants (*Monomorium pharoaonis*) use attractive or repulsive chemical signals to sign their foraging routes. The researchers used two ant colonies in the experiment (Fig.1).

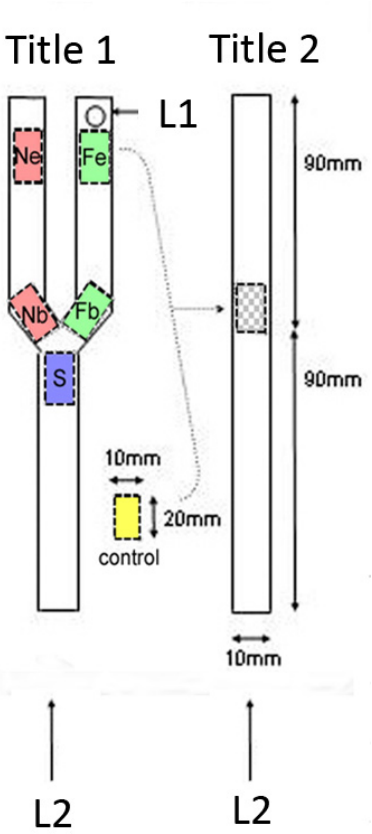


Fig.1. Experimental setup. Title 1 = Trail sections. Title 2 = Test position of section. L1 = feeder. L2 = From nest

The first colony was used as trail-laying colony in a paper Y-bifurcation apparatus (left side), where they were able to leave pheromon trails. The researchers put a feeder with sucrose in the end of one branch (feeder branch) and left the other branch's end empty (non-feeder branch). After foraging, they removed five sections (S, F_b, N_b, F_e, N_e) and a control from the apparatus and put them alternately in different unbranched apparatuses (right side). The following sections were used:

- S: 1 mm before bifurcation
- F_b: 3 mm after bifurcation in the feeder branch
- N_b: 3 mm after bifurcation in the non-feeder branch
- F_e: 60 mm after bifurcation in the feeder branch
- N_e: 60 mm after bifurcation in the non-feeder branch
- Control: no ant trail pheromones used

The researchers tested sections with 50 ants from another colony. They checked, how many times the ant made U-turns in each case. The number of U-turns compared to the control is shown in Fig.2.

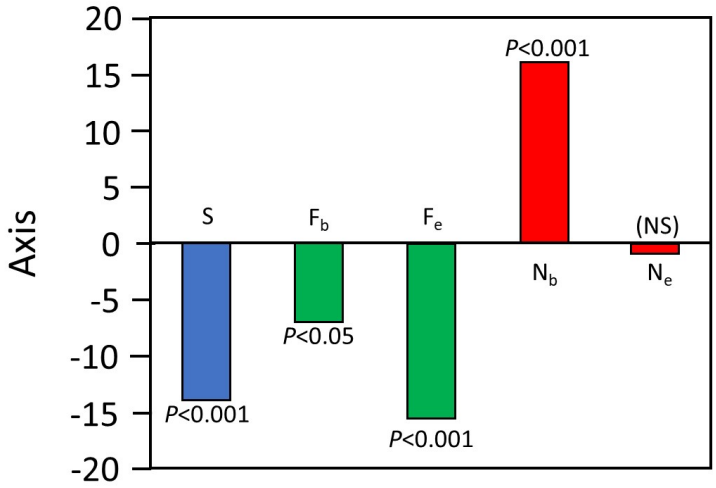


Fig.2. The result of the experiment. The number of U-turns compared to control. P<0.001 and P<0.05 indicates the significance level of the difference compared to control. (The lower the value, the stronger the significance.) NS means no significant difference compared to control. Axis = Number U-turns ants made relative to control

Q.38.1 Based on the **significant** results of the experiment, determine which type of pheromone the ants used in each of the five sections. Indicate your answer by putting an **X** in the appropriate box on the answer sheet.

- A – attractant pheromone
- R – repellent pheromone
- Q – no trail pheromone used