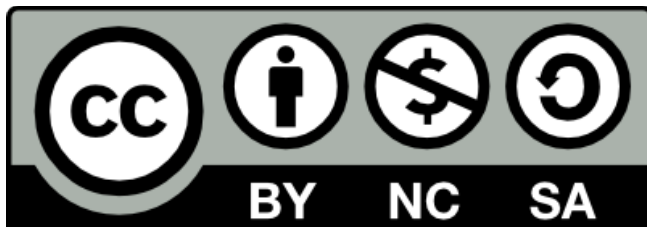




International Biology Olympiad e.V.

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THEORETICAL EXAM 1

OVERVIEW

This exam lasts three hours

- Q 1-13 Animal biology
- Q 14-15 Biosystematics
- Q 16-24 Cell biology
- Q 25-30 Ecology
- Q 31-33 Ethology
- Q 34-43 Genetics & Evolution
- Q 44-50 Plant biology

Each correctly answered question gives you 1 point, i.e. all four statements are correct.

If only three statements in a question are correct, you get 0.6 points

If only two statements in a question are correct you get 0.2

If only one statement in a question is correct you get 0.0

If no statements in a question is correct, you do not get any points.

 | Q. 1

In mammals, a high blood pressure is needed to achieve a high blood flow (cardiac fluid flow) and to overcome any vascular resistance against the flow of blood. In order to make deductions about blood flow, Poiseuille's Law is used (Fig.).

$$Q = \frac{\Delta V}{\Delta t} = \frac{\Delta p \pi r^4}{8 \eta L}$$

$$\Delta p = R \Delta V$$

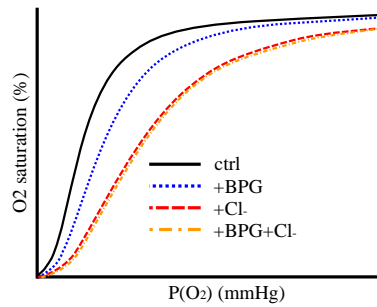
Poiseuille's Law: Q = fluid flow, V = volume, t = time, p = pressure, r = vessel radius, η = viscosity (constant for a given temperature and fluid type), L = vessel length, and R = flow resistance.

Indicate if each of the following statements is true or false.

	TRUE	FALSE
Assuming similar blood flow in a wide and a narrow artery of the same length, the change in mean blood pressure is greater in the former	<input type="radio"/>	<input type="radio"/>
Increased atherosclerosis leads generally to faster blood flow in the circulation	<input type="radio"/>	<input type="radio"/>
Comparing monozygotic twins, one living at sea level and the other at 3,000 m, the latter will have a higher resistance to blood flow	<input type="radio"/>	<input type="radio"/>
In a specific patient suffering from atherosclerosis, the radius of blood vessels on average had decreased by 1/6, which caused blood pressure to double to maintain the blood flow	<input type="radio"/>	<input type="radio"/>

Q. 2

O₂-binding or -affinity to hemoglobin is affected by specific anions, in particular 2,3 bisphosphoglycerate (BPG) and chloride (Cl⁻), which are present in red blood cells and bind to the hemoglobin molecule at specific sites (Fig.).



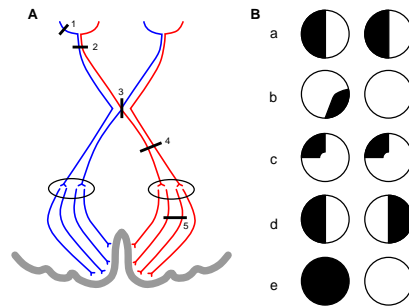
Hemoglobin saturation curves for hemoglobin without anions (ctrl) and with BPG, chloride or both, as a function of the partial pressure of oxygen in the blood.

Indicate if each of the following statements is true or false.

- | | TRUE | FALSE |
|---|-----------------------|-----------------------|
| If peripheral tissue lacks oxygen, red blood cells produce more BPG | <input type="radio"/> | <input type="radio"/> |
| At high altitudes, mutations leading to changes from polar to non-polar amino acid residues in the BPG binding site of the hemoglobin molecule will be favourable for the affinity of O ₂ to hemoglobin in the lungs | <input type="radio"/> | <input type="radio"/> |
| It is likely that chloride and BPG bind at different sites in the hemoglobin molecule | <input type="radio"/> | <input type="radio"/> |
| BPG decreases the total oxygen saturation capacity of the hemoglobin | <input type="radio"/> | <input type="radio"/> |

Q. 3

In humans, lesions in the central visual pathways may have different consequences to the visual field (Fig.).



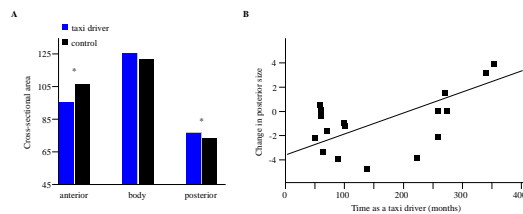
A, lesions (1-5) in the central visual pathways (seen from above); B, visual field deficits (a-e, deficits shown in black, as seen by the affected person) caused by lesions in A.

Indicate if each of the following statements is true or false.

	TRUE	FALSE
Lesion 2 corresponds to visual field deficit a	<input type="radio"/>	<input type="radio"/>
Lesion 3 corresponds to visual field deficit d	<input type="radio"/>	<input type="radio"/>
Lesion 4 corresponds to visual field deficit e	<input type="radio"/>	<input type="radio"/>
Lesion 5 corresponds to visual field deficit c	<input type="radio"/>	<input type="radio"/>

Q. 4

The 2014 Nobel Prize winners in medicine demonstrated that, the hippocampal (HC) region in the human brain stores spatial memory and facilitates spatial orientation. People using space extensively such as taxi drivers may depend on a well-developed HC. A study focused upon differences in HC between London taxi drivers and a control group, and its results are shown in Figs A-B.



A, variation between taxi drivers and others in size of the entire hippocampus (HC, body) and its anterior and posterior parts separately (*, significantly different); B, correlation between volume change (grey matter) of posterior part of HC and employment time as taxi driver (from Maguire et al. 2000).

Indicate if each of the following statements is true or false.

	TRUE	FALSE
Taxi drivers have significantly larger hippocampus than the control group	<input type="radio"/>	<input type="radio"/>
Spatial navigation may be located in the posterior part of hippocampus	<input type="radio"/>	<input type="radio"/>
The study provides evidence that some people are predisposed genetically to become better London taxi drivers than others in the population	<input type="radio"/>	<input type="radio"/>
The study supports the traditional view that the hippocampus is only involved in short-term memory	<input type="radio"/>	<input type="radio"/>

 | Q. 5

In a study on kidney function, several parameters were measured in three healthy persons A–C (Table).

Parameter values describing kidney functions. Assume that 1 millimol O_2 has a volume of 22.4 ml (milli-litre).

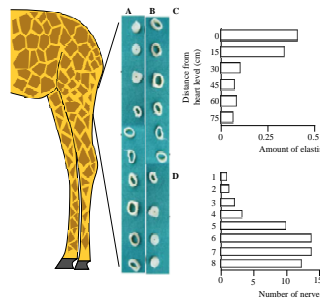
	Person A	Person B	Person C
Glomerular filtration rate (GFR), ml/min	135	140	135
Renal blood flow (RBF), ml/min	1190	1240	1210
Urine production, ml/min	1.0	1.1	0.9
O_2 concentration in arterial blood, ml/L	200	200	199
O_2 concentration in venous blood from the kidneys, ml/L	184	186	184
Na^+ concentration in plasma, mmol/L	137	136	139
Na^+ concentration in urine, mmol/L	121	120	119

Indicate if each of the following statements is true or false.

- | | TRUE | FALSE |
|---|-----------------------|-----------------------|
| The amount of Na^+ filtrated in the kidneys is largest for person A | <input type="radio"/> | <input type="radio"/> |
| The amount of Na^+ excreted in the kidneys is largest for person B | <input type="radio"/> | <input type="radio"/> |
| Renal oxygen consumption is largest for person C | <input type="radio"/> | <input type="radio"/> |
| The amount of Na^+ reabsorbed per mol of O_2 used is largest for person B | <input type="radio"/> | <input type="radio"/> |

Q. 6

The giraffe has the highest mean arterial blood pressure of any mammal. This renders it vulnerable to leg oedema. How the animal prevents this was studied with a focus on vascular adaptations in the leg (Fig.).



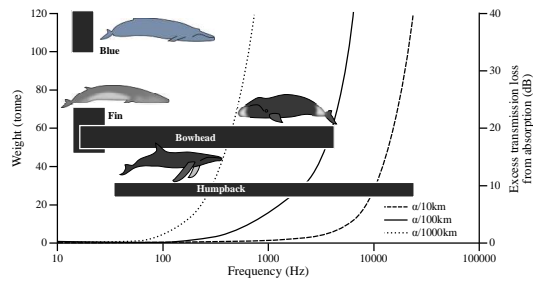
A-B, a series of cross-sections of leg arteries (a true and a false option); C, amount of elastin in arterial walls at increasing distance from the heart; D, number of nerves along arteries in the legs (bars 1-4: 15-30 cm from heart, bars 5-8: ≥ 30 cm from heart) (from Petersen et al. 2013, Østergaard et al. 2011).

Indicate if each of the following statements is true or false.

	TRUE	FALSE
Since arterial pressure at entrance to skull has to be similar to other mammals (c. 100 mm Hg), blood pressure down at the level of the hooves becomes very low	<input type="radio"/>	<input type="radio"/>
The figures show how the diameter and wall thickness of arteries in the leg are expected to change; A is correct and B is wrong	<input type="radio"/>	<input type="radio"/>
Femoral arteries become more rigid distally toward the leg extremities	<input type="radio"/>	<input type="radio"/>
The giraffe has a special arterial mechanism above its knees to regulate blood pressure in the leg extremities	<input type="radio"/>	<input type="radio"/>

Q.7

Whales rely on sound for communication in a diverse way. In a study, vocalization measurements of two distantly related whales, Humpback and Bowhead, were compared to literature data from two other species (Fig.).



Frequency bands of vocalizations (horizontal bars) and range of body mass for 4 whale species together with the transmission loss from sound absorption in seawater at 10, 100 and 1000 km from source (from Tervo et al. 2012).

Indicate if each of the following statements is true or false.

- | | TRUE | FALSE |
|---|-----------------------|-----------------------|
| Larger whales are expected to produce lower frequency signals than smaller whales do | <input type="radio"/> | <input type="radio"/> |
| Based on vocalizations, the Blue whale is expected to have more complex social behaviour than the Humpback. | <input type="radio"/> | <input type="radio"/> |
| Humpback and Bowhead have a signalling frequency that makes it possible for them to have high inter-annual mating site-fidelity | <input type="radio"/> | <input type="radio"/> |
| The similar vocalization patterns of Humpback and Bowhead whales are most likely due to convergent evolution | <input type="radio"/> | <input type="radio"/> |



Q. 8

The coldwater Goldfish have a high tolerance to anoxia. They can degrade carbohydrates to lactate and further reduce lactate to ethanol. In a study running for 12 hours with two groups of goldfish, data on these processes were gathered (Table).

Concentration of lactate and ethanol in fish tissue, and compared with levels in the water of the aquarium, measured in terms of fish mass (kg) (from Shoubridge & Hochachka 1980).

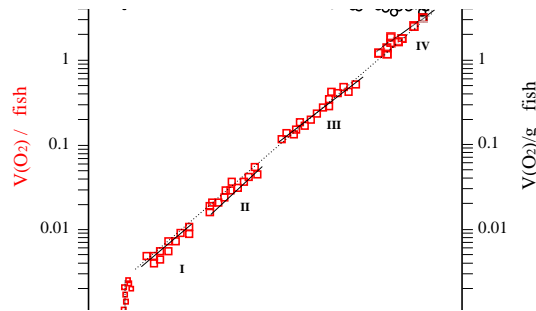
	Fish tissue	Fish tissue	Water in aquarium	Water in aquarium
	Lactate mmol/kg	Ethanol mmol/kg	Lactate mmol/kg	Ethanol mmol/kg
Control: + O ₂	0.18	0.00	0.00	0.00
Treatment: no O ₂	5.81	4.58	0.00	6.63

Indicate if each of the following statements is true or false.

- | | TRUE | FALSE |
|---|-----------------------|-----------------------|
| During the study, lactate accumulation in fish tissue amounts to about half of the total ethanol produced | <input type="radio"/> | <input type="radio"/> |
| Goldfish are able to survive long periods under ice cover | <input type="radio"/> | <input type="radio"/> |
| Goldfish have no tolerance to ethanol | <input type="radio"/> | <input type="radio"/> |
| Transformation of lactate to ethanol may be a means of avoiding acidosis | <input type="radio"/> | <input type="radio"/> |

Q. 9

Size-scaling metabolism is of general importance in biology, i.e. relating metabolic processes to body mass. In a study, the metabolic rate of the fish Japanese Flounder was measured during its early life stages (Fig.).



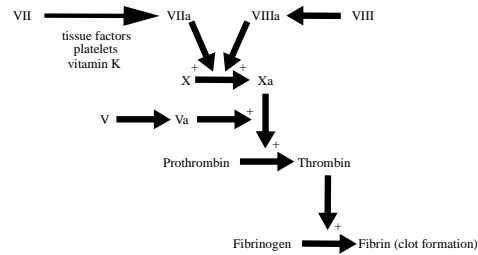
Ontogenetic changes in rate of respiration (V_{O_2} , squares, left Y-axis) and mass-specific rate of respiration (V_{O_2}/M , circles, right Y-axis) with increase in body mass M . Four early life stages (I-IV) from hatching were measured (from Yagi & Oikawa 2014).

Indicate if each of the following statements is true or false.

- | | TRUE | FALSE |
|---|-----------------------|-----------------------|
| Just after hatching, respiration increases without any increase in M | <input type="radio"/> | <input type="radio"/> |
| For a given unit of body mass, the rate of respiration seems to increase with the age of fish | <input type="radio"/> | <input type="radio"/> |
| The general equation for the lower curve in the figure is $V_{O_2}=aM^b$ (a : scaling parameter; b : scaling exponent) | <input type="radio"/> | <input type="radio"/> |
| In the log-log plot there is a continuous linear increase in V_{O_2} over 4 orders of magnitude of body mass | <input type="radio"/> | <input type="radio"/> |

Q. 10

In a classic experiment (1935) by the Danish Nobel laureate H. Dam, chickens that were fed a lipid-depleted diet developed hemorrhage and started bleeding within a couple of weeks, because their uptake of vitamin K was inhibited. The bleeding may be stopped by adding vitamin K to the food (Fig.).



The blood coagulation cascade. Several of the pathways involved in coagulation are omitted for reasons of simplification. +, positive regulation; a, active form of compound.

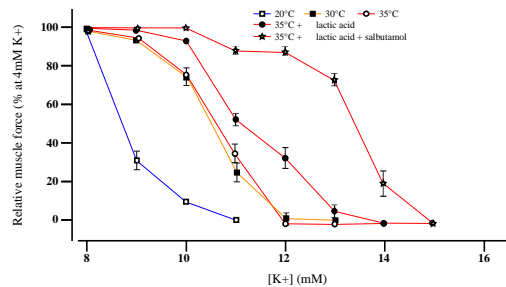
Indicate if each of the following statements is true or false.

	TRUE	FALSE
A mutation called Factor V Leiden causes patients to produce a highly active form of factor V (Va in Fig.), therefore there is an increased risk of embolism	<input type="radio"/>	<input type="radio"/>
Bone-marrow insufficiency leads to increased coagulation	<input type="radio"/>	<input type="radio"/>
A lipid-rich diet may promote coagulation	<input type="radio"/>	<input type="radio"/>
People, suffering from a high risk of embolism, may be treated with heparin (antithrombin activator)	<input type="radio"/>	<input type="radio"/>



Q. 11

Muscle fatigue during work results in increasing extracellular concentration of K^+ . This may be modified by changes in physiological temperature and lactic acid level, and can be treated medically with the drug salbutamol. This was studied experimentally with rat muscles stimulated electrically once every 20 minutes (Fig.).



Effect of warm-up at 20°C, 30°C and 35°C before work or addition of lactic acid or a combination of lactic acid and salbutamol at 35°C on the change in muscle force (as percent of force at 4 mM $[K^+]$) (from Pedersen et al. 2003).

Indicate if each of the following statements is true or false.

	TRUE	FALSE
During work, contracting muscles lose K^+ , leading to increased extracellular $[K^+]$	<input type="radio"/>	<input type="radio"/>
Temperature increase, and addition of lactic acid and drug operate mainly additively	<input type="radio"/>	<input type="radio"/>
The study design is incomplete	<input type="radio"/>	<input type="radio"/>
At physiological temperature (here 35°C), lactic acid protects completely against muscle fatigue	<input type="radio"/>	<input type="radio"/>

 | Q. 12

Four groups (A-D), each of 12 diabetic rats, received different diets for four weeks (Table). Researchers wanted to see if a traditional anti-diabetic plant (containing stevioside) had any effect.

Four diets (A-D) and measurements of parameters related to diet. BW, body weight. If figures are different, they are here assumed to be significantly so (from Jeppesen et al. 2006).

Concentration, blood pressure or body weight	Group A: Chow = Standard carbohydrate-rich diet	Group B: Chow + SVS (SVS = 0.03 stevioside g/(kg BW day))	Group C: 20% Chow + 80% SPI (SPI = Soy bean Protein Isolate)	Group D: 20% Chow + 80% SPI + SVS (SPI = Soy bean Protein Isolate + SVS = 0.03 stevioside g/(kg BW day))
Fasting blood glucose (mmol/L)	3.4	3.4	3.4	3.4
Plasma glucose (mmol/L) after 240 min	991	757	819	439
Plasma insulin (ng/mL) after 30 min	11	19	9	24
Plasma insulin (ng/mL) after 240 min	316	375	218	249
Plasma glucagon (pg/ml) after 240 min	21918	17024	26200	17529
Total cholesterol (mmol/L)	2.5	2.3	2.1	1.8

Systolic blood pressure at start (mm Hg)	175	171	165	170
Systolic blood pressure after 4 weeks (mm Hg)	178	148	173	155
BW (g)	226	221	222	204

Indicate if each of the following statements is true or false.

- | | TRUE | FALSE |
|--|-----------------------|-----------------------|
| A pure chow diet is not recommended for diabetic rats as it increases cholesterol level and blood pressure | <input type="radio"/> | <input type="radio"/> |
| SVS and SPI seem to have a synergetic effect | <input type="radio"/> | <input type="radio"/> |
| Stevioside is harmful to diabetics | <input type="radio"/> | <input type="radio"/> |
| When fasting, blood glucose results show that there is no statistical difference between the four groups of rats | <input type="radio"/> | <input type="radio"/> |

Q. 13

Strategies for regulating body temperature include controlling the movement of blood between the body core and surface and by countercurrent heat exchangers (Fig.).

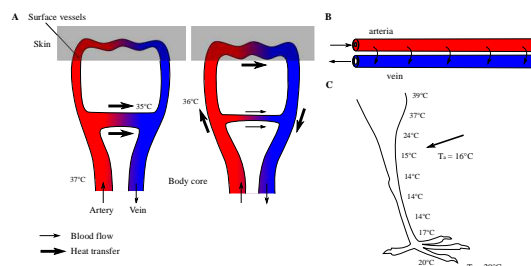


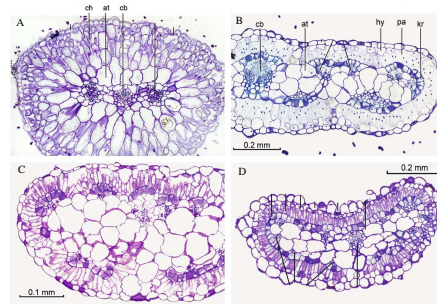
Figure. A, Regulation of heat conductance at body surface; B, thermal countercurrent system; C, body temperature in a bird limb. T_a = ambient temperature. T_f = floor temperature. (from Willmer et al. 2005).

Indicate if each of the following statements is true or false.

- | | TRUE | FALSE |
|--|-----------------------|-----------------------|
| In Fig. A, the shunt vessel to the left is exposed to a lower exterior temperature than the one to the right | <input type="radio"/> | <input type="radio"/> |
| In Fig. B, a countercurrent system often seen in animals from warm habitats is shown | <input type="radio"/> | <input type="radio"/> |
| The animal in Fig. C lives in a warm habitat | <input type="radio"/> | <input type="radio"/> |
| In Fig. C, the venous blood at the arrow has a temperature between 14-15°C | <input type="radio"/> | <input type="radio"/> |

Q. 14

Among plant families, grasses and Chenopodiaceae contain many species using the C₄ photosynthesis pathway, and many C₄ species have evolved independently from C₃ ancestors within these families. The figures show cross-sections of C₃ and C₄ leaf types from different species.



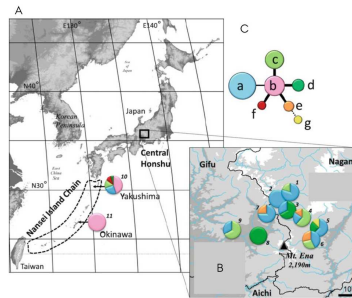
Cross section of leaves from: A, C₃ species; B, C₄ species; C–D, C₃ or C₄ species. ch = chlorenchyma; at = aqueous tissue; cb = central vascular bundle; hy = hypodermis; pa = palisade cells or mesophyll cells; kr = Kranz cells or bundle-sheath cells (from Freitag & Kadereit 2014).

Indicate if each of the following statements is true or false.

	TRUE	FALSE
Evolution of C ₄ species is favoured in a climate of increasing drought, salinity and heat, but with no change in CO ₂ level	<input type="radio"/>	<input type="radio"/>
Leaf in Fig. C is from a C ₃ plant	<input type="radio"/>	<input type="radio"/>
Leaf in Fig. D is from a C ₃ plant	<input type="radio"/>	<input type="radio"/>
During a period of global CO ₂ increase, without a concomitant increase in temperature, the global distribution of C ₄ plants is likely to expand	<input type="radio"/>	<input type="radio"/>

Q. 15

Genetic variation in three chloroplast DNA (cpDNA) regions was studied in populations of a rare orchid *Vexillabium yakushimense*. Material from nine populations on Honshu and two populations on the Japanese Nansei Islands (Yakushima and Okinawa) were sampled (Fig.).



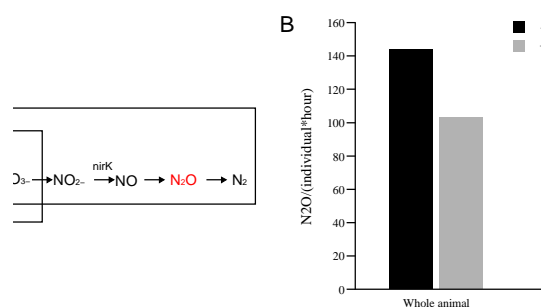
A–B, geographic distribution of 7 cpDNA haplotypes of *V. yakushimense*. Pies are populations, and each colour indicates a haplotype. The size of each coloured slice shows proportion of each haplotype in the population; C, parsimony network: circles a to g are seven different haplotypes in the 11 populations. Circle size indicates frequency of each haplotype. Linked haplotypes differ by only 1–2 mutations (from Saeki et al. 2014).

Indicate if each of the following statements is true or false.

	TRUE	FALSE
The origin of the orchid in Japan might be mainland Honshu because of the high genetic diversity observed here	<input type="radio"/>	<input type="radio"/>
It is likely that a founder effect can be seen in Okinawa	<input type="radio"/>	<input type="radio"/>
CpDNA is better than nuclear DNA in revealing maternal origins of individuals	<input type="radio"/>	<input type="radio"/>
The study suggests that mountains and river basins are more effective barriers to gene flow than the sea separating islands	<input type="radio"/>	<input type="radio"/>

Q. 16

Nitrous oxide (N_2O) is a greenhouse gas, produced by bacteria through either nitrification or denitrification (Fig. A). Many aquatic invertebrates (e.g. zebra mussel) emit N_2O , due to the activity of bacteria in their gut and the biofilm covering their shell (Fig. B, Table).



A, pathways for N_2O production in bacteria, with key genes *amoA* (encoding ammonia monooxygenase AMO, nitrification) and *nirK* (encoding nitrite reductase NIR, denitrification); B, N_2O emission from living zebra mussels and shells dissected from living animals, incubated with (+ATU) or without (-ATU) allylthiourea, which is a specific inhibitor of nitrification (from Svenningsen et al. 2012).

Expression sites of key genes for N_2O production in zebra mussels. *amoA* produces the enzyme AMO, which catalyses nitrification; *nirK* produces the enzyme NIR, which reduces nitrite.

Material	Expression of	Expression of
	<i>amoA</i> (cDNA copies/mg)	<i>nirK</i> (cDNA copies/mg)
Gut	-	205-1585
Shell biofilm	200-2000	-

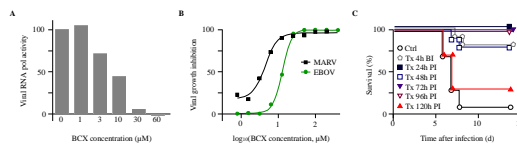
Indicate if each of the following statements is true or false.

- | | TRUE | FALSE |
|---|-----------------------|-----------------------|
| Most N_2O in zebra mussel is produced by bacteria inside the animal (e.g. in gut) | <input type="radio"/> | <input type="radio"/> |
| The N_2O production from mussel shells is mostly due to nitrification in their biofilm | <input type="radio"/> | <input type="radio"/> |
| Nitrification and denitrification are equally important for N_2O emission from mussels | <input type="radio"/> | <input type="radio"/> |
| Increasing nitrate (NO_3^-) concentrations in lakes (e.g. from agricultural run-off) will increase N_2O emissions from freshwater invertebrates | <input type="radio"/> | <input type="radio"/> |



Q. 17

Filoviruses, e.g. Ebola (EBOV) and Marburg (MAR), cause haemorrhagic fever. Case fatality rates are >90%, and among the highest reported for any human pathogen. Vaccine or therapeutic products are not available. Recently, however, researchers tested an adenosine analogue, BCX, which seemed to improve survival of filovirus-infected humans (Fig.).



A, effect of BCX on viral RNA polymerase activity; B, inhibition of EBOV and MAR growth in infected stem cells treated with BCX; C, survival of infected mice after BCX treatments (Tx) administered up to 14 days, beginning either before infection (BI) or post-infection (PI) at varying delays (from Warren et al. 2014).

Indicate if each of the following statements is true or false.

TRUE FALSE

As an adenosine analogue, BCX affects viral gene transcription

 TRUE FALSE

BCX is applicable exclusively against ebola

 TRUE FALSE

BCX can successfully (>50% survival) be administered up to 10 days after Ebola infection

 TRUE FALSE

The half-maximal inhibition of BCX is achieved at a concentration of about 10 µM

 TRUE FALSE

Q. 18

Botanists may identify plants to family using diagrams, showing the different floral parts (Fig. A). According to the ABC gene model, development of a flower is based on expression of the A-, class-B- and C-genes. In dicots, sepals develop if gene-A is expressed alone, petals develop if both gene-A and gene-class-B are expressed, stamens develop if both gene-class-B and gene-C are expressed, and an ovary develops if only gene-C is expressed.



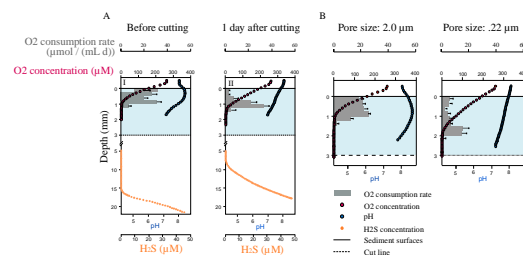
A, diagram of a monocot flower; B, tulip flower (a monocot), parts of the flower are removed in photo to the right; C, the ABC gene model of monocot flower development (I, ovary; II, stamens; III, petals; IV, sepals; the latter two are similar in most monocots). Gene-class-B consists of 3 genes B1-B3 (from Johansen et al. 2006).

Indicate if each of the following statements is true or false.

	TRUE	FALSE
Tulips do not have any sepals	<input type="radio"/>	<input type="radio"/>
Gene-C has different expression in monocots and dicots	<input type="radio"/>	<input type="radio"/>
Selective suppression of gene C-expression in region II leads to development of unisexual flower	<input type="radio"/>	<input type="radio"/>
Complete development of stamens in the tulip requires the expression of gene-B1+gene-B3+gene-C	<input type="radio"/>	<input type="radio"/>

Q. 19

In the sea, O_2 diffuses from the free water down into the top oxic layer in the sediment and here becomes reduced to water. Anoxic layers are beneath this layer, and here bacteria-mediated processes take place. One process is the oxidation of H_2S to SO_4^{2-} , which is tightly coupled to the O_2 -reduction in the oxic layer above. This coupling between oxic and anoxic processes can only be explained by “electric currents” transporting electrons from H_2S oxidation to O_2 reduction. In experiments, attempts were made to identify the electron conductor (Fig.).



In an experimental set-up, upper oxic (< 3 mm, blue area) and lower anoxic sediment layer (> 3 mm) were: A, physically cut apart by a thin “knife” (before: left diagram, and after: right diagram); B, the two layers were separated by filters with pores of two sizes (lower horizontal line) (from Pfeiffer et al. 2012). O_2 concentration (red curve), O_2 consumption rate (O_2 c.r., grey-coloured histogram), pH (blue), H_2S (orange line) and sediment surface (upper grey line at value 0) are shown (after Pfeiffer et al. 2012)

Indicate if each of the following statements is true or false.

	TRUE	FALSE
The pH peak in the oxic layer is due to production of water from oxygen	<input type="radio"/>	<input type="radio"/>
Physically interrupting the sediment by the “knife” did not affect O_2 reduction	<input type="radio"/>	<input type="radio"/>
The filters demonstrated that any specific solutes were not transporting the electrons	<input type="radio"/>	<input type="radio"/>
Electrons for the O_2 -reduction most likely came from donors in the oxic layer	<input type="radio"/>	<input type="radio"/>

 | Q. 20

In an experiment, two bacterial strains, I and II, were allowed to conjugate. Strain I contained genes allowing it to grow on media lacking arginine and uracil, and with galactose as its sole carbon source, and even in the presence of the antibiotic Kanamycin (+KM). Strain II could not grow on these media. After a certain incubation time, Strain II was grown on selective media until 100 isolated colonies were obtained. The success of conjugation was assessed (Tab.).

Table. Success of growth of Strain II in (%) after conjugation.

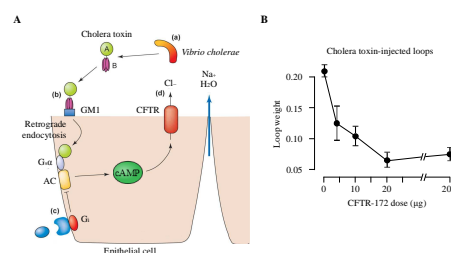
Incubation time of conjugation (min)	5 min	10 min	15 min	20 min	25 min	30 min
Complete medium	100	100	100	100	100	100
Without arginine	0	4	100	100	100	100
Without uracil	5	98	100	100	100	100
With galactose	0	0	0	0	2	100
With KM	4	6	2	6	99	100

Indicate if each of the following statements is true or false.

- | | TRUE | FALSE |
|---|-----------------------|-----------------------|
| The gene marker 'KM resistance' is transferred before the gene required for uracil synthesis | <input type="radio"/> | <input type="radio"/> |
| The data suggest that a full bacterial genome can be transferred via conjugation in less than 15 minutes | <input type="radio"/> | <input type="radio"/> |
| The data suggest that a small fraction of recipient colonies can be expected to grow on +KM medium even in the absence of conjugation | <input type="radio"/> | <input type="radio"/> |
| More than 20% of all colonies incubated for 15 minutes are expected to grow on a medium lacking both arginine and uracil | <input type="radio"/> | <input type="radio"/> |

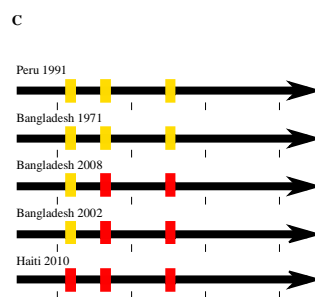
Q. 21

Cholera is caused by a toxin secreted by the bacterium *Vibrio cholerae* (Fig. A). One symptom is severe diarrhea, which leads to dehydration and perhaps death. Scientists tested a new CFTR-inhibitor, CFTR-172 (Fig. B) as a potential treatment for cholera.



A, action of cholera toxin on an intestinal epithelial cell. In the figure, A and B are cholera toxin subunits; GM1 (GM1 ganglioside receptor); $G_s\alpha$ (G protein); AC (adenylate cyclase); G_i (G protein); cAMP (cyclic AMP); and CFTR (cystic fibrosis transmembrane conductance regulator Cl^- channel); B, dose-dependent reaction of cholera toxin-induced fluid secretion into closed loops of mouse ileum as a function of applied 'CFTR-172' dose (the small molecule 'CFTR-172' was injected into the body cavity).

After the 2010-earthquake in Haiti, a cholera outbreak led to discussions about the origin of the epidemic (Fig. C). Two theories were proposed: Either the infection originated from similar cases in Peru, or UN-soldiers from near Bangladesh carried it to the island, when they came to help after the earthquake.



C, five variants of the cholera enterotoxin subunit B open reading frame. "Yellow" loci differ from "red" loci. Labels tell where each variant has caused cholera (from Thiagarajah & Verkman 2005, Chen-Shan et al. 2011).

Indicate if each of the following statements is true or false.

TRUE FALSE

The water loss of patients with cholera is due to osmosis

 TRUE FALSE

The cholera toxin binds to transmembrane ion channels thereby starting a cascade reaction

 TRUE FALSE

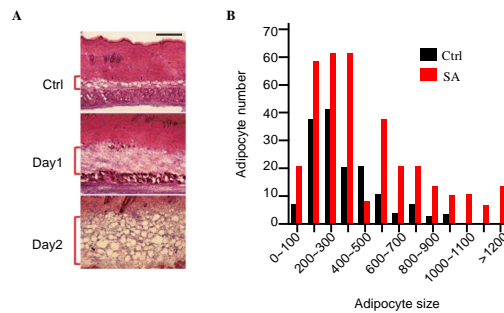
TRUE FALSE

Based on Figure B, one might treat cholera-induced diarrhea with CFTR inhibitor, CFTR 172

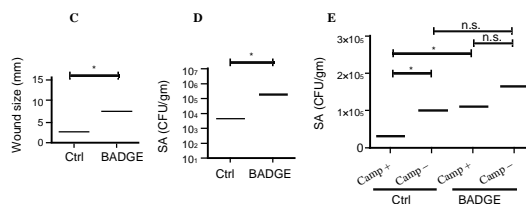
The results in Fig. C support that the cholera outbreak could be caused by infection from the UN soldiers

Q. 22

Staphylococcus aureus (SA) causes skin infection in humans and is a common cause of death. Immediate protection or intervention by local epithelial cells restrict spread of infection. These cells produce antimicrobial peptides (amp), e.g. cathelicidin (Camp). A newly discovered host response to such infections is changes in subcutaneous adipose (fat) tissue (fig A-B). The antibacterial role of this was studied by using BADGE, an ether that inhibits adipogenesis (fig C-E)



A, mouse skin infected with SA and compared to control (ctrl) (red brackets: subcutaneous fat layer); B, change in number and size of adipocytes 3 days after SA infection.



C-D, effects of BADGE on wound size and SA CFU (the ether BADGE inhibits adipogenesis, CFU=Colony-Forming Units); E, effects of + and - Camp (*, significant differences; n.s., no difference (from Zhang et al. 2015).

Indicate if each of the following statements is true or false.

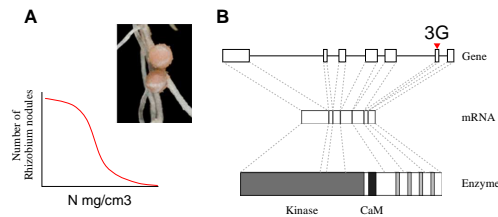
- | | TRUE | FALSE |
|---|-----------------------|-----------------------|
| An SA infection induces the average subcutaneous fat cell to increase in size | <input type="radio"/> | <input type="radio"/> |
| Number of adipocytes is important against spread of infection | <input type="radio"/> | <input type="radio"/> |
| Badge destroys the effect of Camp | <input type="radio"/> | <input type="radio"/> |

TRUE FALSE

Results in Fig. C-D and in Fig. E support each other well

Q. 23

The effect of the nodule bacterium *Rhizobium* on the growth of the legume *Lotus japonicus* has often been studied, e.g. in relation to the enzyme/gene system of the interaction (Fig.).



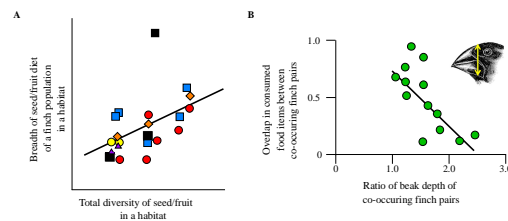
A, *Rhizobium* nodule and the relationship between the number of *Rhizobium* nodules and the nitrogen (N) content of soil. B, the enzyme CaMK with its mRNA and associated gene. The kinase domain (large dark grey) regulates other enzymes. The black band is the CaM domain, and the four narrow grey bands are EF-hand domains. Boxes in the gene are exons.

Indicate if each of the following statements is true or false.

	TRUE	FALSE
Nodulation mainly occurs in nitrogen-poor soil	<input type="radio"/>	<input type="radio"/>
<i>Rhizobium</i> stimulates growth of <i>Lotus</i> by enlarging the surface of its root system; and consequently uptake of NO_3^- increases	<input type="radio"/>	<input type="radio"/>
Mutation 3G in Fig. B inhibits the transcription of CaMK	<input type="radio"/>	<input type="radio"/>
Each exon encodes a specific protein domain	<input type="radio"/>	<input type="radio"/>

Q. 24

The Galápagos Islands are well known for the adaptive radiation of 14 species of finch. The drivers of this radiation are either competition for food in the community of finch species (Hypothesis 1), diversity of available food, i.e. seeds and fruits (Hypothesis 2), or both. Choice of diet is determined by size and structure of the beak. These hypotheses were tested using the six ground finches, which have very different beaks (Fig.).



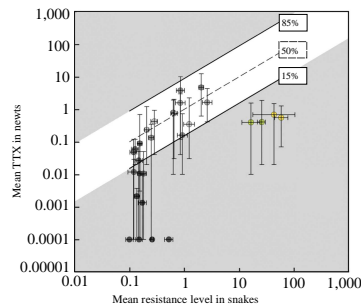
A, relationship between seed/fruit diversity within a habitat and breadth of seed/fruit diet of a finch population in the same habitat. Each dot is a finch population in a habitat, and different shapes and colours of dots indicate different finch species; B, relationship between ratio of beak depth of co-occurring pairs of finch species and overlap in consumed food items between a pair of species, i.e. each dot is a species pair. Yellow arrow on inserted finch head indicates beak depth (from Abbott et al. 1977).

Indicate if each of the following statements is true or false.

- | | TRUE | FALSE |
|---|-----------------------|-----------------------|
| According to Fig. A, Hypothesis 2 is more likely than Hypothesis 1 | <input type="radio"/> | <input type="radio"/> |
| According to Fig. B, Hypothesis 1 is more likely than Hypothesis 2 | <input type="radio"/> | <input type="radio"/> |
| Different finch species respond to the same extent to an increase in seed and fruit diversity | <input type="radio"/> | <input type="radio"/> |
| Figures . A–B show that interspecific competition is low when food is more diverse | <input type="radio"/> | <input type="radio"/> |

Q. 25

Rough-skinned Newts (a salamander) produce the toxin TTX, which is lethal to other vertebrates. Individual newts vary in their level of TTX. Garter Snakes eat almost any prey, including newts, and individual snakes vary in their resistance to TTX. The higher the TTX level in a newt population is, the greater the resistance of co-occurring snakes, which, however, still may reject newts, which are too poisonous (Fig.).



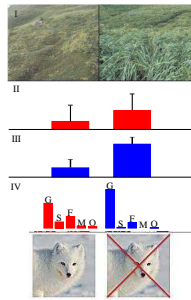
Relationship between levels of resistance of snakes and toxicity of newts. Each dot represents a site with interacting snake and newt populations. In the white zone, snakes consume newts, but with a cost to their mobility. Dots in grey-coloured zones are toxicity/resistance mismatches. Bars give variation in levels among individuals within a population. The 50% dashed line reflects the TTX dose that would reduce snake performance 50%; 15% and 85% lines delimit the range of functionally relevant TTX doses for snakes across all sampled sites (from Hanifin et al. 2008).

Indicate if each of the following statements is true or false.

	TRUE	FALSE
Coevolution/reciprocal selection between newt and snake mainly takes place in the white zone	<input type="radio"/>	<input type="radio"/>
The figure agrees with the "life-dinner principle", i.e. survival is under stronger selection than demand for food in a prey-predator interaction	<input type="radio"/>	<input type="radio"/>
Per individual, resistance seems to be less costly than toxin production	<input type="radio"/>	<input type="radio"/>
It is likely that the snake populations in the two 'green' and two 'yellow' sites at the extreme right of the figure have won the arms race.	<input type="radio"/>	<input type="radio"/>

Q. 26

The Aleutians Islands west of Alaska are rich in sea birds. The Arctic Fox was not originally present here, but was introduced as a fur game-animal and is now present on many islands. The fox decimates sea bird populations severely. Indirect effects of foxes on island vegetation were compared on islands with and without foxes (Fig.).



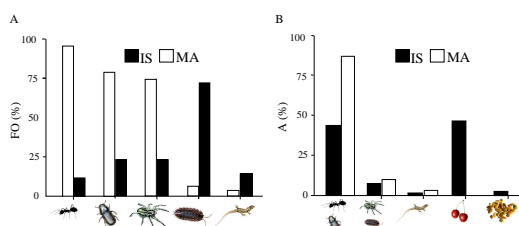
Mean values (\pm standard error) for parameters sampled on fox-infested islands (red, left-hand bars) and fox-free islands (blue, right-hand bars). I, view of the plant community on an island; II, logarithm10 of density of breeding sea birds; III, total soil Phosphorus; and IV, relative abundance of grasses (G), shrubs (S), non-grass herbs (F, forbs), mosses (M), and others (O) (from Croll et al. 2005).

Indicate if each of the following statements is true or false.

- | | TRUE | FALSE |
|---|-----------------------|-----------------------|
| The study is based on the assumption that sea bird-derived nutrients are distributed all over an island | <input type="radio"/> | <input type="radio"/> |
| The presence of foxes on an island changes the vegetation from grassland to tundra- shrubland | <input type="radio"/> | <input type="radio"/> |
| Diversity and number of major plant groups are reduced in islands with fox populations | <input type="radio"/> | <input type="radio"/> |
| The ecological changes on islands with fox introduction represent exclusively top-down processes | <input type="radio"/> | <input type="radio"/> |

Q. 27

The bird Red-billed Chough has a wide diet. It lives on the oceanic Spanish island La Palma (IS) and on mainland Spain (MA). The bird's diet on IS and MA was compared (Fig.). As a food source, invertebrates are rich in protein and lipid, whereas fleshy fruit is rich in carbohydrates. IS-nestlings have more poorly developed feather barbs than MA-nestlings.



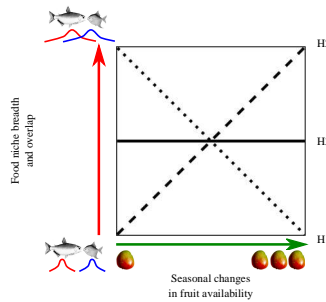
A, frequency of occurrence in habitat (FO%, i.e. percentage of samples with a given food item) of animal groups (from left: Ants, Other insects, Spiders, Other arthropods (i.e. myriapods, woodlice), and Lizards); B, chough nestling diet (A%: relative abundance of food item in diet, i.e. all white bars and all black bars each add up to 100%) (from left: Insects, Other arthropods, Other animals, Fleshy fruit, and Seeds) (from Blanco et al. 2014).

Indicate if each of the following statements is true or false.

- | | TRUE | FALSE |
|--|-----------------------|-----------------------|
| Generally, food of animal origin is more scarce on IS than on MA | <input type="radio"/> | <input type="radio"/> |
| Mainland nestlings have a wider food niche than island populations | <input type="radio"/> | <input type="radio"/> |
| In general, insects are the favorite food of nestlings | <input type="radio"/> | <input type="radio"/> |
| Island nestlings are expected to have a faster growth rate and shorter generation time than mainland nestlings | <input type="radio"/> | <input type="radio"/> |

Q. 28

Within a single year, the Amazon floodplain forests have a high-water (HW) and a low-water (LW) season with a high and low fruit production, respectively. Fruit consumption is widespread among Amazonean fishes, and the relationships between fish diet and fruit production have been explained by three hypotheses H1-H3 (Fig.). Two species of fish (*Brycon falcatus* and *Myloplus asterias*) were studied in detail.



Three hypotheses (H1-H3) explain how food niche breadth and overlap among fish species (Y) respond to seasonal changes in fruit availability (X) (from Correa & Winemiller 2014).

TRUE FALSE

Fact: Diet overlap among fish increased from 28% to 95% from low-resource to high-resource season: This relationship is best explained by H1

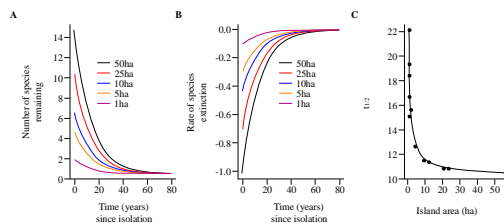
Fact: *B. falcatus* was, at first, observed not to change its food niche, when food became more plentiful, but then at higher food availability it became increasingly selective: This relationship is best explained by a combination of H1 and H3

Fact: Some fish had a constant food niche throughout the year, irrespectively of fruit availability: This is best explained by H1

Fact: During HW, *M. asterias* had a fruit-dominated diet, but switched to leaves instead of fruit in the LW season: This is best explained by H2

Q. 29

In 1986-1987 in Thailand, a water reservoir was established by flooding a forest area. In the reservoir, former hilltops now became new islands and on 16 of these, the small mammal fauna was monitored until 2013, i.e. 27 years after establishment (Fig.). The focus of the study was extinction of the hilltop fauna due to isolation.



A, number of species remaining on different-sized islands (1–50 ha) T years after reservoir establishment (graph part after T = 27 years is expected future change); B, rate of species extinction on different-sized islands as a function of T; C, time to extinction of half of the fauna (T1/2) on different-sized islands (from Gibson et al. 2013).

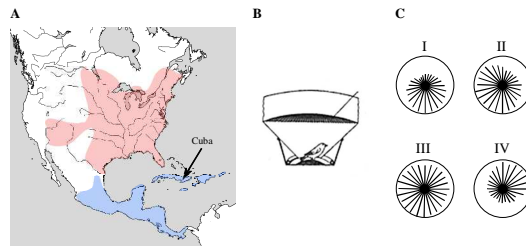
Indicate if each of the following statements is true or false.

- | | TRUE | FALSE |
|--|-----------------------|-----------------------|
| Smaller islands (1–10 ha) lose more species per year than larger islands (25–50 ha) | <input type="radio"/> | <input type="radio"/> |
| At reservoir establishment, a linear relationship existed between species number and island area | <input type="radio"/> | <input type="radio"/> |
| The study supports the hypothesis that in the long run, a single large protected island will support biodiversity better than several small ones | <input type="radio"/> | <input type="radio"/> |
| In all islands, which are larger than 10 ha, the mean time to extinction of half of all species, is comparable | <input type="radio"/> | <input type="radio"/> |



Q. 30

Stephen Emlen experimentally studied seasonal migration of an American bird, the Indigo bunting. He used a funnel-shaped test cage (Fig. B), at the bottom of which he placed an ink pad. Each time a bunting tried to fly out of the cage, the location of its footprint was marked by ink on a piece of paper, so its orientation pattern easily could be recorded (Fig. C). The bird migrates at night, using stars as cues.



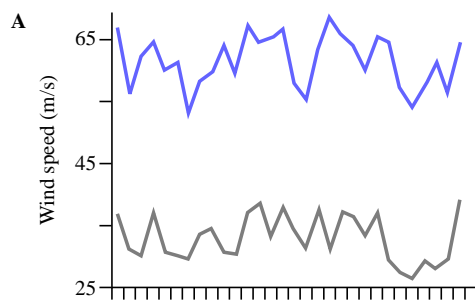
A, distributional range of the bird (pink area = summer range; blue area = winter area); B, Emlen's experimental cage; and C, four examples of footprint pattern; each radius is a take-off attempt by the bird (from Emlen 1967).

Indicate if each of the following statements is true or false.

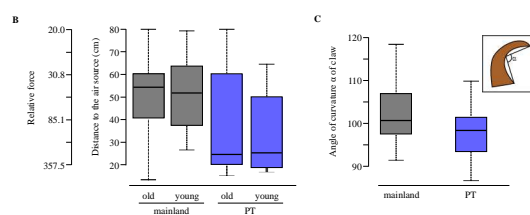
	TRUE	FALSE
The bird breeds in Central America and the Caribbean (blue area, Fig. A)	<input type="radio"/>	<input type="radio"/>
Fig. C-I is made by a north-eastern USA bird ready for autumn migration to the western part of Central America	<input type="radio"/>	<input type="radio"/>
Fig. C-II is made by a western USA bird ready for autumn migration to Cuba	<input type="radio"/>	<input type="radio"/>
Fig. C-III: The footprint of a young bird, suggesting that migration patterns are genetically determined	<input type="radio"/>	<input type="radio"/>

 | Q. 31

About 100 individuals of the butterfly *Melitaea cinxia* lives on a tiny island PT in the Gulf of Finland. Researchers studied how the butterflies on PT coped with the very windy conditions on the island. In the lab, they exposed butterflies from mainland and PT to a wind source (hair dryer) (Fig. B) and they also studied the morphology of the claws of the butterfly (Fig. C).



A, wind speed in June on PT (blue) and mainland (gray)



B, distance (cm) to wind source, when a butterfly loses its grip on a surface; old and young butterflies from mainland (grey boxes) and PT (blue boxes) are compared (mainland vs. PT, $p = 0.003$); C, The angle of curvature α of tarsal claw on mainland (grey box) and PT (blue box) (mainland vs. PT, $p = 0.001$). The inset indicates the tarsal claw, with its angle of curvature and how it is measured. (from Duployé & Hanski 2014).

Indicate if each of the following statements is true or false.

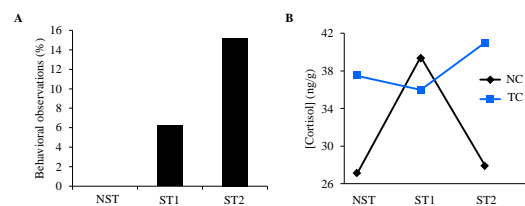
- | | TRUE | FALSE |
|--|-----------------------|-----------------------|
| Island insects in general are more often flightless than are mainland insects | <input type="radio"/> | <input type="radio"/> |
| If more curved tarsal claws are a disadvantage in escaping predators, then PT probably has very few insect-eating birds as compared to mainland localities | <input type="radio"/> | <input type="radio"/> |
| In general, butterflies do not evolve flightlessness because of their mode of foraging | <input type="radio"/> | <input type="radio"/> |

TRUE FALSE

With age, island butterflies learn to hide from the wind

Q. 32

In farms, a study of mink looked at how reduced welfare, e.g. postponed feeding, led to abnormal behaviours, such as stereotypic pacing and tail-chewing. Indicators of abnormal behaviours could also be elevated levels of the hormone cortisol and increased fearfulness. Based on their behavioural response to stress, minks were classified into three groups, NST = no stereotypic pacing, ST1 = low level of pacing and ST2 = high level of pacing. The differences between these groups of minks in their stress responses to postponed feeding are shown in figures A and B.



A, frequency of stereotypic pacing, caused by postponed feeding; B, mean cortisol concentration in the two stereotypic groups (ST1 and ST2) and in the control (NST), and in absence (NC) or presence of tail-chewing (TC) (from Svendsen et al. 2013).

Indicate if each of the following statements is true or false.

	TRUE	FALSE
Animal welfare studies always require behavioural observations	<input type="radio"/>	<input type="radio"/>
Stereotypic pacing is affected by postponed feeding	<input type="radio"/>	<input type="radio"/>
Tail-chewing and stereotypic pacing are closely correlated	<input type="radio"/>	<input type="radio"/>
Very high behavioural stress levels seem to suppress cortisol production	<input type="radio"/>	<input type="radio"/>

 | Q. 33

In order to make safe blood transfusions, we have to know the blood types of both patient and donor. Mixing incompatible blood types is dangerous and may be lethal. In this problem we consider only the ABO blood group system and transfusions that do not include plasma.

Indicate if each of the following statements is true or false.

	TRUE	FALSE
Blood transfusion with A-blood causes an incompatibility reaction in an O-recipient	<input type="radio"/>	<input type="radio"/>
A traffic accident victim needed blood fast, and without knowing the blood group type of the victim the doctor prescribed blood of type O, and the patient showed signs of incompatibility	<input type="radio"/>	<input type="radio"/>
Persons with type AB can receive blood from all ABO types	<input type="radio"/>	<input type="radio"/>
Persons with type B can receive blood of type AB	<input type="radio"/>	<input type="radio"/>

Site 5	0	0/3
Site 6	0	0/3
Site 7	0	2/3
Site 8	79	0/3

Indicate if each of the following statements is true or false.

TRUE FALSE

In this study eDNA may be an effective tool to detect marine animals far away from their habitat

Most likely, the eDNA from site 7 was from an animal more closely related to the porpoise than to harbour seal

Based on the short sequence in the Fig., the two marine animals, seal and porpoise, are more closely related to each other than seal and human are to each other

eDNA seems to be a poorer detection method than acoustic monitoring

 | Q. 35

In a criminal case about rape, which was brought to court, four men (1–4; Table), the victim (Mother) and the resulting child (Daughter) (1–4, Table) were blood-type scored for ABO (alleles I^A and I^B are co-dominant, i recessive), Rhesus (allele Rh^+ dominant to Rh^-), MN (alleles M and N are co-dominant), and the X-linked $Xg^{(a)}$ (allele $Xg^{(a+)}$ dominant to $Xg^{(a-)}$). Results are shown in the Table.

Results of blood-type testing. Man 1–4 are potential fathers.

Individual	ABO phenotype	Rh phenotype	MN phenotype	$Xg^{(a)}$ phenotype
Mother	AB	Rh-	MN	$Xg^{(a+)}$
Daughter	A	Rh+	MN	$Xg^{(a-)}$
Man 1	AB	Rh+	M	$Xg^{(a+)}$
Man 2	A	Rh-	N	$Xg^{(a-)}$
Man 3	B	Rh+	N	$Xg^{(a-)}$
Man 4	O	Rh-	MN	$Xg^{(a-)}$

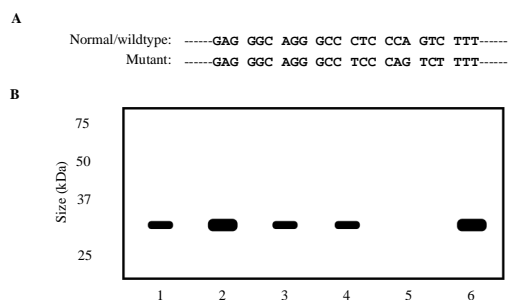
Indicate if each of the following statements is true or false.

- | | TRUE | FALSE |
|---|-----------------------|-----------------------|
| Both Man 2 and Man 3 can be the father | <input type="radio"/> | <input type="radio"/> |
| The father could be identified unambiguously with less than four blood type systems | <input type="radio"/> | <input type="radio"/> |
| Using the ABO system alone, the daughter's genotype had to be $I^A i$ | <input type="radio"/> | <input type="radio"/> |
| If the daughter bears a boy with a man, whose genotype is $Xg^{(a+)}$, then her son must be $Xg^{(a+)}$, because the allele $Xg^{(a+)}$ is dominant | <input type="radio"/> | <input type="radio"/> |

Q. 36

Ficolins are important immune system proteins, e.g. ficolin-3. Consequently, patients with ficolin-3 deficiency may suffer from several complications. This deficiency is caused by a mutation in the ficolin exon (A).

Samples of ficolin-3 in the blood from five family members were analyzed, using electrophoresis (B).



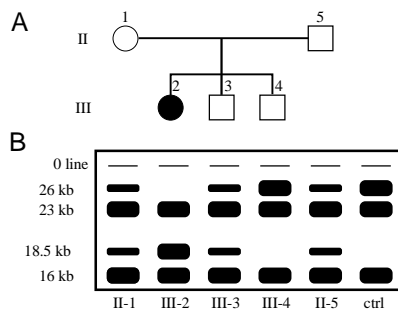
Western blots of serum ficolin-3 from a family without any sick members except for the patient (5): The patient's sisters (1 and 2), mother (3), and father (4), compared to a control with ficolin-3 added (6). (from Munthe-Fog et al. 2014).

Indicate if each of the following statements is true or false.

- | | TRUE | FALSE |
|--|-----------------------|-----------------------|
| The mutation is a frame-shift mutation | <input type="radio"/> | <input type="radio"/> |
| If a child lacks ficolin-3 protein, at least one of her/his parents should have the same phenotype | <input type="radio"/> | <input type="radio"/> |
| All three possible genotypes of the ficolin-3 gene can be determined using Western blots | <input type="radio"/> | <input type="radio"/> |
| Sister (1) might be heterozygous | <input type="radio"/> | <input type="radio"/> |

Q. 37

DNA from five members of a family, in which dwarf growth occurs (Fig. A), was examined using restriction enzymes, DNA probes, and gel electrophoresis (Fig. B). Dwarf growth occurs due to deficiency of growth hormone.



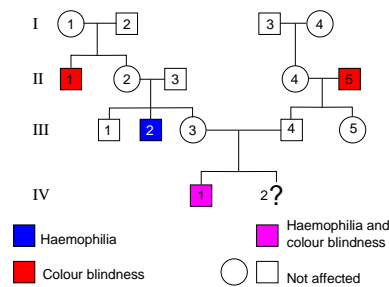
A, pedigree with a dwarf member (2); B, gel electrophoresis plate with size of fragments to the left. DNA from a control person (ctrl) without this type of mutation was also examined (from Phillips et al. 1981).

Indicate if each of the following statements is true or false.

- | | TRUE | FALSE |
|---|-----------------------|-----------------------|
| The gene for growth hormone is situated within the 26 kb DNA sequence | <input type="radio"/> | <input type="radio"/> |
| The mutation is due to a deletion of the size of 26 kb | <input type="radio"/> | <input type="radio"/> |
| III-4 will most probably not have children that lack growth hormone | <input type="radio"/> | <input type="radio"/> |
| The risk that a fourth child of II-1 and II-5 will be a dwarf is 50% | <input type="radio"/> | <input type="radio"/> |

Q. 38

Two human genetic disorders, haemophilia and red-green colour blindness, are both located on chromosome X. The pedigree in the Fig. shows a family with both disorders.



Pedigree of a family suffering from both haemophilia and red-green colour blindness. Blue symbols = haemophilic individuals; red symbols = colour blind individuals; purple symbol (IV-1) = haemophilic+colour blind individuals; white symbols = unaffected individuals. It is assumed that no new mutations related to the two disorders occur in the family.

Indicate if each of the following statements is true or false.

	TRUE	FALSE
Person II-2 is a carrier of both disorders	<input type="radio"/>	<input type="radio"/>
At least two individuals in the pedigree carry recombinations due to genetic crossover	<input type="radio"/>	<input type="radio"/>
If IV-2 (unborn) has Klinefelter's syndrome (XXY) and also has colour blindness, then a non-disjunction must have taken place in the first meiotic division of the mother's egg cell	<input type="radio"/>	<input type="radio"/>
III-5 marries a man from a population in which the frequency of the allele for colour blindness is 1%. The probability that their firstborn child is a colourblind daughter is 0.25%	<input type="radio"/>	<input type="radio"/>



Q. 39

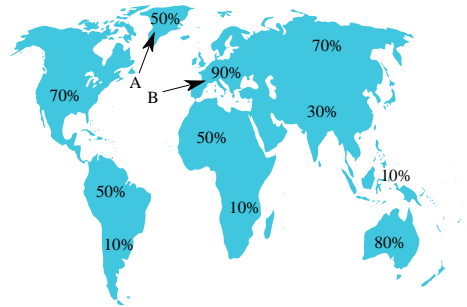
Egg producers prefer hens to roosters, and they select these by using sex-specific traits. Roosters have the sex chromosomes ZZ and hens have ZW (W is a dwarf chromosome perhaps without coding information). In a parental crossing (P) between a black-coloured rooster and a barred (coloured stripes) hen all male chickens became barred and all female chickens black. Breeders knew beforehand that only one gene was involved in the trait.

Indicate if each of the following statements is true or false.

	TRUE	FALSE
Black plumage dominates over barred	<input type="radio"/>	<input type="radio"/>
All barred chickens in F2 can be regarded as hens and used for egg production	<input type="radio"/>	<input type="radio"/>
Half of the male chickens in F2 are heterozygous	<input type="radio"/>	<input type="radio"/>
All male chickens in F2 are black	<input type="radio"/>	<input type="radio"/>

Q. 40

The proportion of lactose-tolerance in adults varies globally (Fig.). Lactose tolerance is a 1-locus dominant trait (dominant allele K and recessive allele k).



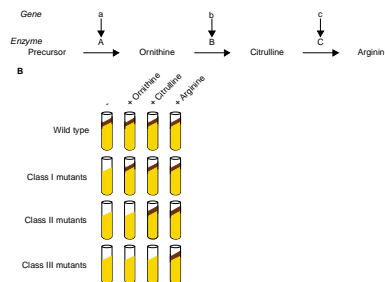
Lactose tolerance (%) among adults around the world. A points to Greenland, B to Europe.

Indicate if each of the following statements is true or false.

	TRUE	FALSE
Assuming that the European (B) population is in Hardy-Weinberg equilibrium, the frequency of K in the next generation will be 0.968	<input type="radio"/>	<input type="radio"/>
Differences in the frequencies of the K allele between populations prove that selection has been acting on this trait	<input type="radio"/>	<input type="radio"/>
In Greenland (A) where the percentage of lactose tolerance is 50%, the frequencies of the alleles k and K are equal	<input type="radio"/>	<input type="radio"/>
Lactose tolerance is assumed to be the ancestral trait among adult humans	<input type="radio"/>	<input type="radio"/>

Q. 41

In mold/mould, synthesis of the amino acid arginine requires prior conversion of a precursor to ornithine, which is then converted to citrulline, which further is converted to arginine. Each of these three steps is catalyzed by a separate enzyme, coded for by a separate gene (Fig.).



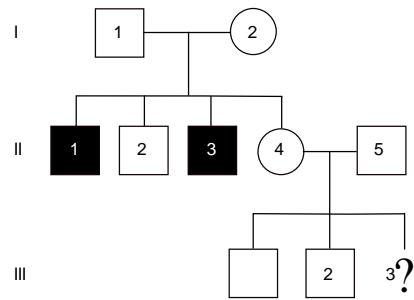
A, biosynthetic pathway for arginine in mold; B, experimental set-up to confirm pathway; dark brown stripe denotes mold growth. The wild type grows on minimal medium, while the mutants only grow with addition of specific nutrients.

Indicate if each of the following statements is true or false.

- | | TRUE | FALSE |
|--|-----------------------|-----------------------|
| Class III mutants may have mutations in more than one gene involved in the pathway | <input type="radio"/> | <input type="radio"/> |
| Class I mutants lack activity of all three enzymes | <input type="radio"/> | <input type="radio"/> |
| Mutants, lacking both enzyme A and C, will grow if ornithine and citrulline are both added | <input type="radio"/> | <input type="radio"/> |
| Assuming that an inhibitor to enzyme B is added to the wild type, gene B will be inactivated | <input type="radio"/> | <input type="radio"/> |

Q. 42

This pedigree shows the occurrence of a rare disease phenotype (shown in black) with full penetrance. The genetic disorder is caused by a recessive autosomal allele d .



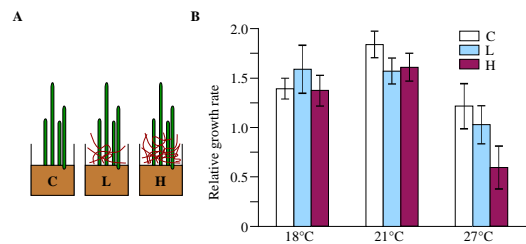
Pedigree of family with an autosomal recessive disease.

Indicate if each of the following statements is true or false.

- | | TRUE | FALSE |
|---|-----------------------|-----------------------|
| The probability that II-4 carries the disease allele is 0.50 | <input type="radio"/> | <input type="radio"/> |
| II-2 and II-4 have the same probability of carrying the disease allele | <input type="radio"/> | <input type="radio"/> |
| If assume that II-5 does not carry allele d , the probability that III-3 carries this allele is 0.30 or higher | <input type="radio"/> | <input type="radio"/> |
| If we assume, that II-5 is heterozygous and III-3 has the disease, then the probability that II-4 is a carrier is 0.5 | <input type="radio"/> | <input type="radio"/> |

Q. 43

Eelgrass (*Zostera marina*) is a key species in Danish coastal waters, which during summer rarely get warmer than 18°C. In an experiment, the growth rate of eelgrass was measured at three temperatures and under the influence of the invasive red alga *Gracilaria vemiculophylla* (Fig.). A hypothesis is that global warming and the presence of *Gracilaria* negatively affect eelgrass.



A, three buckets with eelgrass were exposed to increasing amounts of *Gracilaria*. C = no *Gracilaria*; L = Low *Gracilaria* content; H = High, *Gracilaria* content per bucket; Fig. B, relative growth rate of eelgrass at three temperatures and together with increasing amounts of *Gracilaria* (white bar = C; light blue bar = L, purple bar = H in Fig. A) (from Höffle et al. 2011). If error bars do not overlap, the differences are statistically significant.

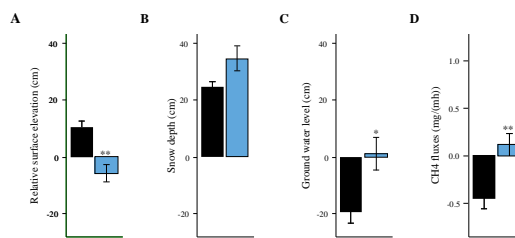
Indicate if each of the following statements is true or false.

- | | TRUE | FALSE |
|---|-----------------------|-----------------------|
| Irrespective of temperature, <i>Gracilaria</i> inhibits the growth rate of eelgrass | <input type="radio"/> | <input type="radio"/> |
| In general, temperature affects the growth rate of eelgrass | <input type="radio"/> | <input type="radio"/> |
| There is a combined effect of <i>Gracilaria</i> and temperature on the growth of eelgrass | <input type="radio"/> | <input type="radio"/> |
| In Danish waters without <i>Gracilaria</i> , eelgrass growth is temperature limited | <input type="radio"/> | <input type="radio"/> |



Q. 44

Arctic tundras are warming faster than the global average. This influences their soil carbon reservoirs. The permafrost layer in the tundra is covered by an active layer, which has an annual thaw/refreeze dynamic. The influence of tundra vegetation as a driver of this dynamics was studied in Siberia from 2006 to 2012. Four parameters were measured in plots, where the woody vegetation was removed (blue bars in the figure), and in undisturbed control plots (black bars).



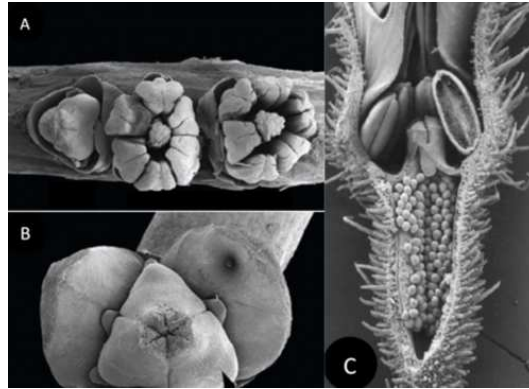
A, Surface elevation relative to ground surface level (0); B, spring snow depth; C, summer ground water level compared to soil surface level; D, August CH₄ emission (+ value, emission).
*, significant differences (from Nauta et al. 2014).

Indicate if each of the following statements is true or false.

	TRUE	FALSE
Soil subsides when its woody vegetation is removed	<input type="radio"/>	<input type="radio"/>
Undisturbed tundra woody vegetation functions as a source of global methane emission	<input type="radio"/>	<input type="radio"/>
Removal of woody vegetation initiates a cycle, leading to more dominance of water-tolerant plants	<input type="radio"/>	<input type="radio"/>
After removal of woody vegetation, the chain of events will be: Fig. B --> Fig. C --> Fig. A --> Fig. D	<input type="radio"/>	<input type="radio"/>

Q. 45

The structure of flowers has many morphological characters important to reproductive success, e.g. sexual dimorphism (dioecy, monoecy). Such characters show phylogenetical conservatism, and thus may be used in evolutionary analysis.



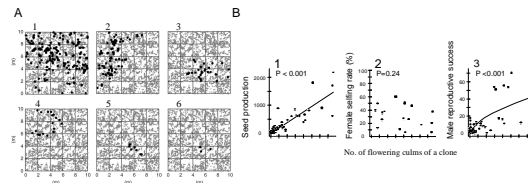
A-B, flowers of a palm; C, longitudinal section of a flower of species saxifrage (from Soltis et al. 2003, Castaño et al. 2014).

Indicate if each of the following statements is true or false.

	TRUE	FALSE
The palm in Fig. A is monoecious (i.e. hermaphroditic plants with unisexual flowers)	<input type="radio"/>	<input type="radio"/>
The palm in Fig. A originates from an ancestor, which most likely had hermaphroditic flowers	<input type="radio"/>	<input type="radio"/>
The palm and the saxifrage are both most likely dicots	<input type="radio"/>	<input type="radio"/>
If structures through evolution become more specialized, one would expect the saxifrage to be phylogenetically older than the palm	<input type="radio"/>	<input type="radio"/>

Q. 46

Many plants reproduce both sexually and vegetatively (clonally). A hypothesis says: As both reproductive modes require energy, a negative trade-off is expected to exist between the two reproductive modes. This was studied in a population of Japanese bamboo (*Sasa veitchii*) (Figs A-B).



A, six plots (10 x 10 m) each presenting the spatial distribution of a bamboo clone; black dots show the positions of all flowering culms of the clone, whereas all the grey dots show the positions of all flowering culms of all the other clones in the plot; B, relationships between no. of flowering culms of a clone and its sexual success (measured in three ways). A regression line is present, if the relationship is significant (from Matsuo et al. 2014).

Indicate if each of the following statements is true or false.

	TRUE	FALSE
More "investment" in clonal growth negatively affects male reproductive success of an individual bamboo	<input type="radio"/>	<input type="radio"/>
More "investment" in clonal growth negatively affects female reproductive success of an individual bamboo	<input type="radio"/>	<input type="radio"/>
Larger bamboo clones have more self-pollination	<input type="radio"/>	<input type="radio"/>
The gain in female fitness per produced flowering culm diminishes with increasing clone size	<input type="radio"/>	<input type="radio"/>

 | Q. 47

The carnivorous plant sundew, *Drosera capensis*, has tentacles with mucilage on their leaf surface. In an experiment, plants were each fed 50 fruit flies per day for ten weeks (Table). The weight of each fruit fly was measured before and after digestion, showing an average dry weight loss of 60%. Estimates of different parameters are given in table. Enzyme activity in mucilage was estimated 24 h after either being fed with fruit flies or exposed to mechanical irritation (the addition of polystyrene balls, which were the size of fruit flies).

Activities of AP and PD, PA and nutrient levels in leaf tissue.

	Enzyme activity in mucilage	Enzyme activity in mucilage	Enzyme activity in mucilage	Ratio of nutrients in leaf tissue	Ratio of nutrients in leaf tissue
	Acid phosphatase (AP), millimol/(mg protein x hour)	Phosphodiesterase (PD), micromol/(mg protein x hour)	Total proteolytic activity (PA), unit/mg protein	N:P	N:K
Mechanical irritation	65.4	4.07	297		
Control = unfed plants	24.7	2.04	363	47.6	1.2
Fruit fly-fed plants	297	11.6	2000	30.1	2.8

Indicate if each of the following statements is true or false.

TRUE FALSE

Results indicate that growth of *D. capensis* plants is normally limited by N

Mechanical irritation increases enzyme activity, but proteolytic activity requires the presence of insects

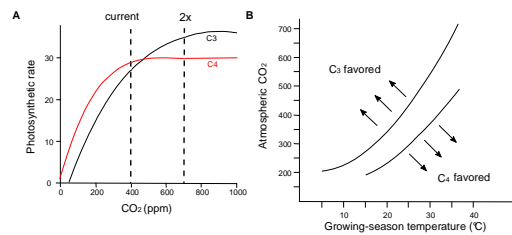
No chitinase activity was observed in the mucilage, which might explain the fact that the weight of the fruit flies was only reduced by 60%

TRUE FALSE

N was a more efficiently absorbed nutrient from fruit flies than K

Q. 48

Plants have different photosynthetic systems. Most plants have the C₃ system, but others, especially grasses, have a C₄ system. The two systems show different photosynthetic rate, when CO₂ and ambient temperature vary (Fig.).



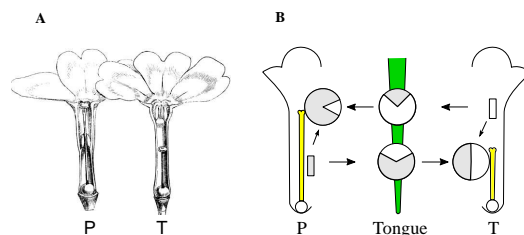
Photosynthetic rate (A) and expected dominance (B) of C₃ and C₄ plants as a function of ambient CO₂ level and temperature (from Ehleringer et al. 1997).

Indicate if each of the following statements is true or false.

	TRUE	FALSE
The proportion of C ₄ -plant species increases towards the poles	<input type="radio"/>	<input type="radio"/>
At current atmospheric CO ₂ levels, CO ₂ is limiting the growth of both C ₃ - and C ₄ -plants	<input type="radio"/>	<input type="radio"/>
The predicted CO ₂ -increase can be more advantageous to C ₄ - than C ₃ -plants	<input type="radio"/>	<input type="radio"/>
In dry and warm regions during the last glacial period, C ₄ -plants were probably more widespread	<input type="radio"/>	<input type="radio"/>

Q. 49

Primrose has heterostyly, i.e. two flower forms on different individuals: P-plants with long style and short stamens inside the corolla tube, and T-plants with short style and stamens higher in the corolla (Fig. A). Darwin crossed T x P primroses (Table), and found that heterostyly increases outcrossing and thus fruit set. A bee inserts its tongue in a P-flower and gets pollen on the tip of its tongue, and then places the pollen on the stigma of a T-plant and vice versa for T-pollen to P-stigma (Fig. B). Heterostyly is controlled by one gene (T is Ss and P is ss; SS is non-viable, S is dominant to s).



A, flower forms P (left) and T (right) of primrose; B, flowers P and T, with a bee's tongue (green) in between; arrows show amount of pollen transferred along different routes from the anther, to tongue and to the stigma (white and grey slices are T- and P-pollen, respectively).

Fruit set (Number of fruits) after 100 T x T and P x P crossings and 100 T x P and P x T crossings.

	Number of fertilized flowers	Number of fruits
T x T and P x P	100	63
T x P and P x T	100	75

Indicate if each of the following statements is true or false.

- | | TRUE | FALSE |
|--|-----------------------|-----------------------|
| Frequencies of T and P in a primrose population stay the same, if mating is random with respect to form, and all crossings give the same fruit set | <input type="radio"/> | <input type="radio"/> |
| Incomplete sterility within the same flower form is seen in the population as a deviation from a 1: 1 T: P ratio | <input type="radio"/> | <input type="radio"/> |
| The two routes of pollen transfer (T --> P or P --> T) are equally efficient in terms of the pollen transferred | <input type="radio"/> | <input type="radio"/> |
| Pollen deposition from tongue to stigma is more difficult than pollen harvesting from anther to tongue | <input type="radio"/> | <input type="radio"/> |

END