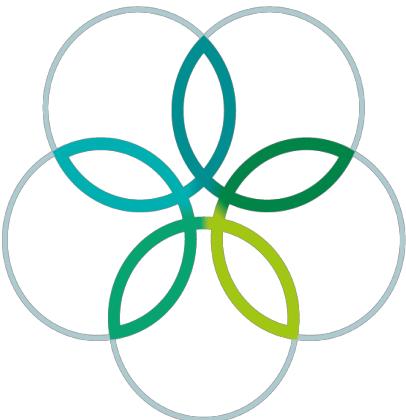
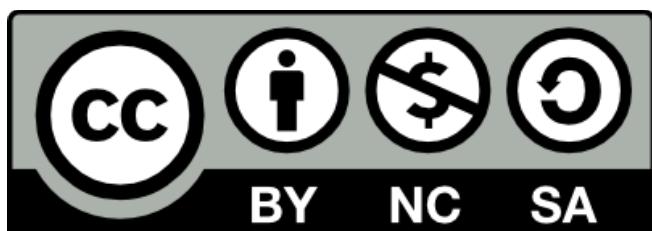


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# THEORETICAL EXAM 1

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## 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,  $\eta$  = 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

Increased atherosclerosis leads generally to faster blood flow in the circulation

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

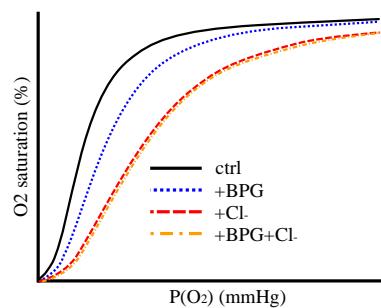
 

In a specific patient suffering from atherosclerosis, the radius of blood vessels on average had decreased by 1/6, which caused blood pressure to double to maintain the blood flow



## Q. 2

$\text{O}_2$ -binding or -affinity to hemoglobin is affected by specific anions, in particular 2,3 bisphosphoglycerate (BPG) and chloride ( $\text{Cl}^-$ ), 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

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<sub>2</sub> to hemoglobin in the lungs

It is likely that chloride and BPG bind at different sites in the hemoglobin molecule

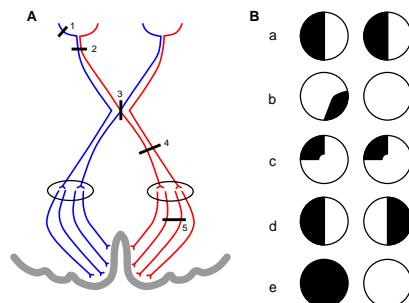
 

BPG decreases the total oxygen saturation capacity of the hemoglobin



## 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

Lesion 3 corresponds to visual field deficit d

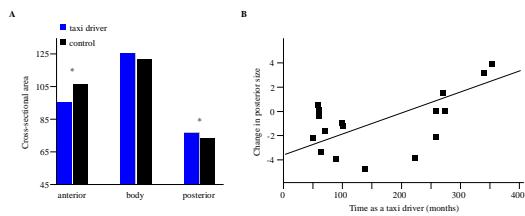
Lesion 4 corresponds to visual field deficit e

Lesion 5 corresponds to visual field deficit c



## 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

Spatial navigation may be located in the posterior part of hippocampus

The study provides evidence that some people are predisposed genetically to become better London taxi drivers than others in the population

The study supports the traditional view that the hippocampus is only involved in short-term memory

 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<sub>2</sub> 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 <sub>2</sub> concentration in arterial blood, ml/L	200	200	199
O <sub>2</sub> concentration in venous blood from the kidneys, ml/L	184	186	184
Na <sup>+</sup> concentration in plasma, mmol/L	137	136	139
Na <sup>+</sup> 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<sup>+</sup> filtrated in the kidneys is largest for person A

The amount of Na<sup>+</sup> excreted in the kidneys is largest for person B

Renal oxygen consumption is largest for person C

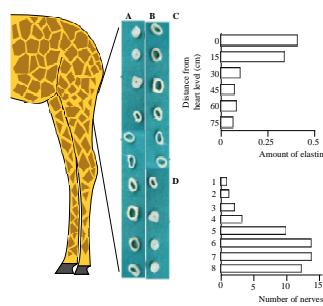
 

The amount of Na<sup>+</sup> reabsorbed per mol of O<sub>2</sub> used is largest for person B



## 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:  $\geq 30$  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

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

Femoral arteries become more rigid distally toward the leg extremities

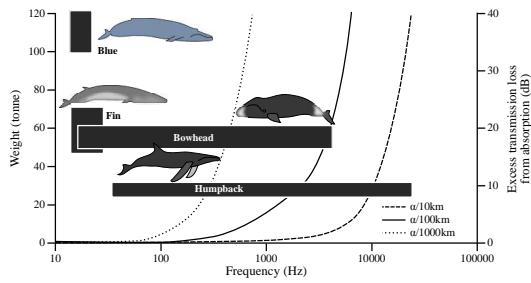
 

The giraffe has a special arterial mechanism above its knees to regulate blood pressure in the leg extremities



## 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

Based on vocalizations, the Blue whale is expected to have more complex social behaviour than the Humpback.

Humpback and Bowhead have a signalling frequency that makes it possible for them to have high inter-annual mating site-fidelity

The similar vocalization patterns of Humpback and Bowhead whales are most likely due to convergent evolution



## 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 Lactate mmol/kg	Fish tissue Ethanol mmol/kg	Water in aquarium Lactate mmol/kg	Water in aquarium Ethanol mmol/kg
Control: + O <sub>2</sub>	0.18	0.00	0.00	0.00
Treatment: no O <sub>2</sub>	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

Goldfish are able to survive long periods under ice cover

Goldfish have no tolerance to ethanol

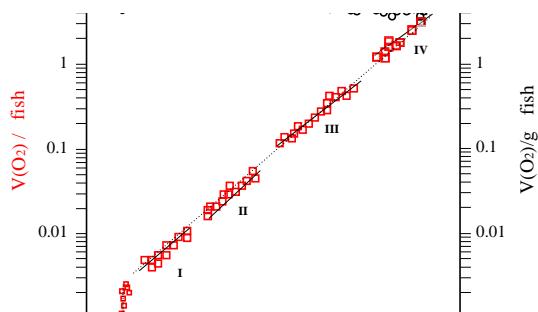
 

Transformation of lactate to ethanol may be a means of avoiding acidosis



## 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  $M$

For a given unit of body mass, the rate of respiration seems to increase with the age of fish

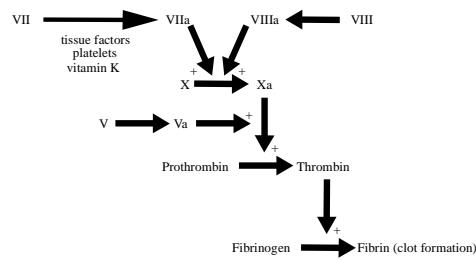
The general equation for the lower curve in the figure is  $V_{O_2} = aM^b$  (a: scaling parameter; b: scaling exponent)

In the log-log plot there is a continuous linear increase in  $V_{O_2}$  over 4 orders of magnitude of body mass

| 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

Bone-marrow insufficiency leads to increased coagulation

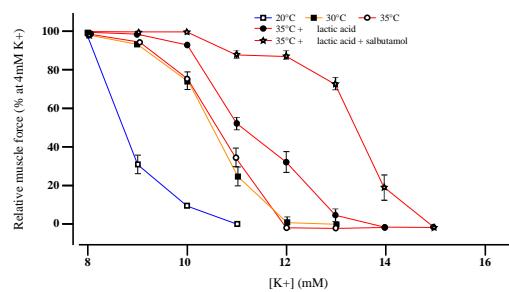
A lipid-rich diet may promote coagulation

People, suffering from a high risk of embolism, may be treated with heparin (antithrombin activator)

**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  $[K^+]$

Temperature increase, and addition of lactic acid and drug operate mainly additively

The study design is incomplete

At physiological temperature (here 35°C), lactic acid protects completely against muscle fatigue

 | 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

SVS and SPI seem to have a synergistic effect

Stevioside is harmful to diabetics

When fasting, blood glucose results show that there is no statistical difference between the four groups of rats

| 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.).

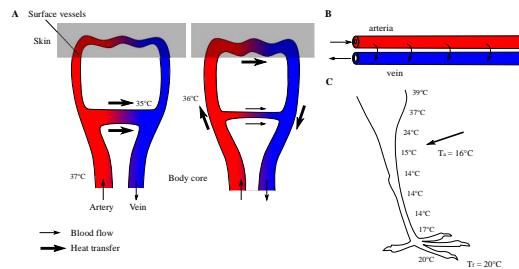


Figure. A, Regulation of heat conductance at body surface; B, thermal countercurrent system; C, body temperature in a bird limb.  $T_a$  = ambient temperature.  $T_f$  = floor temperature. (from Willmer et al. 2005).

**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

In Fig. B, a countercurrent system often seen in animals from warm habitats is shown

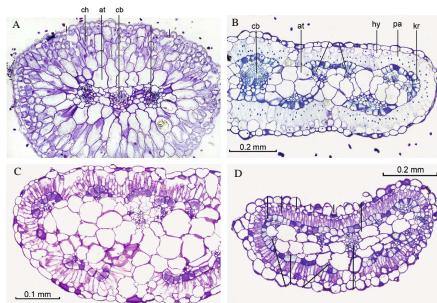
The animal in Fig. C lives in a warm habitat

In Fig. C, the venous blood at the arrow has a temperature between 14-15°C

 | 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 C4 species is favoured in a climate of increasing drought, salinity and heat, but with no change in CO<sub>2</sub> level

Leaf in Fig. C is from a C3 plant

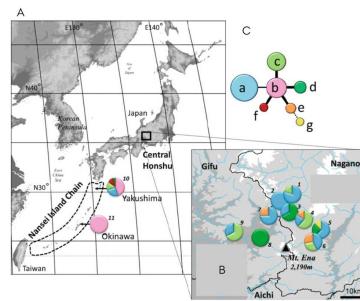
Leaf in Fig. D is from a C3 plant

During a period of global CO<sub>2</sub> increase, without a concomitant increase in temperature, the global distribution of C4 plants is likely to expand

| Q. 15

Genetic variation in three chloroplast DNA (cpDNA) regions was studied in populations of a rare orchid *Vexillarium 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

It is likely that a founder effect can be seen in Okinawa

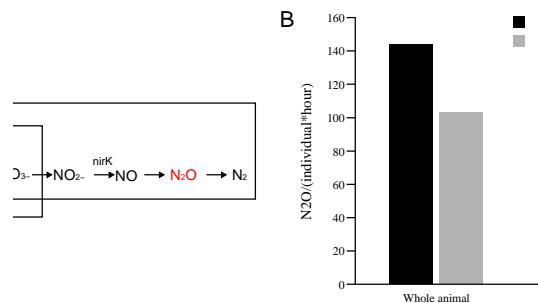
CpDNA is better than nuclear DNA in revealing maternal origins of individuals

The study suggests that mountains and river basins are more effective barriers to gene flow than the sea separating islands

| Q. 16

Nitrous oxide ( $\text{N}_2\text{O}$ ) is a greenhouse gas, produced by bacteria through either nitrification or denitrification (Fig. A). Many aquatic invertebrates (e.g. zebra mussel) emit  $\text{N}_2\text{O}$ , due to the activity of bacteria in their gut and the biofilm covering their shell (Fig. B, Table).



A, pathways for  $\text{N}_2\text{O}$  production in bacteria, with key genes amoA (encoding ammonia monooxygenase AMO, nitrification) and nirK (encoding nitrite reductase NIR, denitrification); B,  $\text{N}_2\text{O}$  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  $\text{N}_2\text{O}$  production in zebra mussels. amoA produces the enzyme AMO, which catalyses nitrification; nirK produces the enzyme NIR, which reduces nitrite.

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

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

TRUE      FALSE

Most  $\text{N}_2\text{O}$  in zebra mussel is produced by bacteria inside the animal (e.g. in gut)

The  $\text{N}_2\text{O}$  production from mussel shells is mostly due to nitrification in their biofilm

Nitrification and denitrification are equally important for  $\text{N}_2\text{O}$  emission from mussels

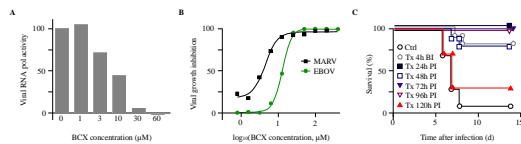
 

Increasing nitrate ( $\text{NO}_3^-$ ) concentrations in lakes (e.g. from agricultural run-off) will increase  $\text{N}_2\text{O}$  emissions from freshwater invertebrates



 | 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

BCX is applicable exclusively against ebola

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

The half-maximal inhibition of BCX is achieved at a concentration of about 10  $\mu\text{M}$



## 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

Gene-C has different expression in monocots and dicots

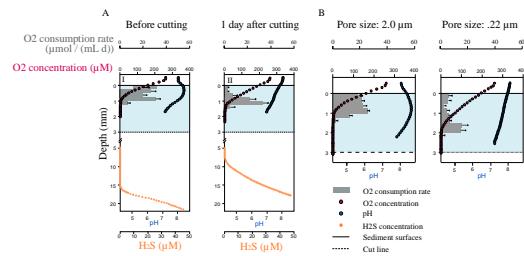
Selective suppression of gene C-expression in region II leads to development of unisexual flower

Complete development of stamens in the tulip requires the expression of gene-B1+gene-B3+gene-C

 | 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 Pfeffer 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 Pfeffer 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

Physically interrupting the sediment by the “knife” did not affect  $O_2$  reduction

The filters demonstrated that any specific solutes were not transporting the electrons

Electrons for the  $O_2$ -reduction most likely came from donors in the oxic layer



## 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

The data suggest that a full bacterial genome can be transferred via conjugation in less than 15 minutes

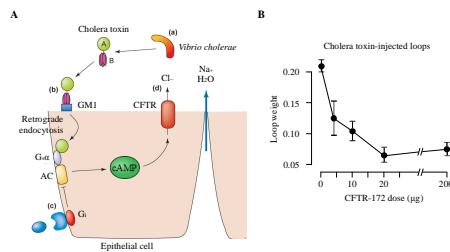
The data suggest that a small fraction of recipient colonies can be expected to grow on +KM medium even in the absence of conjugation

More than 20% of all colonies incubated for 15 minutes are expected to grow on a medium lacking both arginine and uracil

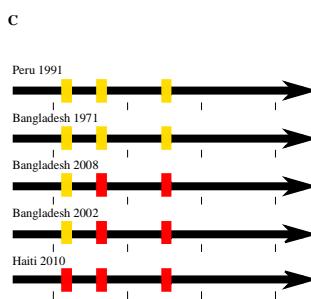
| Q. 21

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 $\alpha$  (G protein); AC (adenylate cyclase); Gi (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

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

TRUE FALSE

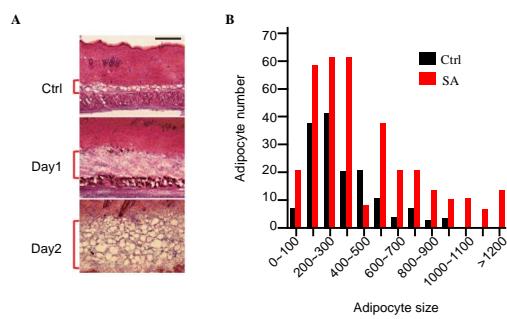
Based on Figure B, one might treat cholera-induced diarrhea with CFTR inhibitor, CFTR 172

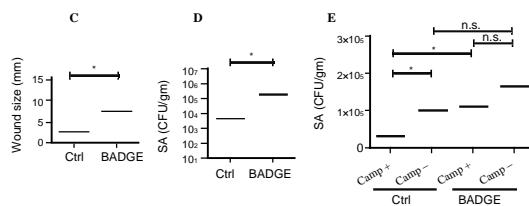
The results in Fig. C support that the cholera outbreak could be caused by infection from the UN soldiers

 | 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

Number of adipocytes is important against spread of infection

Badge destroys the effect of Camp

TRUE FALSE

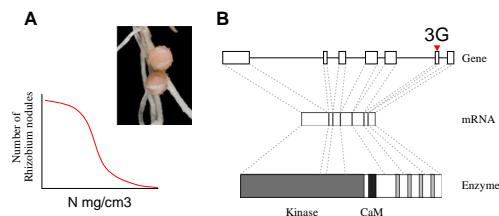
Results in Fig. C-D and in Fig. E support each other well





## 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

Rhizobium stimulates growth of Lotus by enlarging the surface of its root system; and consequently uptake of  $\text{NO}_3^-$  increases

Mutation 3G in Fig. B inhibits the transcription of CaMK

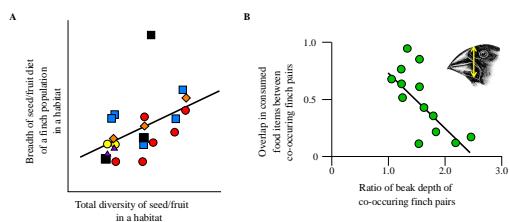
 

Each exon encodes a specific protein domain



## 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

According to Fig. B, Hypothesis 1 is more likely than Hypothesis 2

Different finch species respond to the same extent to an increase in seed and fruit diversity

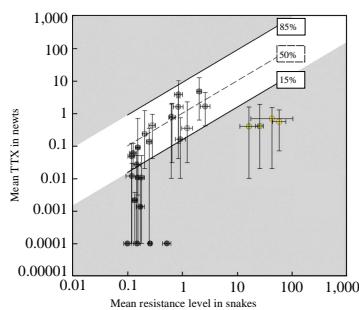
 

Figures . A-B show that interspecific competition is low when food is more diverse



## 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

The figure agrees with the "life-dinner principle", i.e. survival is under stronger selection than demand for food in a prey-predator interaction

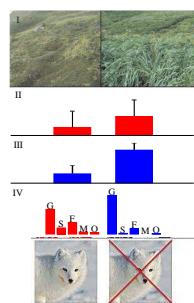
Per individual, resistance seems to be less costly than toxin production

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.

 | 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 Phosphor; 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

The presence of foxes on an island changes the vegetation from grassland to tundra- shrubland

Diversity and number of major plant groups are reduced in islands with fox populations

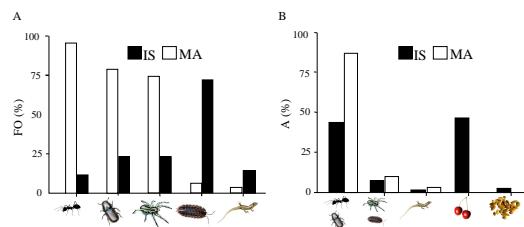
 

The ecological changes on islands with fox introduction represent exclusively top-down processes



## 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

Mainland nestlings have a wider food niche than island populations

In general, insects are the favorite food of nestlings

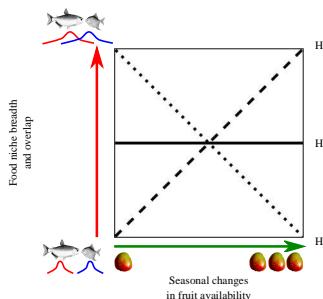
 

Island nestlings are expected to have a faster growth rate and shorter generation time than mainland nestlings



## 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

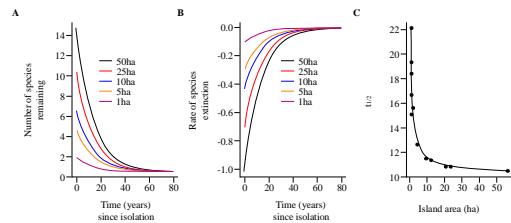
 

Fact: During HW, *M. asterias* had a fruit-dominated diet, but switched to leaves instead of fruit in the LW season: This is best explained by H2



## 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 ( $T_{1/2}$ ) 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)

At reservoir establishment, a linear relationship existed between species number and island area

The study supports the hypothesis that in the long run, a single large protected island will support biodiversity better than several small ones

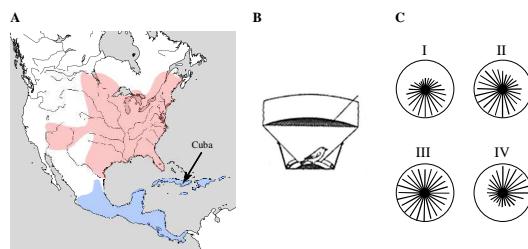
 

In all islands, which are larger than 10 ha, the mean time to extinction of half of all species, is comparable



## 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)

Fig. C-I is made by a north-eastern USA bird ready for autumn migration to the western part of Central America

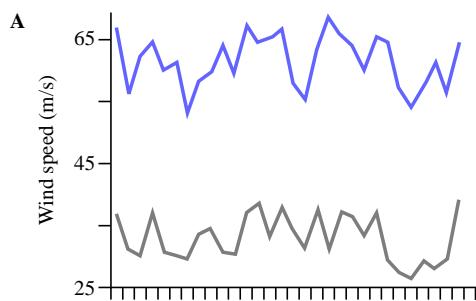
Fig. C-II is made by a western USA bird ready for autumn migration to Cuba

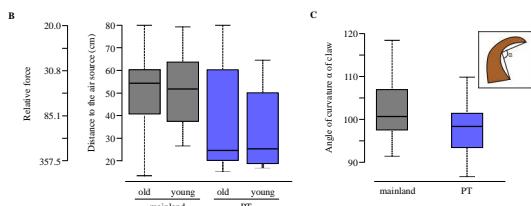
Fig. C-III: The footprint of a young bird, suggesting that migration patterns are genetically determined

 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  $\alpha$  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 Duplouy & 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

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

In general, butterflies do not evolve flightlessness because of their mode of foraging

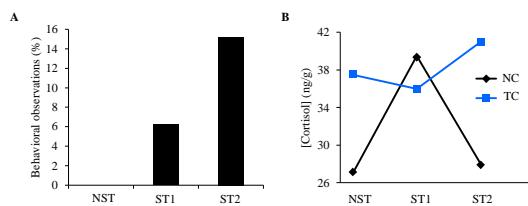
TRUE FALSE

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

Stereotypic pacing is affected by postponed feeding

Tail-chewing and stereotypic pacing are closely correlated

Very high behavioural stress levels seem to suppress cortisol production



## 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

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

Persons with type AB can receive blood from all ABO types

Persons with type B can receive blood of type AB

 Q. 34

Use of environmental DNA (eDNA) is a new tool in tracking of marine organisms. In a study, a base sequence from the mitochondria of the cetacean Harbour Porpoise was analysed. Samples were taken both from a harbour pen and outside from natural sites (fig.).

Human Harbour seal Harbour porpoise Harbour eDNA Site 1 eDNA Site 7 eDNA	11111111111111111111111111 88888888899999999000000000011111111111 23456789012345678901234567890123456789 <b>TCCGTAGCGTTTCTATTAGCTGTTAA</b> TAAGATTTACAT <b>TCCGTGGCTTTCTATTAGCTGTTACAGCCTTACACAT</b> <b>TCCGTGGCTTTCTATTAGCTGTTAGCAGCCTTACACAT</b> <b>TCCGTGGCTTTCTATTAGCTGTTAGCAGCCTTACACAT</b> <b>TCCGTGGCTTTCTATTAGCTGTTAGCAGCCTTACACAT</b>
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Base sequences (base no. 82 to 119) from human, seal, porpoise, and 3 samples of eDNA (Fjord Baelt, Site 1 and Site 7) (from Foote et al. 2012).

In addition, echolocation clicks were used for acoustic monitoring (table).

Detection of harbour porpoise DNA and sounds at 11 sites, including a control DNA from skin; values in right column are numbers of positive PCRs out of a sample of 3.

Location	Acoustic detection % Porpoise positive days	Genetic detection Positive PCRs
Positive control (DNA extracted from skin)		3/3
Fjord & Bælt pen		3/3
< 10 m from F&B pen		1/3
> 10 m from F&B pen		0/3
Site 1	94	1/3
Site 2	42	0/3
Site 3	63	0/3
Site 4	6	0/3

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

The father could be identified unambiguously with less than four blood type systems

Using the ABO system alone, the daughter's genotype had to be  $I^A i$

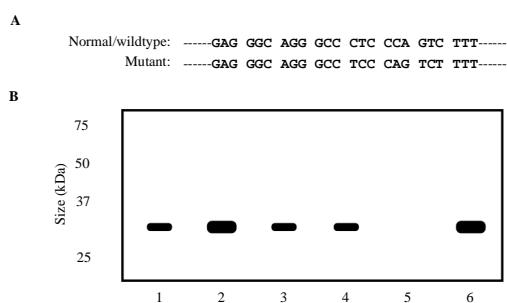
If the daughter bears a boy with a man, whose genotype is  $Xg^{(a+)}$ , then her son must be  $Xg^{(a+)}$ , because the allele  $Xg^{(a+)}$  is dominant



## 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

If a child lacks ficolin-3 protein, at least one of her/his parents should have the same phenotype

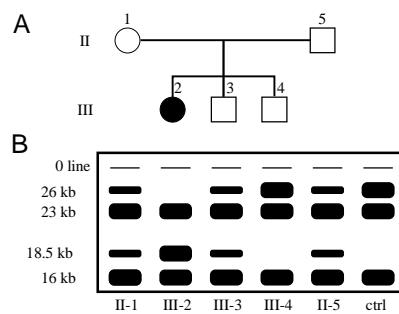
All three possible genotypes of the ficolin-3 gene can be determined using Western blots

Sister (1) might be heterozygous

 | 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

The mutation is due to a deletion of the size of 26 kb

III-4 will most probably not have children that lack growth hormone

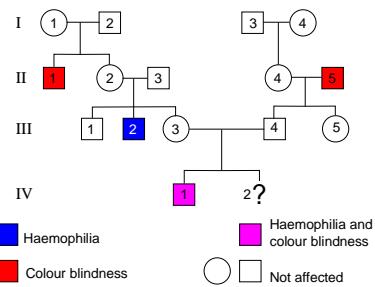
 

The risk that a fourth child of II-1 and II-5 will be a dwarf is 50%



## 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

At least two individuals in the pedigree carry recombinations due to genetic crossover

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

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%



## 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

All barred chickens in F2 can be regarded as hens and used for egg production

Half of the male chickens in F2 are heterozygous

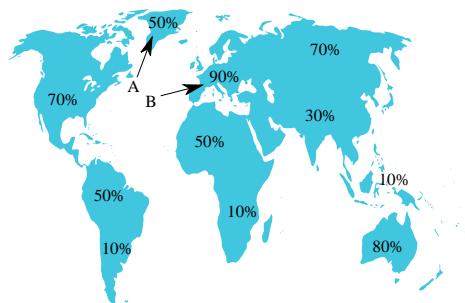
 

All male chickens in F2 are black



## 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

Differences in the frequencies of the K allele between populations prove that selection has been acting on this trait

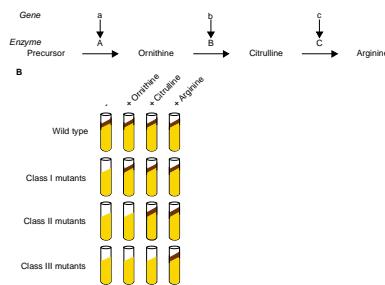
In Greenland (A) where the percentage of lactose tolerance is 50%, the frequencies of the alleles k and K are equal

Lactose tolerance is assumed to be the ancestral trait among adult humans

 | 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

Class I mutants lack activity of all three enzymes

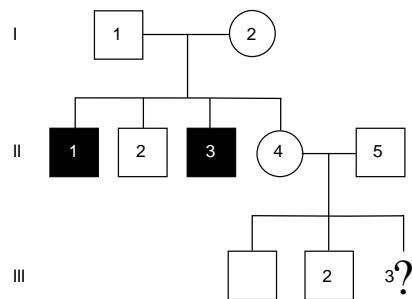
Mutants, lacking both enzyme A and C, will grow if ornithine and citrulline are both added

Assuming that an inhibitor to enzyme B is added to the wild type, gene B will be inactivated

 | 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

II-2 and II-4 have the same probability of carrying the disease allele

If assume that II-5 does not carry allele d, the probability that III-3 carries this allele is 0.30 or higher

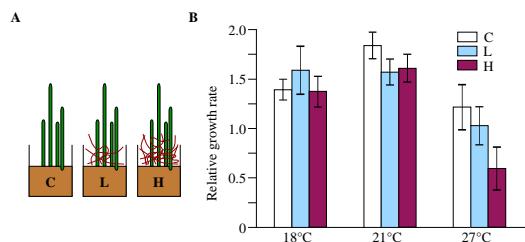
 

If we assume, that II-5 is heterozygous and III-3 has the disease, then the probability that II-4 is a carrier is 0.5



## 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 vermiculophylla* (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, *Gracilaria* inhibits the growth rate of eelgrass

In general, temperature affects the growth rate of eelgrass

There is a combined effect of *Gracilaria* and temperature on the growth of eelgrass

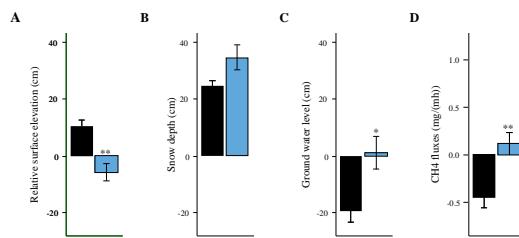
 

In Danish waters without *Gracilaria*, eelgrass growth is temperature limited



## 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 CH<sub>4</sub> 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

Undisturbed tundra woody vegetation functions as a source of global methane emission

Removal of woody vegetation initiates a cycle, leading to more dominance of water-tolerant plants

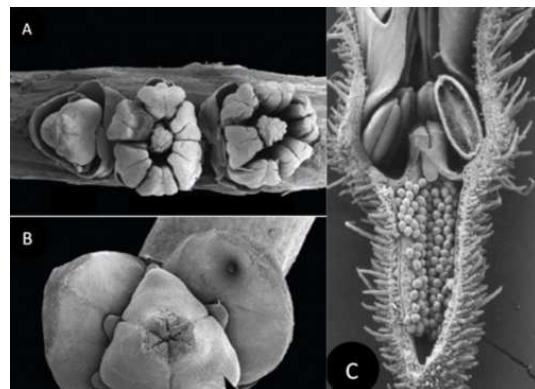
 

After removal of woody vegetation, the chain of events will be: Fig. B --> Fig. C --> Fig. A --> Fig. D



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)

The palm in Fig. A originates from an ancestor, which most likely had hermaphroditic flowers

The palm and the saxifrage are both most likely dicots

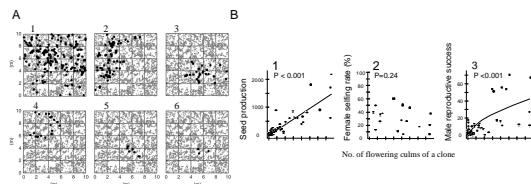
 

If structures through evolution become more specialized, one would expect the saxifrage to be phylogenetically older than the palm



## 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

More "investment" in clonal growth negatively affects female reproductive success of an individual bamboo

Larger bamboo clones have more self-pollination

The gain in female fitness per produced flowering culm diminishes with increasing clone size



## 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%

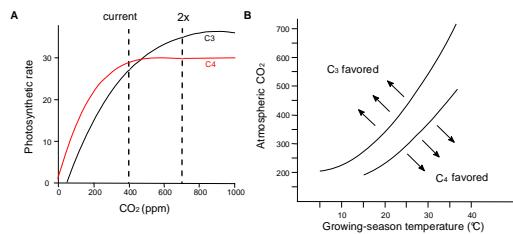
TRUE FALSE

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 CO<sub>2</sub> and ambient temperature vary (Fig.).



Photosynthetic rate (A) and expected dominance (B) of C<sub>3</sub> and C<sub>4</sub> plants as a function of ambient CO<sub>2</sub> 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<sub>4</sub>-plant species increases towards the poles

At current atmospheric CO<sub>2</sub> levels, CO<sub>2</sub> is limiting the growth of both C<sub>3</sub>- and C<sub>4</sub>-plants

The predicted CO<sub>2</sub>-increase can be more advantageous to C<sub>4</sub>- than C<sub>3</sub>-plants

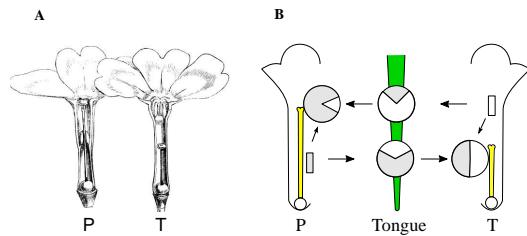
 

In dry and warm regions during the last glacial period, C<sub>4</sub>-plants were probably more widespread



Q. 49

Primrose has heterostyly, i.e. two flower forms on different individuals: P-plants with long style and short stamens inside the corollar 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

Incomplete sterility within the same flower form is seen in the population as a deviation from a 1: 1 T: P ratio

The two routes of pollen transfer (T --> P or P --> T) are equally efficient in terms of the pollen transferred

Pollen deposition from tongue to stigma is more difficult than pollen harvesting from anther to tongue

END