INTERNATIONAL BIOLOGY OLYMPIAD e. V. IBO

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THEORETICAL EXAM 2

This exam lasts three hours

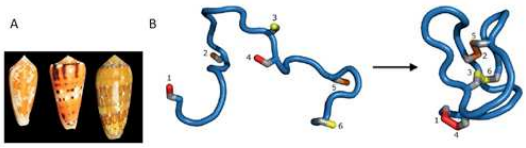
Q 1-11 Animal biology
Q 12-14 Biosystematics
Q 15-23 Cell biology
Q 24-29 Ecology
Q 30-31 Ethology
Q 32-41 Genetics & Evolutionary biology
Q 42-49 Plant biology

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

Conus snails produce potent conotoxins (peptides), which are used in defense and paralysis of prey. Conotoxins affect the neuromuscular end plates. Four toxins, A-D, have the following effects:

A prevents the inactivation of Na^+ channels in the presynaptic axon
B blocks K^+ channels in the presynaptic axon
C blocks Ca^{2+} channels in the presynaptic end plate
D blocks acetylcholine receptors



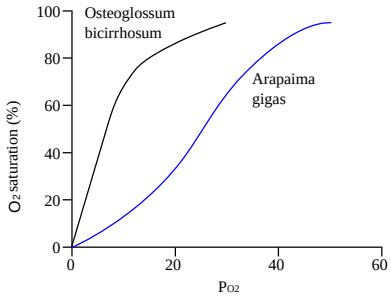
A, Conus snails; B, model of an unfolded Conus toxin (left) (1-6 are cysteine side chains) and, to the right, one possible 3-D folding through disulphide binding between pairs (e.g. 2 and 5) of cystein (from Safavi-Hermami et al. 2014).

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

	TRUE	FALSE
Toxin D inactivates the skeletal muscles	○	○
Toxins A and B will cause muscle twitching when injected in the prey	○	○
Toxin C interferes with the exocytosis of neurotransmitters	○	○
The peptide in Fig. B may be folded in various ways, but all folded molecules have the same effect, if the primary structure of the peptides remains unchanged	○	○

Q. 2

Fish vary in the way they take up oxygen. The precise uptake is reflected in their hemoglobin dissociation curve, and its shape is determined both by phylogeny and the habitat of the fish (Fig.).



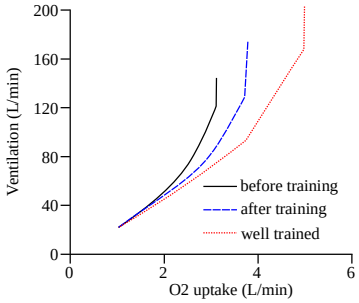
Hemoglobin dissociation curves for two species of fish Osteoglossum bicirrhosum and Arapaima gigas.

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

	TRUE	FALSE
O. bicirrhosum lives in faster-running water than A. gigas	○	○
O. bicirrhosum has a lower metabolic rate than A. gigas	○	○
O. bicirrhosum is an air breather (going to the surface), whereas A. gigas is a gill-breather	○	○
O. bicirrhosum lives at the surface, whereas A. gigas is a deep water species	○	○

Q. 3

Lung ventilation (or minute ventilation, V) at increasing workload (oxygen uptake) was measured for two men. Person 1 (black) was untrained, and his V was measured before and after a few weeks of training. His body weight before and after intensive training was 70 kg and 75 kg, respectively. Person 2 (red) weighed 70 kg and was well trained. His V as a function of work was measured only once (Fig.).



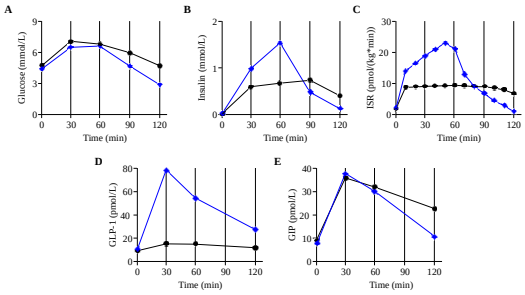
Lung ventilation V (atmospheric air L/min) as a function of total maximum oxygen uptake (L/min) for person 1 before training (black) and after training (blue dashed), and for person 2 (red dotted).

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

	TRUE	FALSE
After training, person 1 has improved his VO_2max (i.e. max. oxygen uptake/L/min/kg body weight) about 30% (±5%)	○	○
Training by person 1 affected both start and extent of hyperventilation	○	○
Further training is expected to increase person 1's anaerobic endurance significantly	○	○
A very high V is mainly achieved by an increase in breathing frequency and not depth of breathing	○	○

Q. 4

Morbid obesity can be treated surgically by a gastric bypass, where a part of the stomach and the proximal part of the intestine are bypassed. A group of obese individuals were enrolled in a study, in which their glucose and hormone levels were measured after an ingestion of glucose before and after gastric bypass surgery (Fig.).



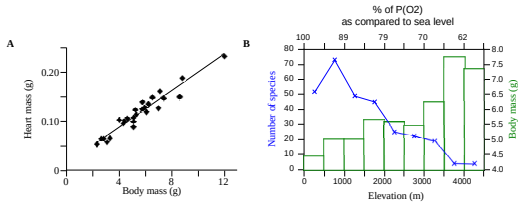
Effects of a glucose ingestion at time = 0 on the level of various parameters. Black circles indicate levels before gastric bypass, and blue diamonds indicate levels 3 months after gastric bypass. A, glucose level; Fig. B–C, insulin concentration and its secretion rate (ISR); Fig. D, Glucagon-Like Peptide 1 (GLP-1, gut hormone); and Fig. E, Gastric Inhibitory Polypeptide (GIP, gut hormone) (from Jørgensen et al. 2013).

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

	TRUE	FALSE
Gastric bypass leads to a stronger and shorter insulin response to an increased glucose level	○	○
From the study, GIP is expected to induce insulin secretion	○	○
Change in GLP-1-level after gastric bypass surgery may explain the faster increase in ISR	○	○
Blocking the effect of GLP-1 might be an efficient way to treat diabetes	○	○

Q. 5

Partial atmospheric oxygen pressure P_{O2} and ambient temperature decrease with increased elevation above sea level. This affects the respiratory physiology and species richness of many animal groups, e.g. hummingbirds (Fig.). An important physiological feature of hummingbirds is their ability to enter torpor, a state of reduced physiological activity, to save energy.



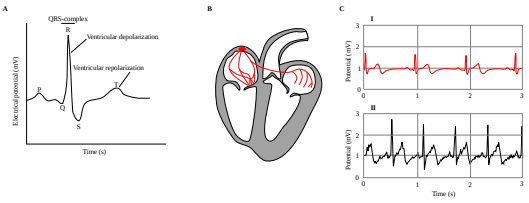
A, relationship between heart mass and body mass of hummingbird species; B, average body mass (grams) per 500 m altitudinal zone (histogram, right Y-axis) and number of species of hummingbirds (x–x–line, left Y-axis) at different elevations (lower X-axis). The percentage of partial oxygen pressure compared to sea level is also given (from Altshuler & Dudley 2002).

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

	TRUE	FALSE
Daily decreased physiological activity is common in montane hummingbirds	○	○
Above 500 m, diversity of hummingbirds is negatively correlated with height above sea level	○	○
The heart mass is negatively correlated to the partial pressure of oxygen	○	○
Hummingbird wing load (body mass/wing area) declines with altitude	○	○

Q. 6

An important function of an electrocardiogram (ECG) is to give information about the general health of a person. The ECG of two students was compared (Fig. C).



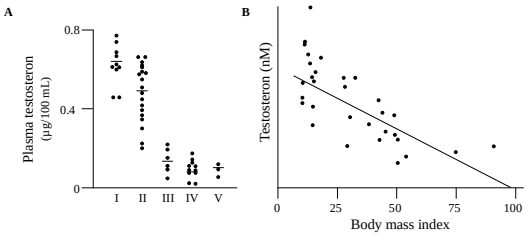
A, schematic representation of a standardized ECG; B, a snapshot of a heart with activitated innervations in red, pictured as if facing the student; C, electrocardiograms of two young male students (I and II) measured over 3 seconds.

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

	TRUE	FALSE
Blood flows from the right ventricle to the lungs, to the left atrium, to the left ventricle, to the body, and back to the right atrium	○	○
Students I has a heart rate of 80 beats/minute	○	○
If the stroke volume of student 1 is 70 mL/beat, then his cardiac output will be about 4.4 L/minute	○	○
The heart in fig. B is at the R peak	○	○

Q. 7

Variation in testosterone levels has major effects on general male physiology. Concentration of testosterone was measured in blood plasma from five groups of men (Fig.).



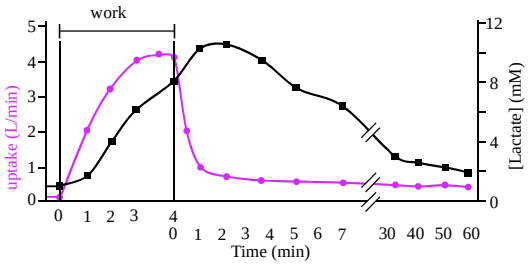
A, plasma level of testosterone in: I, Males 16-43 years old; II, Males 44-92 years; III, Males with underdeveloped pituitary glands; IV, Males with removed testes; and V, Males after treatment with injections of estrogen for some time. Each dot represents an individual, and the horizontal bars are group averages; B, plasma testosterone level in men as a function of body mass index (T = 23.94 – 0.26 BMI) (from Zumoff et al. 1990).

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

	TRUE	FALSE
Males–IV have reduced testosterone level due to negative feed-back regulation	○	○
Males–IV have a high LH concentration compared to Males–I	○	○
Estrogen injections in males lead to very low concentrations of LH	○	○
Even mild obesity (25<BMI < 30) might be much more important to testosterone level than higher age (> 43 years)	○	○

Q. 8

Oxygen uptake and lactate concentration in the blood were measured in a 70 kg male person before, during and after he had exercised (worked) for 4 minutes. The intensity of the exercise (work) corresponded to the consumption of 5 L oxygen/min.



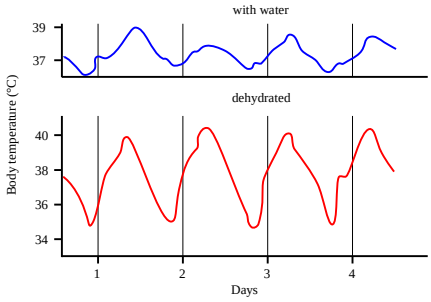
Changes in oxygen uptake (purple, left Y-axis, L/min) and lactate concentration (black, right Y-axis, mM lactate in blood) before, during and after an exercise or work period of 4 min.

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

	TRUE	FALSE
The person cannot work for 4 min at intensities equal to 5 L O_2-uptake/min, as his maximum aerobic work capacity is 4.2 L/min	○	○
The person has an aerobic capacity of 60 ml O_2/(kg min)	○	○
When blood lactate exceeds 11 mM, excretion begins through the kidneys, which is why its concentration declines	○	○
Excess O_2-uptake after the end of work is partly due to metabolism of lactate and not to gluconeogenesis	○	○

Q. 9

Camels are well adapted to desert life. Their hump consists mainly of fat, especially tripalmitin ($C_{51}H_{98}O_6$). A dehydrated camel's body temperature may vary from 34.5° C at night to 40.5°C during day.



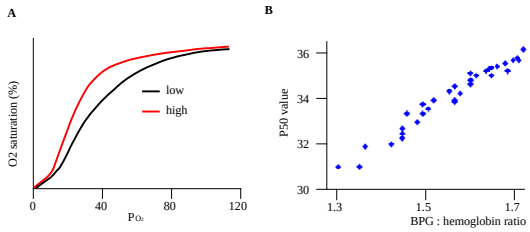
Body temperature of a dehydrated (red) camel compared to one well supplied with water (blue) (from Schmidt-Nielsen et al. 1957).

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

	TRUE	FALSE
The respiration of 1 kg tripalmitin will provide the camel with more than 1 liter of water (molar mass for C = 12, H = 1, O = 16)	○	○
The respiratory quotient of tripalmitin (CO_2 eliminated/O_2 consumed) is 1.4	○	○
During the day, a 500 kg dehydrated camel accumulates 2000 kcal of heat in its body (about 0.9 cal is required to increase one gram of tissue 1°C)	○	○
To keep a constant body temperature, a camel would need 2500 ml of water to get rid of 1000 kcal (1 ml water needs 580 cal to evaporate)	○	○

Q. 10

Deer mice have a wide geographic range, e.g. with respect to altitude. This is partly explained by their respiratory physiology (Fig.).



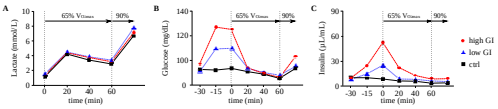
A, oxygen saturation (%) of blood of deer mice from low and high altitude habitats as a function of the partial pressure of atmospheric oxygen PO2; B, P50 is the partial PO2 at which the blood is 50% O2-saturated, here plotted against the BPG (2,3-bisphosphoglycerate) : hemoglobin ratio. BPG affects the oxygen affinity of hemoglobin (from Tufts et al. 2013).

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

	TRUE	FALSE
Hemoglobin in high-altitude deer mice does not release oxygen as easily as compared to that low-altitude mice	○	○
High-altitude mice have lower P_{50} than low-altitude mice	○	○
If BPG concentration in blood increases, the saturation curve in Fig. A will shift to the right	○	○
Assuming that adaptation to altitude is genetically determined, P_{50} values will most likely remain the same if a mouse is transferred to another altitude	○	○

Q. 11

The effect of consuming foods, which varied in their glycemic index (GI), on prolonged exercise were studied. GI expresses the effect of a particular type of food on a person's blood glucose level. At start of test, each person either got 1) Control, i.e. water (black squares); 2) LGI, i.e. a low GI meal + water (blue triangles), or 3) HGI, i.e. a high GI meal + water (red circles). Afterwards, each person rested, then cycled for 1 hr at 65% of her VO_{2max}, and finally at 90% VO_{2max} until exhaustion. Blood samples were taken before and during tests to measure levels of lactate, glucose and insulin (Fig.).



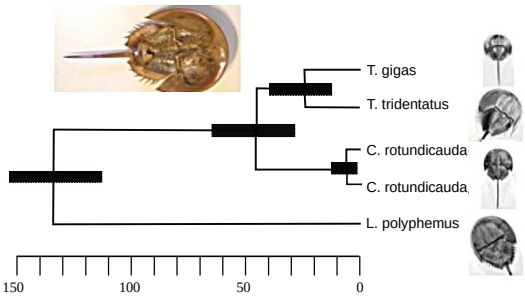
Levels of lactate A), glucose (B) and insulin in blood (C) before (pre-exercise) and during test. Each curve represents a treatment (red circles: high GI, blue triangles: low GI, black squares: control) (from Jamurtas et al. 2011).

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

	TRUE	FALSE
At the time of exhaustion, O_2 uptake was sufficient for complete metabolism	○	○
The level of lactate in the blood during exercise is influenced by the diet	○	○
Final test result at the time of exhaustion seems to be significantly affected by the kind of diet	○	○
The observed increase in blood glucose at the last phase of 90% VO_{2max} is due to an increase in fat metabolism and a reduced use of glucose	○	○

Q. 12

Horseshoe crabs are marine and only four extant species are known, while many have gone extinct. Tachypleus gigas (Tg), T. tridentatus (Tt) and Carcinoscorpius rotundicauda (Cr) are from southeast Asia, whereas Limulus polyphemus (Lp) lives on the east coast of N America. Tg and Cr overlap in their geographic range (from Andaman Sea (close to Thailand and Malaysia) to the South China Sea). Tt lives from Vietnam to Japan. Horseshoe crabs are "living fossils".



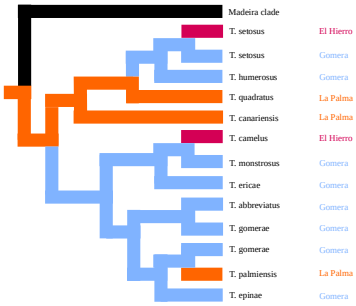
Phylogeny of extant horseshoe crabs. The unit of scale is a million years. Black bars indicate 95% confidence interval. The two populations of Cr are from Andaman Sea and Thailand (from Obst et al. 2012).

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

	TRUE	FALSE
From the Fig., we can conclude that horseshoe crabs must be a slowly evolving group	○	○
According to Fig., the Asian species constitute a monophyletic clade	○	○
Speciation in horseshoe crabs seems to take between 5 and 45 million years	○	○
The genera Tachypleus and Limulus are sister taxa	○	○

Q. 13

The flightless beetle genus Tarphius lives in humid forests and has 29 endemic species on the Canary Islands. The species are found on the five western islands of the archipelago, but not on the two eastern islands, closest to Africa. The more northern archipelago Madeira has additional species. A species may evolve on one island and then disperse to another island (ex situ-speciation) or it may evolve within an island from another Tarphius species already present there (in situ-speciation).



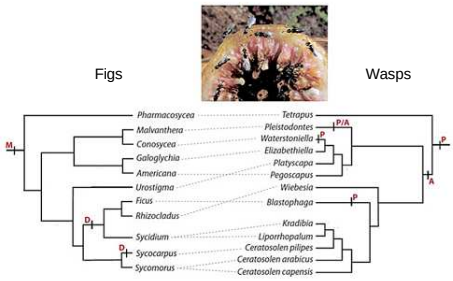
Part of the cladogram of Tarphius from the Canary Islands with the Madeira clade as an outgroup (black branch). Only species from three (La Palma, Gomera and El Hierro) of the five western islands are included (from Emerson & Oromí 2005).

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

	TRUE	FALSE
The Canarian phylogeny suggests both ex situ-and in situ-speciation events	○	○
From Madeira, Tarphius colonized the island of El Hierro	○	○
All three islands were colonized twice	○	○
Gomera is likely to be the Canarian Island with the highest habitat diversity of humid forest	○	○

Q. 14

Figs and wasps have a long coevolutionary history. Figs depend on tiny wasps for pollination, which depend on fig inflorescences, because they lay eggs in the flowers and their larvae develop in the fruits. The breeding system of fig species may either be dioecy (with male and female trees) or monoecy (with hermaphroditic trees with male and female flowers). Wasps pollinate either actively, by carrying pollen in special body pockets or passively, without any specific pollen behaviour (Fig.).



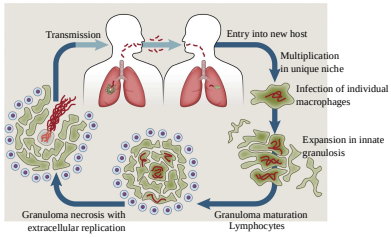
Phylogenies of some groups of figs (left) and wasps (right). Breeding system (M = monoecy, D = dioecy) and pollination mode of wasps (P = passive, A = active; P/A = dimorphic) are mapped onto the phylogenies. Transitions between breeding systems and between pollination modes are shown as small vertical bars on phylogenies. Dashed lines give the mutualistic relationships (from Herre et al. 2008).

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

	TRUE	FALSE
Passive pollination mode is ancestral in the evolution of fig wasps	○	○
Dioecy in figs is correlated to active pollination mode in wasps	○	○
The coevolutionary match between figs and wasps is only seen at the level of genus and higher	○	○
Pollination mode seems to be more labile evolutionarily than breeding system	○	○

Q. 15

Tuberculosis is caused by the bacterium Mycobacterium tuberculosis. One third of the world's population is currently infected with M. tuberculosis, and about 10% of these suffer from tuberculosis (TB). TB annually kills more than 1 million people. The pathogenic life cycle of M. tuberculosis is shown in Fig.



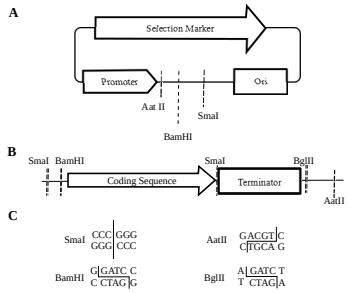
Pathogenic life cycle of M. tuberculosis (Mt). A granuloma is a group of tightly linked macrophages (from Cambier et al. 2014).

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

	TRUE	FALSE
Transmission of tuberculosis requires physical contact	○	○
Theoretically, a person with macrophage deficiency would be expected to suffer greatly from an Mt attack	○	○
The granuloma of macrophages is the host's succesful way of reducing the spread of the disease within the body	○	○
A new generation of Mt is released when the macrophages in the granuloma die	○	○

Q. 16

A gene (coding sequence) can be expressed by cloning it into an expression plasmid using restriction enzymes and DNA-ligase. A plasmid (A), a gene of interest (B), and the recognition sequences for four restriction enzymes (C) are shown in the figure. Different cloning strategies, expressed in the statements below, could be used to insert the"Coding sequence and Terminator" of this gene into the plasmid to produce a recombinant plasmid that expresses the gene.

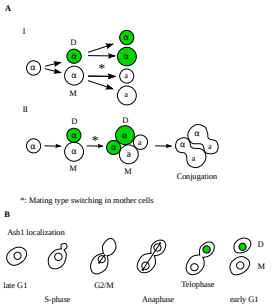


Indicate if each of the following statements is true or false.

	TRUE	FALSE
Digestion with SmaI followed by ligation can produce the desired recombinant plasmid.	○	○
Digestion with AatII and BamHI followed by ligation can produce the desired recombinant plasmid.	○	○
Digestion with BamHI + BglII followed by ligation can produce the desired recombinant plasmid.	○	○
The 'coding sequence' needs to be in-frame with the promoter	○	○

Q. 17

Yeast (Saccharomyces cerevisiae) has a mating pattern with both haploid and diploid cells, mitosis and meiosis, and two kinds of mating types. Haploid cells may even switch mating type (Fig.).



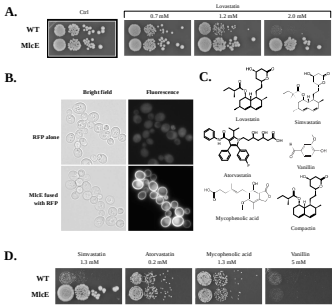
A, mating-type switching in budding yeast (M, mother cell; D, daughter cell. a and α, mating types). Fig. A I. mitosis in haploids; A II: mating and diploid formation; B, budding in haploid yeast. Both in Fig. A and B, green filling indicates the repressor factor protein Ash1p.

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

	TRUE	FALSE
Mating in yeast can only take place between two different kinds of haploid cells	○	○
Mating-type switching occurs only in the mother cell of each haploid generation	○	○
Mating type shift is induced by the repressor factor Ash1p	○	○
Mating type shift of haploids and the meiosis of diploids result in maximum mixing of mating types	○	○

Q. 18

Statin-drugs are used to lower blood cholesterol levels in patients that are at risk for cardiovascular diseases due to elevated blood cholesterol levels. One type of statins functions by inhibiting the de novo synthesis of cholesterol (or ergosterol) in eukaryotic cells via competitive binding and inhibition of the enzyme 3-hydroxy-3-methyl-glutaryl-CoA reductase (HMG). This enzyme also exists in S. cerevisiae and high concentrations of this group of statins can hence act as fungicides. In the current experiment aimed at identifying genes/enzymes that could make yeast resistant to statins.



A: An agar plate-based experiment, where a dilution series of two yeast cell cultures (wild type (WT) and MIcE expressing (MIcE)) have been spotted onto agar plates containing different concentrations of the statin lovastatin. The highest cell concentration is on the left of each plate; B: Bright field and fluorescence microscopy of yeast strains expressing red fluorescent protein (RFP) alone or RFP fused with MIcE (MIcE-RFP), respectively; C: The chemical structure of the compounds tested in A and D; D: Plate based-experiment, as described in A, testing different toxic compounds.

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

	TRUE	FALSE
S. cerevisiae is naturally resistant to the effects of lovastatin up to 0.7 mM	○	○
MIcE encodes a protein that localizes primarily to the plasma membrane	○	○
The MIcE offers general protection against all tested statins	○	○
MIcE will likely also protect yeast from the harmful effects of compactin	○	○

Q. 19

The amino acid sequence MYTHELL is essential for the activity of a given enzyme. Analysis of this enzyme in three related species (A–C, see statements) reveals some diversity. The table below shows the codon usage for the different amino acids in the three organisms

TTA Leu L	TCA	TAA STOP	TGA STOP
TTG	TCG	TAG	TGG Trp W
CTT Leu L	CCT Pro P	CAT His H	CGT Arg R
CTC	CCC	CAC	CGC
CTA	CCA	CAA Gln Q	CGA
CTG	CCG	CAG	CGG
ATT Ile I	ACT Thr T	AAT Asn N	AGT Ser S
ATC	ACC	AAC	AGC
ATA	ACA	AAA Lys K	AGA Arg G
ATG Met M	ACG	AAG	AGG
GTT Val V	GCT Ala A	GAT Asp D	GGT Gly G
GTC	GCC	GAC	GGC

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

	TRUE	FALSE
In species A, the enzyme-encoding sequence has changed to MTTHYLL, which can be explained by two point mutations	○	○
In species B, the sequence is MYYS, which is best explained by a frame shift mutation	○	○
In species C, the sequence is in fact MYTHELL, but this can be due to 512 different nucleotide sequences	○	○
On average, a change from MYTHELL to MYTQELL is more likely than a change to MYTHEHL	○	○

Q. 20

The adenine (A) content in DNA extracted from tissues of horse, donkey, mule and zebra has been determined. A mule is a horse x donkey hybrid. A zonkey is a zebra x donkey hybrid.

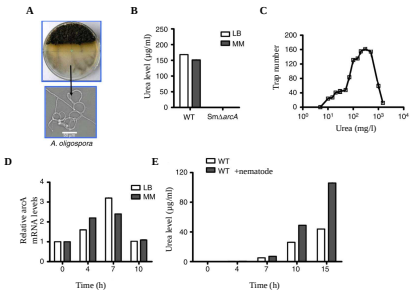
	Horse	Donkey	Mule	Zebra
Tissue	Muscle (HM)	Kidney (DK)	Muscle (MM)	Kidney (ZK)
Relative genome size	3.4	4.1	3.7	4.1
Adenine (A) content (%)	25	20	not determined	not determined

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

	TRUE	FALSE
In the samples DK and ZK, the A content is likely to be identical	○	○
The A content of MM is likely to be approximately the weighted average of HM and DK, i.e. 23%	○	○
If the A content is 20%, then the G (guanine) content must also be 20%	○	○
The relative genome size of a zonkey is likely to be 4.1	○	○

Q. 21

Bacteria are the food of many nematodes, and many bacteria have a toxic secretion defence. Nematodes are also preyed upon, e.g. by the fungus Arthrobotrys oligospora (Ao). This fungus lives in cow dung and is either saprophytic or predatory. When it encounters a nematode, it becomes predatory by producing traps to capture nematodes (Fig. A). This shift is induced by chemicals, e.g. urea produced by bacteria, e.g. Stenotrophomonas maltophilia (Sm) (bacterial urea production below 300 mg/L soil). The interactions between bacterium, fungus, and nematode were studied (Fig.).



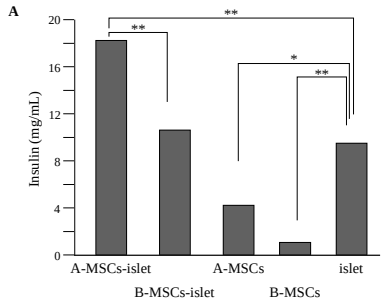
A, trap-formation by Ao near cow dung on a plate; B, urea is produced from arginine and formation is catalysed by arginase, being controlled by the gene arcA; SmΔarcA is a bacterial strain without arcA (WT is wild type); LB and MM are nutrient-rich and -poor media, respectively; C, trap number as a function of urea concentration; D, arcA is expressed in bacteria, when nematodes are added; E, urea levels in bacteria with and without nematodes. (from Wang et al. 2014).

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

	TRUE	FALSE
Under normal conditions of bacterial urea production, trap production by the fungus increases	○	○
Only bacteria with the specific gene arcA can produce urea	○	○
Bacteria produce urea in both nutrient-rich and -poor conditions	○	○
Urea production seems to be triggered by stimuli from the nematode	○	○

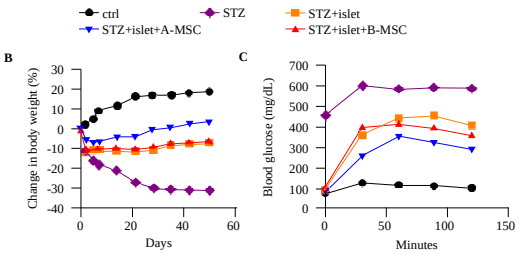
Q. 22

Differentiation of a kind of stem cells (mesenchymal stromal cells MSC) derived from adipose rat tissue (A-MSC) and bone marrow (B-MSC) was analyzed in vitro and in vivo. Diabetic rats (STZ rats) were used and MSCs were co-transplanted with pancreatic islets to confirm the in vitro results (Fig. A).



A, in vitro: insulin secretion levels after 38 days of culture of islets and stem cells

The insulin-producing capacities of the islets transplanted with stem cells were compared and reduction of hyperglycemia symptoms in the rats was examined (Fig. B-C).



B, in vivo: body weight change after transplantation of islets into the rats. Body weight change (%) compared to the time of transplantation (day 0); C, in vivo: Glucose tolerance test was performed after injection of 2 g glucose/kg rat (from Karaoz et al. 2013).

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

	TRUE	FALSE
There is no added advantage in cultivating pancreatic islets together with stem cells in order to obtain a high insulin production in vitro	○	○
Transplanting stem cells and islets may potentially reduce the blood glucose level in a glucose tolerance test, but not to the level observed in control rats	○	○

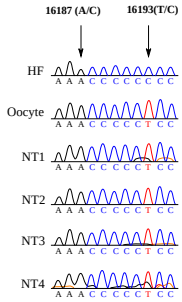
	TRUE	FALSE
Transplantation of stem cells from adipose tissue together with islets seems to be the most efficient way to help people, who suffer from diabetes	○	○
The conclusion from all experiments is that there are no observed effects of islets + bone marrow stem cells together as compared to islets alone	○	○

Q. 23

Researchers succeeded in reprogramming human somatic cells into embryonic stem cells (ESC) by a somatic cell nucleus transfer (SCNT) into oocytes from which the nucleus had been removed. After the transfer, the origin of the nuclear and mitochondrial (mt) DNA were analysed (Fig.).

Nuclear DNA genotyping from three nucleus transfer (NT)-ESC lines (NT1-3) determined by microsatellite analysis; D2S1333 and D4S413 are locus names and numbers in columns are sequence length of specific alleles.

Origin	D2S1333 locus	D4S413 locus
Somatic donor cell	293/301	123/123
Oocyte	297/305	133/153
NT1	293/301	123/123
NT2	293/301	123/123
NT3	293/301	123/123



mtDNA sequences of the NT-ESC lines (HF = human foetus); 16187 and 16193 are two nucleotide positions used as markers after SCNT (from Tachibana et al. 2013).

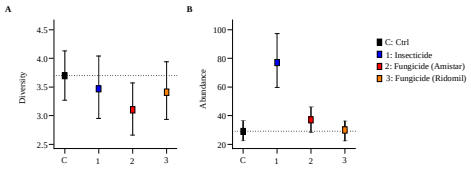
Indicate if each of the following statements is true or false.

	TRUE	FALSE
The nuclear DNA composition of the ESCs is a combination of nuclear DNA from the somatic donor cell and nuclear DNA from the oocyte donor	○	○
The mtDNA of the ESC lines originates from the oocyte	○	○

	TRUE	FALSE
After nuclear transfer the oocyte becomes a haploid	○	○
It is most likely, that different oocyte donors were used	○	○

Q. 24

Tropical forest plant communities are very diverse. The Janzen–Connell hypothesis argues that insect herbivores and pathogens are positive drivers of this diversity. This was tested in a rainforest by excluding herbivores and pathogens through pesticide application and observing if this affected plant diversity and abundance (Fig.).



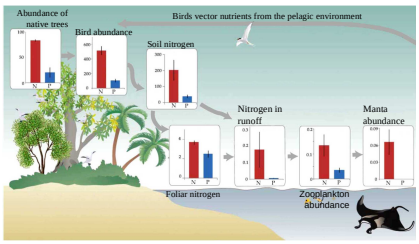
Effects of an insecticide and two fungicides upon: seedling diversity (A) and mean seedling abundance (B) of the forest community. Error bars represent 95% confidence intervals of the mean of all study sites with a given treatment (from Bagchi et al. 2014).

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

	TRUE	FALSE
All treatments had a statistically significant effect upon seedling diversity	○	○
In the study area, most insects were predators	○	○
Ridomil is stronger in its effects on fungi than Amistar	○	○
The hypothesis is supported in the present study by the combined effect of insects and fungi	○	○

Q. 25

The fragility of an ecological food chain is examined on an atoll, where native forest was replaced by coconut palms (Fig.). This created a problem for seabirds which could not nest in palms.



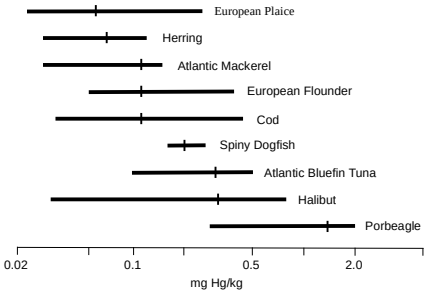
Changes in the ecological chain, when native forest (N) is replaced by palms (P). Each bar graph compares processes in N and P (from McCauley et al. 2012).

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

	TRUE	FALSE
Bird presence benefits manta rays	○	○
Palm growing might harm corals in the atoll	○	○
If forest was cleared and land instead used for intensive modern farming with fertilizers, manta rays might disappear from the coast	○	○
The food chain includes only top-down effects, and no bottom-up effects	○	○

Q. 26

The World Health Organisation (WHO) recommends a Maximum acceptable Daily Intake (MDI) of 0.1 microgram Hg (Mercury) per kg consumer body mass. Consequently, Hg levels in Danish fish for human consumption are under permanent control. Mercury level in nine species was measured (Fig.).



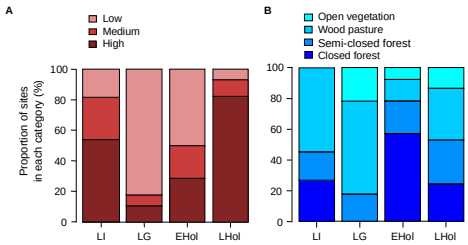
Hg level in milligram/kg fish; horizontal bars span the 95% confidence interval (small vertical bars are averages).

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

	TRUE	FALSE
Mackerel is placed higher in the marine food chain than Halibut	○	○
Hg-level generally increases with body weight	○	○
Mean Hg concentration in Tuna allows a 75 kg person to consume a maximum 1 kg Tuna per ca. 10 days	○	○
Tuna has a wider diet than Halibut	○	○

Q. 27

Large herbivores have a high impact upon ecosystems, but most have become extinct during the last 100 kY (1kY = 1000 years). This mass extinction also affected their associated dung beetle fauna. Subfossil findings in Northern Europe show that this beetle fauna was richer and belonged to more open woodland before the mass extinction than afterwards, when dung beetles became fewer and most lived in closed forest. Modern humans and agriculture arrived to Northern Europe 50 kY and 10 kY ago, respectively.



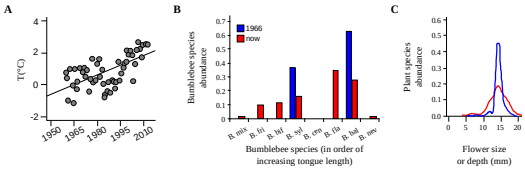
Proportions of excavation sites classified according to their fossil dung beetle density (A), and vegetation type (B); the latter being identified by its characteristic beetle fauna. LI, last interglacial period (132–111 kY ago); LG, last glacial period (50–15 kY ago); EHol, early Holocene (10–5 kY ago); and LHol, late Holocene (2 kY ago to present) (from Sandom et al. 2014).

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

	TRUE	FALSE
The decline of the large herbivore fauna during LG might partly be explained by climate change	○	○
The decline of the large herbivore fauna during LG might partly be explained by human arrival	○	○
The small increase in dung beetle density during the warmer EHol is due to a return of large native herbivores after the LG	○	○
The strong increase in dung beetle density during LHol is due to agriculture	○	○

Q. 28

High-altitude Rocky Mountains (U.S.A.) bumblebee communities were studied 40 years ago and again today, and a set of changes was noted, and these were related to climate change (Fig.).



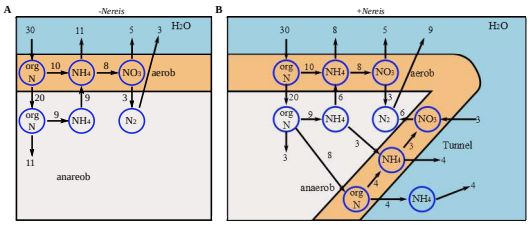
A, change in summer temperature in the Rocky Mountains; B, change in tongue length in a mountain bumblebee community (blue bars, 1966; red bars, now); and C, change in diversity of flowering plant species with different depth, i.e. access to bees, between 1966 (blue) and today (red) (from Miller-Struttmann et al. 2015).

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

	TRUE	FALSE
The present-day bumblebee community is less diverse than in 1966	○	○
Higher temperature favours nectar-plant specialist bumblebees	○	○
Low-altitude bumblebee species have not been able to invade the higher altitudinal zones during the 40 study years	○	○
Average depth of flowers has decreased during the 40 study years, favoring shorter-tongued bumblebees	○	○

Q. 29

The polychaete Nereis virens lives in the bottom sediment of shallow coastal waters. It digs tunnels in the sediment and pumps water through these tunnels. The decomposition turnover of nitrogen (N) compounds has been investigated in the sediment at two sites: one without Nereis (Fig. A) and one with 600 Nereis per m^2 (Fig. B).



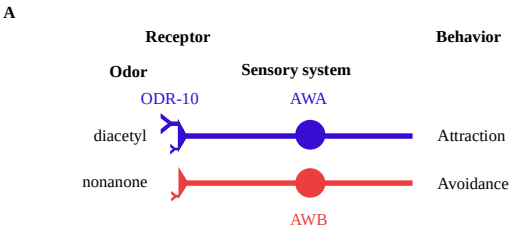
Sediment N-processes without (A) and with (B) Nereis. Numbers at arrows give the annual N turnover in g N per m2.

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

	TRUE	FALSE
Less organic N is deposited in the bottom sediment in B compared to A	○	○
Denitrification rate is increased threefold in the presence of Nereis	○	○
In the tunnels made by Nereis, 5 g N per m^2 per year are deposited in the sediment	○	○
Concentrations of nutrients, which may lead to algal bloom, are lowered in the presence of Nereis	○	○

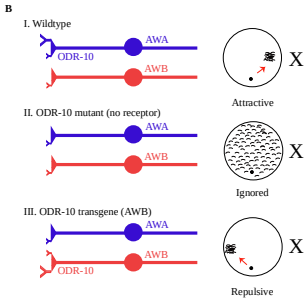
Q. 30

The worm C. elegans shows sophisticated behaviour in response to odour. It has 11 pairs of chemosensory neurons. Odours are detected by G protein-coupled receptors (GPCR) on the outside of these neurons. The receptor protein ODR-10 on the neuron AWA initiates the movement of C. elegans towards the odour diacetyl (its location shown as X in figure B). The neuron AWB, however, initiates movement away from the toxin nonanone (A).



A, diacetyl elicits an attraction (+) of the worm via AWA, nonanone elicits a repulsion (–);

The behaviour of mutant and transgenic worms was compared to the one of wild-type worms (B).



Mutant animals don't express ODR-10. Transgenic animals only express ODR-10 receptors on AWB. The receptor still reacts to the presence of diacetyl, but its reaction is avoidance (–). I, WT = wild type; II, mutant without receptor; III, transgenic animal.

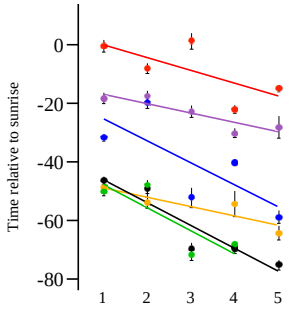
Indicate if each of the following statements is true or false.

	TRUE	FALSE
ODR-10 on AWA is required for attraction towards diacetyl	○	○
ODR-10 can mediate both attraction and repulsion	○	○
Each olfactory neuron has receptors for many odour chemicals	○	○

	TRUE	FALSE
All olfactory neurons are functionally similar even if their receptors are different		

Q. 31

Researchers investigated if street-lighting (artificial night lighting) affected dawn and dusk singing in six common songbirds. They used 5 sets of plots of increasing light intensities (Fig.).



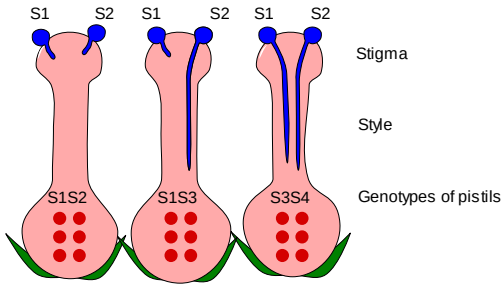
Average start of dawn singing relative to sunrise '0' (mean ± standard error) against increasing light intensity (from 1 to 5) at sites with street-lighting (from Silva et al. 2014).

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

	TRUE	FALSE
Generally, street-lighting seems to have the strongest effect on the earliest birds	○	○
Streetlight increases interspecific competition among birds for time of singing	○	○
The morning pattern may be reversed at dusk	○	○
Rain at dawn may delay the initiation of singing	○	○

Q. 32

In diploid clover species (Trifolium), fertilization is determined by (gametophytic) self-incompatibility alleles (S-alleles). Pollen with a given allele, e.g. S1, cannot germinate on the stigma of another plant, if this plant has the same allele (e.g. if the mother has the genotype S1 S2 or S1 S3), and therefore no fertilization takes place (Fig.). In species with S-systems, one often finds many alleles: S1 … etc. in a population.



Self-(in)compatibility reactions in three pistils; pollen and pollen tubes are coloured blue. S1 to S4 are S-alleles, and S1S2 etc. are genotypes of mother plants.

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

	TRUE	FALSE
The genotypes in the S gene are in Hardy-Weinberg equilibrium	○	○
In a population with three S alleles and equal frequencies of all possible genotypes, 1/3 of all crosses will be incompatible	○	○
The smallest possible number of S alleles in a viable population is four	○	○
In another incompatibility system with only two alleles (S1 and S2, and S1 being dominant over S2), 1/3 of all crossing types are compatible	○	○

Q. 33

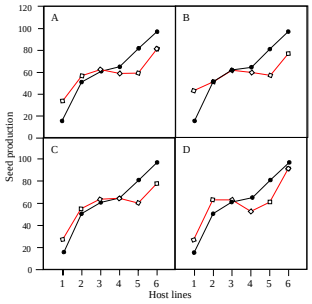
In a single locus with three alleles A, B and C, the population allele frequency of A is 0.25 and the frequency of AC individuals is 0.20. We assume random mating in the population.

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

	TRUE	FALSE
The frequency of the AA genotype will be 0.1875	○	○
The frequency of the AB genotype will be 0.175	○	○
If B is dominant to A and C, then the frequency of the B phenotype will be the frequency of the B allele	○	○
In a single locus with 5 alleles, we get 16 possible genotypes	○	○

Q. 34

The oomycete Hyaloperonospora arabidopsidis (Ha) grows on the plant Arabidopsis thaliana (At). Six genotypes of At (Pyr, Tsu, Sue, Fin, Tch and Gb) were grown with or without Ha in four experiments (Fig.A–D). In each experiment, the Ha sample differed: one came from a laboratory sample kept for years (B), one was collected in the field in Germany (C), another in France (D). Finally, one experiment (A) used a mix of the three others.



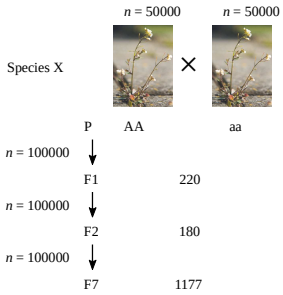
Seed production (mg seeds/plant; Y-axis) of six At genotypes (Pyr, Tsu, Sue, Fin, Tch, Gb; X-axis) in four experiments (a)–(d). At genotypes are ranked according to increasing seed production in the absence of the oomycetes (filled symbols, black); At grown with Ha (open symbols, red) (from Salvaudon et al. 2008).

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

	TRUE	FALSE
In experiment B, Ha is commensal with all At genotypes	○	○
In experiment C, Ha is a parasite on all At genotypes	○	○
For all three fungal strains, the negative impact of Ha is strongest on the most productive genotypes	○	○
The outcome of interactions between Ha and At on the plant depends on the latter's genotype	○	○

Q. 35

Two pure breeding lines of Species X were crossed (Fig.). For each generation, 100 000 plants were allowed to breed. For the generations F1, F2 and F7, a specified number of plants were genotyped for the alleles A and a. The experimenter assumes no selection, no self fertilization and random mating after the first generation.



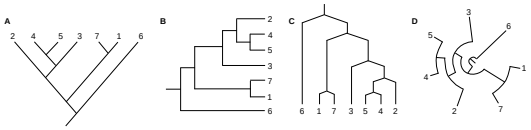
Breeding of pure lines in Species X; n is number of sampled plants. The central column gives number of individuals genotyped in each generation (only generations P, F1, F2 and F7 are shown).

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

	TRUE	FALSE
The parental generation (P) shows Hardy-Weinberg proportions	○	○
Expected number of Aa genotyped individuals in F1 is 110	○	○
Expected number of aa genotyped individuals in F2 is 90	○	○
In F7, 271 plants were genotyped as AA. This is less than expected	○	○

Q. 36

The phylogeny of seven species is presented in four different ways (Fig.).



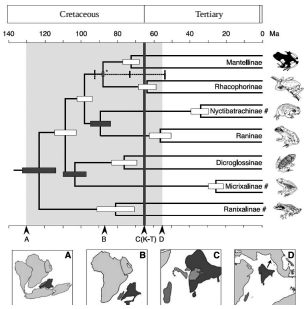
Four phylogenies of seven species (1-7).

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

	TRUE	FALSE
All four trees reflect the same phylogeny	○	○
In all phylogenies, species 6 is expected to have more mutations than species 2	○	○
In phylogeny A, species 1, 6, and 7 constitute a monophyletic group	○	○
In phylogeny C, species 7 is more closely related to species 3 than to 5	○	○

Q. 37

The phylogeny of frogs has a very dynamic geographical history (Fig.).



Phylogeny of frog groups (branch lengths proportional to absolute time). Error bars on internal nodes are confidence intervals on the node dates; below and above the phylogeny is a geological time scale, and below the lower time scale is a cartoon for the period between the isolation of the Madagascar-India continental block from Africa (A) (130 mill. years ago, Ma) to the collision of India with Eurasia (D) (56 Ma) (shaded area in phylogeny, A–D in cartoon refer to A–D in lower time scale; K–T = Cretaceous–Tertiary boundary) (from Bossuyt & Milinkovitch 2001).

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

	TRUE	FALSE
No individual living before 60 million years ago is an ancestor of Raninae	○	○
Raninae and Dicroglossinae shared a common ancestor about 75 million years ago	○	○
Divergence of Raninae and Nyctibatrachinae most likely occurred after the 85 million year old separation of India and Madagascar	○	○
The last common ancestor of Micrixalinae and Dicroglossinae lived before India and Madagascar became separated (85 million years ago)	○	○

Q. 38

The marine transition area between the Bothnian Bay (the northernmost part of the Baltic Sea between Sweden and Finland) and the Eastern Atlantic ocean is characterized by a steep cline in salinity (Fig. B) and it is inhabited by a number of fish species. Studies show genetic differences, measured as F_{ST} (Fig.) between two populations, one being the Bothian Bay population, which is considered the reference population. F_{ST} = 0 means complete random mating across populations, F_{ST} = 1 means no mating between populations.

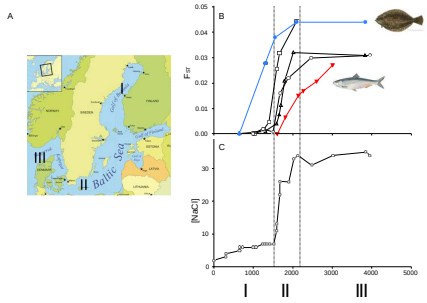


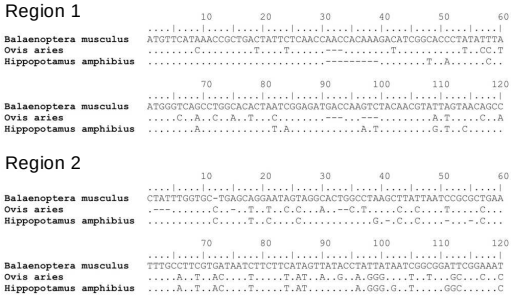
Figure. A, Bothnian Bay (I), Southern Baltic Sea (II), and North Sea (III); B, changes in genetic variation among populations (F_{ST}) of five fish species (blue filled circles = flounder (inset); red filled inverted triangles = herring (inset); open squares, triangles, and circles= three other fish species); C, change in salinity [NaCl] from the Bothnian Bay (I) towards the North Sea (III) (from Limborg et al. 2009).

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

	TRUE	FALSE
Salinity might be important in shaping the genetic structure of marine fish	○	○
Baltic Sea fish are adapted to local environmental conditions	○	○
The random mating of Herring is less affected by salinity than is that of the other four species	○	○
Flounder is less sensitive to changes in salinity than the other four species	○	○

Q. 39

Base sequences of two genomic regions (1 and 2) from blue whale (Balaenoptera musculus), sheep (Ovis aries) and hippopotamus (Hippotamus amphibius) were aligned and compared (Fig.).



Base sequences.'–' is a base deletion, and '.' means the base is the same as in the sequence above.

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

	TRUE	FALSE
Region 1 is most likely a protein coding sequence	○	○
Region 2 is most likely a protein coding sequence	○	○
In region 1, the blue whale sequence is longer than the other two, which suggests that sheep and hippopotamus are closer related than either are to the blue whale	○	○
Regions 1 and 2 show the same phylogenetic relationship among the three species	○	○

Q. 40

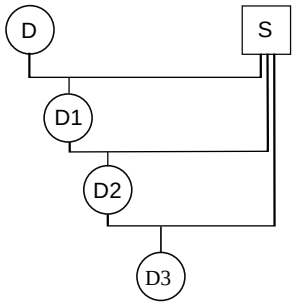
The fast growing model bacterium E. coli (generation time = 20 min) has a single 4.6 million base pair large chromosome that can be replicated in 42 minutes from a single origin of replication.

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

	TRUE	FALSE
In E. coli, DNA polymerase synthesizes about 900 bp/second including proof reading activity.	○	○
An E. coli cell always contains two copies of its genome just prior to cell division when growing at highest possible growth rate	○	○
During replication, the enzyme primase forms a short RNA sequence, which is extended by DNA polymerase. This is why the genome just after replication contains multiple short stretches of RNA	○	○
E. coli DNA polymerase III synthesizes DNA with an error rate of 1 wrong nucleotide per 1000 bases, that is why the genome after replication contains about 4600 mutations	○	○

Q. 41

A plant crop is susceptible to leaf rust. In a screening of old varieties from a gene bank, a resistance allele B was discovered. In an intensive backcrossing program, this allele was introgressed to the crop (Fig.). Resistance was tested in each generation.



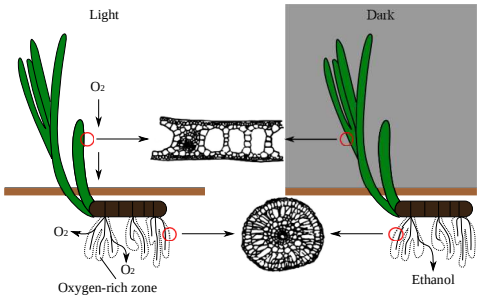
Intensive breeding program. D is donor of a dominant resistance allele B, and b is the allele in the standard crop plant being susceptible to rust. S is the variety into which gene B is introduced

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

	TRUE	FALSE
93.75% of the alleles, not linked to allele B, in D3 come from S	○	○
At least 10 backcrossings are needed to get the percentage of D genes below 1%	○	○
More crosses are needed to introgress a recessive resistance allele than a dominant one	○	○
Introgression cannot be done with quantitative traits	○	○

Q. 42

Eelgrass (Zostera marina) is a submerged marine plant. During the daytime, O_2 is transported via the aerenchyma of the green parts and rhizomes out into the roots, and an oxygen-rich zone develops in the surrounding anoxic sediment. At nighttime it is a different story: now ethanol diffuses out of the roots and into the sediment (Fig.).



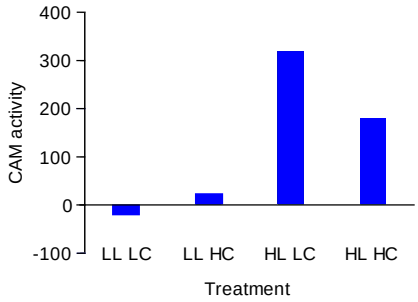
Eelgrass at day and night, and cross-sections of leaf and root.

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

	TRUE	FALSE
For respiratory reasons, Zostera roots are expected to have a thin epidermis	○	○
Both at day and night, O_2 readily diffuse into the roots	○	○
Root uptake of nutrients is independent of time of day	○	○
At nighttime, the concentration of Na^+ is expected to decrease in root cells	○	○

Q. 43

Crassula helmsii is a succesfull aquatic plant with CAM photosynthesis. In a cross-factorial study, including 2 light levels: LL and HL; and 2 CO_2 levels: LC and HC, the CAM activity of C. helmsii was measured (Fig.).



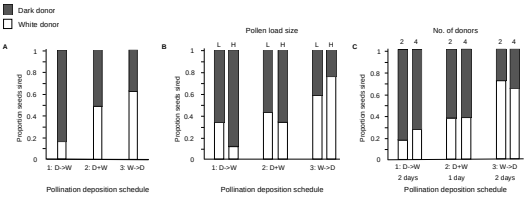
CAM activity measured as dry matter production in plants. LL and HL = low and high light, resp. LC and HC = low and high CO2, resp. (from Klavsen & Maberley 2010).

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

	TRUE	FALSE
CAM seems to be an adaptation to survive in waters rich in carbon	○	○
The circadian stomatal opening rhythm of CAM plants enables them to take up CO_2 at nighttime	○	○
CAM increases nighttime photorespiration	○	○
At LL, there is less dry matter production, because CAM plants also require light for photosynthesis	○	○

Q. 44

Plants compete as pollen donors for siring offspring, i.e. becoming fathers. The stigma becomes an arena, where pollen donors/fathers “fight” for fertilization (paternity), and where the females ”choose” fathers of their seeds. This was studied in the plant Purple Chinese Houses (Collinsia heterophylla) (Fig.).



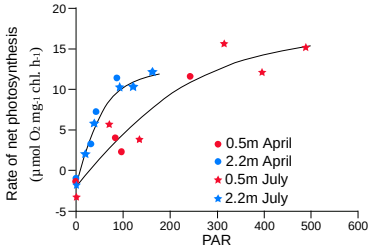
Proportion of seeds sired by either a dark (D) or a white pollen donor (W): A, pollen deposited on stigma in succession (1: D → W, i.e. first D and then W, or 3: W → D) or simultaneously as a mixture (2: D + W); B, size of deposited pollen load (D and W added simultaneously): L and H = low and high pollen load, respectively; and C, two or four donors (i.e. first 2D and then 1–2 days later 2W or vice versa) (from Lankinen & Madjidian 2011).

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

	TRUE	FALSE
There is a first-donor advantage	○	○
No competitive effect of high pollen load is observed	○	○
Increase in number of fathers increases competition	○	○
If lots of pollen from the first donor is deposited, pollen added 2 days later from a second donor does not sire seeds	○	○

Q. 45

The relationship between light intensity and net photosynthesis rate (NPR) was measured in the submerged plant Crassula helmsii in a lake. The plant has CAM photosynthesis. Measurements of the photosynthetic rate (µmol O2 mg-1 chlorophyll h^{-1}) were made on plants growing in shallow water (6.5 mg chlorophyll/g dry weight) and deep water (10.3 mg chlorophyll/g dry weight) in April and July (Fig.).



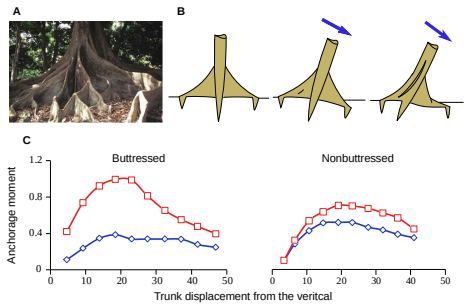
Light response curves in April and in July for C. helmsii, growing in shallow (0.5 m) and deep (2.2. m) water. PAR photosynthetically active radiation (from Klavsen & Maberly 2009).

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

	TRUE	FALSE
Shallow-water plants have higher NPR at 100 PAR than deep-water plants	○	○
Deep-water plants have higher NPR in July than in April	○	○
In the experiment, NPR is light limited	○	○
Deep-water plants have a higher NPR because of their higher chlorophyll content	○	○

Q. 46

Some trees have large triangular, superficial lateral roots called buttresses (Fig. A). Their functions are widely discussed, but poorly understood. They are more common on trees with an asymmetrical crown; they may prevent windfall (Fig. B); presence of buttresses may also depend on soil type and inclination, and wood density. Their stabilizing importance was tested experimentally (Fig. C).



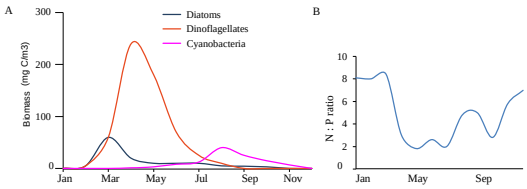
A, tree with buttress roots; B, a tree with buttresses and vertical tap root pulled over by wind (blue arrow is direction of wind); C, an experimental study of change in anchorage moment for buttressed (left) and non-buttressed trees (right) as a function of the tree's displacement from vertical (inclination in degrees): red squares are for trees with an intact root system, and blue diamonds for trees, in which all lateral roots (including buttresses, but excluding vertical tap root)) have been cut off (from Crook et al., 1991).

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

	TRUE	FALSE
Buttresses of a tree help to increase the resistance of the tree to wind	○	○
The tap root is relatively more important to anchorage in buttressed than in non-buttressed trees	○	○
The smallest vessels and lowest vessel frequency are found in the parts of the tree, such as buttress roots, subjected to greatest mechanical stress	○	○
Understorey trees growing below the canopy layer in a rainforest rarely have buttresses	○	○

Q. 47

Countries around the Baltic Sea have agreed to reduce the outlet of nutrients in drainage water, especially N. In a study, growth of diatoms, N-fixing cyanobacteria and dinoflagellates was monitored together with the seawater N: P ratio to estimate the effects of outlet reduction. Optimum N: P ratio for growth in the three groups is approximately 7.



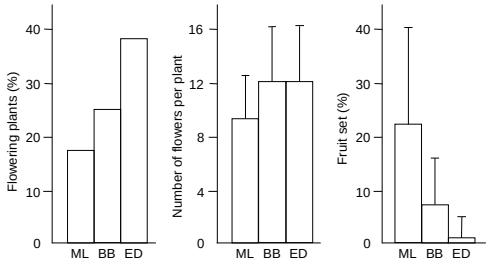
Annual variation in biomass of the three study groups (A) and seawater N: P-ratio (B) (from FF 1998).

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

	TRUE	FALSE
The limiting factor for diatoms during the winter (January–March) is N	○	○
The limiting factor for phytoplankton during the summer (June-Aug.) is P	○	○
Less N from drainage water will, in particular, reduce growth of cyanobacteria	○	○
Autotrophic dinoflagellates begin to increase dramatically in number in early spring (March), because of their mobility	○	○

Q. 48

Some plants deceive their pollinators by emitting odours, mimicking rotten flesh or dung. Such plants are pollinated by carrion and dung flies. This phenomenon is common among orchids, e.g. Bulbophyllum variegatum, three populations (ML, BB and ED) of which were studied at three different locations on the island of Réunion (Fig.).



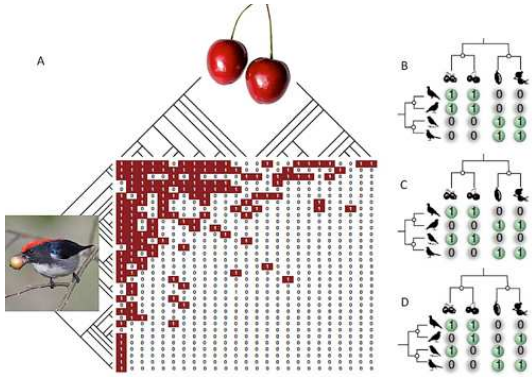
Reproductive data from populations ML, BB and ED (from Humeau et al. 2011).

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

	TRUE	FALSE
Number of fruits produced per plant is higher in BB than in ML and ED	○	○
Compared to ML and BB, fruit set in ED may have severe pollinator limitation	○	○
Compared to ED and BB, ML may be a neighbour to cattle pastures	○	○
Compared to ED and BB, ML may be a relatively young population	○	○

Q. 49

Plants interact with animals, and within a habitat, entire plant and animal communities form complex interaction networks. One important class of plant–animal networks is between fruit-eating birds and plants with fleshy fruit (Fig.). Observed interactions are partly determined by plant traits, but many other factors may be in play, e.g. the phylogenetic history of species communities.



A, interaction matrix between fruit-eating bird species (rows) and fleshy-fruited plant species (columns). Each '1' is an observed interaction, and each '0' is no interaction. The phylogenies of the communities of birds and plants are included; B–D, small artificial networks showing various interaction pattern (from Jordano 2010).

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

	TRUE	FALSE
The bird community has many food generalists, but only few specialists	○	○
The plant community has many fruit consumer specialists, but only few generalists	○	○
Phylogenetic relatedness is an important driver of interactions in network B	○	○
Closely related birds reduce food overlap more in network C than in network D	○	○

END