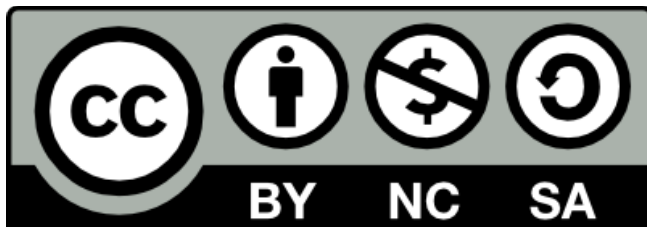




International Biology Olympiad e.V.

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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

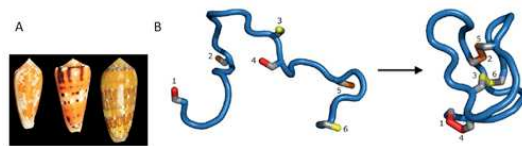
If only one statement in a question is correct you get 0.0

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  $\text{Na}^+$  channels in the presynaptic axon
- B blocks  $\text{K}^+$  channels in the presynaptic axon
- C blocks  $\text{Ca}^{2+}$  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 cysteine (from Safavi-Hermami et al. 2014).

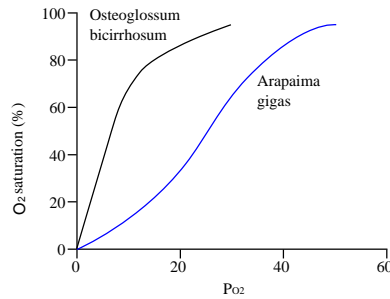
Indicate if each of the following statements is true or false.

- |  | TRUE                  | FALSE                 |
|--|-----------------------|-----------------------|
| Toxin D inactivates the skeletal muscles   | <input type="radio"/> | <input type="radio"/> |
| Toxins A and B will cause muscle twitching when injected in the prey   | <input type="radio"/> | <input type="radio"/> |
| Toxin C interferes with the exocytosis of neurotransmitters  | <input type="radio"/> | <input type="radio"/> |
| 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 | <input type="radio"/> | <input type="radio"/> |



## 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.).



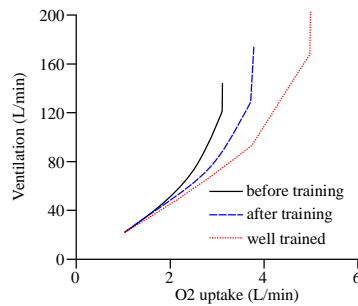
Hemoglobin dissociation curves for two species of fish *Osteoglossum bicirrhosum* and *Arapaima gigas*.

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

- |   | TRUE                  | FALSE                 |
|---|-----------------------|-----------------------|
| <input type="radio"/> <i>O. bicirrhosum</i> lives in faster-running water than <i>A. gigas</i>                                    | <input type="radio"/> | <input type="radio"/> |
| <input type="radio"/> <i>O. bicirrhosum</i> has a lower metabolic rate than <i>A. gigas</i>                                       | <input type="radio"/> | <input type="radio"/> |
| <input type="radio"/> <i>O. bicirrhosum</i> is an air breather (going to the surface), whereas <i>A. gigas</i> is a gill-breather | <input type="radio"/> | <input type="radio"/> |
| <input type="radio"/> <i>O. bicirrhosum</i> lives at the surface, whereas <i>A. gigas</i> is a deep water species                 | <input type="radio"/> | <input type="radio"/> |

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.).



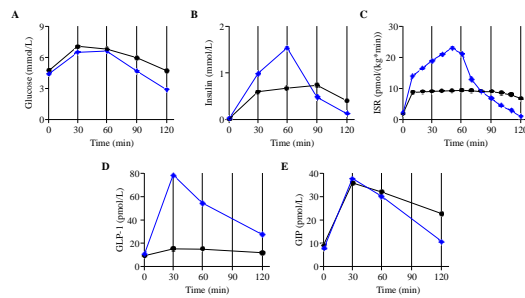
Lung ventilation  $V$  (atmospheric air L/min) as a function of total maximum oxygen uptake (L/min) for person 1 before training (black) and after training (blue dashed), and for person 2 (red dotted).

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

- |  | TRUE                  | FALSE                 |
|--|-----------------------|-----------------------|
| After training, person 1 has improved his $\text{VO}_2\text{max}$ (i.e. max. oxygen uptake/L/min/kg body weight) about 30% ( $\pm 5\%$ ) | <input type="radio"/> | <input type="radio"/> |
| Training by person 1 affected both start and extent of hyperventilation  | <input type="radio"/> | <input type="radio"/> |
| Further training is expected to increase person 1's anaerobic endurance significantly  | <input type="radio"/> | <input type="radio"/> |
| A very high $V$ is mainly achieved by an increase in breathing frequency and not depth of breathing                                      | <input type="radio"/> | <input type="radio"/> |

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.).



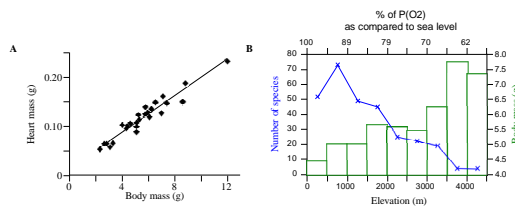
Effects of a glucose ingestion at time = 0 on the level of various parameters. Black circles indicate levels before gastric bypass, and blue diamonds indicate levels 3 months after gastric bypass. A, glucose level; Fig. B-C, insulin concentration and its secretion rate (ISR); Fig. D, Glucagon-Like Peptide 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 | <input type="radio"/> | <input type="radio"/> |
| From the study, GIP is expected to induce insulin secretion                                   | <input type="radio"/> | <input type="radio"/> |
| Change in GLP-1-level after gastric bypass surgery may explain the faster increase in ISR     | <input type="radio"/> | <input type="radio"/> |
| Blocking the effect of GLP-1 might be an efficient way to treat diabetes                      | <input type="radio"/> | <input type="radio"/> |

Q. 5

Partial atmospheric oxygen pressure  $P_{O_2}$  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.



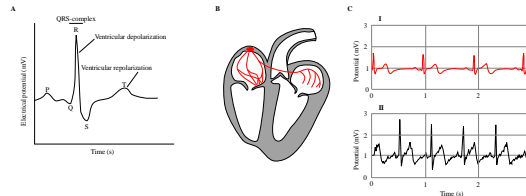
A, relationship between heart mass and body mass of hummingbird species; B, average body mass (grams) per 500 m altitudinal zone (histogram, right Y-axis) and number of species of hummingbirds (x-x-line, left Y-axis) at different elevations (lower X-axis). The percentage of partial oxygen pressure compared 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                    | <input type="radio"/> | <input type="radio"/> |
| Above 500 m, diversity of hummingbirds is negatively correlated with height above sea level | <input type="radio"/> | <input type="radio"/> |
| The heart mass is negatively correlated to the partial pressure of oxygen                   | <input type="radio"/> | <input type="radio"/> |
| Hummingbird wing load (body mass/wing area) declines with altitude                          | <input type="radio"/> | <input type="radio"/> |

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 activated innervations in red, pictured as if facing the student; C, electrocardiograms of two young male students (I and II) measured over 3 seconds.

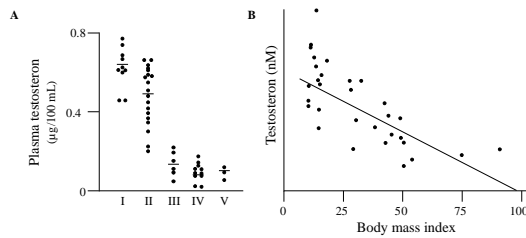
Indicate if each of the following statements is true or false.

- |   | 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 | <input type="radio"/> | <input type="radio"/> |
| Students I has a heart rate of 80 beats/minute  | <input type="radio"/> | <input type="radio"/> |
| If the stroke volume of student 1 is 70 mL/beat, then his cardiac output will be about 4.4 L/minute                                     | <input type="radio"/> | <input type="radio"/> |
| The heart in fig. B is at the R peak  | <input type="radio"/> | <input type="radio"/> |



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.).



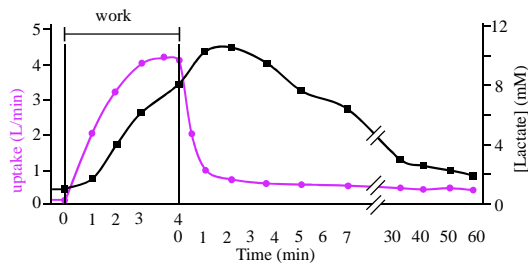
A, plasma level of testosterone in: I, Males 16-43 years old; II, Males 44-92 years; III, Males with underdeveloped pituitary glands; IV, Males with removed testes; and V, Males after treatment with injections of estrogen for some time. Each dot represents an individual, and the horizontal bars are group averages; B, plasma testosterone level in men as a function of body mass index ( $T = 23.94 - 0.26 \text{ BMI}$ ) (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   | <input type="radio"/> | <input type="radio"/> |
| Males-IV have a high LH concentration compared to Males-I   | <input type="radio"/> | <input type="radio"/> |
| Estrogen injections in males lead to very low concentrations of LH  | <input type="radio"/> | <input type="radio"/> |
| Even mild obesity ( $25 < \text{BMI} < 30$ ) might be much more important to testosterone level than higher age ( $> 43$ years) | <input type="radio"/> | <input type="radio"/> |

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.



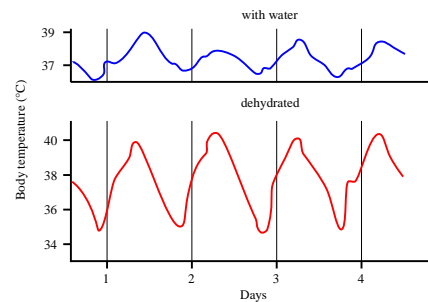
Changes in oxygen uptake (purple, left Y-axis, L/min) and lactate concentration (black, right Y-axis, mM lactate in blood) before, during and after an exercise or work period of 4 min.

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 <sub>2</sub> -uptake/min, as his maximum aerobic work capacity is 4.2 L/min | <input type="radio"/> | <input type="radio"/> |
| The person has an aerobic capacity of 60 ml O <sub>2</sub> /(kg min)   | <input type="radio"/> | <input type="radio"/> |
| When blood lactate exceeds 11 mM, excretion begins through the kidneys, which is why its concentration declines                            | <input type="radio"/> | <input type="radio"/> |
| Excess O <sub>2</sub> -uptake after the end of work is partly due to metabolism of lactate and not to gluconeogenesis                      | <input type="radio"/> | <input type="radio"/> |

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  $34.5^\circ\text{C}$  at night to  $40.5^\circ\text{C}$  during day.



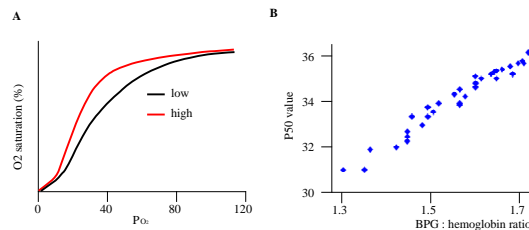
Body temperature of a dehydrated (red) camel compared to one well supplied with water (blue) (from Schmidt-Nielsen et al. 1957).

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)                                 | <input type="radio"/> | <input type="radio"/> |
| The respiratory quotient of tripalmitin ( $\text{CO}_2$ eliminated/ $\text{O}_2$ consumed) is 1.4   | <input type="radio"/> | <input type="radio"/> |
| 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 $1^\circ\text{C}$ ) | <input type="radio"/> | <input type="radio"/> |
| 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)                          | <input type="radio"/> | <input type="radio"/> |

Q. 10

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



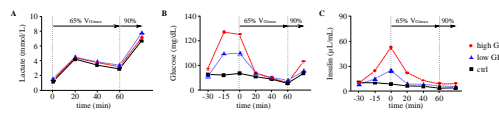
A, oxygen saturation (%) of blood of deer mice from low and high altitude habitats as a function of the partial pressure of atmospheric oxygen PO<sub>2</sub>; B, P<sub>50</sub> is the partial PO<sub>2</sub> at which the blood is 50% O<sub>2</sub>-saturated, here plotted against the BPG (2,3-bisphosphoglycerate) : 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   | <input type="radio"/> | <input type="radio"/> |
| High-altitude mice have lower P <sub>50</sub> than low-altitude mice  | <input type="radio"/> | <input type="radio"/> |
| If BPG concentration in blood increases, the saturation curve in Fig. A will shift to the right   | <input type="radio"/> | <input type="radio"/> |
| Assuming that adaptation to altitude is genetically determined, P <sub>50</sub> values will most likely remain the same if a mouse is transferred to another altitude | <input type="radio"/> | <input type="radio"/> |

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.).



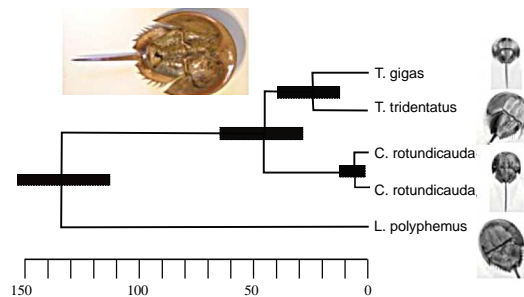
Levels of lactate A), glucose (B) and insulin in blood (C) before (pre-exercise) and during test. Each curve represents a treatment (red circles: high GI, blue triangles: low GI, black squares: control) (from Jamurtas et al. 2011).

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   | <input type="radio"/> | <input type="radio"/> |
| The level of lactate in the blood during exercise is influenced by the diet  | <input type="radio"/> | <input type="radio"/> |
| Final test result at the time of exhaustion seems to be significantly affected by the kind of diet   | <input type="radio"/> | <input type="radio"/> |
| 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 | <input type="radio"/> | <input type="radio"/> |

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".



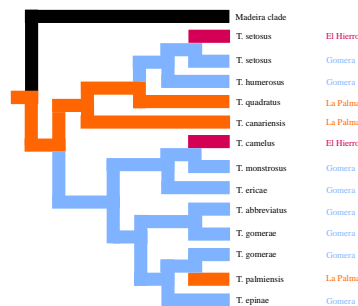
Phylogeny of extant horseshoe crabs. The unit of scale is a million years. Black bars indicate 95% confidence interval. The two populations of Cr are from Andaman Sea and Thailand (from Obst et al. 2012).

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 | <input type="radio"/> | <input type="radio"/> |
| According to Fig., the Asian species constitute a monophyletic clade                | <input type="radio"/> | <input type="radio"/> |
| Speciation in horseshoe crabs seems to take between 5 and 45 million years          | <input type="radio"/> | <input type="radio"/> |
| The genera <i>Tachypleus</i> and <i>Limulus</i> are sister taxa                     | <input type="radio"/> | <input type="radio"/> |

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).



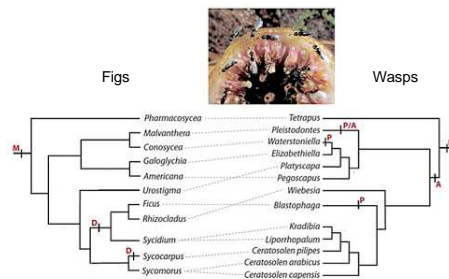
Part of the cladogram of *Tarphius* from the Canary Islands with the Madeira clade as an outgroup (black branch). Only species from three (La Palma, Gomera and El Hierro) of the five western islands are included (from Emerson & Oromí 2005).

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                    | <input type="radio"/> | <input type="radio"/> |
| From Madeira, <i>Tarphius</i> colonized the island of El Hierro                               | <input type="radio"/> | <input type="radio"/> |
| All three islands were colonized twice  | <input type="radio"/> | <input type="radio"/> |
| Gomera is likely to be the Canarian Island with the highest habitat diversity of humid forest | <input type="radio"/> | <input type="radio"/> |

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).

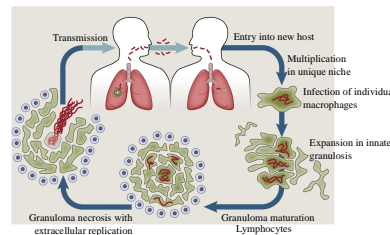
Indicate if each of the following statements is true or false.

- |   | TRUE                  | FALSE                 |
|---|-----------------------|-----------------------|
| Passive pollination mode is ancestral in the evolution of fig wasps                           | <input type="radio"/> | <input type="radio"/> |
| Dioecy in figs is correlated to active pollination mode in wasps                              | <input type="radio"/> | <input type="radio"/> |
| The coevolutionary match between figs and wasps is only seen at the level of genus and higher | <input type="radio"/> | <input type="radio"/> |
| Pollination mode seems to be more labile evolutionarily than breeding system                  | <input type="radio"/> | <input type="radio"/> |



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.



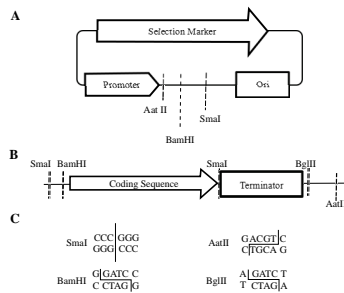
Pathogenic life cycle of *M. tuberculosis* (Mt). A granuloma is a group of tightly linked macrophages (from Cambier et al. 2014).

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

- |   | TRUE                  | FALSE                 |
|---|-----------------------|-----------------------|
| Transmission of tuberculosis requires physical contact  | <input type="radio"/> | <input type="radio"/> |
| Theoretically, a person with macrophage deficiency would be expected to suffer greatly from an Mt attack        | <input type="radio"/> | <input type="radio"/> |
| The granuloma of macrophages is the host's successful way of reducing the spread of the disease within the body | <input type="radio"/> | <input type="radio"/> |
| A new generation of Mt is released when the macrophages in the granuloma die                                    | <input type="radio"/> | <input type="radio"/> |

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.

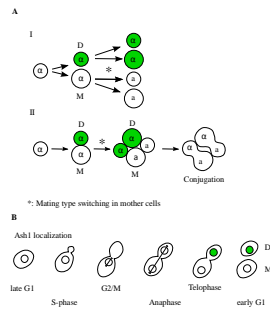


Indicate if each of the following statements is true or false.

- |  | TRUE                  | FALSE                 |
|--|-----------------------|-----------------------|
| Digestion with SmaI followed by ligation can produce the desired recombinant plasmid.            | <input type="radio"/> | <input type="radio"/> |
| Digestion with AatII and BamHI followed by ligation can produce the desired recombinant plasmid. | <input type="radio"/> | <input type="radio"/> |
| Digestion with BamHI + BglII followed by ligation can produce the desired recombinant plasmid.   | <input type="radio"/> | <input type="radio"/> |
| The 'coding sequence' needs to be in-frame with the promoter                                     | <input type="radio"/> | <input type="radio"/> |

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.).



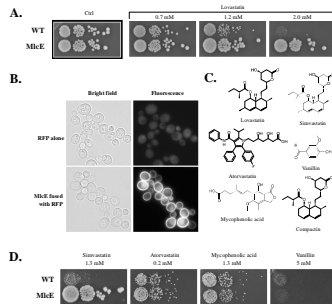
A, mating-type switching in budding yeast (M, mother cell; D, daughter cell.  $a$  and  $\alpha$ , mating types). Fig. A I. mitosis in haploids; A II: mating and diploid formation; B, budding in haploid yeast. Both in Fig. A and B, green filling indicates the repressor factor protein Ash1p.

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	<input type="radio"/>	<input type="radio"/>
Mating-type switching occurs only in the mother cell of each haploid generation	<input type="radio"/>	<input type="radio"/>
Mating type shift is induced by the repressor factor Ash1p	<input type="radio"/>	<input type="radio"/>
Mating type shift of haploids and the meiosis of diploids result in maximum mixing of mating types	<input type="radio"/>	<input type="radio"/>

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-methylglutaryl-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 MlcE expressing (MlcE)) 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 MlcE (MlcE-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 | <input type="radio"/> | <input type="radio"/> |
| MlcE encodes a protein that localizes primarily to the plasma membrane         | <input type="radio"/> | <input type="radio"/> |
| The MlcE offers general protection against all tested statins                  | <input type="radio"/> | <input type="radio"/> |
| MlcE will likely also protect yeast from the harmful effects of compactin      | <input type="radio"/> | <input type="radio"/> |

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

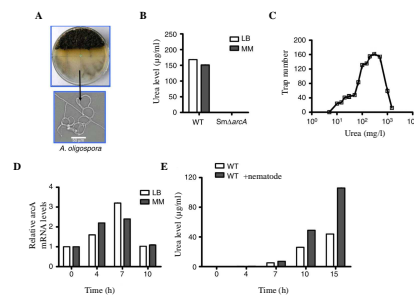
If the A content is 20%, then the G (guanine) content must also be 20%

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*; SmΔ*arcA* 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).

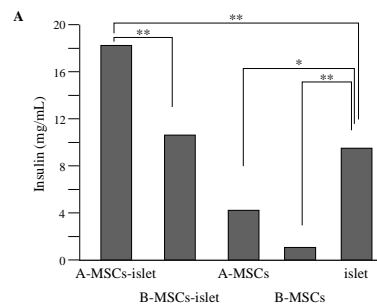
Indicate if each of the following statements is true or false.

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	<input type="radio"/>	<input type="radio"/>
Only bacteria with the specific gene <i>arcA</i> can produce urea	<input type="radio"/>	<input type="radio"/>
Bacteria produce urea in both nutrient-rich and -poor conditions	<input type="radio"/>	<input type="radio"/>
Urea production seems to be triggered by stimuli from the nematode	<input type="radio"/>	<input type="radio"/>

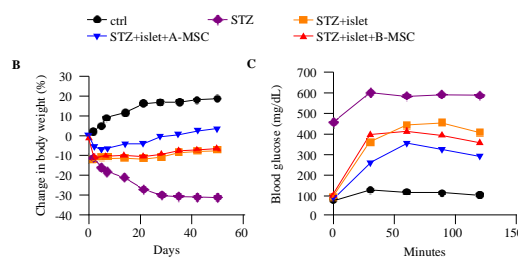
Q. 22

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

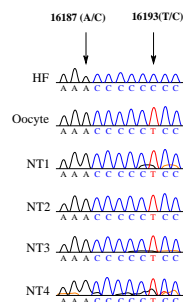
The conclusion from all experiments is that there are no observed effects of islets + bone marrow stem cells together as compared to islets alone

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

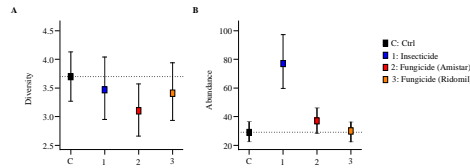
After nuclear transfer the oocyte becomes a haploid

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.).



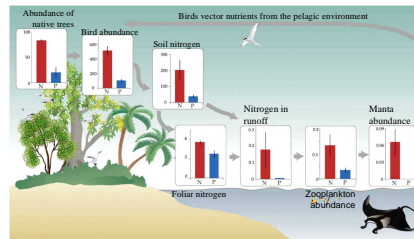
Effects of an insecticide and two fungicides upon: seedling diversity (A) and mean seedling abundance (B) of the forest community. Error bars represent 95% confidence intervals of the mean of all study sites with a given treatment (from Bagchi et al. 2014).

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

- |  | TRUE                  | FALSE                 |
|--|-----------------------|-----------------------|
| All treatments had a statistically significant effect upon seedling diversity                | <input type="radio"/> | <input type="radio"/> |
| In the study area, most insects were predators   | <input type="radio"/> | <input type="radio"/> |
| Ridomil is stronger in its effects on fungi than Amistar                                     | <input type="radio"/> | <input type="radio"/> |
| The hypothesis is supported in the present study by the combined effect of insects and fungi | <input type="radio"/> | <input type="radio"/> |

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.



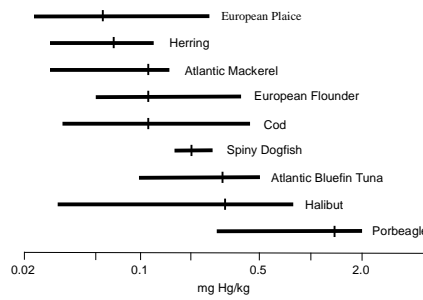
Changes in the ecological chain, when native forest (N) is replaced by palms (P). Each bar graph compares processes in N and P (from McCauley et al. 2012).

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

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

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).

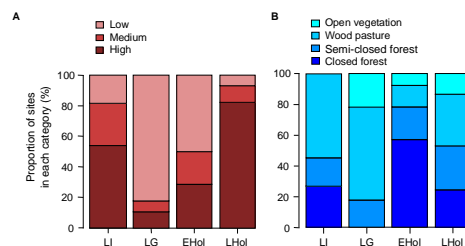
Indicate if each of the following statements is true or false.

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



## 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.



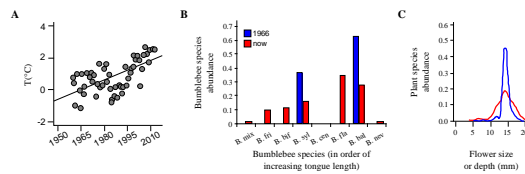
Proportions of excavation sites classified according to their fossil dung beetle density (A), and vegetation type (B); the latter being identified by its characteristic beetle fauna. LI, last interglacial period (132–111 kY ago); LG, last glacial period (50–15 kY ago); EHol, early Holocene (10–5 kY ago); 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	<input type="radio"/>	<input type="radio"/>
The decline of the large herbivore fauna during LG might partly be explained by human arrival	<input type="radio"/>	<input type="radio"/>
The small increase in dung beetle density during the warmer EHol is due to a return of large native herbivores after the LG	<input type="radio"/>	<input type="radio"/>
The strong increase in dung beetle density during LHol is due to agriculture	<input type="radio"/>	<input type="radio"/>

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-Struttman et al. 2015).

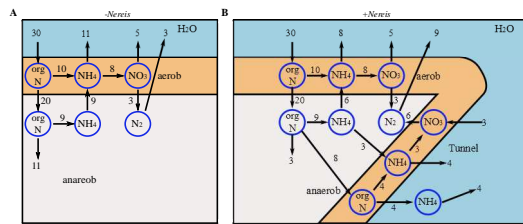
Indicate if each of the following statements is true or false.

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



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<sup>2</sup> (Fig. B).



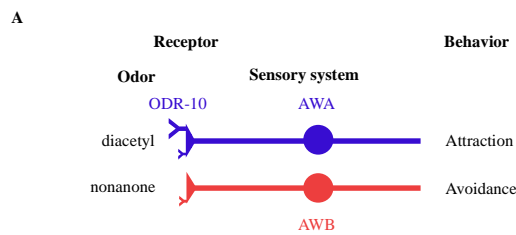
Sediment N-processes without (A) and with (B) *Nereis*. Numbers at arrows give the annual N turnover in g N per m<sup>2</sup>.

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                                    | <input type="radio"/> | <input type="radio"/> |
| Denitrification rate is increased threefold in the presence of <i>Nereis</i>                             | <input type="radio"/> | <input type="radio"/> |
| In the tunnels made by <i>Nereis</i> , 5 g N per m <sup>2</sup> per year are deposited in the sediment   | <input type="radio"/> | <input type="radio"/> |
| Concentrations of nutrients, which may lead to algal bloom, are lowered in the presence of <i>Nereis</i> | <input type="radio"/> | <input type="radio"/> |

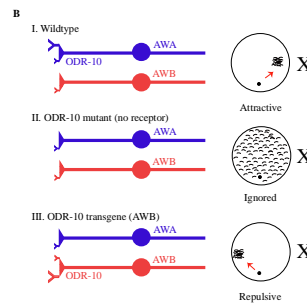
Q. 30

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.

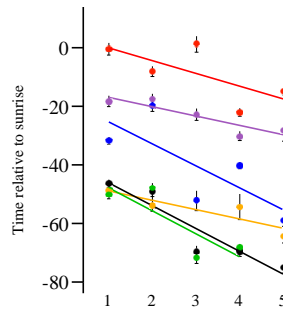
- |  | TRUE                  | FALSE                 |
|--|-----------------------|-----------------------|
| ODR-10 on AWA is required for attraction towards diacetyl    | <input type="radio"/> | <input type="radio"/> |
| ODR-10 can mediate both attraction and repulsion             | <input type="radio"/> | <input type="radio"/> |
| Each olfactory neuron has receptors for many odour chemicals | <input type="radio"/> | <input type="radio"/> |

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.).



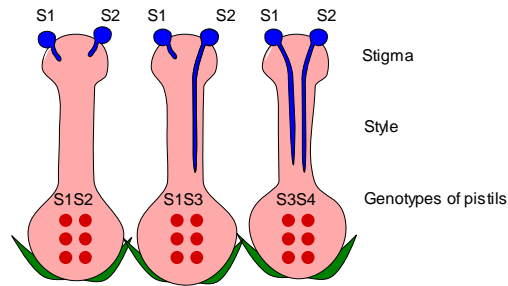
Average start of dawn singing relative to sunrise '0' (mean ± standard error) against increasing light intensity (from 1 to 5) at sites with street-lighting (from Silva et al. 2014).

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 | <input type="radio"/> | <input type="radio"/> |
| Streetlight increases interspecific competition among birds for time of singing     | <input type="radio"/> | <input type="radio"/> |
| The morning pattern may be reversed at dusk   | <input type="radio"/> | <input type="radio"/> |
| Rain at dawn may delay the initiation of singing                                    | <input type="radio"/> | <input type="radio"/> |

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  | <input type="radio"/> | <input type="radio"/> |
| In a population with three S alleles and equal frequencies of all possible genotypes, 1/3 of all crosses will be incompatible                | <input type="radio"/> | <input type="radio"/> |
| The smallest possible number of S alleles in a viable population is four   | <input type="radio"/> | <input type="radio"/> |
| 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 | <input type="radio"/> | <input type="radio"/> |



## 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

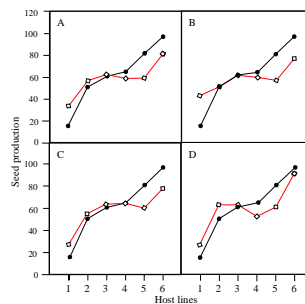
If B is dominant to A and C, then the frequency of the B phenotype will be the frequency of the B allele

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.



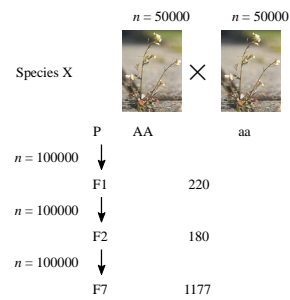
Seed production (mg seeds/plant; Y-axis) of six At genotypes (Pyr, Tsu, Sue, Fin, Tch, Gb; X-axis) in four experiments (a)-(d). At genotypes are ranked according to increasing seed production in the absence of the oomycetes (filled symbols, black); At grown with Ha (open symbols, red) (from Salvaudon 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  | <input type="radio"/> | <input type="radio"/> |
| In experiment C, Ha is a parasite on all At genotypes   | <input type="radio"/> | <input type="radio"/> |
| For all three fungal strains, the negative impact of Ha is strongest on the most productive genotypes | <input type="radio"/> | <input type="radio"/> |
| The outcome of interactions between Ha and At on the plant depends on the latter's genotype           | <input type="radio"/> | <input type="radio"/> |

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).

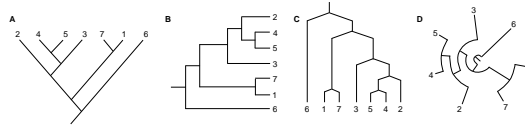
Indicate if each of the following statements is true or false.

- |  | TRUE                  | FALSE                 |
|--|-----------------------|-----------------------|
| The parental generation (P) shows Hardy-Weinberg proportions       | <input type="radio"/> | <input type="radio"/> |
| Expected number of Aa genotyped individuals in F1 is 110           | <input type="radio"/> | <input type="radio"/> |
| Expected number of aa genotyped individuals in F2 is 90            | <input type="radio"/> | <input type="radio"/> |
| In F7, 271 plants were genotyped as AA. This is less than expected | <input type="radio"/> | <input type="radio"/> |



Q. 36

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



Four phylogenies of seven species (1-7).

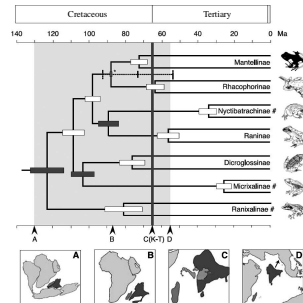
Indicate if each of the following statements is true or false.

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



## 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	<input type="radio"/>	<input type="radio"/>
Raninae and Dicroglossinae shared a common ancestor about 75 million years ago	<input type="radio"/>	<input type="radio"/>
Divergence of Raninae and Nyctibatrachinae most likely occurred after the 85 million year old separation of India and Madagascar	<input type="radio"/>	<input type="radio"/>
The last common ancestor of Micrixalinae and Dicroglossinae lived before India and Madagascar became separated (85 million years ago)	<input type="radio"/>	<input type="radio"/>

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 Bothnian 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.

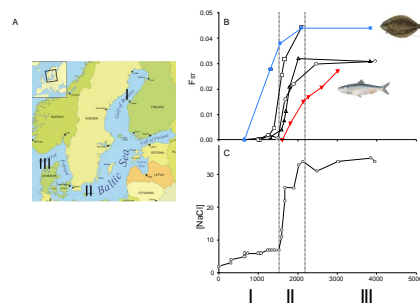


Figure. A, Bothnian Bay (I), Southern Baltic Sea (II), and North Sea (III); B, changes in genetic variation among populations ( $F_{ST}$ ) of five fish species (blue filled circles = flounder (inset); red filled inverted triangles = herring (inset); open squares, triangles, and circles = three other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

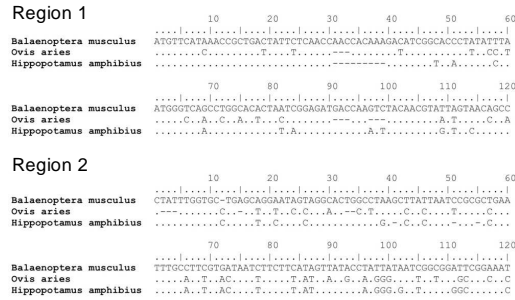
Indicate if each of the following statements is true or false.

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



Q. 39

Base sequences of two genomic regions (1 and 2) from blue whale (*Balaenoptera musculus*), sheep (*Ovis aries*) and hippopotamus (*Hippopotamus 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.

Region 1 is most likely a protein coding sequence

TRUE	FALSE
<input type="radio"/>	<input type="radio"/>

Region 2 is most likely a protein coding sequence

<input type="radio"/>	<input type="radio"/>
-----------------------	-----------------------

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

<input type="radio"/>	<input type="radio"/>
-----------------------	-----------------------

Regions 1 and 2 show the same phylogenetic relationship among the three species

<input type="radio"/>	<input type="radio"/>
-----------------------	-----------------------

 | Q. 40

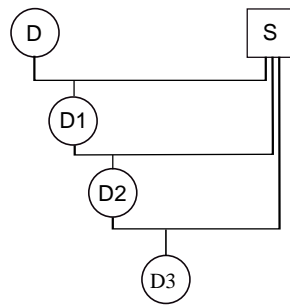
The fast growing model bacterium *E. coli* (generation time = 20 min) has a single 4.6 million base pair large chromosome that can be replicated in 42 minutes from a single origin of replication.

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

	TRUE	FALSE
In <i>E. coli</i> , DNA polymerase synthesizes about 900 bp/second including proof reading activity.	<input type="radio"/>	<input type="radio"/>
An <i>E. coli</i> cell always contains two copies of its genome just prior to cell division when growing at highest possible growth rate	<input type="radio"/>	<input type="radio"/>
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	<input type="radio"/>	<input type="radio"/>
<i>E. coli</i> 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	<input type="radio"/>	<input type="radio"/>

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.



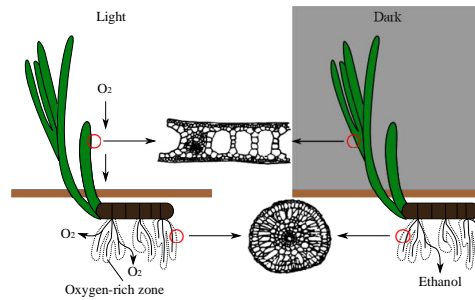
Intensive breeding program. D is donor of a dominant resistance allele B, and b is the allele in the standard crop plant being susceptible to rust. S is the variety into which gene B is introduced

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                        | <input type="radio"/> | <input type="radio"/> |
| At least 10 backcrossings are needed to get the percentage of D genes below 1%          | <input type="radio"/> | <input type="radio"/> |
| More crosses are needed to introgress a recessive resistance allele than a dominant one | <input type="radio"/> | <input type="radio"/> |
| Introgression cannot be done with quantitative traits                                   | <input type="radio"/> | <input type="radio"/> |

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.).



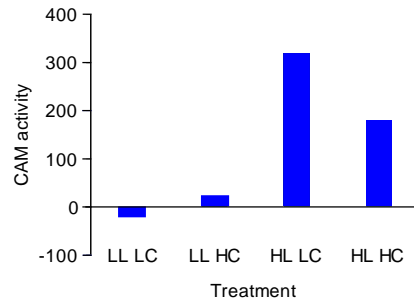
Eelgrass at day and night, and cross-sections of leaf and root.

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

	TRUE	FALSE
For respiratory reasons, <i>Zostera</i> roots are expected to have a thin epidermis	<input type="radio"/>	<input type="radio"/>
Both at day and night, $O_2$ readily diffuse into the roots	<input type="radio"/>	<input type="radio"/>
Root uptake of nutrients is independent of time of day	<input type="radio"/>	<input type="radio"/>
At nighttime, the concentration of $Na^+$ is expected to decrease in root cells	<input type="radio"/>	<input type="radio"/>

Q. 43

*Crassula helmsii* is a successful aquatic plant with CAM photosynthesis. In a cross-factorial study, including 2 light levels: LL and HL; and 2 CO<sub>2</sub> 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 CO<sub>2</sub>, resp. (from Klavsen & Maberley 2010).

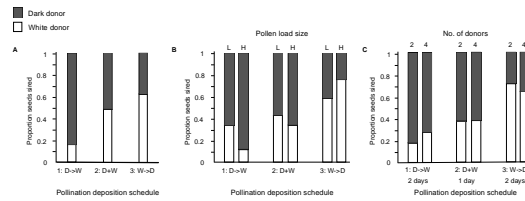
Indicate if each of the following statements is true or false.

- |  | TRUE                  | FALSE                 |
|--|-----------------------|-----------------------|
| CAM seems to be an adaptation to survive in waters rich in carbon  | <input type="radio"/> | <input type="radio"/> |
| The circadian stomatal opening rhythm of CAM plants enables them to take up CO <sub>2</sub> at nighttime | <input type="radio"/> | <input type="radio"/> |
| CAM increases nighttime photorespiration   | <input type="radio"/> | <input type="radio"/> |
| At LL, there is less dry matter production, because CAM plants also require light for photosynthesis     | <input type="radio"/> | <input type="radio"/> |



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.).



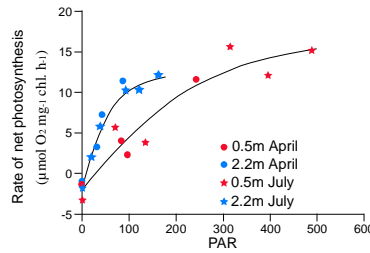
Proportion of seeds sired by either a dark (D) or a white pollen donor (W): A, pollen deposited on stigma in succession (1: D → W, i.e. first D and then W, or 3: W → D) or simultaneously as a mixture (2: D + W); B, size of deposited pollen load (D and W added simultaneously): L and H = low and high pollen 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   | <input type="radio"/> | <input type="radio"/> |
| No competitive effect of high pollen load is observed  | <input type="radio"/> | <input type="radio"/> |
| Increase in number of fathers increases competition  | <input type="radio"/> | <input type="radio"/> |
| If lots of pollen from the first donor is deposited, pollen added 2 days later from a second donor does not sire seeds | <input type="radio"/> | <input type="radio"/> |

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 ( $\mu\text{mol O}_2 \text{ mg}^{-1} \text{ chlorophyll h}^{-1}$ ) 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.).



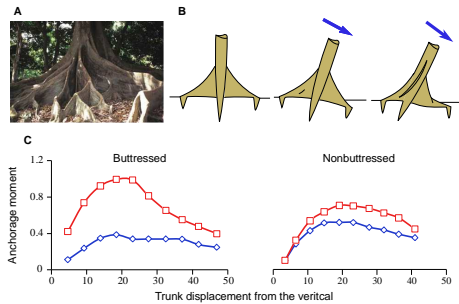
Light response curves in April and in July for *C. helmsii*, growing in shallow (0.5 m) and deep (2.2. m) water. PAR photosynthetically active radiation (from Klavsen & Maberly 2009).

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          | <input type="radio"/> | <input type="radio"/> |
| Deep-water plants have higher NPR in July than in April                         | <input type="radio"/> | <input type="radio"/> |
| In the experiment, NPR is light limited   | <input type="radio"/> | <input type="radio"/> |
| Deep-water plants have a higher NPR because of their higher chlorophyll content | <input type="radio"/> | <input type="radio"/> |

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).



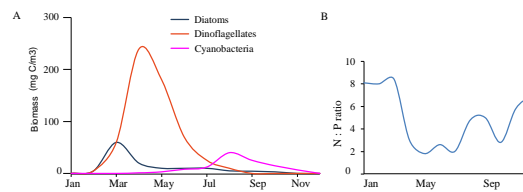
A, tree with buttress roots; B, a tree with buttresses and vertical tap root pulled over by wind (blue arrow is direction of wind); C, an experimental study of change in anchorage moment for buttressed (left) and non-buttressed trees (right) as a function of the tree's displacement from vertical (inclination 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   | <input type="radio"/> | <input type="radio"/> |
| The tap root is relatively more important to anchorage in buttressed than in non-buttressed trees  | <input type="radio"/> | <input type="radio"/> |
| The smallest vessels and lowest vessel frequency are found in the parts of the tree, such as buttress roots, subjected to greatest mechanical stress | <input type="radio"/> | <input type="radio"/> |
| Understorey trees growing below the canopy layer in a rainforest rarely have buttresses  | <input type="radio"/> | <input type="radio"/> |

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.



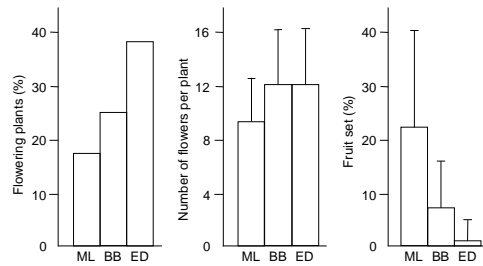
Annual variation in biomass of the three study groups (A) and seawater N: P-ratio (B) (from FF 1998).

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  | <input type="radio"/> | <input type="radio"/> |
| The limiting factor for phytoplankton during the summer (June–Aug.) is P  | <input type="radio"/> | <input type="radio"/> |
| Less N from drainage water will, in particular, reduce growth of cyanobacteria  | <input type="radio"/> | <input type="radio"/> |
| Autotrophic dinoflagellates begin to increase dramatically in number in early spring (March), because of their mobility | <input type="radio"/> | <input type="radio"/> |

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.).



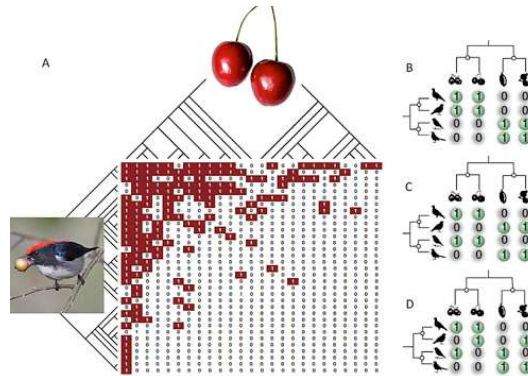
Reproductive data from populations ML, BB and ED (from Humeau et al. 2011).

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        | <input type="radio"/> | <input type="radio"/> |
| Compared to ML and BB, fruit set in ED may have severe pollinator limitation | <input type="radio"/> | <input type="radio"/> |
| Compared to ED and BB, ML may be a neighbour to cattle pastures              | <input type="radio"/> | <input type="radio"/> |
| Compared to ED and BB, ML may be a relatively young population               | <input type="radio"/> | <input type="radio"/> |

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            | <input type="radio"/> | <input type="radio"/> |
| The plant community has many fruit consumer specialists, but only few generalists | <input type="radio"/> | <input type="radio"/> |
| Phylogenetic relatedness is an important driver of interactions in network B      | <input type="radio"/> | <input type="radio"/> |
| Closely related birds reduce food overlap more in network C than in network D     | <input type="radio"/> | <input type="radio"/> |

END