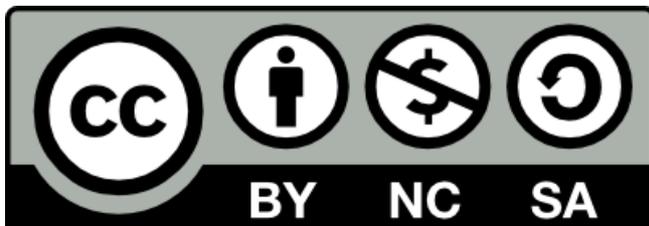




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# IBO 2013 Theoretical Exam 1



Translation version: **English (Official)**, downloaded by: **staff1**

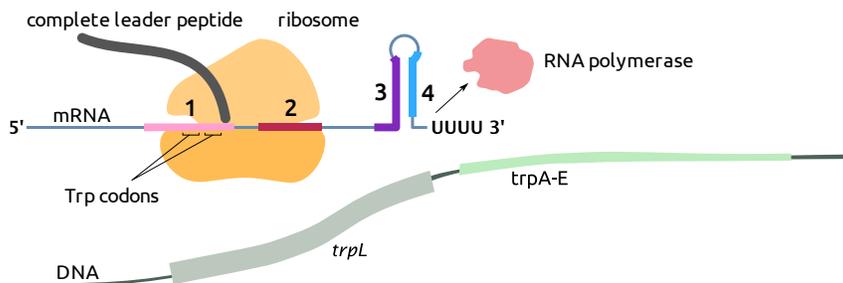
**1**

Cell-, molecular- and microbiology

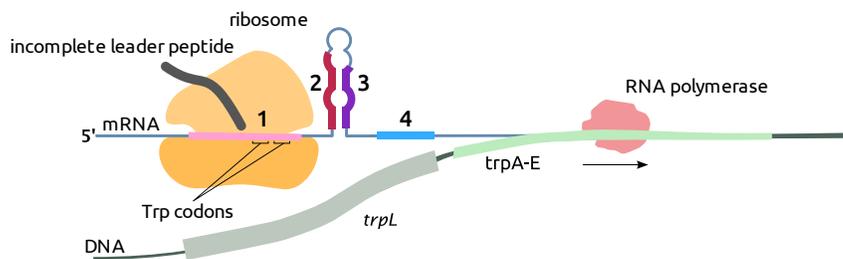
Some bacteria possess an additional mechanism to regulate the production of enzymes involved in tryptophan (Trp) biosynthesis. The (Trp) operon possesses, prior to the actual genes (*trpA-E*), a leader sequence (*trpL*), coding for a leader peptide. *trpL* contains two tryptophan codons next to each other.



At high tryptophan concentrations, the ribosome translates the mRNA of the leader peptide and stalls at its stop codon, thereby masking segment 2 of the mRNA and allowing segments 3 and 4 to form a stem loop. A stem loop followed by poly-U is a termination signal for the RNA polymerase (RNA pol), which falls off the DNA.



However, at low tryptophan concentrations, the ribosome gets stalled at the tryptophan codons allowing 2 and 3 to form a stem loop. The whole tryptophan operon can be transcribed by the RNA polymerase.



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

- A. The same regulation mechanism also works for nuclear genes in eukaryotes.
- B. With reduced concentration of the aminoacyl-tRNA synthetase (attaches tryptophan to  $tRNA^{Trp}$ ), transcription of the *trpA-E* genes will be inactivated at a lower tryptophan concentration.
- C. After deletion of one of the two tryptophan codons in the gene coding for the leader peptide, transcription of the *trpA-E* genes will be inactivated at a lower tryptophan concentration.
- D. In case of a mutation destabilizing the stem loop 2-3, transcription of the *trpA-E* genes will be inactivated at a lower tryptophan concentration.

**A. False B. False C. True D. True**

**Original commentary**

Correct answers

A *false*

the mechanism works only if the translation begins before the transcription finishes. In eukaryotes, the transcription happens in the nucleus, then the mRNA is exported to the cytoplasm where it is translated and this mechanism cannot work in this form.

B *false*

by reduced concentrations of the tryptophan's aminoacyl-tRNA synthetase, tRNA loaded with tryptophan will be formed slower than in the normal case, so that less tRNA-Trp will be present. To inactivate the transcription of the trpA-E genes, a higher tryptophan concentration than in the normal case is needed.

C *true*

with only 1 Trp codon, a lower concentration of Trp can still allow translation of the leader peptide and therefore inhibit the synthesis of the enzymes.

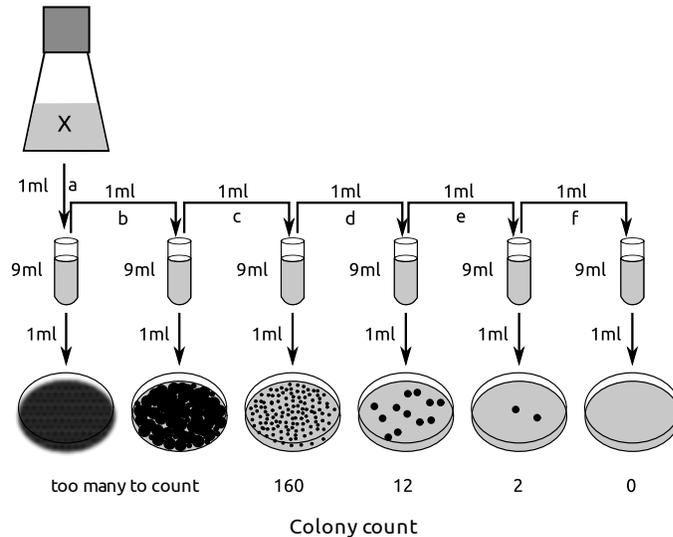
D *true*

a mutation destabilizing stem loop 1-2 will promote the formation of stem loop 2-3 even at low tryptophan concentrations, inhibiting the transcription of the trpA-E genes.

References

[Walsh et al, Biochemistry \(1979\)](#)

Bacterial count of a liquid culture can be determined by different methods: 1) Cells can be counted under a microscope using a counting chamber, 2) the absorbance of the culture can be measured in a spectrophotometer (with  $A_{600} = 1$  corresponding to  $8 \times 10^8$  bacterial cells/ml) or 3) several dilutions of the culture can be plated on agar and the colonies can be counted (see picture) to calculate the number of colony forming units per milliliter (cfu/ml).



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

- A. A culture with  $A_{600} = 0.1$  and a doubling time of 30 minutes will reach  $4 \times 10^8$  cells/ml in less than two hours of growth.
- B. Counting colonies on plates gives a smaller estimate of the number of bacterial cells than counting cells under a microscope.
- C. Using the plate giving the most accurate results (from the figure), the culture X is estimated to contain  $1.6 \times 10^5$  cfu/ml.
- D. When repeating the plating of Dilution *f* (from the figure) many times, some plates will show colonies.

**A. True B. True C. True D. True**

**Original commentary**

Correct answers

A *true*

A culture with an  $OD_{600} = 0.1$  and a doubling time of 30 minutes will have an  $OD_{600} = 0.2$  after 30 minutes, 0.4 after 1 hour, and 0.8 after 1:30 hour, therefore it will reach  $4 \times 10^8$  cells/ml in less than 2 hours ( $4 \times 10^8$ ) cells correspond to an  $OD = 0.5$ ).

B *true*

Counting colonies on plates gives the number of cfu/ml, and only living cells can form colonies, whereas under the microscope, dead cells are also counted.

C *true*

The plate giving the most accurate results is the one with 160 colonies that corresponds to a 1:1000 dilution of the starting culture X.  $160 \times 1000 = 1.6 \times 10^5$

D *true*

The dilution *f* contains 0.16 cells/ml. Statistically, by plating it more than six times, colonies should grow.

In a living organism, cells die either through apoptosis (programmed cell death) or necrosis (cells swell and burst).

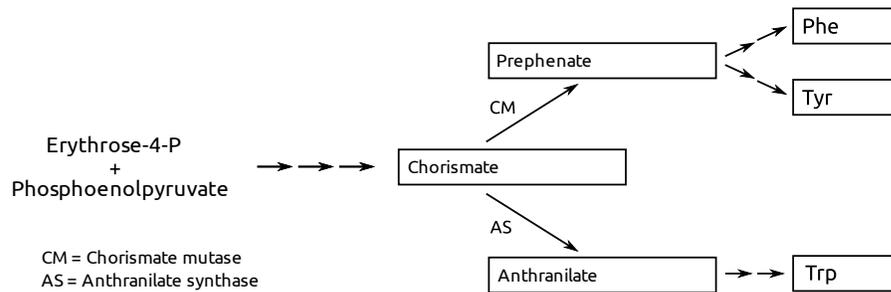
**Indicate if each of the following statements is true or false.**

- A. Apoptosis is induced in immature T-cells that recognize self antigens.
- B. Intestinal epithelial cells losing contact with the basal lamina undergo apoptosis.
- C. Neural stem cells undergoing apoptosis expose on their surface a signal promoting phagocytosis.
- D. Necrosis often induces an inflammatory immune response.

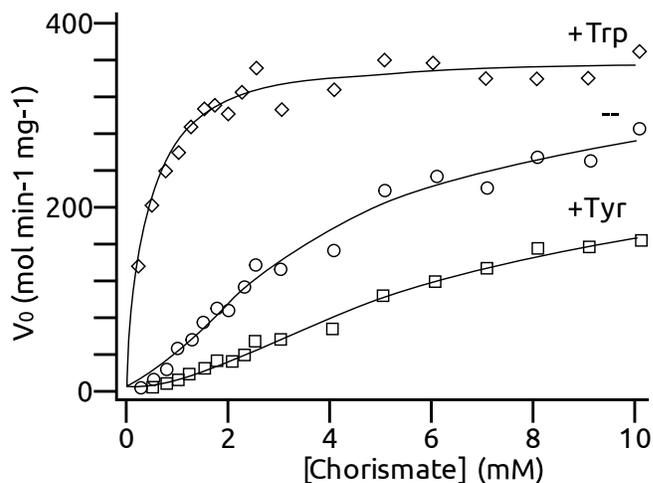
**A. True B. True C. True D. True**

**Original commentary**

The chorismate pathway leading to the synthesis of aromatic amino acids in yeast is presented here.



The velocity of the enzyme chorismate mutase (CM) was measured in the presence of either tryptophan (+Trp) or tyrosine (+Tyr), as well as in the absence of both (--).



Based on these results and the pathway scheme, indicate if each of the following statements is true or false.

- Tryptophan increases the activity of chorismate mutase.
- Tryptophan, but not tyrosine inhibits the synthesis of chorismate.
- A high concentration of tyrosine is likely to increase the synthesis of tryptophan.
- The prephenate and the anthranilate branches compete for chorismate.

**A. True B. False C. True D. True**

#### Original commentary

Correct answers

A true

Under addition of tryptophane, at the same chorismate concentrations, the speed is higher

B false

The synthesis of erythrose-4-P is neither inhibited by tryptophan, nor by tyrosine. It would not make sense that only tryptophan inhibits E4P, since E4P is needed for the synthesis of both tryptophan and tyrosine and their synthesis is regulated differently.

*C true*

When the tyrosine concentration is increased, CM gets slower, and the chorismate will be used by AS instead to produce tryptophane.

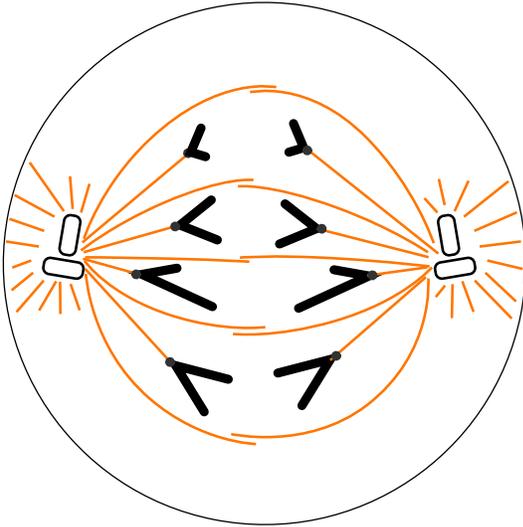
*D true*

Both pathway branches have chorismate as a starting point and the positive/negative regulation by Trp/Tyr hints that chorismate is not present in unlimited supply.

References

[Schnappauf et al, Biochemistry \(1998\)](#)

The following schematic shows a stage of cell division for an eukaryotic diploid cell.



Indicate if each of the following statements is true or not.

- A. The schematic may represent a stage of mitosis.
  - B. The schematic may represent a stage of meiosis II.
  - C. The cell would have failed to reach this stage if microtubular motor proteins were inhibited.
  - D. Transcription of histone genes peaks during this stage.
- A. False   B. True   C. True   D. False**

**Original commentary**

Correct answers

*A false*

as the chromosomes are different from each other in the picture, they cannot arise from pairs of chromosomes, which would need to be the case for mitosis of a eukaryotic diploid cell.

*B true*

during meiosis II, the 2 chromatids are distributed between daughter cells.

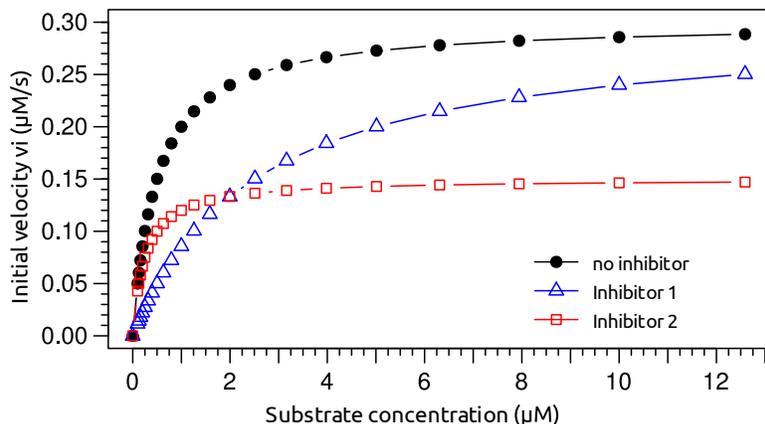
*C true*

to reach anaphase, molecular motors working on microtubule are needed for the expansion of microtubuli

*D false*

in this stage, the DNA is highly condensed and not available to transcription. Furthermore, new histone proteins are particularly necessary during the S-phase where the DNA is duplicated and needs to be packaged, not in the anaphase.

The sensitivity of an enzyme for different inhibitors is assessed. The rate of product formation was measured at different concentrations of substrate with 10 nM enzyme. The initial velocity  $v_i$  (at  $t = 0$  s) was calculated and plotted as a function of the substrate concentration in the absence or presence of two different inhibitors.



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

- A. In the absence of any inhibitor, the  $K_M$  (Michaelis constant) of the enzyme is 0.15  $\mu\text{M}$ .  
 B. The effect of Inhibitor 1 can be partially compensated for by adding more substrate.  
 C. Inhibitor 2 reduces the  $v_{\text{max}}$  (maximal velocity) of the enzyme.  
 D. The turnover number (maximum number of molecules processed per second by one enzyme molecule) under inhibition by Inhibitor 2 is about 10-20/s.

A. False   B. True   C. True   D. True

**Original commentary**

Correct answers

A false

$K_m$  is the [substrate] at which half the maximal velocity is reached, in this case  $v_{\text{max}}$  is 300 nM/s,  $v_{\text{max}}/2 = 150$  nM/s, which corresponds to 0.5  $\mu\text{M}$

B true

With inhibitor 1, only the  $K_M$  is affected, not the  $v_{\text{max}}$ . The reaction to proceed at the same speed as without inhibitor if more substrate is added (corresponds to a competitive inhibitor).

C true

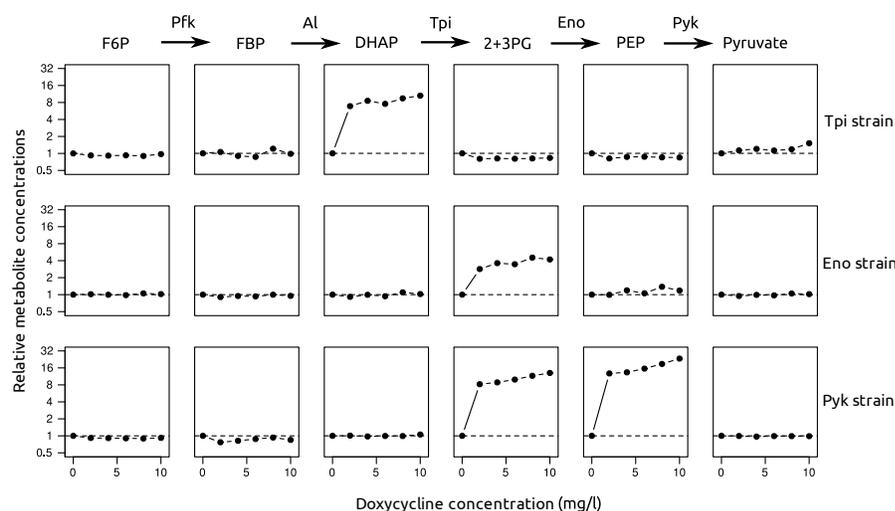
The  $v_{\text{max}}$  is reduced (150 nM/s instead of 300 nM/s without inhibitor): corresponds to an uncompetitive inhibitor.

D true

$k_{\text{cat}} = v_{\text{max}} / [\text{Enzyme}] = (150 \text{ nM/s}) / (10 \text{ nM}) = 15/\text{s}$

Three yeast strains (*Saccharomyces cerevisiae*) have been engineered to each contain a gene for a different enzyme from glycolysis (Tpi, Eno or Pyk) under the control of a doxycycline-repressed promoter such that addition of doxycycline down-regulates the synthesis of the corresponding enzyme. Concentrations of some metabolites are measured in each yeast strain grown on glucose at different doxycycline concentrations, relative to the concentrations without doxycycline. Relevant steps of the glycolysis are shown above the measurements with metabolites and enzymes abbreviated as follows:

Metabolites		Enzymes	
F6P	fructose 6-phosphate	Pfk	ATP-dependent phosphofructokinase
FBP	fructose 1,6-biphosphate	Al	Aldolase
DHAP	dihydroxyacetone phosphate	Tpi	Triose phosphate isomerase
2+3-PG	2- and 3-phosphoglycerate	Eno	Enolase
PEP	phosphoenolpyruvate	Pyk	Pyruvate kinase



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

- Down-regulating any of these enzymes disrupted metabolite concentrations in the whole pathway.
- Down-regulating any of these enzymes affected the concentration of its substrate more than the concentration of its product.
- The equilibrium of the reaction from 2+3-PG to PEP is more on the side of the product than the equilibrium of the reaction from FBP to DHAP.
- The concentration of F6P is expected to be unaffected by a down-regulation of Al.

**A. False B. True C. False D. True**

#### Original commentary

Correct answers

A false

even if the substrate of the down-regulated enzyme undergoes a big concentration change, the concentrations of other metabolites stay similar.

B true

as seen from the graphs, the metabolite undergoing the biggest change is the substrate of the down-regulated enzyme.

C false

down-regulation of Tpi affects strongly (more than 10 fold) the levels of DHAP, its substrate, but the concentration of

FBP stays constant, thus the equilibrium of  $\text{FBP} \rightarrow \text{DHAP}$  is strongly on the side of DHAP. In contrary, down-regulation of Pyk does not only affect the concentration of PEP, its direct substrate, but also of 2+3PG, the substrate of the previous enzyme in the pathway, Eno. This means that the increased level of PEP is enough to shift the equilibrium of  $2+3\text{PG} \rightarrow \text{PEP}$  back to 2+3PG, therefore the equilibrium is not as strongly on the side of the glycolytic product than  $\text{FBP} \rightarrow \text{DHAP}$ .

*D true*

During the reaction of F6P to FBP, ATP is hydrolyzed to phosphorylate F6P. Therefore, the equilibrium is strongly on the side of FBP. Down-regulation of Al would result in an increase of the FBP concentration, but since the equilibrium is strongly on the side of FBP (even more strongly than for the reaction  $\text{FBP} \rightarrow \text{DHAP}$ ), the concentration of F6P will stay unaffected.

#### References

[Fendt et al, Molecular Systems Biology \(2010\)](#)

Some substances need to be transported (actively or passively) from their site of synthesis to the location where they are active.

**Indicate for each of the following substances if they are transported from the cytoplasm to the nucleus.**

- A. tRNAs
  - B. Histone proteins
  - C. Nucleotides
  - D. ATP-synthase subunits
- A. False   B. True   C. True   D. False**

**Original commentary**

Correct answers

*A false*

tRNAs are synthesized in the nucleus, but need to get to the cytoplasm to be used by the ribosome.

*B true*

Histones are proteins synthesized in the cytoplasm, but need to get to the nucleus to bind to the DNA.

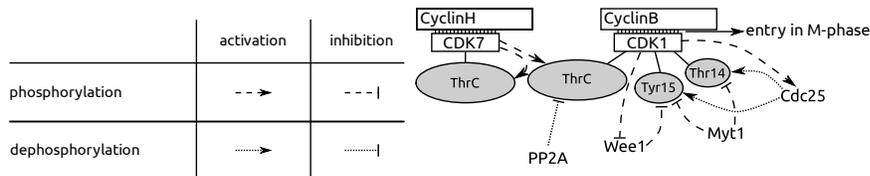
*C true*

Nucleotides are obtained by endo/picocytosis or synthesized in the cytoplasm, but need to get to the nucleus to be used in DNA replication and transcription.

*D false*

The ATP-synthase is a membrane protein synthesised in the cytoplasm (on the ER membrane) and transported to the plasma membrane, but not to the nucleus

Progression through the cell-cycle is mediated by Cyclin-Dependent Kinases (CDKs), which become active only when bound to their respective cyclin and phosphorylated at the ThrC (core threonine). Phosphorylation or dephosphorylation of other amino acids further modulates their activity. The following pathway represents the proteins involved in the entry into the M-phase of the cell-cycle.



**Indicate for each of the following mutations if it would promote entry into the M-phase by activating the CyclinB/CDK1 complex.**

- A. A mutation that reduces the dephosphorylating activity of Cdc25.
- B. A mutation that reduces the phosphorylating activity of Wee1.
- C. A mutation that changes the ThrC of CDK1 to a valine that cannot be phosphorylated.
- D. A mutation that inhibits the binding of CyclinH to CDK7.

**A. False B. True C. False D. False**

#### Original commentary

Correct answers

A *false*

Cdc25 by dephosphorylating CDK1 at Tyr15 and Thr14 activates CDK1 (removes the inactivation). By reducing its activity, CyclinB/CDK1 would be less active

B *true*

Wee1 inactivates CDK1 by phosphorylating it at Tyr15.

C *false*

to be active, CDK1 needs to have Thr161 phosphorylated, with a valine at position 161, CDK1 would be always inactive

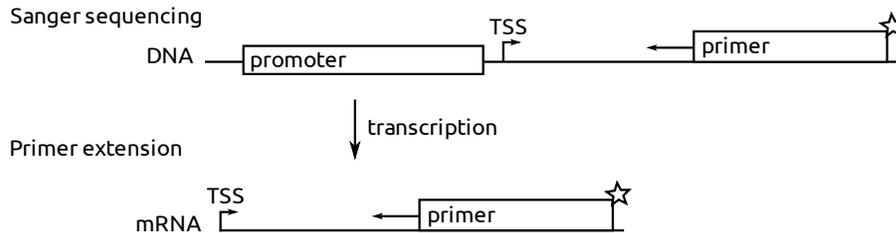
D *false*

CDK7 needs to be bound to CyclinH and phosphorylated at Thr170 to be active and able to phosphorylate (and therefore activate) CDK1 in complex with CyclinB. This mutation in CyclinH would make it unable to bind CDK7 which would stay in an inactive state.

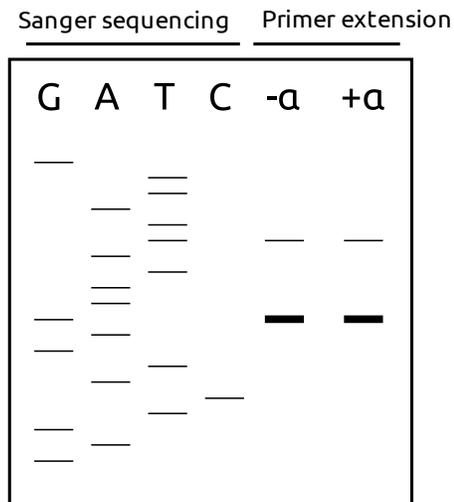
References

[Fussenegger et al, Biotechnol. Prog. \(1998\)](#)

To determine the precise transcription start site (TSS) of a newly discovered bacterial gene promoter, a radioactively labeled primer complementary to the 3'-end of the gene is used both for Sanger sequencing of the DNA construct and for primer extension of the mRNA. Primer extension (similar to cDNA synthesis) is repeated on mRNA transcribed with addition of the transcription factor  $\alpha$ .



The fragments obtained are separated by gel electrophoresis, a radiography is presented below.



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

- Different polymerases are used for the Sanger sequencing and primer extension assays.
- mRNAs of this gene with CUCAUGAC as the first eight bases after the TSS are found in these cells.
- Multiple TSS exist for this gene.
- Transcription is modulated by transcription factor  $\alpha$ .

**A. True B. True C. True D. False**

#### Original commentary

Correct answers

A true

For Sanger sequencing, a DNA polymerase is needed, whereas for primer extension, reverse transcriptase is used.

B true

The PE lane on the radiography gives the length of the mRNA. The first (most 5') base of the main mRNA corresponds to the fragment from the sequencing with the same length (here: G). The second most 5' base of the mRNA corresponds from the sequencing one nucleotide shorter (=one band lower on the radiography) than PE (here: A).

C *true*

For this gene, a main and a secondary TSS exist.

D *false*

Transcription in the absence or presence of  $\alpha$  produces the same ratio of mRNA starting from the main and the secondary TSS.

High levels of triglycerides in the bloodstream have been linked to higher risks of heart diseases. An agonist (activating molecule) S of receptor Y was observed to reduce the triglycerides levels.

**How could one convincingly prove that the effect of S is mediated specifically via receptor Y?**

- A. Generate genetically modified mice which overexpress (more than physiological) receptor Y.
  - B. Generate genetically modified mice in which receptor Y is knocked out (deleted).
  - C. Treat the mice with an antagonist (inactivating molecule) specific for receptor Y.
  - D. Treat the mice with an antibody that sequesters (removing from circulation) S.
- A. False   B. True   C. True   D. False**

**Original commentary**

Correct answers

*A false*

Even if the decrease in triglycerides levels observed would be more important than with wild-type mice, this is not enough to prove that S-Y interaction is either sufficient or necessary for the decrease.

*B true*

If in these mice, triglycerides levels decrease after addition of S, it is not mediated by Y. If no decrease can be observed, the interaction of S and Y is necessary for the decrease in triglycerides levels

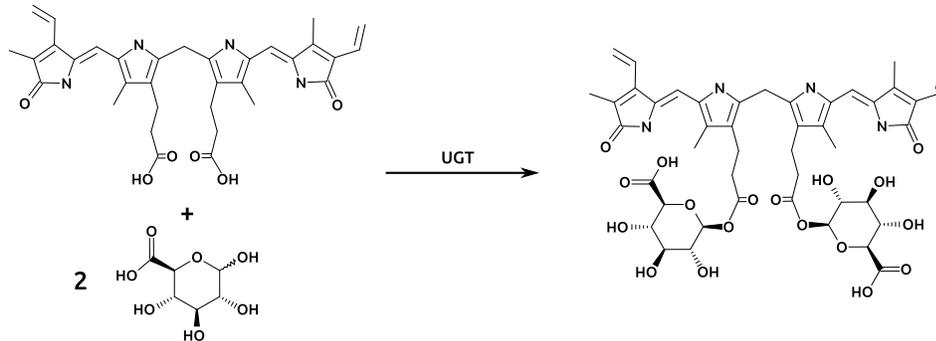
*C true*

If Y is inactivated by an antagonist, treatment with S should not decrease triglycerides levels, it shows that S-Y interaction is necessary for the decrease in triglycerides levels. If a decrease would be observed, it would show that S mediates triglycerides levels decrease via an other mechanism.

*D false*

Even if no decrease in triglycerides levels would be observed, this would only prove that S is necessary to decrease triglycerides, but would not prove that it acts via Y.

Bilirubin is a breakdown product of heme catabolism which is transported to the liver where it is conjugated to two glucuronic acid molecules by the enzyme UGT (see figure below). Conjugated bilirubin is then secreted in the small intestine as a component of the bile.



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

- A. Conjugation to glucuronic acid increases the solubility of bilirubin in water.
- B. A tumor obstructing the bile duct near the junction into the small intestine leads to a decrease in the blood levels of conjugated bilirubin.
- C. A point mutation reducing significantly the activity of UGT leads to a decreased level of unconjugated bilirubin in the blood.
- D. An increased level of conjugated bilirubin in the blood is a symptom of a malaria infection.

**A. True B. False C. False D. True**

**Original commentary**

Correct answers

*A true*

Glucuronic acid is a hydrophilic molecule, whereas bilirubin is hydrophobic and insoluble in water. Conjugation with glucuronic acid increases its solubility in water.

*B false*

When the bile cannot enter the small intestine, the conjugated bilirubin accumulates in the bile duct and moves back upwards in the intrahepatic bile ducts and enters the blood. As a result the conjugation is reduced or even stops causing an accumulation of unconjugated bilirubin too.

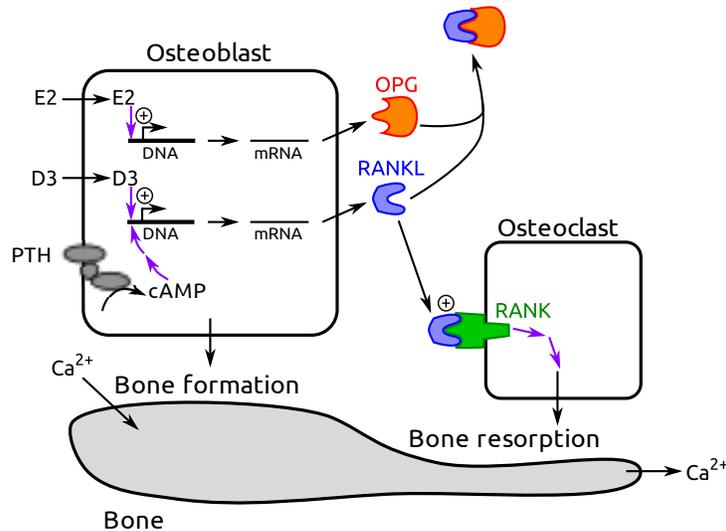
*C false*

If the UGT is not working properly (like in patients suffering from Morbus Meulengracht), the conjugation of bilirubin is reduced and the level of unconjugated bilirubin is increased.

*D true*

At one stage, *Plasmodium falciparum* reproduces in erythrocytes. These erythrocytes burst when releasing offspring parasites, leading to a liberation of hemoglobin, which in turn increases the level of bilirubin in the blood, which will be conjugated.

While osteoblasts are secreting new bone material, they can trigger osteoclasts to break down existing bone by excreting the protein RANKL, which activates its receptor RANK in osteoclasts. This pathway is stimulated by either vitamin D (D3) or parathyroid hormone (PTH). In the presence of oestrogen (E2), however, osteoblasts inhibit that process by secreting osteoprotegerin (OPG), which sequesters RANKL.



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

- Oestrogen replacement therapy prevents bone resorption after menopause.
- A symptom of hyperparathyroidism (excessive function of parathyroid gland) is loss of bone mass.
- D3 and E2 are hydrophilic molecules whereas PTH is lipophilic.
- A consequence of  $\text{Ca}^{2+}$  loss through the urine is a decrease in PTH plasma levels.

**A. True B. True C. False D. False**

#### Original commentary

Correct answers

*A true*

After menopause the estrogen level declines. Estrogen replacement therapy increases OPG levels and prevents thereby RANKL to bind to RANK, which would activate osteoclasts.

*B true*

Loss of bone mass is a symptom of hyperparathyroidism, where increased production of PTH leads to increased levels of RANKL and increased osteoclast activity

*C false*

Estrogen and Vitamin D are lipophilic hormones as shown above they have to cross the cell membrane to operate whereas PTH needs to bind to an extracellular receptor as it is hydrophilic and cannot cross the membrane

*D false*

Renal loss of calcium leads to a decrease of plasma calcium level which causes an elevation of PTH. PTH indirectly activates osteoclasts which resorb bone, process during which calcium is released into the blood. This reestablishes the calcium plasma level.

References

[Seeman et al, NEJM \(2006\)](#)

[Stavros et al, NEJM \(1995\)](#)

[Weinstein et al, NEJM \(2009\)](#)



If it was the case, a digit 2 could only be formed next to a digit 3 itself near to a digit 4. As seen when Z is grafted at somites 15 or 15/16, this is not the case, a digit 2 can be formed even in the absence of a digit 3/4 next to it.

References

Tickle et al, Nature (1975)

A neuron is kept in a solution similar to the extracellular fluid of brain tissue under a pure oxygen atmosphere. After a few minutes, cyanide, a substance that blocks the electron transport chain, is added to the solution.

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

- A. The concentration of  $K^+$  ions in the cell increases.
- B. The probability of a spontaneous action potential increases.
- C. The concentration of  $H^+$  ions in the intermembrane space of the mitochondria increases.
- D. The concentration of bicarbonate in the solution decreases.

**A. False   B. True   C. False   D. True**

**Original commentary**

Correct answers

*A false*

Addition of cyanide leads to a rapid depletion of ATP in the neuron. As a consequence, the  $Na^+ / K^+$  pump will no longer exchange  $Na^+$  against  $K^+$  inside the cell. Through diffusion, the distribution of ions will be equalized across the cell membrane, and hence the concentration of  $K^+$  will decrease in the cell.

*B true*

With an increase of the membrane potential due to diffusion (see A), the probability of a spontaneous action potential increases.

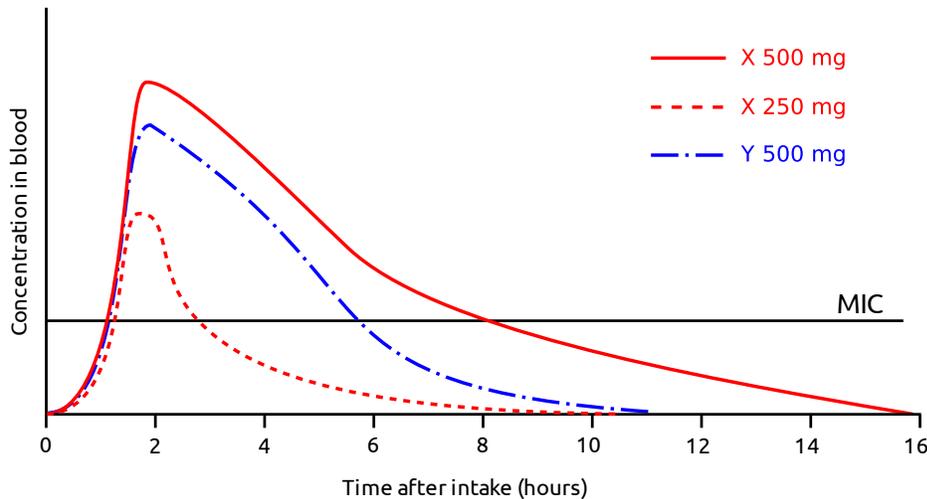
*C false*

The concentration of  $H^+$  is kept high in the intermembrane space of the mitochondria by the electron transport chain. After blocking this chain, the concentration quickly decreases through the production of ATP at the ATP-synthetase.

*D true*

After adding cyanide, the cell stops emitting  $CO_2$ . The  $CO_2$  dissolved as bicarbonate in the solution from before adding cyanide is entering the atmosphere with an extremely low partial pressure of  $CO_2$  (as it was initially pure  $O_2$ ).

The effectiveness of antibiotic treatments depends on the time and concentration at which bacteria are exposed to a specific drug, which in turn depends on the dosage, the intake interval and the rate of drug elimination from the body. Two antibiotics X and Y, both somewhat toxic to humans, are excreted by the kidney, but Y is also eliminated in the liver through cytochrome complexes. While X makes the bacterial cell wall permeable for ions, Y inhibits the synthesis of the cell wall during cell division. The figure below shows the average concentration of drugs X (red) and Y (blue) measured in healthy individuals after a single intake of 500 mg or 250 mg, along with the minimal concentration at which target bacteria are inhibited to grow *in vitro* (MIC, solid black line).



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

- To safely treat patients with significantly reduced renal function, intake intervals of X have to be prolonged.
- When doubling the dosage of X to 500 mg, doubling the intake interval prevents an accumulation of X while ensuring that the concentration stays above the MIC in the blood.
- Patients treated with Y should increase their dosage when consuming fruits containing inhibitors of cytochrome complexes (e.g. grapefruit).
- Ensuring a drug concentration above the MIC in the blood is more important for X than Y.

**A. True B. False C. False D. False**

#### Original commentary

Correct answers

*A true*

Drug X is eliminated only renally and thus in renal insufficient patients, the consideration of the risk of accumulation of drug X is important. By increasing the intake interval, the kidney has more time to eliminate the drug and hence the risk of accumulation is reduced.

*B false*

As shown in the graph a dosage of drug X of 250 mg causes blood concentration higher than MC only for 2-3 h but a dosage of drug X of 500 mg causes blood concentration higher than MC for approx. 8 h, meaning more than double of a dosage of 250 mg and meaning the interval has to be more than doubled.

*C false*

Substances inhibiting the cytochrome complexes (e.g. grapefruit) leads to slower inactivation/excretion of drug Y and hence patients treated with this drug have to be given lower dosages or asked to increase the intake intervals to prevent accumulation and intoxication.

*D false*

As bacteria cell division is a continuing process and bacteria divide not simultaneously the concentration of drug Y has

to be as a therapeutic level (higher than MC). A change in the membrane permeability of ions causes rapid bacterial damage and death consecutively.

References

[Tulane University; MIC & Time- vs Concentration-Dependent Killing](#)

Dysfunctions of endocrine glands can be classified into three types, depending on the hormone directly affected:

- Primary endocrine dysfunctions alter the production of hormones with direct systemic effects on metabolism or development.
- Secondary endocrine dysfunctions alter the production of tropic hormones that act on other glands.
- Tertiary endocrine dysfunctions affect the hypothalamus.

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

- A. A patient with an elevated cortisol level, a reduced corticotropin-releasing hormone (CRH) level and a elevated adrenocorticotrophic hormone (ACTH) level is most likely affected by a primary dysfunction.
- B. An overproduction of the thyroid stimulating hormone TSH can be due to a primary dysfunction.
- C. An increased blood concentration of cortisol may be due to a tumor implying a primary or a secondary dysfunction.
- D. In the case of a tumor leading to a secondary endocrine dysfunctions, the blood concentration of the corresponding releasing hormone is changed.

**A. False   B. True   C. True   D. True**

**Original commentary**

Correct answers

*A false*

The most likely explanation is a secondary dysfunction leading to an overproduction of ACTH, which in turn leads to an elevated Cortisol level and, due to feedback, an decreased CRH level.

*B true*

Due to feedback interactions, a primary underproduction leads to an increase in the corresponding tropic hormone.

*C true*

A hormone-producing tumor of the adrenal gland as a primary dysfunction elevates the cortisol. The same is caused secondary due a overproduction of ACTH causing a stimulation of the adrenal gland. The latter results in a overproduction of cortisol.

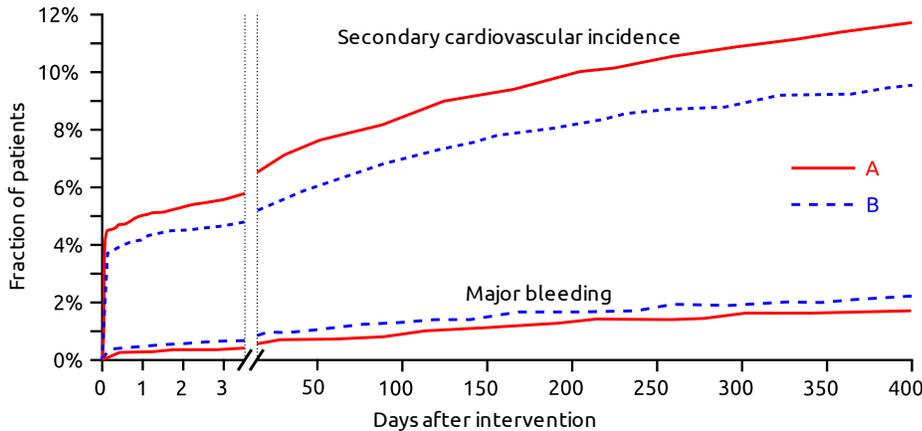
*D true*

A secondary dysfunction affects the tropic hormone through a feedback mechanism.

References

Campbell Biology

Inhibiting platelet aggregation after a coronary intervention has been shown to greatly reduce the risk of complications. The effectiveness of two competing inhibitors was assessed in a clinical study in which 13,608 patients with symptoms of a myocardial infarction were randomly assigned to a treatment with either inhibitor A or B after the intervention. The figure below shows the fraction of patients that suffered from a second cardiovascular incident such as an infarction or a stroke, as well as the fraction of those that suffered from major bleeding in the 400 days post intervention.



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

- This study suggests that using inhibitor B instead of A reduces the risk of a secondary cardiovascular event, but does not reduce the risk of major bleeding.
- This study suggests that a switch from inhibitor B to the cheaper inhibitor A after 3 days is increasing the risk of a secondary cardiovascular event.
- When using inhibitor B instead of A, the total number of patients suffering from a secondary cardiovascular incidence within 3 days after a coronary intervention is reduced by more than 10%.
- Repeating the study with a placebo control group is advised.

A. True B. True C. True D. False

#### Original commentary

Correct answers

A true

Inhibitor B does indeed decrease the risk of a secondary cardiovascular incident, but at the same time increases the risk of a major bleeding.

B true

The study suggests that patients treated with inhibitor B have a reduced risk of a secondary cardiovascular incidence even after day 3. This can be read from the figure since the absolute difference in the fraction of patients with a secondary cardiovascular incident is increasing from day 3 to day 400. If there were no difference in the effects after day 3, the risk to suffer a secondary cardiovascular incident in the following 397 days would be the same in both treatments. Hence the number of patients with such an incident between days 3 and 400 can be calculated as  $n \cdot (1-f(3)) \cdot r$  where  $f(3)$  is the fraction at day 3,  $n$  the total number of patients and  $r$  the rate. The total fraction of patients at day 400 is then given by  $f(400) = (f(3) \cdot n + (1-f(3)) \cdot n \cdot r) / n = f(3) + (1-f(3)) \cdot r = f(3) \cdot (1-r) + r$ . The absolute difference at day 400 is thus  $(f_A(3) \cdot (1-r) + r) - (f_B(3) \cdot (1-r) + r) = (1-r) \cdot (f_A(3) - f_B(3))$ , which is always smaller than  $f_A(3) - f_B(3)$  unless  $r=0$ . But note that the students do not need to make these calculations but just realize that the absolute difference increases.

C true

To calculate the reduction in the total amount of affected patients, one need to compute the reduction from 5.8% to 4.9% of all patients, which is a reduction by  $1 - 4.9/5.8 = 15.5\%$ . Note that the exact numbers the students read off the graph do not matter, as to get a reduction of less than 10%, the student would need to misread the percentage of inhibitor A to be 9% or more.

*D false*

Given the known reduction in the risk of complications when inhibiting platelet aggregation it would not be ethical not to give some patient any platelet inhibitor. In addition, the use of a placebo could only reaffirm the beneficial use of such an inhibitor but not add value to the comparison between inhibitors A and B.

References

[Wiviott et al, NEJM \(2007\)](#)

There is variability in the proteins transporting  $O_2$ , and their affinities for  $O_2$ , both within and between organisms.

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

- A. At the same partial pressure of  $O_2$ , the saturation of fetal hemoglobin is higher than the saturation of the maternal hemoglobin.
- B. Hemoglobin has a lower affinity to  $O_2$  in the vicinity of cells performing anaerobic glycolysis heavily.
- C. The hemoglobin of deep-diving mammals has a higher oxygen affinity than the hemoglobin of mammals adapted to high altitude.
- D. Hemoglobin is more efficient in transporting  $O_2$  than is hemocyanin, the equivalent protein of many arthropods that binds  $O_2$  non-cooperatively.

**A. True B. True C. False D. True**

**Original commentary**

Correct answers

*A true*

This is an adaptation of the fetal hemoglobin to recruit oxygen from the maternal blood.

*B true*

Cells relying heavily on anaerobic glycolysis recycle their NADH by fermenting lactate, which increases the acidity of the blood in the vicinity. In a more acidic environment, hemoglobin changes its conformation, which in turn reduces its affinity for oxygen (Bohr effect). This is an effective way to release oxygen where it is needed most.

*C false*

The opposite is true. Mammals that are deep divers need hemoglobin that releases most of the oxygen in the blood.

Mammals adapted to high altitude, in contrast, need to fill their hemoglobin with oxygen in the lungs even at low partial pressure, and hence have hemoglobin with higher affinity.

*D true*

The cooperativity between the different hemoglobin subunits allow for a larger difference in affinity between the place of oxygen uptake and oxygen release (a sigmoid dissociation curve).

The Hepatitis B virus contains the antigens HBs, HBc and HBe, of which HBs is commonly used as a vaccine. HBe is expressed in only some strains. The following table shows the presence (+) or absence (-) of viral antigens and antibodies measured in some patients. A question mark (?) indicates that the respective test was not performed.

Patient	HBs	HBc	HBe	Anti-HBs IgG	Anti-HBs IgM	Anti-HBc IgG	Anti-HBe IgG
P1	-	-	?	+	?	-	?
P2	-	-	-	+	-	+	+
P3	+	?	+	-	+	-	?
P4	+	?	?	?	?	+	+
P5	?	-	-	-	+	-	?

Indicate for each of the following statements if it is likely to be true or false.

- A. Patient P1 was vaccinated a while ago, but never suffered from a Hepatitis B infection.
- B. Patient P2 successfully overcame a Hepatitis B infection.
- C. Patients P3 and P4 are currently suffering from a Hepatitis B infection.
- D. Patient P5 has been vaccinated recently.

**A. True B. True C. True D. True**

**Original commentary**

Correct answers

*A true*

Since vaccination is done using HBs, a vaccinated person is producing anti-HBs IgG after several weeks. A Hepatitis infection, however would also lead to anti HBc and often anti-HBe antibodies, which were not found in P1.

*B true*

While no antigens were found, P2 produces IgG against all three antigens, even those not used in vaccination.

*C true*

The antigen HBe was found in P3, which is a good indication that the virus is present. In addition, the immune system of P3 started its first response by producing IgM antibodies. Since P4 shows anti-HBc and anti-HBe IgG, he or she must have been infected at one point. The presence of HBs strongly suggest that the infection is still in progress since the only alternative would be a very recent vaccination, which is unlikely to be applied to an already immunized person.

*D true*

The presence of anti-HBs IgM suggest a recent and exposure to HBs. However, since HBc and HBe antigens are not present, the likely source of exposure was a recent vaccination.

Participants of the IBO 2013 are going to visit mount Niederhorn. Before and right after a rapid ascent by cable car from 400 m to 2000 m and just before descent 3 hours later, physiological parameters of several participants will be measured and compared to the same measurements obtained from an alpine herder who stayed on the Niederhorn for more than two consecutive months. The participants are expected to hyperventilate at this altitude and get dehydrated.

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

- A. The heart rate of an IBO participant just after arriving on top is expected to be higher than just before the ascent.
- B. The pH of the blood of the alpine herder is expected to be higher than the pH of the blood of an IBO participant when arriving on top.
- C. The pH of the urine of an IBO participant is expected to be higher just before descent than just after arriving on top.
- D. Some IBO participants are expected to show a transient increase in the hemoglobin concentration while on top.

**A. True B. False C. True D. True**

**Original commentary**

Correct answers

*A true*

The hypoxemia due to the lower partial concentration of oxygen will be compensated by an increased heart and respiratory rate .

*B false*

The blood pH is tightly controlled and is not expected to change substantially. If any change is observed, then the pH of the IBO participant is expected to increase due to hyperventilation, followed by a rapid reduction in the carbondioxyde concentration in the blood.

*C true*

Due to hyperventilation, the carbondioxyde concentration in the blood is decreased rapidly. To prevent an increase of the blood pH, the body excretes basic metabolites through the urine, leading to an increase of the urine pH.

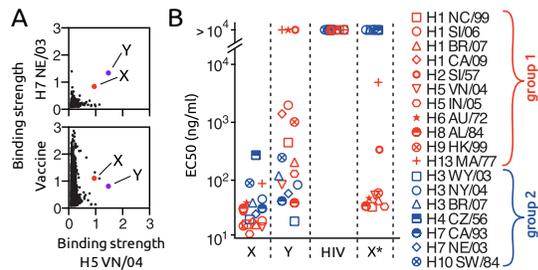
*D true*

To avoid an increase of the blood pH (see answer to C), the kidney excretes basic metabolites, often leading to dehydration, which is followed by an increase of the hemoglobin concentration in the blood. What is more hyperventilation (especially on high altitudes) leads to dehydration, too.

References

Campell Biology

The rapid evolution of the influenza antigen Hemagglutinin (HA) is a major challenge for the development of efficient treatments. In order to identify antibodies effective against a wide variety of influenza strains, 13,000 plasma cells of a vaccinated person were individually isolated and triggered to produce antibodies. These antibodies were tested against different types of HA (H5 VN/04, H7 NE/03 and the mix present in the vaccine) by measuring their binding strength (figure A). The binding efficacy of two particularly promising antibodies X and Y against several HA types from groups 1 (red) and 2 (blue) was further assessed by measuring the required concentration to achieve half the maximal binding efficacy (EC50, figure B). As a comparison, the EC50 was also measured for an anti-HIV antibody (HIV) and an antibody X\* produced by plasma cells originally producing X but in which all mutations have been reverted to obtain the corresponding sequence originally inherited from the parents.



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

- An immune response against the influenza vaccine is mediated by a diverse set of antibodies.
- While efficient against HA from group 2 strains, antibody Y does not confer immunity against all group 1 strains tested.
- The widespread immunity found for antibody X has in part arisen from somatic mutations.
- An injection of antibody X confers effective immunity against a wide range of influenza strains for several years.

A. True B. True C. True D. False

#### Original commentary

Correct answers

A true

As can be seen in the lower panel of figure A, there are a large number of plasma cells producing antibodies against the HA present in the vaccine.

B true

This can be seen in figure B where antibody Y does not bind all group 1 HA better than the control antibody against HIV.

C true

Since the germ line copies of all genes do not confer immunity, the difference between X and X\* antibodies must be due to somatic mutations that occurred in the cell line leading to the plasma cell producing X. Note that somatic mutations and rearrangements are common in antibody producing cells, a likely adaptation to deal with a wider range of antigens.

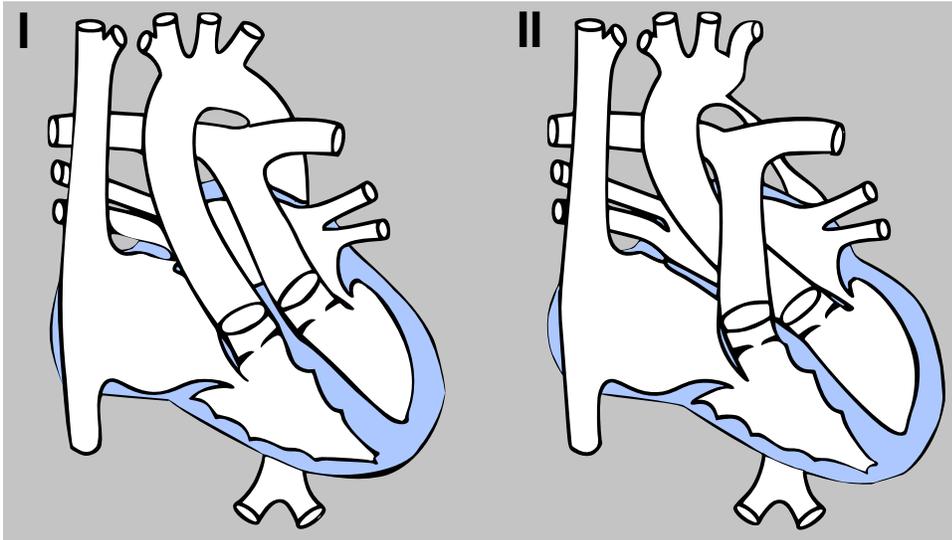
D false

While an injection of antibody X confers passive immunity against a wide range of influenza strains, it does not provide active immunity. Therefore, immunization will not last for more than a couple of weeks or maximally month.

References

[Corti et al. Science \(2011\)](#)

The following schematics illustrate two severe congenital heart malformations occasionally found in newborns.



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

- A. In Malformation I, the oxygen saturation is higher in the pulmonary artery than in the carotid artery.
- B. Surgically swapping the aorta and the pulmonary artery in the case of Malformation I restores proper blood circulation.
- C. In Malformation II, the blood pressure in the carotid artery is increased compared to healthy individuals.
- D. Surgically swapping the *venae cavae* and the pulmonary vein in the case of Malformation II restores proper blood circulation.

**A. True B. True C. True D. False**

#### Original commentary

##### Note

In the heart Malformation I, the aorta comes out of the right ventricle (instead of the left one) and the pulmonary artery out of the left ventricle (instead of the right one). In Malformation II, the aorta is narrowed.

##### Correct answers

A *true*

This is true because there is no connection between the pulmonary blood circulation and the systemic one.

B *true*

As mentioned in the "answer note" the origins of the aorta and pulmonary artery are swapped.

C *true*

The narrowing of the isthmus of the aorta causes an increased resistance at this location leading to a reduced flow downwards the aorta which increases the blood flow in the arteriae of the upper extremities and the head/brain. The latter increases the blood pressure consecutively.

As a second mechanism the decreased blood flow in the aorta descendens/aorta abdominalis and in the flow renal arteries consecutively. As a physiological mechanism the kidney rises the circular blood pressure to try to increase the renal blood flow.

D *false*

The suggested operation does not change the patients problem. What is more it would create the same separation of the pulmonary and systemic circulation as in Malformation I.

##### References

[Universitätsklinikum Bonn; D-Transposition der großen Arterien](#)



In a community of marine brown algae (*Phaeophyta*), two multicellular life forms are observed among the species:

- 1) A tall and fast-growing form that is strongly affected by environmental seasonality and shows a high mortality.
- 2) A tiny and slow-growing form that is less sensitive to seasonality and shows a low mortality.

All species alternate between a haploid and a diploid generation. Isomorphic species show the tall form both in the haploid and diploid generation. The life form of heteromorphic species, however, depends on ploidy.

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

- A. Proportion of isomorphic species is likely to increase with more intense seasonality.
- B. In heteromorphic species, the tall and fast-growing life form is observed during the more productive season.
- C. Heteromorphic species are limited to one generation each season (winter/summer).
- D. In these algae, haploid full siblings from diploid parents are genetically less related than diploid full siblings from haploid parents.

**A. False B. True C. True D. True**

**Original commentary**

Correct answers

*A false*

The description of the small life form is giving a hint that it is adapted to endure a tougher, less productive season (winter). A species with the tall and fast growing form alone will have an increasing handicap in regions with a more intense winter compared to heteromorphic species more adapted to endure a tough season.

*B true*

As the tall life form is adapted to fast growth during summer, it will be more competitive during summer as compared to individuals with the small life form present during summer.

*C true*

The small life form is adapted to outlive the unproductive winter - during summer the small life form would implicate a loss of productivity. On the same time, the tall life form would be very vulnerable during winter and most likely not survive. So heteromorphic species only make one new generation at the end of each season.

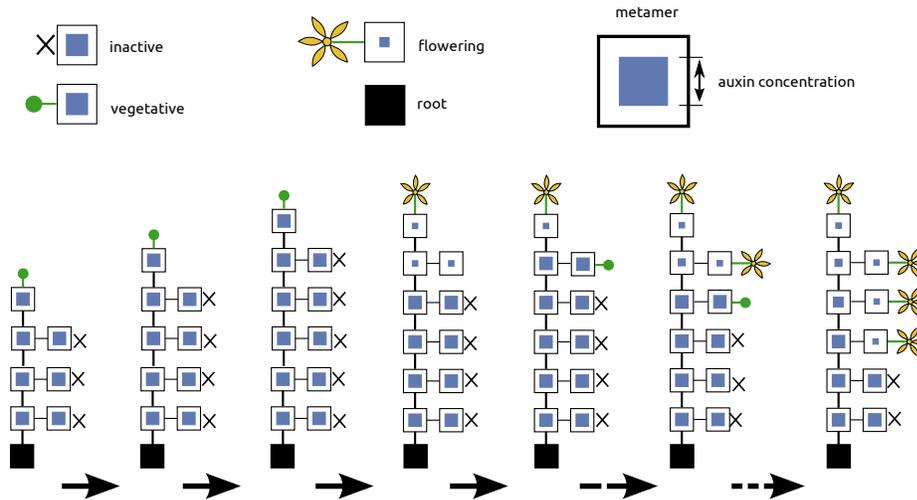
*D true*

Haploid plants derive from spores which are products of a meiosis and have only one parent. Therefore siblings share half of their genome in average. Diploid plants derive from a zygote out of two gametes, resulting themselves from a meiosis of their parents. All gametes from each parent are genetically identical, as are the full siblings among each other.

References

[Bessho et al, Evolutionary Ecology Research \(2009\)](#)

A growing plant can be described by units called metamers (illustrated by boxes) that are produced by a vegetative meristem. Each metamer consists of a stem segment and an additional meristem that is inactive at first, but may become active and develop into a vegetative meristem. Vegetative meristems can develop into a flowering meristem. Vegetative and flowering meristems produce auxin, which is constantly transported downwards to lower metamers. The figure below shows a plant at different ages ending up flowering and illustrates the auxin concentration found in each metamer.



**Based on the observed auxin concentrations, indicate if each of the following statements is true or false.**

- Exceeding a minimal auxin threshold invariably activates meristems.
- An apex turning to a flowering stage is losing its apical dominance.
- A high auxin concentration is enough to trigger the development of flowers.
- Auxin from different apical metamers can have cumulative effects on subsequent metamers.

**A. False B. True C. False D. True**

#### Original commentary

Correct answers

*A false*

The opposite is true, below a certain threshold the apical dominance is lost and the uppermost inactive meristem is activated.

*B true*

A metamer turning into a flower is reducing its production of auxin, so the concentration of auxin sinks in the subsequent metamer and falls under the threshold needed to suppress meristem activation.

*C false*

If this was true, all meristems would turn into a flowers.

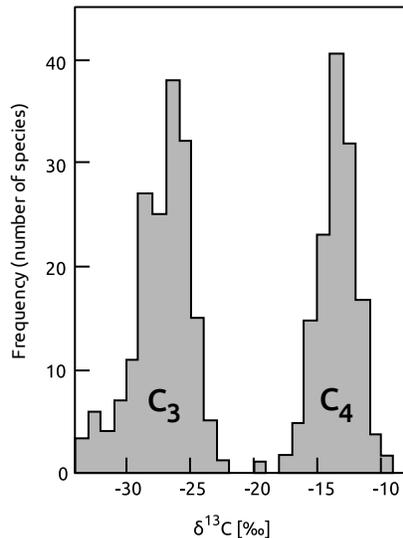
*D true*

The residual auxin from all four flowering apices accumulates along the stem and prevents the subsequent metamer from being activated. /br>

References

[Przemyslaw et al, PNAS \(2009\)](#)

Two stable carbon isotopes  $^{12}\text{C}$  and  $^{13}\text{C}$  are present in the atmosphere, but  $^{12}\text{C}$  is approximately 100 times more frequent. Diverse metabolic processes discriminate against  $^{13}\text{C}$  in favor of  $^{12}\text{C}$ , leading to a smaller proportion of  $^{13}\text{C}$  in biomass than in the atmosphere. The relative difference between expected and observed proportion is indicated by  $\delta^{13}\text{C}$ , with a more negative value indicating a stronger discrimination. The figure shows the distribution of  $\delta^{13}\text{C}$ -values found in plant species with  $\text{C}_3$  and  $\text{C}_4$  metabolism.



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

- RuBisCO is discriminating more strongly against  $^{13}\text{C}$  under higher than under lower partial pressure of  $\text{CO}_2$ .
- Fixation of  $\text{CO}_2$  into oxaloacetate is discriminating more strongly against  $^{13}\text{C}$  than the reaction of RuBisCO.
- Meat from cattle feeding on a meadow in the Swiss mountains is likely to have a lower  $^{13}\text{C}$  content than from cattle feeding in a central African savanna.
- It is possible to distinguish between purified sugar from sugar cane ( $\text{C}_4$ ) and sugar beet ( $\text{C}_3$ ) based on their mass.

**A. False B. False C. True D. True**

**Original commentary**

Correct answers

*A false*

Actually the opposite is true. The aim of the  $\text{C}_4$  metabolism is to increase the partial pressure of  $\text{CO}_2$  for RuBisCO to increase the proportion of the carboxylase reaction compared to the oxygenase reaction. The higher partial pressure is actually the reason of weaker discrimination of  $^{13}\text{C}$  in  $\text{C}_4$  plants.

*B false*

This reaction is the first fixation step in  $\text{C}_4$ -plants which are less discriminative than  $\text{C}_3$  plants.

*C true*

$\text{C}_4$  plants are much more present in tropical ecosystems than in temperate or cold ecosystem. The isotope ratio is reported upwards in the food chain to herbivores and predators.

*D true*

As  $^{13}\text{C}$  is slightly heavier than  $^{12}\text{C}$ , the mean weight of a sugar molecule from cane is slightly higher.

Seeds of most plants are more resistant to environmental stress before germination has been initiated. To demonstrate this, seeds of wheat (*Triticum aestivum*) were exposed to one of the following four treatments.

Treatments	Soaked	Incubated	Transferred to wet paper and kept at room T
A	5 h at room T	5 h; -20°C	+
B	5 h at room T	5 h; 30°C	+
C	-	5 h; 4°C	+
D	-	5 h; 50°C	+

**Indicate for each of the following treatments, if the seeds are expected to produce sprouts (true), or not (false).**

A. Treatment A.

B. Treatment B.

C. Treatment C.

D. Treatment D.

**A. False B. True C. True D. True**

**Original commentary**

Correct answers

A *false*

B *true*

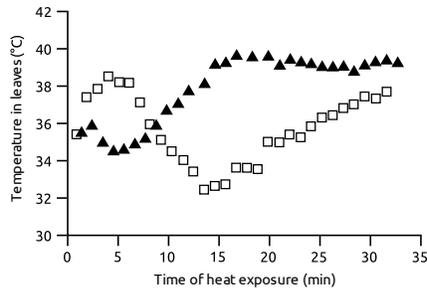
C *true*

D *true*

References

Campbell Biology, 9th ed., p. 84-85 and figure 5.22 ("What determines protein structure?") and pages 807ff. and figure 39.11 ("Seed Development, Form, and Function").

The figure below shows the leaf temperature of two groups of common bean (*Phaseolus vulgaris*) plants exposed to infrared light. One group (open squares) was kept at optimal water supply and the other group (triangles) was drought stressed for 4 month before the experiment.



**Based on these results, indicate if each of the following statements is likely to be true or false.**

- After 8 minutes of heat exposure, drought stressed plants kept more stomata open than control plants.
- The ability to regulate the opening and closing of stomata decreases over time in plants of both groups.
- Following about 15 minutes of heat exposure, leaves of drought stressed plants absorbed roughly the same amount of thermal energy as they emitted.
- Plants experience a trade-off between preventing water loss and protection from over-heating.

**A. False B. False C. True D. True**

#### Original commentary

Note

If stomata are open, transpiration increases and therefore leaf temperature decreases (through evaporative cooling). The opposite is true for closing of stomata.

Correct answers

A *false*

B *false*

C *true*

D *true*

References

[Reynolds-Henne et al, Environmental and Experimental Botany et al \(2009\)](#)

Campbell, Biology (9th ed.) page 778 ("Effects of Transpiration on Wilting and Leaf Temperature").

In a buffered suspension of freshly isolated thylakoids incubated in light, the rate of the Hill reaction (photolysis) can be measured using DCPIP. DCPIP is reduced at Photosystem I and changes its colour from blue to colourless.

**Indicate for each of the following modifications of the experimental setting if it would significantly reduce the rate of this reaction.**

- A. Raising the temperature of the solution from 20 °C to 30 °C.
- B. Removing soluble gases from the buffer solution prior to adding thylakoids.
- C. Adding DCMU, a herbicide that binds to Photosystem II.
- D. Adding 2,4-D, a herbicide acting as a synthetic auxin.

**A. False B. False C. True D. False**

**Original commentary**

Correct answers

*A false*

Temperature remains in the physiological optimum and the rate is expected to increase with temperature.

*B false*

No oxygen nor CO<sub>2</sub> is needed for electron transport chain.

*C true*

If the electron transport chain is interrupted, DCPIP will not be reduced and the suspension will not turn colourless.

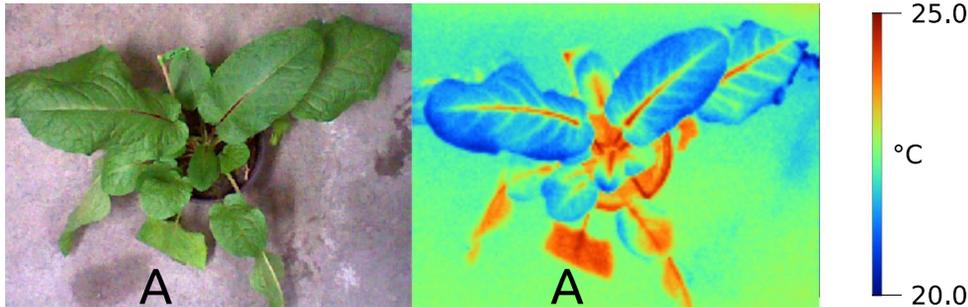
*D false*

Auxin has no effect on electron transport chain.

References

Campbell Biology, 9th ed., p. 193-194 (electron transport chain).

Infrared pictures are used to visualise the temperature of a plant surface. The figure below shows the photograph of a plant and the corresponding infrared picture.



Based on the figure, indicate for each of the following statements if it is true or false.

- A. Due to growing in the shade of older leaves, younger leaves of this plant are cooler than older leaves.  
 B. Plant parts with high metabolic activity get several degrees warmer than parts with lower metabolic activity.  
 C. Transpiration in leaf veins is significantly lower than in leaf blades.  
 D. The high temperature of leaf A indicates that this plant begins suffering drought stress.
- A. False   B. False   C. True   D. False**

#### Original commentary

Correct answers

*A false*

Younger leaves are actually warmer than older leaves because they are transpiring less. The really old leaves in senescing state are warmer, but do not provide shade.

*B false*

While metabolism may indeed increase the temperature of plant parts, this is usually a negligible factor. In addition, the hottest parts of the plant (shoot and veins) are actually not those parts with the highest metabolism. Those would rather be leaves producing starch, actively growing meristems and roots (which are not visible). Finally, non-metabolizing structures such as the pot, the substrate or the small pole with a tag get equally warm as the hottest parts of plants.

*C true*

The temperature of leaf veins is higher than that of the leaf blade because their transpiration is very low.

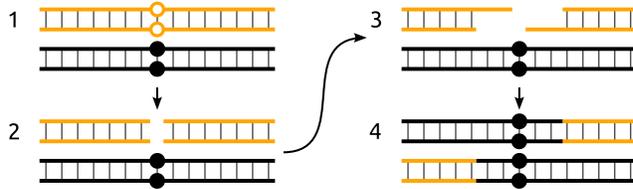
*D false*

Leaf A is senescing and thus not transpiring any more. Other leaves are healthy and transpiring, hence the reason cannot be that the plant is suffering from drought stress.

References

Campbell, Biology (9th ed.)page 778 ("Effects of transpiration on wilting and leaf temperature")

According to the current model of recombination, a recombination event is initiated by a double strand break (DSB) in one of the two sister chromatids, followed by a trimming of the 5' ends. During the repair process after recombination, the information immediately flanking the DSB site is lost and supplied by the other chromatid.



Consider the situation in which two Alleles A and B of a locus have probabilities  $r_A$  and  $r_B$  to initiate a DSB and are initially present at equal frequencies in a large, isolated population.

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

- If  $r_A$  is twice as large as  $r_B$ , the frequency of Allele A is expected to change faster when  $r_B=0.05$  than when  $r_B=0.01$ .
- If  $r_B$  is large and  $r_A$  is much smaller, the frequency of Allele A is expected to reach fixation (frequency=1) almost linearly.
- If  $r_A=r_B$ , the frequency of Allele A will remain constant even if the population were small.
- Unless there is an additional mechanism involved, recombination in the population is expected to decrease over time.

**A. True B. False C. False D. True**

**Original commentary**

**Note**

It should be clear from both the figure and the text that the allele initiating the DSB is not transmitted, which leads a bias in transmission in heterozygotes if the probabilities  $r_A$  and  $r_B$  are different.

**Correct answers**

**A true**

The larger the recombination rate, the more often the described mechanism can actually play. Hence the allele frequency changes more rapidly.

**B false**

While such a setting will lead to a rapid increase in allele A, the increase cannot be linear because the process depends on the frequency of heterozygous individuals, which become rapidly rare as the frequency of A approaches 1. Thus, the frequency of A is expected to increase asymptotically.

**C false**

In the case of  $r_A=r_B$ , this mechanisms will not necessarily lead to a change. However, due to genetic drift, an allele frequency is never expected to remain constant, unless the population is extremely (infinitely) large.

**D true**

This mechanism effectively leads to a reduction in the recombination rate since alleles with a lower recombination rate are favored.

In female fruit flies (*Drosophila melanogaster*), the oocyte is located between maternal nurse cells and follicle cells providing nutrients, proteins and mRNA crucial for the development of the embryo. In one of the genes whose mRNA is transported to the oocyte, a mutation X has been found that leads to deformed, non-viable embryos.

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

- A. If the mutation is dominant, the female offspring of a heterozygous male and a wild type female will be viable.
  - B. If the mutation is dominant, no adult individuals homozygous for X can be observed.
  - C. If the mutation is recessive, only the female embryos of a mother heterozygous for X will be deformed.
  - D. If the mutation is recessive and two individuals heterozygous for X are crossed to produce the F1, 1/6 of the F2 will be homozygous for X.
- A. True   B. True   C. False   D. True**

**Original commentary**

Correct answers

A *true*

Female with a mutation in a maternal effect gene are viable, even if they are sterile.

B *true*

To be homozygous for the mutation, an individual need to receive a mutant allele from each parent, however, females with a dominant mutation are sterile and therefore cannot transmit the mutation to offspring.

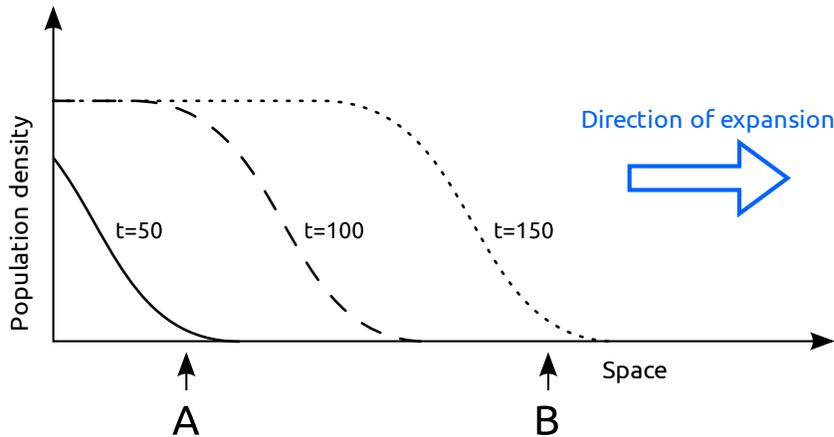
C *false*

If the mutation is recessive, all offspring of a heterozygous mother will be viable.

D *true*

To be homozygous for the mutation, an individual need to receive a mutant allele from each parent. In the F1 of a cross between heterozygotes, the genotypes are distributed 1:2:1. Males can give the mutant allele with a probability of 1/2, however, the homozygous mutant female are sterile, therefore, only heterozygous females, representing 2/3 of the fertile females can give the mutant allele to their offspring, this with a probability of 1/2. The final probability of being homozygous in the F2 is  $1/2 * 2/3 * 1/2 = 1/6$ .

Assume a one-dimensional, homogeneous habitat with carrying capacity  $K$  that is inhabited by an annual plant species only at the left most point at generation  $t=0$ . In each generation, a fraction  $m=0.01$  of the seeds disperses to neighbouring locations while the remaining  $1-m$  seeds remain at the same location. The following figure displays the plant density over the habitat at different generations.



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

- A mutation doubling  $m$  would increase the speed of the expansion.
- A beneficial mutation appearing at time  $t=100$  at Position A will almost certainly become fixed in the population.
- A neutral mutation appearing at time  $t=50$  in Position A has a higher probability to become fixed in the whole population than a neutral mutation appearing at time  $t=150$  in Position B.
- A harmful but not lethal mutation appearing at time  $t=150$  is expected to persist in the population longer if it appears in Position B than Position A.

**A. True B. False C. True D. True**

#### Original commentary

Correct answers

*A true*

The speed of the expansion is primarily dependent on the growth rate and, up to a limit, on the migration rate. If the migration rate is very small (as is the case here), it will, on average, take multiple generations until the next deme is colonized. Hence, an increase in the migration rate does lead to an increased colonization speed.

*B false*

The most likely fate of every mutation appearing in a population is that it is lost by genetic drift.

*C true*

While both mutations have the same probability to become common at their receptive positions, a mutation that becomes common at position B will have a very low probability to become common at position A. In contrast, a mutation that becomes frequent at position A is likely contributing to the newly colonized demes and will thus have a higher chance to get fixed in the whole population.

*D true*

Since the population density will increase rapidly at Position B, selection is very weak and genetic drift is not efficient in losing new alleles. In contrast, both drift and selection are acting more strongly on a new mutation at position A since the population is large and stable in size. Hence, a deleterious mutation is much more likely to persist in the population when appearing at position B than when appearing at position A.

The red colour of a haploid fungus is produced by a pathway converting a precursor pigment through several intermediates. To study this pathway, several mutant strains (I through IV) of various colours have been obtained. The following table lists their colours along with those observed in the haploid progeny of crosses among them.

Strain or cross	Colours observed			
	red	beige	yellow	pink
wild type	X			
I		X		
II		X		
III			X	
IV				X
I x wild type	X	X	X	
II x III	X	X	X	X
II x IV		X		X
III x IV	X		X	X

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

- A. At least four genes are involved in this pathway.  
 B. Strain I has mutations in more than one gene involved in this pathway.  
 C. In the pathway, the enzyme turning the pigment pink is located upstream of the enzyme turning it beige.  
 D. Red progeny can be observed when crossing Strains I and IV.

**A. False B. True C. False D. True**

**Original commentary**

Correct answers

*A false*

In this pathway, 3 steps catalyzed by a total of 3 enzymes are enough to explain the results.

*B true*

Crossing I (beige) with the wild-type produces, besides beige and red (wild-type) offspring, also yellow offspring which can only be explained if strain I is mutant both for the enzyme metabolizing the beige intermediate and the one transforming the yellow one. Since strain I appears beige, it also means that the yellow pigment is situated further downstream in the pathway as the beige one.

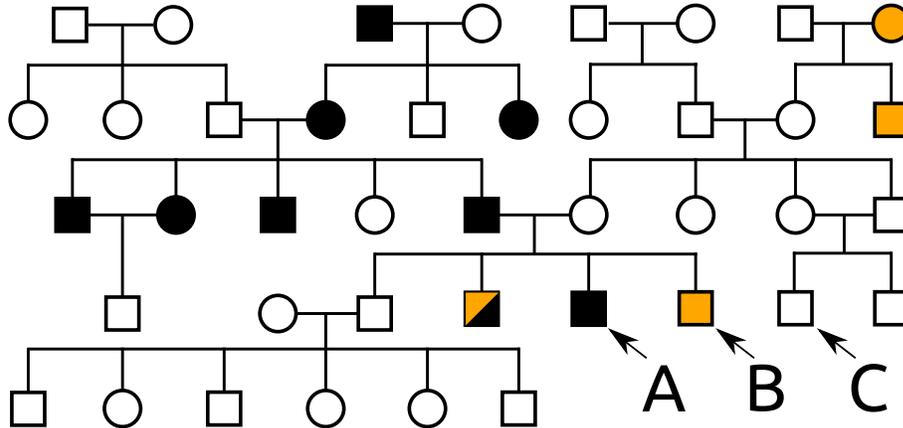
*C false*

Crossing II (beige) with IV (pink) does not produce any red (wild-type) offspring, this means that at least one of the two strains is mutant for both alleles. Crossing III (yellow) with IV (pink) does not produce beige offspring. Since we know from B that beige is upstream of yellow, this can only be explained if IV is only mutant for the gene metabolizing the pink intermediate, therefore strain II is mutant both for the enzyme metabolizing beige and the one metabolizing pink. Since II appears beige and not pink, the beige intermediate is upstream of the pink one.

*D true*

Offspring can only be red if between the 2 parents, at least one copy of each gene is wild-type. We know from B that I is mutant only for the enzymes converting yellow and beige and from C that IV is only mutant for the enzyme converting, therefore red (wild-type) offspring can be observed when crossing I and IV.

Three male members (A, B and C) of a family consult a genetic counsellor. The genealogy of the family is given below with individuals affected by two genetic diseases X (black) and Y (orange) are indicated. While Disease X is extremely rare, the disease causing allele of Disease Y has a frequency of 6% in the population.



Indicate if each of the following statements is true or false under the most likely modes of inheritance.

- Individual B must be a carrier of Disease X.
- Individual C cannot be a carrier of Disease Y.
- If Individual A was to have a son with an unrelated and unaffected woman, the probability that the son will be affected by Disease X is 50%.
- If Individual B was to have a son with an unrelated and unaffected woman, the probability that the son will be affected by Disease Y is  $> 5.65\%$ .

**A. False   B. True   C. True   D. True**

#### Original commentary

Note

##### Mode of inheritance disease X

Since two affected individuals have a healthy son, disease X must be dominant and since both males and females are affected, it cannot be Y-linked. Finally, since we know that the disease is extremely rare and thus most likely absent in the family of the mother of A and B, the disease must be autosomal then an X-linked disease can not be inherited from father to son (individual A).

##### Mode of inheritance of disease Y

Dominant inheritance can be excluded because two healthy individual have an affected son (individual B). Autosomal recessive is unlikely because the father of individuals A and B has healthy parents, grand parents, uncles, aunts and siblings. Hence the most likely mode of inheritance is X-linked recessive.

Correct answers

*A false*

Given a dominant inheritance of disease X, individual B cannot be a carrier of this disease. Note that it is enough to realize that the disease must be dominant but not to distinguish between autosomal or gonosomal to answer this questions.

*B true*

A male cannot be carrier of a X-linked recessive disease.

*C true*

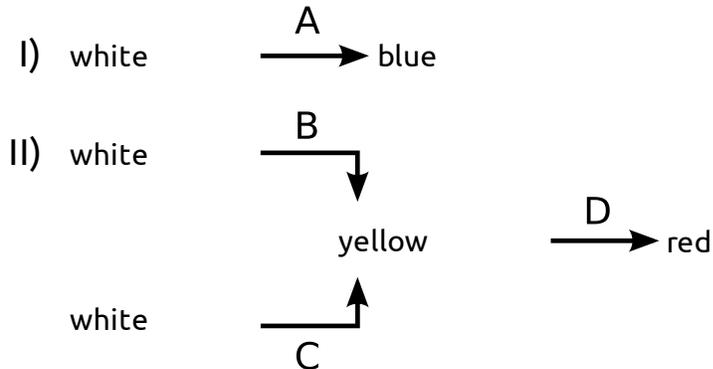
Since the disease is dominant, individual A will pass on the affected allele in 50% of the cases.

*D true*

While individual B will pass on his Y-chromosome and hence not the disease causing allele, the probability that the mother will pass it on is non zero. Given the allele frequency of 6% in the population and given that the mother is

healthy, she is a carrier with a probability of  $(2 \cdot 0.06 \cdot 0.94) / (1 - 0.06 \cdot 0.06) = 11.32\%$ , in which case she has a probability of 50% to transmit the disease causing allele. Hence, the probability to have an affected son is 5.67%. A common mistake is to assume the probability that the mother is a carrier to be  $2 \cdot 0.06 \cdot 0.94 \cdot 0.5 = 5.64\%$ , and hence to ignore the fact that we already know that the mother is not affected.

Several inbred lines with recessive mutations are studied in a plant species. Wild type flowers are purple due to a mix of a red and a blue pigment synthesized by two separate biochemical pathways I and II involving enzymes encoded by genes A-D (all colorless compounds are named "white"):



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

- If all genes were unlinked, less than 25% of all F<sub>2</sub> individuals of a cross between a red and a blue inbred line are expected to be red.
- If back-crossing the F<sub>1</sub> of a purple and a yellow inbred line to their yellow parents results in 160 yellow, 40 red, 40 green and 160 purple individuals, genes A and D are 20 cM apart on the same chromosome.
- If B was more closely linked to A than to C and A was more closely linked to C than to B, gene B must be between genes A and C.
- If the distance between B and C was 28.5 cM and crossing purple F<sub>1</sub> individuals from a cross of two purple inbred lines gives rise to blue individuals in the F<sub>2</sub>, their frequency is less than 5%.

A. True   B. True   C. False   D. True

#### Original commentary

Correct answers

A true

A red inbred line is homozygous for a loss of function mutation in gene A (genotype aaBBCCDD). A blue inbred line is homozygous for a loss of function mutation both in gene B and gene C (genotype AAbbccDD), as otherwise the plants turn green. The F<sub>1</sub> of such a cross has the genotype AaBbCcDD. F<sub>2</sub> individuals with red flowers must be homozygous for a (which they are with probability  $1/2 \cdot 1/2 = 1/4$ ) and may not be homozygous for both b and c at the same time, which they are with probability  $1 - (1/2)^4 = 15/16$ . The total frequency of red individuals among the F<sub>2</sub> is thus  $1/4 \cdot 15/16 = 15/64 = 23.9\%$ . However, note that the red inbred line might also be homozygous for either b or c, in which case the F<sub>1</sub> individuals have genotypes AabbCcDD or AaBbccDD. In this setting, the probability that an F<sub>2</sub> individual is not homozygous for both b and c is reduced to  $1 - (1/2)^2 = 3/4$ , and hence the frequency of red F<sub>2</sub> individuals would be  $1/4 \cdot 3/4 = 3/16 = 18.75\%$ . So independent of the assumptions, the frequency is always  $< 25\%$ .

B true

Yellow inbred lines must be homozygous for loss of function mutations a and d. In a back-cross setting with an individual homozygous for A and D (as the purple inbred line must be), the genetic distance can easily be computed as the frequency of non-parental phenotypes (green and red) among the progeny (see Campbell chapter 15). Thus, the distance is  $80/400 = 20\text{cM}$ .

C false

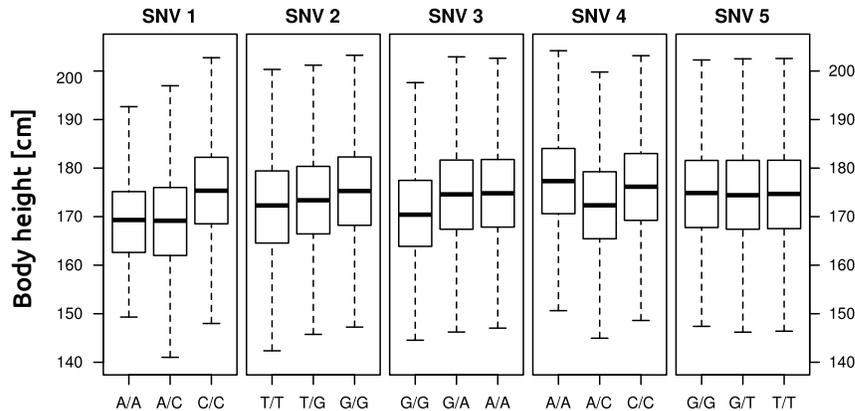
From them stem we know that B and C are linked. We further know that B is closer to A than to C. This leaves us with the orders A-B-C or B-A-C. Since A is closer to C than to B, only B-A-C remains (or C-A-B read from the other side).

D true

The only possible inbred purple genotypes that result in a purple F<sub>1</sub> but some blue F<sub>2</sub> when crossed are AAbbCCDD and AABbCcDD. Under this setting, the F<sub>1</sub> is AABbCcDD, and hence purple. A blue F<sub>2</sub> individual has then the genotype

AabbccDD, which requires a recombination to happen in both F1 parents (from the haplotypes AbCD and ABcD to AbcD and ABCD). This occurs with probability 0.285 (since the two genes B and C are 28.5 cM apart). After recombination, the needed haplotype is transmitted with a 50% chance. Hence the total probability for an F2 individual to be blue is  $(0.285 \times 0.5)^2 = 2.03\%$ .

A common strategy to detect genes underlying a particular trait is to test for statistical associations between the phenotype and a very large number of SNVs (single nucleotide variants) in a large sample of individuals. The charts below give the results of such an approach for body height and five independent SNVs typed in 20,000 random individuals from Switzerland.



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

- In contrast to SNV2, SNVs 1 and 3 are closely linked to a gene with an allele affecting body height dominantly.
- If the frequency of the C allele at SNV 4 decreases from 50% to 30% in the population, the average body height increases.
- Since the median body height in the population is 175 cm, the frequency of allele A at SNV 1 has to be below 30%.
- These results are sufficient to demonstrate that most of the variation in body height is genetically determined.

**A. True B. True C. True D. False**

#### Original commentary

Correct answers

*A true*

All three SNVs seem to be linked to a gene with an allele affecting body height. The difference to SNV 2 is only that the pattern observed at SNVs 1 and 3 is very likely due to the effect of a dominant-recessive locus in close proximity since the heterozygous genotype results in a very similar phenotype as one of the homozygous genotypes, but the pattern observed at SNV 2 is best explained with incomplete dominance.

*B true*

If the frequency of the C allele decreases from 50% to 30%, the number of heterozygous individuals decreases from 50% to 42%, and hence the average body height is expected to increase.

*C true*

SNV 5 has no effect on body height, and hence gives a direct estimate of the average height in the population (about 175 cm). If the A allele at SNV 1 has a frequency of 30%, the frequency of the dominant C/C genotype is only 49%, which is not possible since the average height for this genotype had then to be > 180cm to obtain a population average of 175cm. Higher allele frequencies of A would even make it worse. Note: the true allele frequency in the example is 7%.

*D false*

All SNVs together can explain only 10% of the variation. The students are not able to calculate this value from the data. However, they are able to judge that SNVs 1 through 4 each explain about 5cm max, which makes about 20cm difference between the most extreme genotypes ([A/A, T/T, G/G, A/C] vs [C/C, G/G, A/A, A/A]). However, the body height in the populations spans a multiple of this difference. Hence the conclusion from this data that a majority of the variation is genetically determined is false. But note that in fact body height in humans is 60-80% heritable, yet one needs different data to show this.



In cats, there is a genetic locus with two alleles (A, a). In a population, 1300 cats have genotype AA, 7400 are heterozygous and 1300 individuals carry the recessive genotype aa.

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

- A. The frequency of Allele A in the population is 0.5.
- B. Under Hardy-Weinberg equilibrium, only 6000 cats are expected to be heterozygous for this locus.
- C. If this population was isolated and mating randomly, the next generation of cats is expected to be in Hardy-Weinberg equilibrium.
- D. Sterility of homozygous individuals can explain this pattern.

**A. True B. False C. True D. False**

**Original commentary**

Correct answers

A *true*

The frequency of allele A is given by  $(2 \times 1300 + 7400) / (2 \times (1300 + 7400 + 1300)) = 10000 / 20000 = 0.5$ .

B *false*

Under Hardy-Weinberg,  $2 \times p \times q = 2 \times 0.5 \times 0.5 = 5000$  cats are expected to be heterozygous.

C *true*

A population is always in the Hardy-Weinberg equilibrium after only a single generation of random mating.

D *false*

If only heterozygous individuals were fertile, the allele frequency would indeed be 0.5. However, the offspring would still be expected to be heterozygous in only 50% of the cases.

To elucidate the phylogenetic relationship among three fly species of the *Lauxaniidae*, the nucleotide sequence of the 18S RNA and the cytochrome oxidase gene was determined in all species. Dots indicate the same nucleotide as the first sequence (*Minettia*) and hyphens represent deletions or insertions of one or more base pairs.

```

18S RNA
Minettia AAAAAATGATAGCTAGCTGACTTAGCGATCGTAGTTTCGATCGAAATTGGCTTAGCGTAGC
Lauxania C . . G --- . . . . . T . . . . . A . . . . . C . . . . .
Lyciella . . . . . T . . . . . A . . . . .

Cytochrome Oxidase
Minettia AGCCTCGATCGATCGTTTAGGCTTTTCGACCGTCGGGAGAGCTGCTTGCCCTCTAGCTGGGTT
Lauxania . . G . . . . . C . . . . C . . . . T . . . A . . . C . . . TA . . . . .
Lyciella . TG . . AA . . . . . C . A . . . . . T . . . . .

```

**Based on these data, indicate if each of the following statements is true or false.**

- The gene for cytochrome oxidase accumulates mutations faster than the gene for 18S RNA.
- Sequences of *Minettia* are evolutionarily more conserved than those of *Lauxiana* or *Lyciella*.
- The fact that the cytochrome oxidase sequence of *Minettia* is 8 nucleotides longer than the sequences of both *Lauxiana* and *Lyciella* suggest that the latter two taxa are more closely related than either is with *Minettia*.
- Single nucleotide substitutions of 18S RNA and cytochrome oxidase suggest different relationship between *Minetti*, *Lauxiana* and *Lyciella*

**A. True B. False C. False D. False**

**Original commentary**

Correct answers

A true

Cytochrome oxidase has 13 point mutations and 4 deletions, 18S RNA has 6 point mutations and 1 deletion.

B false

*Minettia* was arbitrarily chosen as reference to align the other two species and do not mean that it is the most primitive one.

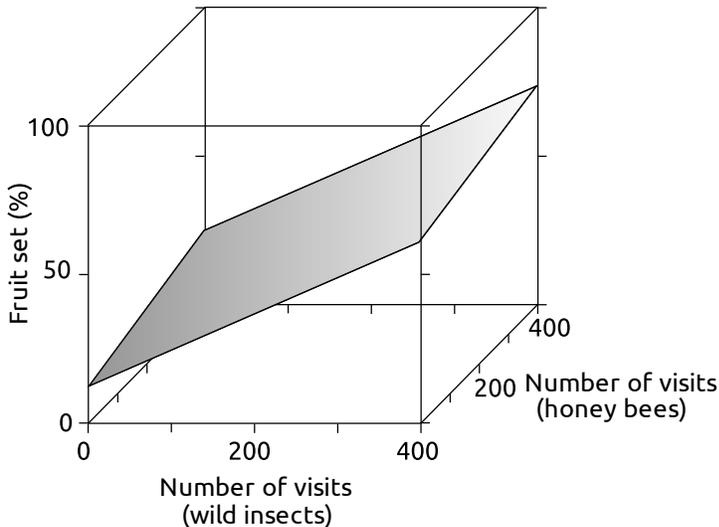
C false

Between *Lyciella* and *Minettia* is only one deletion, *Lauxiana* has 3 independent deletions compared with *Minettia* and *Lyciella*.

D false

False, 18S RNA and cytochrom oxidase do show the same general topology of the genetic tree.

Flowers of cherry trees (*Prunus avium*) can be pollinated by both domesticated honey bees and wild insects such as wild bees or bumblebees. To study the influence of these pollinators on the fruit set (percentage of flowers of a tree that develop into fruits), flower visits of domestic honey bees and wild insects were counted during a standardized observation period for cherry trees worldwide. The figure below shows a linear model best explaining the data.



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

- Cherry trees produce no fruits when domesticated honey bees and wild insect are completely absent.
- Domestic honey bees were more efficient pollinators than wild insects, needing fewer visits to increase fruit set.
- To maximize fruit set, cherry farmers are advised to limit the number of visits by wild insects when domestic honey bees are visiting.
- An isolated cherry tree is likely to have a higher fruit set when situated in a flower-rich backyard than in the middle of a wheat field.

**A. False B. False C. False D. True**

#### Original commentary

Correct answers

*A false*

The regression predicts that about 10% of cherries would still be pollinated. This might be due to wind pollination or self-pollination.

*B false*

The slope of wild bees~fruit set is steeper than the one for honey bees, thus wild insects are more efficient.

*C false*

Both regressions (domestic bees~fruit set and wild insect~fruit set) are linear. Wild pollinators enhance fruit set regardless of the abundance of domestic honey bees.

*D true*

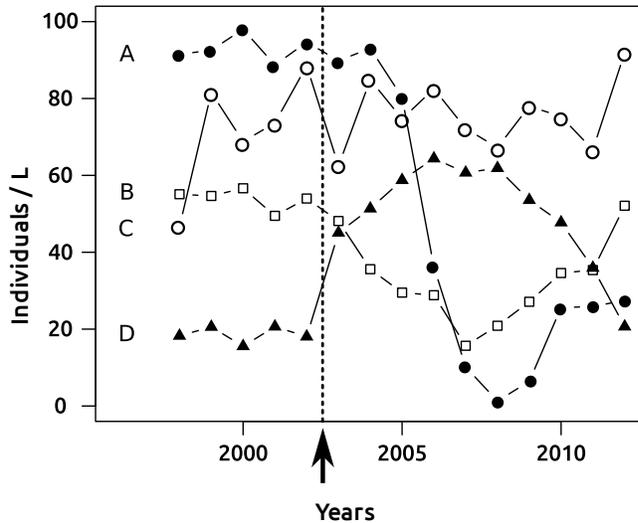
In a flower-rich backyard the density of both wild pollinators and domestic bees is expected to be higher than in a monoculture of wheat because the backyard is likely to offer a more breeding sites and a more diverse flowers spectrum to feed on.

References

[Garibaldi et al, Science \(2013\)](#)



In an accident in spring 2003, a large quantity of fertilizer was spilled into a small lake in Switzerland. The figure shows the abundance of four species of zooplankton measured during August for several years before and after the accident. The accident is indicated with an arrow



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

- A. Species C reacts on the accident with a quick decline in population density.  
 B. The fertilizer is likely to be poisonous for species A.  
 C. Species D is more useful as a bioindicator than is species B or C.  
 D. The relative species densities in the community are re-established within ten years of the accident.  
 A. False   B. False   C. True   D. False

#### Original commentary

Correct answers

A *false*

The decline in density of species C after the accident is in the range of its normal annual fluctuation. A causal relation with the accident is very unlikely.

B *false*

Zooplankton has short generation times. If the fertilizer itself were poisonous, the effect would be a drastic reduction already within the first two years after the accident.

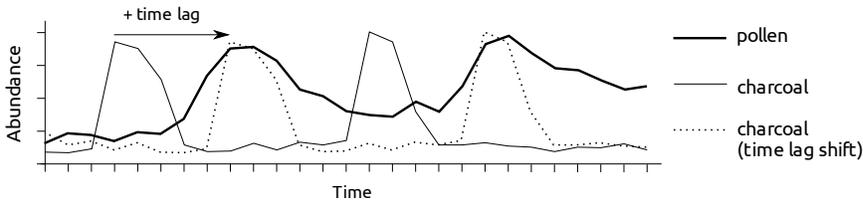
C *true*

After the accident, species A and D show drastic and stable shifts in population densities. Those shifts are much bigger than the stochastic fluctuation before and some years after the accident and therefore seem to be reliable. The shift in population density of species B is much smaller. Species C does not seem to react at all.

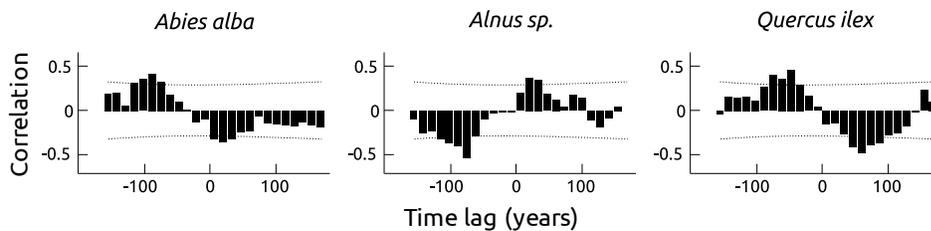
D *false*

After 10 years, species is likely to still have a much smaller density than before the accident. During the years 7-9 after the accident, no significant increase in population density happened.

To study the effects of fire events on forest ecosystems around a Mediterranean lake, the amount of microscopic (smaller than 10  $\mu\text{m}$ ) charcoal particles and pollen of three different tree species were counted in several slices of sediment layers dating from approximately 6000 years before present. Since the response of forest ecosystems may be visible only after many years, the correlation between the abundance of charcoal and pollen of a tree species was analyzed for different time lags. The hypothetical tree species in the figure below, for instance, reaches the highest abundance many years after the actual fire event. Hence, the highest correlation is achieved when the charcoal abundance is shifted with a specific time lag.



The figure below shows the results of such an analysis for three tree species, of which *Abies alba* has recently become locally extinct. Correlation coefficients exceeding the threshold (dotted lines) are statistically significant at  $\alpha=0.05$ .



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

- An increase in the frequency of fire events may have contributed to the extinction of *Abies alba*
- The pattern observed for *Alnus* trees can be explained by smoke from the fire events stimulating their flowers to produce more pollen.
- The dominance of *Quercus ilex* in recent Mediterranean forests can be explained by its tolerance to periodic fire events.
- The abundance of *Abies*-pollen is affected by fire events more quickly than the abundance of *Quercus*-pollen.

**A. True B. False C. False D. True**

#### Original commentary

Correct answers

*A true*

According to the data shown the amount of *Abies* pollen is negatively correlated with the amount of charcoal for a few decades after a fire. Therefore the species seems not to be tolerant to fire. An increase of frequency of fires will lead to successive regression of this species.

*B false*

The positive correlation between charcoal and pollen approximately 20-40 years after fire event cannot be explained by a reaction of individual flowers or even trees to fire stimulus. The period of increased pollen production lasts several decades what is much too long for being explained by a punctual stimulus.

*C false*

As it is for *Abies*, *Quercus* seems to be less present during the period after a fire event. The recent dominance must have other reasons than tolerance to fire.

*D true*

The negative correlation to fire events is significant after a time lag of about 10-15 years in *Abies*, but only after about 40 years in *Quercus*.

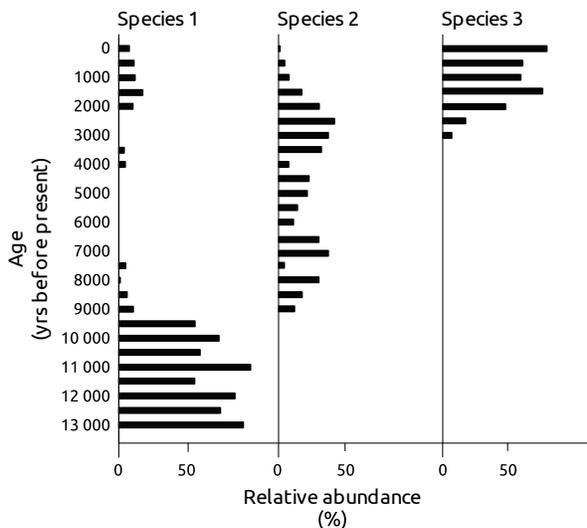
References

[Colombaroli et al, \*Journal of Ecology\* \(2007\)](#)

Many chironomid species (non-biting midges) are known to be abundant only within well-defined ecological niches, as is shown below for three species commonly found in Switzerland.

	Optimal trophic state	Mean T of air in July	Most common adjacent vegetation
Species 1	Oligotrophic	7.1 - 12.9 °C	Alpine grassland
Species 2	Mesotrophic	9.3 - 17.6 °C	Mixed forests
Species 3	Hypertrophic	10.7 - 19.2 °C	Farmland

Fossil chironomids in lake sediments can be used to reconstruct the past climatic and ecological conditions in the vicinity of the lake. In a sequence of sediment layers of a small swiss lake, head capsules of all chironomid species have been identified and counted. The relative abundance of the three listed species in each sediment layer is shown in the figure.



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

- Human impact is evident since 9000 years BP.
- An intermittent cooler period can be presumed between 2000 years BP and the present.
- Species 3 seems to be a better indicator species for the trophic state than for average temperature.
- Fluctuation in abundance of Species 2 is likely to be best explained by the Lotka-Volterra (predator-prey) model including an insectivorous predator.

**A. False B. True C. True D. False**

#### Original commentary

Correct answers

*A false*

The apparent increase in temperature and change of vegetation type at about 9000 years BP coincides with the end of the last ice age, when alpine vegetation was replaced by forests. However, human impact seems to be clearly indicated by appearance of species 3, whose optimal niche is in human made farmland that appeared about 3000 years BP.

*B true*

Since 2000 years, species 1 reappears in the sediment after an absence of several thousand years. It is the same species that was predominant at the end of the ice age. This indicates that the average temperature fell below a maximal level for this species.

*C true*

The sediment of the past 2000 years show that Species 3 is able to live in abundance at the same place as species 1, which has a much different temperature range. Therefore it is not a very good indicator species for temperature. But species 3 seems to be very closely linked to human farming activity, and predominates since the decline of forest

indicated by species 2.

*D false*

Interactions between predators and prey show fluctuation periods of several years at maximum (insects are short living), but will not be visible on a time scale of several hundreds of years.

References

[Heiri et al, Palaeogeography, Palaeoclimatology, Palaeoecology \(2003\)](#)

Cladistic analysis is an approach to infer the evolutionary relationship among organisms based on the presence or absence of morphological or molecular characters. In order for cladistics to work correctly, the following three assumptions have to be met:

- Along a lineage, characters change over time.
- Any pair of two organisms shares a common ancestor.
- Evolutionary lineages split in a bifurcating manner.

**Indicate if each of the following statements is in line with these assumptions (true), or whether one or more of them are violated (false).**

- A. The presence or absence of nematocysts can be used in a cladistic analysis to reconstruct phylogenetic relationship of metazoa. Nematocysts are complex cells of cnidaria (e.g. sea anemone) that certain sea slugs incorporate into their own body for self defense by feeding on sea anemones.
- B. Cladistics can be used to reconstruct the phylogenetic relationship of ecologically distinct plant species, of which one arose by hybridisation of two distinct parental species.
- C. Cladistics can be used to reconstruct the phylogenetic relationship of two finch species that arose from a generalist finch that colonized a remote island. The species differ in bill length and depth, tarsus length and plumage color.
- D. Cladistics can be used to reconstruct the phylogenetic relationship of lichen multicellular eukaryotes. Lichen are a symbiotic interaction between green algae or cyanobacteria with fungi.

**A. False   B. False   C. True   D. False**

**Original commentary**

Correct answers

*A false*

Although both taxa have nematocysts, this trait cannot be used to put both of them in a distinct clade within metazoa, as sea slugs do not produce nematocyst themselves. In regard of this trait the evolutionary lineages do not split in bifurcating manner.

*B false*

Here, evolutionary lineages do not split in bifurcating manner, but the origin of one lineage is the fusion of two initially separated lineages.

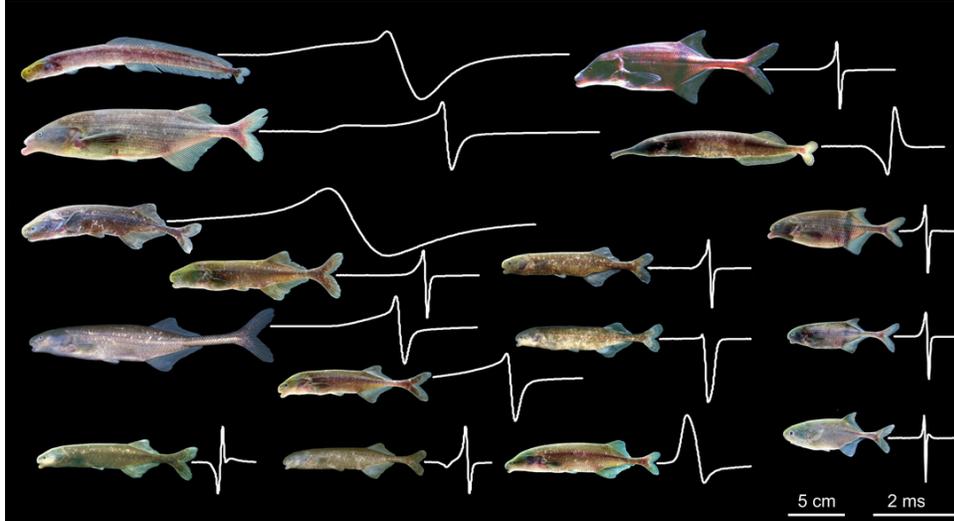
*C true*

This example is in agreement with all assumptions.

*D false*

Lichen behave functionally a single organism, but consists of two independent organisms with a completely different phylogenetical background. Therefore the principle of splitting lineages in bifurcating manner is violated.

Fish species of the family *Mormyridae* are known for their ability to locate objects and communicate by weak electric fields called electric organ discharges (EOD). They are also able to sense EODs of other *Mormyridae*. The figure shows body shape, relative body size and and EOD-waveform used for communication (white lines) for 16 *Mormyridae* species living in a central African rainforest drainage system.



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

- Mormyridae* show characteristics typical for fish specialized on preying on other fish of similar size.
- Mormyridae* show characteristics typical for a group of fish warning their predators of an electric shock via shared visual warning signs (Müllerian mimicry).
- Mormyridae* show characteristics typical for fish living in highly turbid water or are mainly nocturnal.
- Mormyridae* show characteristics typical of fish that attract mates with non-visual cues.

A. False B. False C. True D. True

#### Original commentary

##### Note

Since the students cannot be expected to know these fish, the question focuses on testing if the students can think of typical features of fish of a specific lifestyle, and are then asked to check if the *Mormyridae* show such features. This gets us around asking the students to judge the life style of *Mormyridae*.

##### Correct answers

##### A false

Fish specialized on preying other fish of similar size typically have a relatively large mouth with large conical teeth, both absent from all species of *Mormyridae*.

##### B false

If Müllerian mimicry would be important to reduce pressure from predators, all shown Mormyrids should show very similar, extremely contrasting colours most likely in combination of yellow and black or orange/red and black. In contrast, all shown *Mormyridae* are of dull / camouflage color. Furthermore, *Mormyridae* do not produce harmful electric shocks which could be used as an anti-predation behavior (mentioned in the text).

##### C true

*Mormyridae* live in turbid water and are mostly nocturnal. They have very small eyes compared to body size what indicates that vision is limited and seems to play a minor role for these fish. Large eyes are common in diurnal fish species that live in clear water. The complex systems for object localization and communication via the generation and reception of weak electric fields are very useful for nocturnal fish in turbid water.

##### D true

All *Mormyroiadea* are of dull color and have impaired vision. Hence, a system to attract mates using non-visual cues

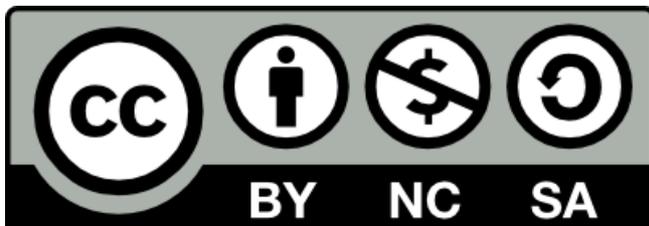
is highly expected. In addition, the electric signals produced vary greatly between species and are used to attract mates. /br>

References

[Hopkins, Electroreception \(1986\)](#)



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# IBO 2013 Theoretical Exam 2

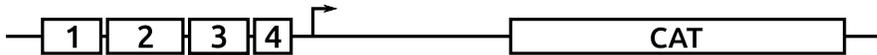


Translation version: **English (Official)**, downloaded by: **staff1**

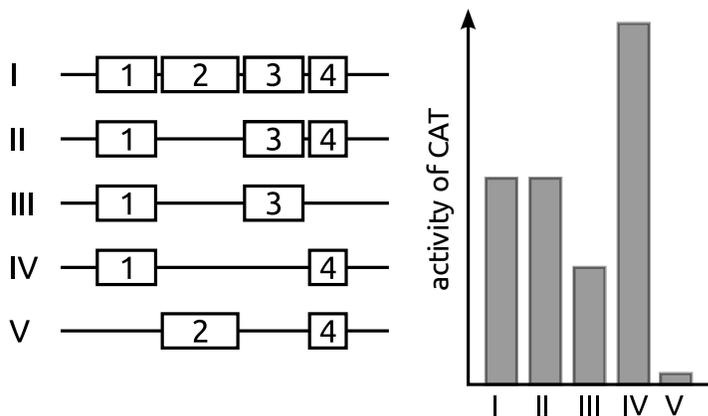
**1**

**Cell-, molecular- and microbiology**

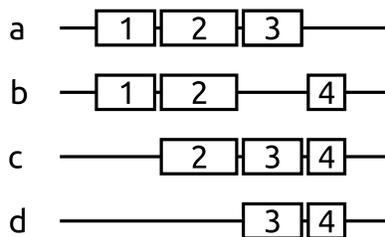
A newly discovered gene promoter is characterized by a reporter gene assay using chloramphenicol acetyltransferase (CAT) as a reporter gene. Linear pieces of double-stranded DNA of four potential promoter elements (white boxes, numbered 1 to 4) are placed upstream of the CAT reporter gene. --restored!



After transfection of individual constructs into cells, the [new text here] following CAT activities were determined.



The following constructs have not tested yet.



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

- A. Construct a is a stronger promoter than construct I.
- B. Construct a is a stronger promoter than construct b.
- C. Construct c is a stronger promoter than construct b.
- D. Construct c is a stronger promoter than construct d.

**A. False B. False C. False D. False**

**Original commentary**

Notes

I = II -> 2 plays no role,

I > III -> deletion of 4 reduces the promoter strength -> 4 enhances promoter activity,

I < IV -> removal of 3 increases promoter strength -> 3 reduces promoter activity,

V shows almost no activity -> 1 provides basal promoter activity

Correct answers

A *false*

4 enhances promoter activity, removal of it in a decreases the activity of a.

B *false*

This case is similar to III versus IV, since 2 does not affect promoter strength.

C *false*

Without 1, c will show almost no activity, further decreased by the presence of 3.

D *false*

2 does not play a role, c and d have the same promoter strength.

In genetic engineering, it is often desired to increase the yield of secreted proteins.

**Indicate if each of the following strategies is expected to increase the yield in a mammalian cell.**

- 
- 
- 
- 

- A. Overexpression of chaperones (proteins assisting others to fold) present in the endoplasmatic reticulum.
- B. Deletion of the genes coding for glycosylating enzymes present in the endoplasmatic reticulum.
- C. Overexpression of proteins facilitating the fusion of secretory vesicles with the cell membrane.
- D. Duplicating the gene encoding the desired protein.

**A. True B. False C. True D. True**

**Original commentary**

Correct answers

*A true*

secretory proteins are folded in the ER, chaperones assist them in their folding and can increase the yield

*B false*

most secretory proteins are glycosylated, without glycosylation they are not recognised and are not trafficked further, and without glycosylating enzymes, the cell's membrane proteins cannot be glycosylated, the cells are not so healthy, this will also reduce the yield.

*C true*

secretory proteins are transported from the Golgi to the plasma membrane by vesicles

*D true*

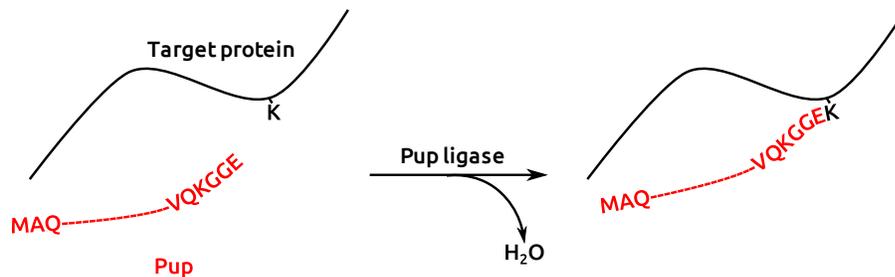
Since each of the gene copies can be transcribed independently, genes with multiple copies are generally expressed more.

References

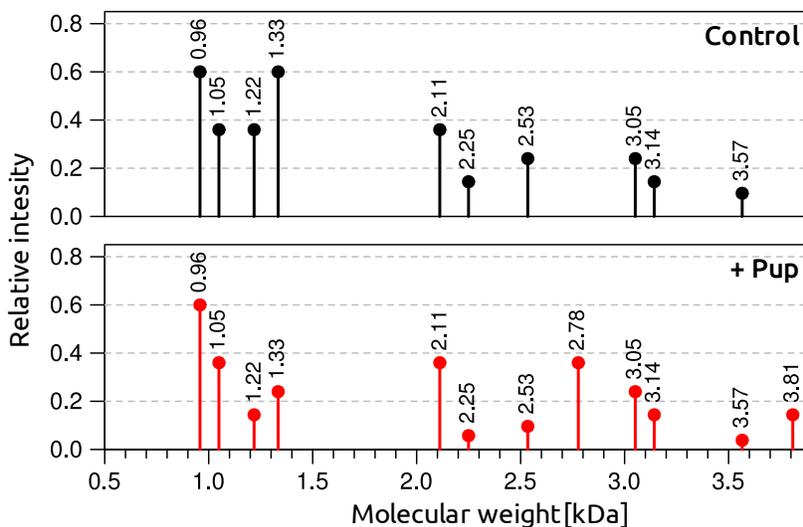
[Peng et al, Biotechnology and Bioengineering \(2009\)](#)

[Tigges et al, Metabolic engineering \(2006\)](#)

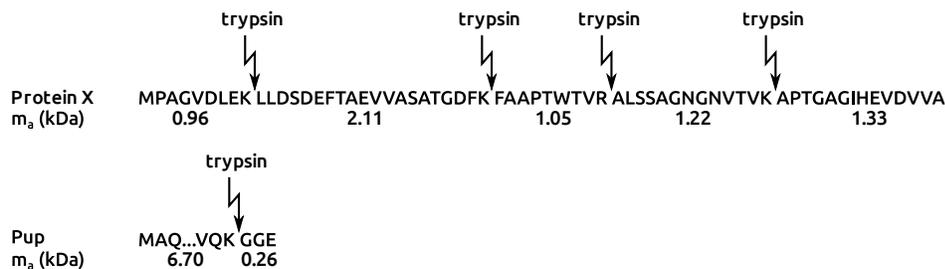
Pupylation is a post-translational protein modification found in some *Actinobacteria* in which the short protein Pup is ligated to a lysine side chain of a target protein by the Pup ligase.



To determine if a protein X is pupylated, purified X is incubated with Pup and the Pup ligase over night. Trypsin, which hydrolyses (by addition of water of 0.018kDa) proteins next to lysines (K) and arginines (R), is added and the masses of the peptides are determined by mass spectrometry (red). A control reaction where Pup was not added was processed similarly (black). The masses were rounded to two decimals. Note that the Pup fragments are out of the range to be detected.



The sequences of protein X and Pup as well as the molecular weight ( $m_a$ ) of the peptides are indicated below.



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

A. Trypsin efficiency is such that several peptides are left partly uncut.

- B. Hydrolysis by trypsin is inhibited next to lysines that are pupylated.  
C. Under these conditions, pupylation is specific to a single lysine.  
D. The target protein is pupylated at about 90%.  
**A. True B. True C. True D. False**

**Original commentary**

*Note*

The masses given in the second figure correspond to tryptic mono-peptides. During trypsin hydrolysis, water ( $m_a$  18.02 Da) is added, therefore, when calculating the mass of a dipeptide, the mass of water needs to be subtracted.

*Correct answers*

*A true*

Masses corresponding to dipeptides can be observed in the black spectra, e.g. the mass 3.05 kDa corresponds to a dipeptide formed by the two first tryptic peptides.

*B true*

The peak of the pupylated peptide at 2.78 kDa corresponds to a pupylated dipeptide and no pupylated mono-peptide can be observed (the peak would be at 1.46 kDa for this lysine).

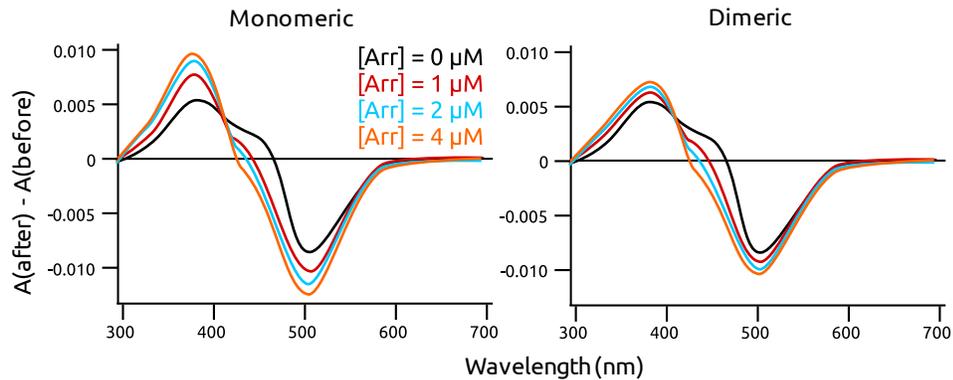
*C true*

Only two peaks (2.78 and 3.81 kDa) are present in the red spectra (with Pup) but not in the black one. The peak at 2.78 kDa corresponds to a pupylated dipeptide formed by the last two peptides of the protein, the peak at 3.81 corresponds to a pupylated tripeptide formed by the last three peptides of the protein.

*D false*

Two peaks (1.22 and 1.33 kDa) are reduced after ligation with Pup. The peak at 1.33 kDa goes from 0.6 to about 0.25 relative intensity. Therefore, the protein is pupylated to about  $1 - (0.25/0.6) = 58\%$ , not 90%. Furthermore, the peak corresponding to a pupylated peptide (2.78 kDa), has a relative intensity of only 0.4, added to the peak corresponding to the pupylated tripeptide (3.81 kDa) with a relative intensity of about 0.15, the pupylation level would be only about 55%.

Upon light activation, rhodopsin proceeds to Meta-states, of which Meta-I and Meta-II are in a dynamic equilibrium. This shifts towards Meta-II in the presence of arrestin (Arr) as some Meta-II binds to arrestin. To study the minimal functional unit of rhodopsin, the difference in absorption of rhodopsin (absorption after light activation minus absorption before light activation) is measured at different arrestin concentrations ( $[Arr]$ ) for both monomeric and dimeric rhodopsin, as shown below. Meta-II is known to show a stronger absorption at 380 nm than Meta-I.



**Based on these results, indicate if each statement is true or false.**

- A. Before light activation, rhodopsin absorbs light at 500 nm.
- B. The fraction of rhodopsin in the Meta-II state increases linearly with the concentration of arrestin.
- C. Dimeric rhodopsin binds tighter to arrestin than monomeric rhodopsin.
- D. Monomeric rhodopsin is the minimal functional unit.

**A. True B. False C. False D. True**

#### Original commentary

Correct answers

A *true*

the negative difference absorption at 500 nm shows that dark-state rhodopsin absorbs light at 500 nm.

B *false*

as can be seen from the graph, the difference in absorption between 2 and 4  $\mu\text{M}$  is smaller than the one between 1 and 2  $\mu\text{M}$ . If Meta-II would increase linearly with the arrestin, it should be equal to the double. Furthermore, one can think, that as more arrestin is added, less free rhodopsin is present, therefore, less increase in absorption is observed.

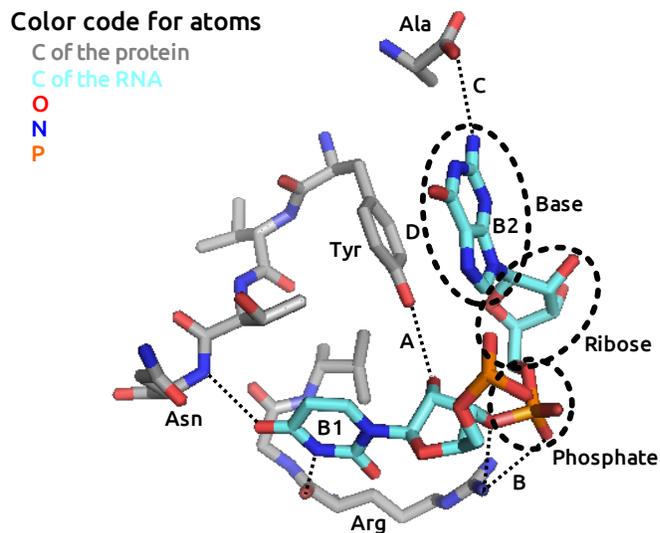
C *false*

with monomeric rhodopsin, the increase of absorption at 380 nm is bigger than with oligomeric rhodopsin

D *true*

monomeric rhodopsin is enough for arrestin-binding, it is the minimal functional unit

The following picture depicts part of the binding site of a protein which recognizes RNA specifically over DNA, in complex with two RNA bases (B1 and B2).



**Indicate for each of the following interactions if it provides specificity for RNA over DNA.**

- A. Hydrogen bond A with Tyr
  - B. Hydrogen bonds B with Arg
  - C. Hydrogen bond C with Ala
  - D. Hydrophobic stacking D between Tyr and B2
- A. True B. False C. False D. False**

**Original commentary**

Correct answers

A *true*

Only RNA, not DNA, has a hydroxyl group at the 2' position in the sugar.

B *false*

Both RNA and DNA have phosphate groups in the backbone.

C *false*

This hydrogen bond is specific for B2, but B2 is a guanine present both in RNA and DNA (the only difference in term of bases between RNA and DNA is uracil vs. thymine, both are pyrimidines, small bases with only 1 ring).

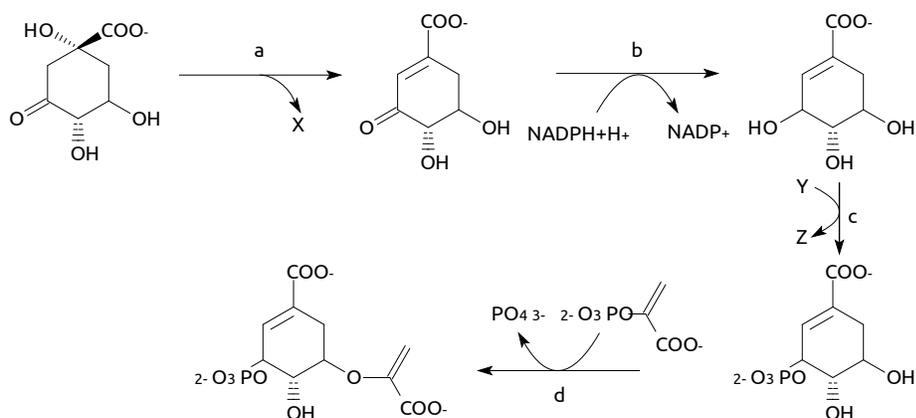
D *false*

Hydrophobic stacking is a non specific interaction which is found in interactions both with DNA and RNA.

References

[Handa et al, Nature \(1999\)](#)

The following figure depicts the shikimate pathway, which is part of the synthetic pathway producing aromatic amino acids in bacteria.



Indicate if each statement is true or false.

- A. In reaction a, X represents  $H_2O$ .
- B. In reaction b, the substrate is reduced.
- C. In reaction c, Y represents ADP or GDP.
- D. Reaction d is a phosphorylation of the substrate.

**A. True B. True C. False D. False**

**Original commentary**

Correct answers

A true

A is a dehydration, the -OH group as well as a hydrogen are removed and form water.

B true

$NADPH+H^+$  is a reducing agent. The oxidation number of the carbon of the carboxyl in the substrate changes from +2 to +1 in the product of b: this is a reduction.

C false

GDP cannot phosphorylate substrates, Y represents here ATP.

D false

In d, a phosphate group is released as part of the condensation of the 2 substrates.

To separate DNA fragments on an agarose gel, one liter of 10x TAE buffer (consisting of Tris base, Acetic acid and EDTA) has to be prepared. The desired concentrations for TAE as well as the available stocks are as follows:

Chemical	Desired concentration	Available stocks
Tris base	0.40 M	Powder (121 g/mol)
Acetic acid	1.14%	Solution 100 %
EDTA	0.01 M	Solution 0.50 M

Distilled water

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

- A. 4.84 g of Tris base are required.
- B. 11.4 ml of acetic acid are required.
- C. 0.2 ml EDTA are required.
- D. Tris base, EDTA and acetic acid have to be added to 1 l of distilled water.

**A. False B. True C. False D. False**

**Original commentary**

Correct answers

A *false*

Tris base:  $0.4 \text{ mol/l} * 1 \text{ l} * 121 \text{ g/mol} = 48.4 \text{ g}$

B *true*

acetic acid: dilution:  $V_1 = c_2 * V_2 / c_1 = 1.14\% * 1 \text{ l} / 100\% = 11.4 \text{ ml}$

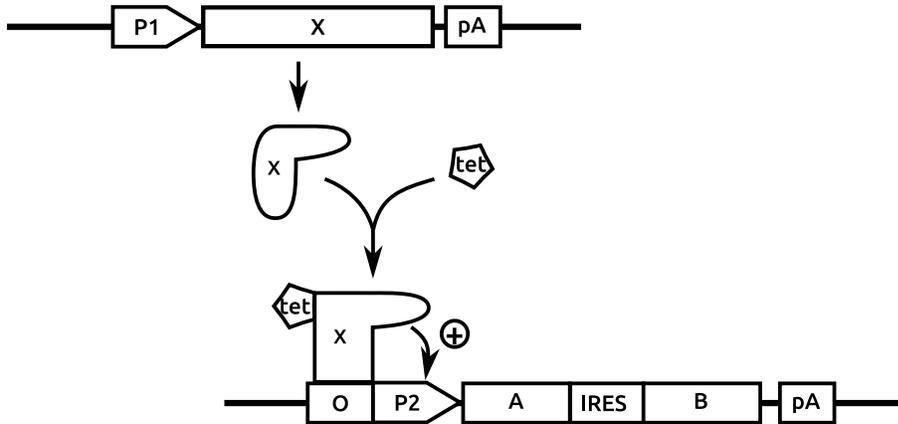
C *false*

EDTA: dilution:  $c_1 * V_1 = c_2 * V_2 \Leftrightarrow V_1 = c_2 * V_2 / c_1 = 0.01 \text{ mol/l} * 1 \text{ l} / 0.5 \text{ mol/l}$

D *false*

Tris, EDTA and acetic acid are first added to a smaller amount of water. When Tris is completely dissolved, the volume is adjusted to 1 l with water. If they were added to 1 l of water, the final volume would be greater than 1 l and the concentrations would be wrong.

A protein complex consisting of two polypeptides A and B needs to be expressed. To ensure proper folding and complex formation, a eukaryotic host is employed. To achieve this, eukaryotic cells are co-transfected with two artificial gene constructs. In the first construct (above), the gene coding for Transcription Factor X is under the control of Promoter P1. In the second construct (below), the genes coding for A and B are separated by an internal ribosomal entry site (IRES) and under the control of a specific Promoter P2. In the presence of tetracycline, X can bind to the Operator O and activate P2, as shown below (pA indicates polyadenylation sites).



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

- The expression of the genes coding for A and B can only be induced by tetracycline if P1 is active.
- In the presence of tetracycline, the gene coding for B is expressed at higher levels than the gene of A if the ribosome binds stronger to the 5'-cap than to the IRES.
- If the DNA-binding domain of X is removed, the genes coding for A and B are expressed even in the absence of tetracycline.
- The length of the polyadenine tail of the mRNA of X influences the amount of synthesis of protein X in the cell.

A. True B. False C. False D. False

#### Original commentary

Correct answers

A *true*

A and B can only be expressed if X is present in the cell, for this, P1 needs to be active.

B *wrong*

gene B would be more expressed than A if the ribosome would bind stronger to the IRES than the 5'-cap

C *false*

if the DNA-binding domain of X was removed, X could not bind the DNA and activate gene expression, so neither A nor B would be produced.

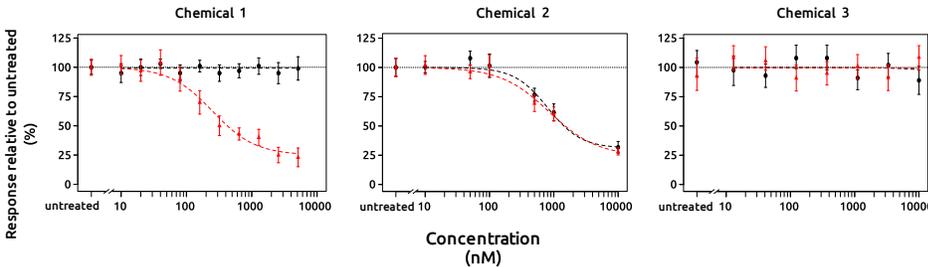
D *true*

an mRNA with a longer or shorter poly-A tail may survive longer in the cell and can be translated during a longer time, so more X-protein could be produced.

References

[Fussenegger et al, Biotechnol. Prog. \(2001\)](#)

The toxicity of three different chemicals 1-3 was tested *in vitro* on neural crest cells by counting the number of viable cells (black circles) and the number of cells migrating (red triangles). The average and standard deviation of multiple replicates obtained at different concentrations are plotted relative to the average counts from untreated cultures.



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

- A. These results are compatible with Chemical 1 affecting receptors receiving migration signals.
  - B. These results are in agreement with Chemical 2 affecting cell viability only.
  - C. 100 to 500 nM of Chemical 3 are likely beneficial for the viability of neural crest cells.
  - D. Measuring viability of neural crest cells is sufficient to establish maximum permissible concentrations of these chemicals.
- A. True   B. True   C. False   D. False**

#### Original commentary

Correct answers

A *true*

Chemical 1 affects only migration, not viability of neural crest cells. This could be explained e.g. by chemical 1 inhibiting receptors involved in migration.

B *true*

Even if the migration is reduced with increasing concentrations of chemical 2, it is so with the same amplitude as the viability is reduced. The reduction in viability is enough to explain the reduction in migration (since dead cells do not migrate).

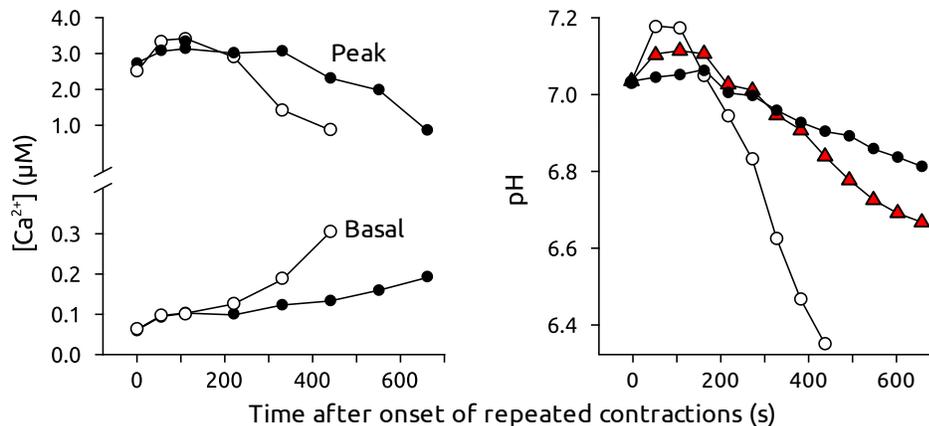
C *false*

Even if the viability in the presence of 100 to 500nM of chemical 3 is higher than the viability of untreated neural crest cells, this is due to the large standard deviation in the measurements, not to a beneficial effect of chemical 3.

D *false*

As for chemical 1, the response in cell viability and migration is not always similar. Since during embryonic development, neural crest cells need to migrate to create different tissues, it is important to take cell migration into account when establishing maximum permissible concentrations.

The contraction of a muscle fiber is triggered by an electric impulse that leads to the release of  $\text{Ca}^{2+}$  ions from the sarcoplasmic reticulum (SR) into the cytosol. After contraction, the  $\text{Ca}^{2+}$  ions are pumped back to the SR by sarcoplasmic reticulum  $\text{Ca}^{2+}$  ATPases (SERCA). To better understand the relative energy consumption of the actual contraction and the pumping of  $\text{Ca}^{2+}$  ions, skeletal muscle fibers of the frog species *Xenopus laevis* were treated with the chemicals BTS and cyanide. BTS inhibits cross-bridging between myosin and actin and cyanide inhibits the cytochrome c oxidase. The figure below shows the basal and peak cytosolic  $\text{Ca}^{2+}$  concentration as well as the pH of individual fibers during repeated contractions under natural conditions (open circles), in the presence of BTS (filled circles) and in the presence of both BTS and cyanide (red triangles).



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

- The hydrolysis of ATP at both myosin heads and SERCA contributes to tiring of muscle fibers.
- In these fibers, aerobic respiration is an almost exclusive source of ATP after about 200 sec of repeated contractions.
- The phosphorylation of ADP from creatine phosphate releases  $\text{H}^+$  ions.
- In the presence of cyanide only, the acidification of the cytosol over time was expected to be intermediate between the reduction observed under natural conditions and in the presence of both BTS and cyanide.

A. True B. False C. False D. False

#### Original commentary

Correct answers

A true

This can be seen easily from the right figure where the pH decreases over time (due to anaerobic glycolysis) is substantial even when no ATP is hydrolyzed at actin heads (in the presence of BTS).

B false

The decrease in pH over time is due to anaerobic glycolysis. Since the pH decreases well beyond 200 seconds, aerobic respiration may be contributing substantially to the production ATP, but is far from being the only important source. In the first 60 seconds, substantial sources of ATP are the stock of ATP and the phosphorylation of ADP from creatine phosphate.

C false

It actually absorbs  $\text{H}^+$  ions ( $\text{ADP} + \text{PCr} + \text{H}^+ = \text{ATP} + \text{Cr}$ ). This can easily be seen in the right figure since the pH is increasing at first.

D false

In the absence of aerobic respiration, the drop in pH is expected to be even quicker than for the natural conditions.

References

[Nogueira et al, AJPRIIP \(2013\)](#)



*Myasthenia gravis* is an autoimmune disease caused by autoantibodies that competitively bind and block postsynaptic nicotinic acetylcholine receptors on neuromuscular junctions of skeletal muscles.

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

- A. Reduced motility of the intestines is a likely symptom of this disease.
- B. Repetitive muscle contractions without relaxation (tetanic contractions) are a likely symptom of this disease.
- C. Drugs slowing down the degradation of acetylcholine in the synaptic clefts are likely to reduce symptoms.
- D. Drugs inhibiting cytotoxic T-cell proliferation are likely to reduce symptoms.

**A. False B. False C. True D. False**

**Original commentary**

Correct answers

*A false*

The guts contain no skeletal but smooth muscles. The latter are usually not affected by *Myasthenia gravis* due to the absence of neuromuscular junctions.

*B false*

The antibodies block the access of acetylcholine to the post-synaptic receptor (as mentioned in the stem), which cause a paralyzation or a reduced postsynaptic neuronal stimulation.

*C true*

Slowing down the degradation of Acetylcholin (for instance by inhibiting the Acetylcholinesterase) allows it to act longer on the post synaptic receptors, which leads to a stronger signal since antibodies bind reversible on the ACh Receptors (they are in competition).

*D false*

B-Lymphocytes not T-Lymphocytes produce antibodies.

In blood capillaries, fluid movement ( $J_v$ ) across the capillary membrane, between the lumen of the capillary and the interstitial space, depends on the difference in hydrostatic and oncotic pressures between these two compartments. (Oncotic pressure is a form of osmotic pressure exerted by proteins.)

- The following equation applies for  $J_v$
- $J_v = K_f \times [(P_c - P_i) - \sigma(\pi_c - \pi_i)]$
- with
- $P_c$ : the capillary hydrostatic pressure
- $P_i$ : the interstitial hydrostatic pressure
- $\pi_c$ : the capillary oncotic pressure
- $\pi_i$ : the interstitial oncotic pressure
- $K_f$ : the filtration coefficient
- $\sigma$ : the reflection coefficient

**Indicate for each of the following situations if the risk of edema (accumulation of fluid in the interstitial space) is increased.**

- A. Tennis competition in the sun leading to dehydration
- B. Wearing anti thrombotic stockings
- C. Inflammation leading to increased blood vessel permeability
- D. Proteinuria (excessive protein excretion by the kidneys)

**A. False   B. False   C. True   D. True**

**Original commentary**

Correct answers

A *false*

Excessive sweating causes a reduction of intravascular fluid which lowers the hydrostatic pressure in the capillaries.

B *false*

Anti thrombotic stockings increase the interstitial hydrostatic pressure and peripheral edema are decreased consecutively.

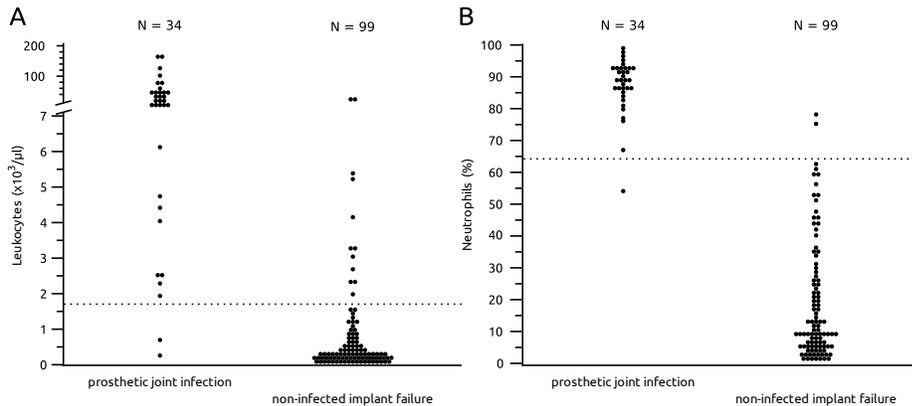
C *true*

Increased blood vessel permeability/leak -> plasma proteins move to the interstitium increasing the interstitial oncotic pressure -> more water movement to the interstitial space.

D *true*

Proteinuria reduces the concentration of proteins in the blood resulting in a reduced capillary oncotic pressure.

Proper treatment of chronic bacterial infections of artificial implants (e.g. prosthetic joints) requires expensive and demanding surgery. Unfortunately, such infections are often difficult to distinguish from non-infected implant failures. To propose new diagnostic tests, the absolute leucocyte count (A) and the fraction of neutrophils among white blood cells (B) were measured in 34 patients with true prosthetic joint infections and 99 patients with known non-infected implant failures. For each test, dotted lines indicate proposed cut off values to diagnose a true infection.



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

- Raising the cut off of absolute leucocyte counts to  $7000/\mu\text{l}$  would lower the risk of false positive results for a prosthetic joint infection.
- With the leucocyte cut off at  $1500/\mu\text{l}$ , more than 90% of patients with a prosthetic joint infection are expected to be correctly diagnosed.
- Lowering the cut off of the fraction of neutrophils to 50% would prevent missing prosthetic joint infections in the future.
- These results suggest that the fraction of neutrophils is a better diagnostic test than leucocyte count.

**A. True B. True C. False D. True**

#### Original commentary

Correct answers

*A true*

By rising the cut off less patients without an infection would get the incorrect diagnosis (but less real infections would be detected).

*B true*

With the cut off of  $1700 \mu\text{l}$ , 2/34 Pat with a real joint infections get missed, so  $32/34 = 94\%$  were correctly diagnosed.

*C false*

By lowering the cut off all patients with a true infection in the study would be detected. However, given that 2 out of 34 patients show low proportion of neutrophils, there is no guarantee that in a larger sample no individual with an even lower proportion was present. Given the distribution it seems even likely.

*D true*

Using the neutrophil count, more patient with a prosthetic joint infection were correctly diagnosed ( $33/34$  vs.  $32/34$  for the leucocyte count) and less patients without an infection got false-positive results ( $2/99$  vs.  $12/99$  for the neutrophil count).

References

[Trampuz et al, AJM \(2004\)](#)

While the glomerular filtration rate (GFR) is determined by blood pressure in the glomerulus, it does not directly reflect the systemic blood pressure. Instead, a stable GFR is maintained by either dilation or constriction of the afferent (flow in) and efferent (flow out) arterioles of glomeruli by an autoregulation mechanism. Several drugs interfere with this mechanism as side-effects. Those include non-steroidal anti-inflammatory drugs (NSAIDs) that reduce the capability of the afferent arterioles to dilate, as well as angiotensin-converting-enzyme inhibitors (ACEIs) that inhibit the production of Angiotensin II, and therefore reduce the capability of the efferent arterioles to constrict.

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

- A. NSAID intake reduces glomerular blood flow.
- B. ACEI intake reduces glomerular blood pressure.
- C. The effects of NSAID and ACEI on the GFR may compensate each other when taking both drugs together.
- D. While a chronic overproduction of aldosterone can be treated with ACEIs, using an Aldosterone antagonist affects the autoregulation mechanism less.

**A. True B. True C. False D. True**

**Original commentary**

Correct answers

*A true*

A side effect of NSAIDs is to inhibit dilation of the afferent arterioles. Hence the glomerulus is unable to increase blood flow through that mechanism.

*B true*

If the glomerular filtration pressure is not high enough, Renin is produced, which converts the pre-hormone Angiotensinogen into Angiotensin I, which is then converted into Angiotensin II by the Angiotensin-converting-enzyme. By inhibiting this enzyme, the ability to constrict the efferent arterioles is reduced (as mentioned in the stem). In addition, the production of Angiotensin II rises the blood pressure by rising the vascular pressure and rising the production of Aldosterone, which itself rises the renal reuptake of Sodium and water. Inhibiting this further decreases blood pressure system wide.

*C false*

While NSAID decrease the blood flow into the glomerulus, ACEI increase the outflow of blood. Hence both lead to a reduction on the glomerular pressure and lead to a reduction of the GFR.

*D true*

An Aldosterone overproduction can be treated by inhibiting the Angiotensin-converting-enzyme, as this leads to a lower level of Angiotensin II, which is a stimulant for the production of Aldosterone. However, due to the larger role of Angiotensin, a direct antagonist of Aldosterone implies a smaller effect, including the one described in this question.

References

Campbell Biology

The respiratory quotient (RQ) of an adult woman was measured at 0.7, along with an oxygen concentration of 170ml/l in her exhaled air. The RQ is the ratio between the eliminated amount of carbon dioxide and the absorbed amount of oxygen of the body. The metabolization of glucose and palmitic acid is as follows:

- Glucose:  $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$
- Palmitic acid:  $C_{16}H_{32}O_2 + 23O_2 \rightarrow 16CO_2 + 16H_2O$

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

- A. The woman adds about 119ml of  $CO_2$  to every liter of exhaled air.
- B. If the woman was metabolizing solely glucose, her RQ would be larger than when solely metabolising palmitic acid.
- C. The measurements are consistent with the woman solely metabolizing palmitic acid.
- D. If the woman was forced to sprint for a few minutes, her RQ is expected to decrease rapidly.
- A. False   B. True   C. True   D. False**

**Original commentary**

Correct answers

*A false*

The adult woman is exhaling 170ml of  $O_2$  per liter of air. Since the concentration of oxygen in the atmosphere is about 210 ml/l, the woman is absorbing around 40 ml of oxygen per liter of air. Given an RQ of 0.7, 28 ml of carbon dioxide (and not 119ml) must be eliminated per liter of exhaled air.

*B true*

An RQ of about 1 is expected when metabolizing glucose, but only 0.7 in the case of palmitic acid. Note that the students do not need to make the full calculations to answer this question, but just observe that there is an imbalance of  $O_2$  absorbed and  $CO_2$  eliminated when metabolizing palmitic acid, compared to a balance when metabolizing glucose.

*C true*

Metabolizing solely palmitic acid requires an absorption of 23  $O_2$  per 16  $CO_2$  eliminated (see equation 2). Hence the expected RQ is  $16/23=0.69565$ , or 0.7 when rounded to the significant digits provided in the question.

*D false*

Short but heavy exercise leads to a large usage of anaerobic metabolism by muscle cells. At first, this is not expected to change the RQ at all as lactate fermentation does neither eliminate  $CO_2$  nor absorb  $O_2$ . However, through time, Lactate build up leads to an increase in RQ due to an inhibition of fatty acid metabolism. While the students are not required to know the latter, they should know that anaerobic metabolism cannot lead to a decrease in RQ as less  $O_2$  is absorbed.

Mammalian herbivores use different strategies to digest cellulose. Ruminants (e.g. cattle) use multiple stomachs, whereas monogastrics rely on an extended caecum or colon.

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

- A. The relative abundances of different amino acids in the small intestine of ruminants differ from the relative abundances of the swallowed food.
  - B. Ruminants eat their faeces digested in the caecum to cover their nutritional need.
  - C. In monogastric herbivores, the absorption of nutrients occurs primarily in the colon.
  - D. The majority of the bacteria in the stomach of monogastric herbivores are able to produce cellulase.
- A. True   B. False   C. False   D. False**

**Original commentary**

Correct answers

*A true*

Microorganisms metabolise inorganic nitrogen to build their own proteins which have a different amino-acid-pattern than the food they swallowed. In the abomasum, microorganisms are killed by the HCL and their proteins are digested from the ruminant.

*B false*

Not ruminants but monogastric herbivores like rabbits have to eat their faeces from the coecum.

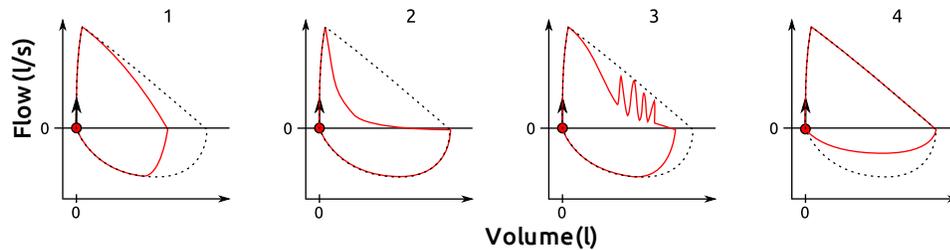
*C false*

In most monogastric herbivores, it is still the small intestine where most nutrients are absorbed. That is why several monogastric herbivores eat their faeces.

*D false*

Monogastric stomachs are not supposed to host bacterias.

To assess respiratory function, the flow and the volume of the exhaled air are measured during a forced expiration (positive flow) followed by a full inspiration (negative flow). Shown below are the measurements from four different patients with an airway problem. The black dotted line indicates normal respiratory function.



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

- A. The results of Patient 1 are expected if he had his left lung removed.
- B. The effect of the medication to reduce the symptoms of Patient 2 on the airways is similar to that of the parasympathetic nervous system.
- C. No diagnosis can be established for Patient 3 because of a cough attack.
- D. Patient 4 is likely suffering from an airway obstruction in the thorax.

**A. True B. False C. True D. False**

#### Original commentary

Correct answers

A *true*

Restrictive lung diseases reduce the lung volume which is shown/documentated in patients flow/volume graph #1.

B *false*

The patient suffers from a obstructive disease. He's volume is normal, but the flow is reduced. Sympathic effect on the bronchial system causes an dilatation, the parasympathic effect an obstruction. An adaequate drug has either to inactivate the parasympathetic nervous system or activate the sympathetic nervous system.

C *true*

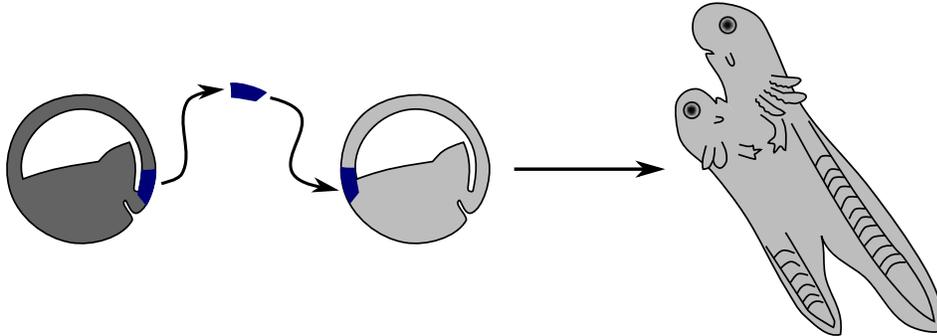
The results shown are indeed typical for a cough attack in which a rhythmic pulse of fast expiration are observed.

D *false*

As mammals have a negative pressure breathing (rise of intrathoracal volume causes a negative intrathoracal pressure leading to inspiration), an extrathoracal stenosis (obstruction) causes a fixed air-flow reduction apparent during inspiration.

The opposite is true for an intrathoracal obstruction, because the negative pressure during inspiration widens the intrathoracal air ways. Vice-versa in expiration.

The following figure shows an experiment in which a dorsal lip from a darkly pigmented donor embryo was transplanted to the ventral ectoderm of a lightly pigmented recipient embryo which was allowed to develop into a tadpole. The developing second body axis consisted mostly of non-pigmented cells.



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

- A. The second body axis came solely from the transplanted dorsal lip.
- B. Transplanting the presumptive ectoderm to a host in the neurula stage would likely result in a tadpole with two body axes.
- C. Cell fate is predetermined and results from cell-intrinsic properties.
- D. If the presumptive endoderm was transplanted instead of the ectoderm, the secondary body axis would consist mostly of pigmented cells.

**A. False   B. False   C. False   D. False**

**Original commentary**

Correct answers

*A false*

The experiment shows, that the resulting tadpole on the ventral side had a lightly pigmented surface too, so this cells originate from the receiving embryo.

*B false*

A second body axis can only be induced when the cells are still able to differentiate in all tissues, this is not anymore the case at the neurula stage.

*C false*

The grafted cells are able to induce neurulation in the receiving embryo where "cell fate" was not to neurulate.

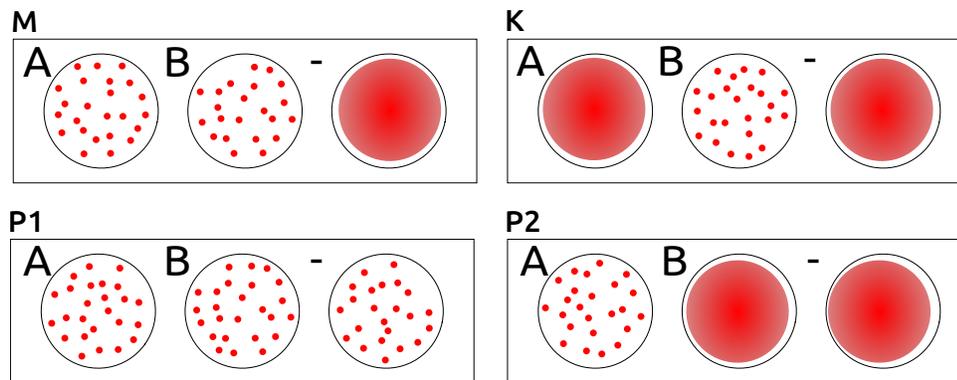
*D false*

The endoderm would not undergo neurulation and hence would not induce the cells to develop a secondary body axis at all.

Three blood groups have been characterized in cats, all of which are encoded by a single gene with three alleles, of which allele A is dominant over allele B, and allele AB is dominant over B, but recessive to A. Most cats with blood groups A or B have anti-B or anti-A antibodies, respectively. Cats with blood group AB do not produce either antibodies anti-A nor anti-B.

Antigens	Produced antibodies		
	Anti-A	Anti-B	Anti-AB
A	-	+	-
B	+	-	-
AB	-	-	-

The figure below shows the results of blood transfusion compatibility tests performed for a mother cat (M), her kitten (K) and two potential father cats (P1 and P2). The cards consist of three circles that contain anti-A (A) and anti-B (B) antibodies, or no antibodies at all as a negative control (-). When adding a drop of blood to the circles, the occurrence of an agglutination reaction becomes visible (red dots).



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

- Mixing blood of kitten K with serum from P2 should lead to agglutination.
  - M could receive erythrocytes from P2.
  - A back-cross between mother M and kitten K might donate erythrocytes to P2.
  - These results suggest that P1 is the more likely father of K than P2.
- A. True B. True C. False D. False**

#### Original commentary

Correct answers

A true

P2 produces anti-B, which are present in its serum and would cause an agglutination of erythrocytes of kitten K.

B true

The P2 serum has no anti-A and causes therefore no agglutination with antigens of erythrocytes in M.

C false

A cat with the blood group A has anti-B, which react both with AB and B antigens on erythrocytes. Since the mother has genotype AB/B and the kitten B/B, any offspring of them has either blood group AB or B.

D false

The negative control indicates that the test failed. So the genotype of P1 is unknown and hence these results do not suggest anything. Note, however, that if P1 had indeed blood group AB, he would have the same probability as P2 to

be the father of K. The corresponding probability for P2 is either 0% if he had genotype A/B or A/AB or 25% if he had genotype A/B.

The urea-to-creatinine ratio is used to assess renal function. It is calculated by dividing blood urea concentration by blood creatinine concentration. Urea and creatinine are both able to freely pass the glomerular filtration barrier. However, while creatinine is not reabsorbed, a percentage of urea is reabsorbed in the collecting ducts. An elevated rate of reabsorption is only observed when the total blood volume is increased.

**Indicate if each of the following statements is true or false. Compared to a healthy individual, the urea-to-creatinine ratio is expected to be higher...**

- A. ... in a patient suffering from an acute obstruction of the urethra (urinary retention).
- B. ... in a patient suffering from an acute necrosis of the collecting duct epithelium.
- C. ... in a patient suffering from dehydration.
- D. ... in a healthy individual after intensive exercise but with sufficient water intake.

**A. False B. False C. True D. False**

**Original commentary**

Correct answers

*A false*

Urinary retention affects urea and creatinine equally, and hence does not lead to a change in the ratio.

*B false*

Less urea reabsorption leads to a decrease in the ratio.

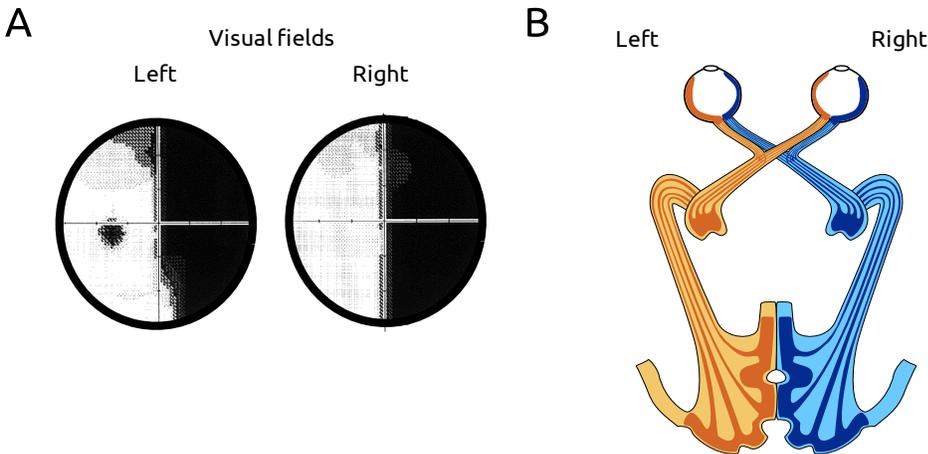
*C true*

Due to volume depletion, a higher percentage of urea is reabsorbed in the kidney, which leads to a larger ratio.

*D false*

In case of intensive exercise, muscles release more creatinine, and hence the ratio is decreased.

Figure A illustrates the results of an examination of the visual field of a patient's left and right eyes, whereby dark areas indicate poor, and white areas good visual reception. The way sensory information is received by the eyes and transferred to the visual cortex is presented in figure B.



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

- A. After an injury of the left visual cortex, a patient would lose vision on its left side.
- B. A tumor of the hypophysis, situated below the optic chiasma, usually causes a loss of view of the lateral visual fields of both eyes.
- C. The visual field of the patient above is most likely caused by a problem between its optic chiasm and both retinae.
- D. Total visual loss from only one eye may be caused by a trauma of the eyeball or an inflammation of the optic nerve of the blind eye.

**A. False B. True C. False D. True**

**Original commentary**

Correct answers

*A false*

It causes a loss of function of the retinal receptors on the left side of both eyes which causes a visual loss of the right side from patients view.

*B true*

The hypophysis is situated right below the optic chiasm. Tumors of the hypophysis consequently mainly affect those nerves crossing at the optic chiasm, which are the nerves innervating the retinal receptors on the medial part of the retina causing lateral visual field defects.

*C false*

a lesion between the optic chiasm and retinae would affect both eyes but would most likely cause blindness in both visual fields (right and left) of both eyes. A dysfunction of both visual pathways between the optic chiasm and the retinae is much more unlikely to be the reason for the indicated visual field than a single or multiple lesion(s) affecting both orange part of the optic nerve (and not affecting the blue ones at the same time). The visual fields given are typical for a lesion between the optic chiasm and the left visual cortex.

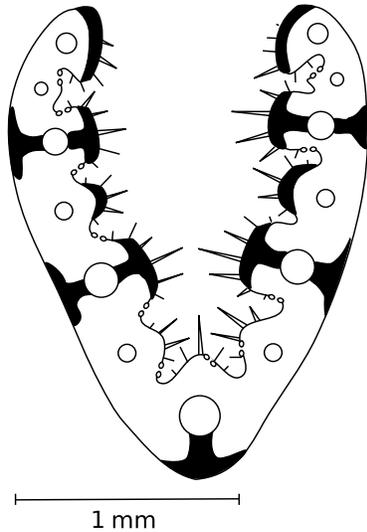
*D true*

A lesion affecting 100% visual field of only one eye is usually located between the optic chiasm and the retina.

References

[Duanes's Ophthalmology: E-book: Evaluation of Visual Function](#)

The figure shows a schematic and representative cross section through a leaf of an angiosperm plant. Vascular bundles are represented by circles and sclerenchyma fibers by black surfaces. Additionally, the position of trichomes and stomata is indicated. The relative position of the vascular bundles is constant along the leaf.



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

- A. The leaf shown most likely represents a monocotyledon plant.  
 B. The plant is most likely to be found in wetlands.  
 C. The overall leaf shape is expected to be long and thin rather than oval or round.  
 D. In a freshly cut section of this leaf the sclerenchyma fibers can be recognized by its intensely green color.
- A. True   B. False   C. True   D. False**

#### Original commentary

Note

The section belongs to a fescue (*Festuca*) out of the family of *Poaceae*.

Correct answers

*A true*

The regular position of vascular bundles that is constant all along the leaf indicates a parallel pattern of leaf veins without branching. This is a typical trait of monocotyledons.

*B false*

The stomata are situated in cavities of the leaf surface and protected by trichomes. This is a typical trait of drought adapted plants, reducing transpiration.

*C true*

The amount of supporting tissue (sclerenchyma) within the thin leaf is a hint to a very long length. A relatively short (laceolate or round) leaf would not need such a tissue.

*D false*

Sclerenchyma contains dead cells without cytoplasm. Therefore they do not contain chlorophyll and appear colorless in a fresh section.

Plant organelles can be isolated from plant lysate by multiple rounds of centrifugation and washing. To distinguish between different organelles, centrifugation fractions are subjected to simple assays before and / or after incubation for 30 minutes under specific conditions. Possible assays include:

- 1) measuring the concentration of glucose and other aldoses using a Fehling reaction,
- 2) detecting the presence of DNA by measuring absorption at 260 nm,
- 3) observing gas bubbles.

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

- A. A Fehling assay before and after incubating in light distinguishes fractions of chloroplasts from those of amyloplasts.
- B. A Fehling assay before and after incubating with glucose distinguishes fractions of Golgi from those of mitochondria.
- C. Fractions of endoplasmic reticulum and nuclei can be distinguished by incubating with lipases and proteases, followed by centrifugation and measuring absorbance at 260 nm in both supernatants.
- D. The presence or absence of gas bubbles after incubating with  $H_2O_2$  distinguishes fractions of peroxisomes from those of endosomes.

**A. True B. False C. True D. True**

**Original commentary**

Correct answers

*A true*

Amyloplasts convert glucose in starch that does not react with the Fehling reagent, whereas in light, chloroplasts produce sugars that will turn the Fehling solution blue.

*B false*

Neither Golgi nor Mitochondria are involved in the central sugar metabolism.

*C true*

Nuclei treated with lipases and proteases will liberate DNA that stays in the supernatant after pelleting the nuclei debris. Endoplasmic reticulum does not contain DNA, therefore even if lipases break it down, no change in absorption at 260nm will be observed.

*D true*

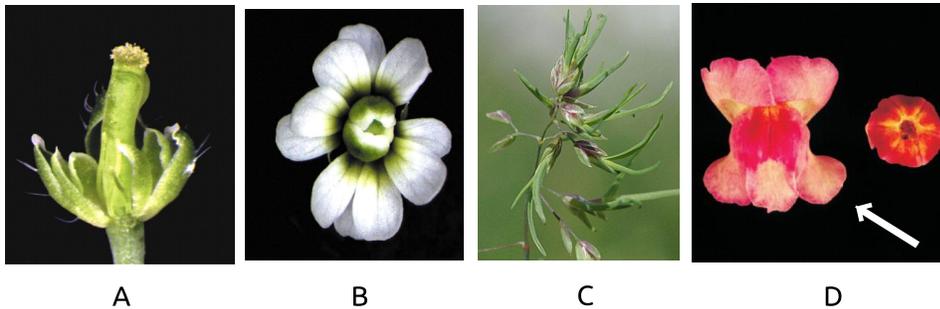
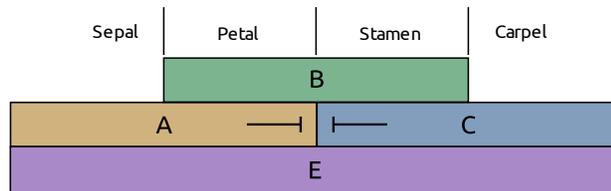
Peroxisomes transform  $H_2O_2$  in  $H_2O$  and  $O_2$ , thereby liberating  $O_2$  bubbles, whereas endosomes do not.

References

[Lang, Plant Cell Rep \(2011\)](#)

[Peroxisome Database](#)

According to the ABCE-Model of flower development, activity of genes from different classes A, B, C or E determines the identity of floral parts. Expression of class A genes is needed to determine future sepals and petals, class B genes to determine future petals and stamen and class C genes to determine future stamen and carpels. A and C genes inhibit each other's expression. Differentiation of each floral part additionally requires activity of class E genes. The figure illustrates the ABCE-model and shows flower samples of *Arabidopsis* (A and B), the alpine grass *Poa alpina* (C) and two flowers of the snapdragon *Antirrhinum majus* (D; the arrow indicating the bilateral wildtype, while the radial symmetric to the right is a mutant).



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

- A. The phenotype of *Arabidopsis* A is best explained by a loss of function of class B genes.
- B. The phenotype of *Arabidopsis* B is best explained by a loss of function of class A and C genes.
- C. The phenotype of Grass C is best explained by a loss of function of class E genes.
- D. The symmetry of the mutant flower of Snapdragon D is best explained by a loss of function of class C genes.

**A. True B. False C. False D. False**

#### Original commentary

Correct answers

A true

B false

The best explanation is the loss of only class C genes.

C false

The leaves emerging from the flowers represent grass seedlings and not altered flowers with leaves at the position of floral parts. The picture shows a viviparous plant with grains germinating before falling off the mother plant.

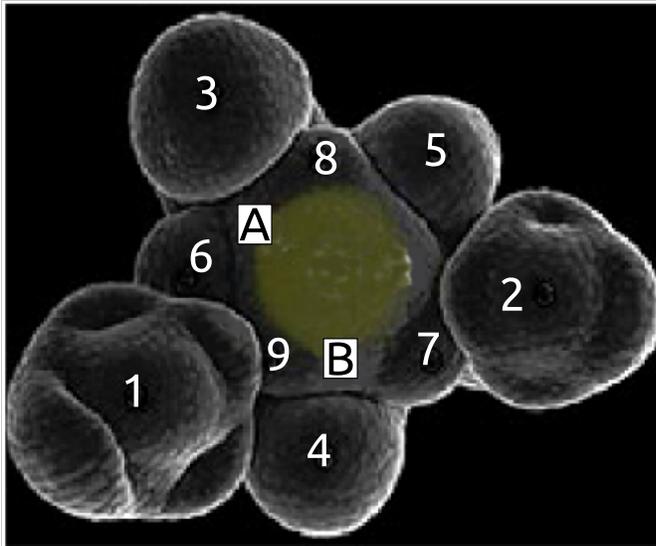
D false

The mutant shows a loss of bilateral symmetry and not an alteration in the differentiation of floral parts.

References

[Krizek, Nature \(2005\)](#)

The pattern of leaf primordia (future leaves) at the apical meristem is determined by active auxin transport. Auxin is transported towards the meristem tip. Young primordia act as auxin sinks through the auxin efflux carriers PIN1 and thus decrease the auxin level in nearby meristem cells. A new primordium will be induced at the place with the highest remaining auxin level. The image below shows the meristem of *Arabidopsis* with the primordia 1-9, with 1 being the oldest.



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

- Assuming PIN1 was only present in the two youngest primordia, its activity must be different in them.
- The next primordium will emerge at position A.
- If PIN 1 is inhibited at the stage shown in the figure, the next primordium is most likely to emerge at position B.
- In a mutant where only the youngest primordium is acting as an auxin sink, leaves will grow opposite to each other.

**A. True B. False C. False D. True**

#### Original commentary

Correct answers

A true

The characteristic angle of  $137^\circ$  between two subsequent primordia can be only explained with the youngest primordium being a stronger auxin sink than the second youngest.

B false

According to the order of older primordia the next primordium will emerge between primordium 2 & 5.

C false

In this mutant the primordial pattern would be aberrant, as well as the leaf shape. But it would emerge at a random position. There is no reason to assume that it will be position B.

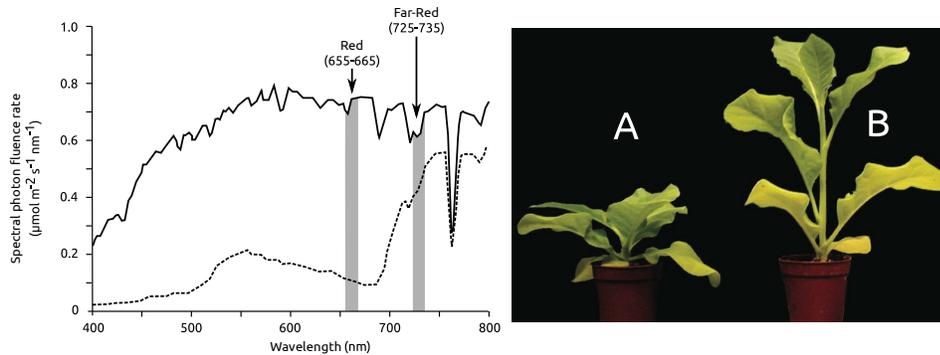
D true

In this case the highest auxin concentration would be present directly opposite of the youngest primordium.

References

[Reinhard, Nature \(2003\)](#)

Many plants use, among other means, the ratio of red/far-red light to detect other plants competing for light and react with adaptive growth to avoid shade. The ratio of red to far-red light is detected by the photoreceptor phytochrome. Phytochrome is converted between two forms  $P_X$  and  $P_Y$ , depending on the wavelength of the photon it has absorbed. The ratio between both forms reflects the red/far-red ratio in the environment. A high proportion of  $P_X$  mediates the expression of genes responsible for shade-avoiding growth. The figure shows the spectra of normal daylight (solid line) and daylight filtered through a tobacco canopy (dashed line). Tobacco plant A has been grown under normal sunlight, plant B under a canopy of older plants.



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

- A. The genes leading to the shade-avoiding phenotype are expressed when the red/far-red ratio is between 3 : 1 and 4 : 1.
- B. A high proportion of red light increases the proportion of  $P_X$  to  $P_Y$ .
- C. Upward orientation of leaves is a typical feature for shade-tolerant species.
- D. The shade-avoiding phenotype includes activation of lateral meristems.
- A. False B. False C. False D. False**

#### Original commentary

Correct answers

*A false*

The maximal ratio is observed in normal light and is slightly above 1.

*B false*

The opposite is true. Plant B has the genes activated with a red/far-red ration of about 0.5. As the far-red-converted phytochrome form is dominant, this must be the active form.

*C false*

Shade-tolerant plants do not need to express the plant B-phenotype of growing out of the shade. In the shade they keep the normal leaf exposition, allowing to maximize the amount of photons collected by the leaves.

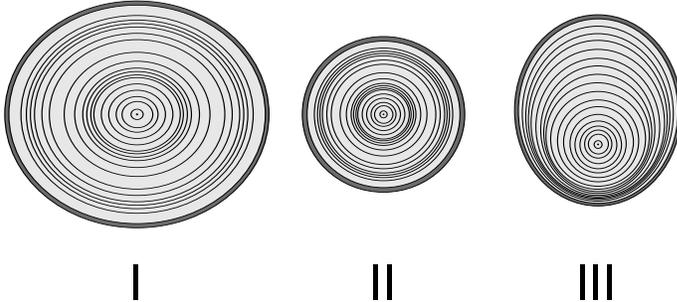
*D false*

A plant trying to avoid shade by enhanced growth will invest in few elongated stems and not in a multitude of branches that stay in the shade. Plant B doesn't show any branching.

References

[Vandenbussche, Current Opinion in Plant Biology \(2005\)](#)

In the wood of trees of temperate climates, annual growth rings are present and reflect different growth conditions between years and individuals. Three coniferous trees of the same species were cut at the same stem height in the same year. The stem cuts in the figure are drawn to the same scale.



**Based on these stem sections, indicate for each of the following statements if it is true or false.**

- A. Trees I and II likely grew in the same region, whereas Tree III likely grew in a more distant region.  
 B. Tree III is likely to have experienced more climate variation between years than Tree I.  
 C. Trees I and II may originate from the same forest.  
 D. The asymmetric pattern of Tree III may be due to constant exposure to strong wind beginning roughly ten years ago.
- A. True   B. False   C. True   D. True**

**Original commentary**

Correct answers

*A true*

I and II show the same pattern of two periods of narrow rings (bad growth conditions) 2-6 and 9-13 years before they have been cut. Thus they have been growing in the same climatic conditions present in one same region. Tree III shows a different, much more regular pattern and did not suffer those two periods of bad years.

*B false*

Tree III has relatively regular rings throughout the lifetime on one side of the section. The asymmetric pattern can be explained by very local effects like a physical obstacle or shadow on one side of the tree.

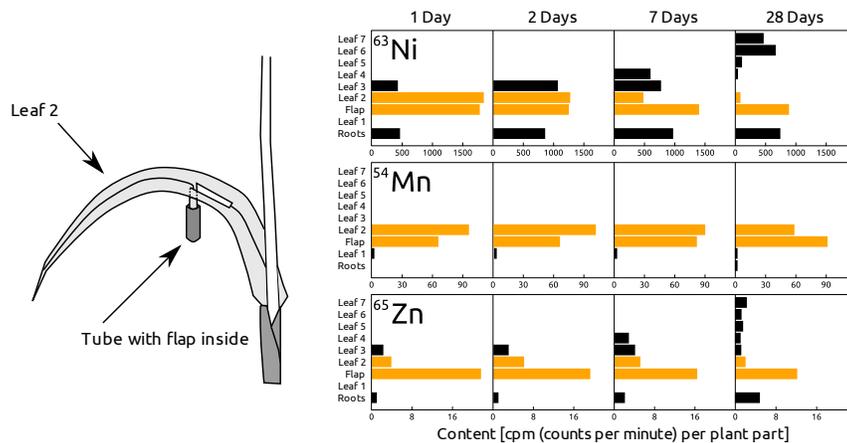
*C true*

Local ecological factors such as available light or soil conditions can result in very different growth rates even for neighboring trees.

*D true*

The first rings are regular, indicating an equilibrated light supply. The last rings are more and more asymmetric. A likely explanation is that faster growing trees are competing for sunlight on one side of the tree, whereas on the other side the tree is still sufficiently exposed to sunlight.

The second leaf (Leaf 2) of a young and growing plant of wheat (*Triticum aestivum*) was fed via a rectangular flap cut symmetrically in the middle of the lamina and brought into a tube with a feeding solution containing radioactive nickel ( $^{63}\text{Ni}$ ), manganese ( $^{54}\text{Mn}$ ) and zinc ( $^{65}\text{Zn}$ ). After 1, 2, 7 and 28 days, the contents of radioactive elements were measured in different parts of the plant. Concentrations measured in the flap and Leaf 2 are shown in orange in the figure.



Indicate if each of the following statements is in agreement with the results shown above.

- A. The plants absorbed the entire feeding solution provided before the first measurement.  
 B. Nickel is mostly transported to growing organs.  
 C. Manganese has higher phloem mobility than zinc or nickel.  
 D. Leaf 2 is turning into a net sugar exporter after Day 1.

A. True B. True C. False D. False

#### Original commentary

Correct answers

A true

B true

Nickel is first accumulated in leaf 3, then in leaf 4. After several days when these leaves are grown up nickel is exported again towards leaves 5-7.

C false

Manganese (known to have low phloem mobility) stays in the second leaf, whereas Zn and Ni is reduced in leaf 2 and appears in significant amounts in other parts of the plant.

D false

Leaf two is an "adult" leaf already at the beginning of the experiment. At day one a fraction of nickel already has been transferred from leaf 2 to 3. As the transfer is done by phloem transport, leaf 2 must already have a net sugar export.

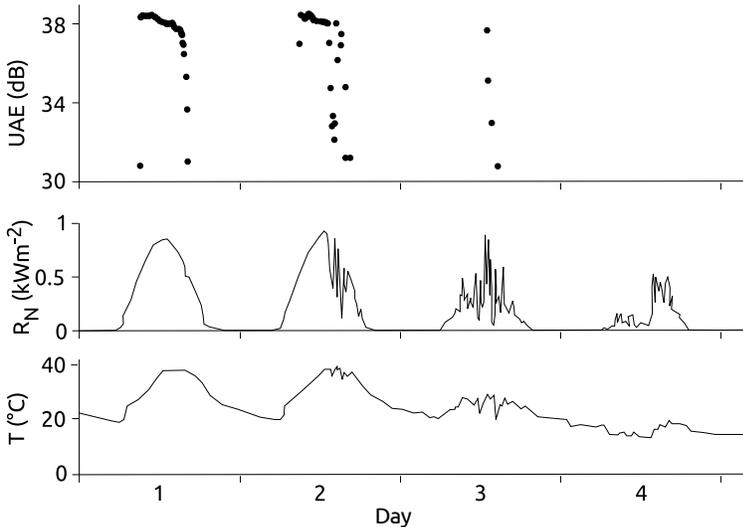
References

[Riesen, Journal of Plant Nutrition \(2003\)](#)

Plant Physiology 5th ed., Lincoln Taiz and Eduardo Zeiger, section "Essential nutrients, deficiencies, and plant disorders" page 108 and following.

Campbell, Biology (9th ed.), table 37.1 page 791.

In xylem, water conduits occasionally undergo embolism, characterized by an inflow of air into the conduit lumen, followed by collapse of the water column. Each event of embolism emits a sound called ultrasonic acoustic emission (UAE) that can be detected with adequate sensors. The figure below shows such measurements of an oak tree (*Quercus pubescens*) during four subsequent summer days. Radiation of sunlight ( $R_N$ ) and air temperature (T) were measured simultaneously.



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

- A. Embolisms occur during periods of elevated water tension in xylem conduits.
- B. The sound intensity of a single UAE event is correlated with the difference in water potential between the air and the leaves.
- C. The decrease in UAE events over time is likely due to an increase in cloud cover.
- D. Embolisms reduce the conductivity of xylem and therefore the water supply of distal tissues.

A. True B. True C. True D. True

#### Original commentary

Correct answers

A true

The UAEs are recorded during periods of high radiation and temperatures. During this time the water potential in the surrounding air is very low, leading to increased evaporation. During increased evaporation the difference in water potential between leaves and roots is big and therefore the tension forces within xylem is high.

B true

The audibility is indicated by the decibel value. At mornings and evenings the few measured UAEs have lower decibel values and are therefore less loud. Keep in mind that the decibel scale is logarithmic. The difference between the water potential of air and leaves depends on radiation and temperature and is maximal at noon and early afternoon but lesser at morning and evening. Therefore a relation is given.

C true

The radiation diagram shows how the cloud covers increases (huge variation within short time), leading to a decrease in overall radiation, and hence to a decrease in water tension within water conduits.

D true

Water transport depends on a permanent water column. An embolism is leading to the interruption of a xylem conduit. Until it is refilled, further water transport through this conduit will be null or very limited.

References

[Zweifel et al, New Phytologist \(2008\)](#)



In a plant species, the level of anthocyanin pigments produced is controlled by a single gene G, for which only a "dark" and a "light" allele are present. To more accurately map the position of gene G on chromosome 3, two inbred lines (P1 and P2) are crossed and F2 individuals (X1 through X5) are genotyped at five single nucleotide variant loci (SNV1 through SNV5) on the same chromosome.

	SNV1	SNV2	SNV3	SNV4	SNV5	Anthocyanin [mM]
P1	A/A	C/C	A/A	T/T	C/C	120
P2	T/T	T/T	C/C	G/G	G/G	25
X1	A/T	C/T	A/C	T/G	C/G	115
X2	A/A	C/C	A/A	T/G	C/G	123
X3	A/A	T/T	C/C	T/G	C/G	22
X4	A/A	C/T	C/C	T/G	C/C	29
X5	A/T	C/T	A/A	T/T	C/C	118

**Based on these results, indicate if each of the following statements is true or false.**

- A. One recombination event happened in each parent of X2 between the genotyped loci.  
 B. F1 individuals are likely showing intermediate levels of anthocyanin.  
 C. Among the studied loci, SNV3 is closest to gene G.  
 D. The phenotype ratio in the progeny of a cross between X4 and X5 is 2:1.  
**A. False B. False C. True D. False**

**Original commentary**

Correct answers

*A false*

Most likely, a single recombination event happened in only one of the parents, as one of the haplotype is parental (ACATC) and the other shows a recombination between SNV3 and SNV4.

*B false*

Gene G is linked to SNV3, and the table lists a heterozygous individual (X1) with an elevated anthocyanin level (which is the dominant allele). But note that the students do not need to identify the most closely linked locus as for each of them heterozygous individuals are given and the conclusion would remain unchanged.

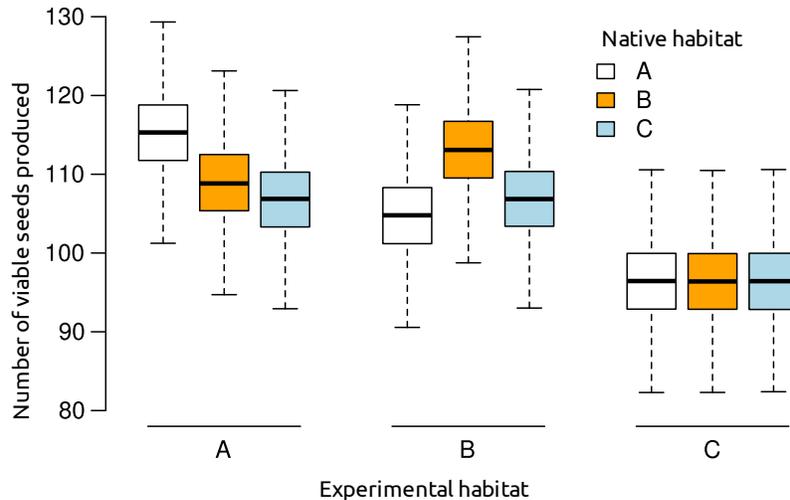
*C true*

This is the only locus for which the genotypes match the phenotypes in a Mendelian fashion.

*D false*

A 2:1 ratio is impossible for any crossing, as we clearly have dominant-recessive inheritance. So it is possible to answer this question even if the truly linked locus is not identified.

A plant species grows in three different habitats A, B and C, and populations from different habitats also differ genetically. To test if some of these genetic differences are driven by local adaptation, a so-called reciprocal transplant experiment is carried out where seeds collected from different habitats are grown in all three habitats. After a year, the fitness of the plants are measured by counting the number of viable seeds produced per individual.



**Based on these results, indicate if each of the following statements is true or false.**

- A. Plants from Habitat A are locally adapted to their native environment.  
 B. Plants from Habitat B are locally adapted to their native environment.  
 C. Plants from Habitat C are locally adapted to their native environment.  
 D. Habitat C is less suitable for these plant species than habitats A or B.  
**A. True B. True C. False D. True**

**Original commentary**

Correct answers

*A true*

Plants grown from seeds collected in habitat A show, on average, a much higher fitness when grown in habitat A than seeds collected from other habitats.

*B true*

Plants grown from seeds collected in habitat B show, on average, a much higher fitness when grown in habitat B than seeds collected from other habitats. Note that the fact that seeds from habitat B perform better in habitat A than in habitat B is likely due generally better conditions in habitat A.

*C false*

Plants grown from seeds collected in habitat C follow the habitat quality, but do not indicate that they are specifically adapted to environment C since they do not perform better there than plants adapted to different environments.

*D true*

All plants perform much worse in environment C than environments A or B, including the individuals originating from this environment.

Consider a large and constant population of a diploid organism with non-overlapping generations and sexual reproduction happening in spring. In addition, there is no difference in allele frequencies between sexes and there is no migration or natural selection acting. In such a population, the frequencies of alleles fluctuate at a given rate between generations due to the random nature of reproduction.

**Indicate if each of the following statements is true or false. Allele frequencies are expected to fluctuate at ...**

- A. ... a higher rate if the population was growing exponentially.
- B. ... a lower rate if all individuals had the same number of offspring.
- C. ... a similar rate even if there was strong inbreeding.
- D. ... a higher rate if the population crashed every winter.

**A. False B. True C. True D. True**

**Original commentary**

Correct answers

*A false*

If a population is growing exponentially, stochasticity in reproduction is reduced due to a larger number of offspring "sampling" alleles from the parent generation, and hence allele frequencies fluctuate at a lower rate.

*B true*

If all individuals had the same number of offspring, allele frequencies are almost constant since each individual leaves a fixed number of copies of his alleles in the population. The only stochastic variation left comes from heterozygous individuals randomly passing one of their alleles per offspring.

*C true*

While inbreeding decreases the frequency of heterozygotes, it does not lead to a faster change in allele frequencies.

*D true*

A population crash in winter leads to a recurrent bottleneck which removes alleles randomly from the population and leaves a smaller number of individuals reproducing in spring. This leads to an increased stochasticity.

The effect of various mutations in a gene *x* coding for a protein X, essential for the synthesis of leucine, is studied in a haploid yeast. The beginning and the end of the complete sequence of the coding strand of *x* is given below.

10
20
30
40
490

atg gcg caa gag cag aag cgt ggt acg ggc ttg gat agc gac ... gga cag tag

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

- A. Cells with a C → T mutation at position 13 produce shorter mRNA of *x*.  
 B. Cells with a A → T mutation at position 16 are able to grow on a medium lacking leucine.  
 C. Cells with a T → A mutation at position 31 only produce an alternative protein X\* missing the first 10 amino acids.  
 D. Cells with an additional G between positions 33 and 34 produce functional X.

**A. False   B. False   C. False   D. False**

**Original commentary**

Note

Students are expected to know the start and stop codons. Nevertheless, for those who don't, they can find out by looking at the sequence, that ATG is a start codon and TAG a stop codon.

Correct answers

*A false*

Introducing the mutation C13T results in the TAG stop codon, but the transcription stops only at the transcription termination sequence independently of the codons

*B false*

Introducing the mutation A16T results in the TAG stop codon. With a stop codon at the beginning of the sequence, no functional protein is produced and no leucine can be synthesized by the yeast that would need to take it up from the medium.

*C false*

Introducing the mutation T31A results in the ATG start and methionine codon. This will simply result in a methionine at this position. The eukaryotic ribosome binds at the 5'-cap of the mRNA and starts translation at the first AUG encountered. Further AUG are simply translated into methionine.

*D false*

Introducing a G between positions 33 and 34 results in a shift of the translation frame. Instead of reading ...GAT AGC... (positions 34-39), the ribosome will read ...GGA TAG... and reaches a stop codon. Translation stops there, the protein will not be functional.

An operon encoding enzymes 1 and 2 is regulated by metabolite X and consists of four sequences A, B, C and D of unknown function. To elucidate their function, the effect of mutations in the sequences A-D on the synthesis of the enzymes is assessed in the presence and absence of X.

Mutation in sequence	X present		X absent	
	Enzyme 1	Enzyme 2	Enzyme 1	Enzyme 2
no mutation	-	-	+	+
A	-	-	-	+
B	+	+	+	+
C	-	-	+	-
D	-	-	-	-

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

- A. Enzymes 1 and 2 are likely part of the synthetic pathway for X.
- B. The sequence A codes for enzyme 2.
- C. The sequence B is the promoter region.
- D. The sequence D is the regulatory gene.

**A. True B. False C. False D. False**

**Original commentary**

Correct answers

*A true*

This operon is repressed by X. This kind of negative transcriptional regulation is mostly found in biosynthetic pathways.

*B false*

In the absence of X and mutation in A, enzyme 2 is still produced, enzyme 1 isn't, therefore A codes for enzyme 1.

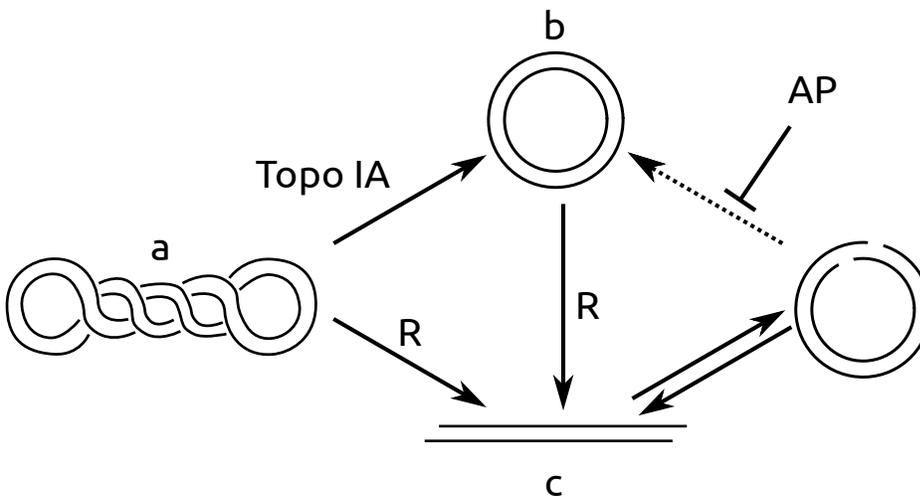
*C false*

In the case of a mutation in B, enzymes 1 and 2 are produced even in the absence of X, therefore B corresponds to the regulatory gene.

*D false*

In the case of a mutation in D, neither enzyme is produced, even in the absence of X, therefore D corresponds to the promoter region.

In cells, most plasmids are supercoiled (a in figure below). While such plasmids can be uncoiled to relaxed circles (b) using Topoisomerase IA (TopoIA), using restriction enzymes (R) linearizes plasmids through cutting (c). A linearized plasmid may spontaneously self-anneal and subsequently be ligated to form a relaxed circle. The ligation reaction can be inhibited by the addition of phosphatase (AP).



In an experiment, a plasmid was treated with different restriction enzymes (R1, R2, R3) under similar conditions and separated on an agarose gel together with an untreated sample (P0) and a marker consisting of linear DNA pieces. Topoisomerase IA and AP treatments in combination with R3 were also analyzed, but the tubes were mixed up (R3+E1 and R3+E2 on gel).



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

- On this plasmid, the restriction site for R2 is closer to the one for R3 than to the one for R1.
- The plasmid is about 5000 bp long.
- R1 cuts more efficiently than R3.
- E1 represents AP, E2 represents Topo IA.

A. False B. True C. True D. True

**Original commentary**

Correct answers

A *false*

R1 and R2 are distant from 1000 bp, R2 and R3 from 2000 bp, even if 2 vector maps are possible:

R1 - 1000 bp - R2 - 2000 bp - R3 - 2000 bp -

R1 - 1000 bp - R2 - 3000 bp - R3 - 1000 bp -

B *true*

Since the shape of DNA plays a role in the migration, the length of DNA can only be determined by comparing fragments with the same shape. The plasmid is linearized when using only 1 restriction enzyme. The supercoiled plasmid from P0 (thick band) is converted to linearized DNA which migrates around 5000 bp (see R1 or R2).

C *true*

In R3, some uncut supercoiled is still present, only about half was cut, whereas in the same time, R1 could cut everything

D *true*

Treatment with AP removes prevents re-formation of relaxed circles, the slowest migrating band disappeared in R3+E1. Treatment with E2 converted the uncut supercoiled plasmid into relaxed circles, this corresponds to Topo IA.

A child affected by a rare genetic disease is born to two healthy parents. The child has a healthy sister.

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

- A. If the disease was known to be segregating in the family of the father, the disease is more likely autosomal than sex-linked recessive.
- B. If the disease was sex-linked recessive, the probability of the sister being a carrier is 50%.
- C. If the disease was autosomal recessive, the probability of the sister being a carrier is 50%.
- D. If the disease was not known to be segregating in either family, the causal mutation is either autosomal recessive or, within the family, unique to the child.

**A. True B. True C. False D. True**

**Original commentary**

Correct answers

*A true*

X-linked recessive would imply that the father was affected.

*B true*

In this case, the mother is carrier and the father healthy. Hence the sister inherits an unaffected X chromosome from the father and has a 50% chance to inherit the affected chromosome from the mother.

*C false*

In this case, both parents are carriers. But since we know that the sister is healthy, the probability is 2/3 (and not 1/2).

*D true*

A rare autosomal recessive disease is likely not to show up in an outbred family for many generations. An alternative explanation for the disease, however, might indeed be a spontaneous mutation being unique to the child.

In a small pasture, 500 individuals of two closely related snail species were sampled. Genetic analyses detected a locus at which none of the individuals were found to be heterozygous, despite the presence of two alleles in each species. The two species and all genotypes were randomly distributed in the homogenous habitat.

Snail species	Genotype	Number of snails
<i>A. sulfis</i>	AA	126
<i>A. sulfis</i>	BB	125
<i>A. andea</i>	CC	122
<i>A. andea</i>	DD	127

**Indicate if each of the following statements is a likely explanation of the observed pattern.**

- A. These snails generally self-fertilize.
  - B. Both species experience strong genetic drift due to low population sizes.
  - C. These snails reproduce hermaphroditically.
  - D. These snails mate preferably with individuals of the same genotype.
- A. True   B. False   C. False   D. True**

**Original commentary**

Correct answers

*A true*

Self-fertilization would indeed lead to all snails being homozygous.

*B false*

If the populations were experiencing strong drift through low population sizes, this would lead to a reduction in diversity. However, there is no reason why this should affect heterozygous individuals preferentially.

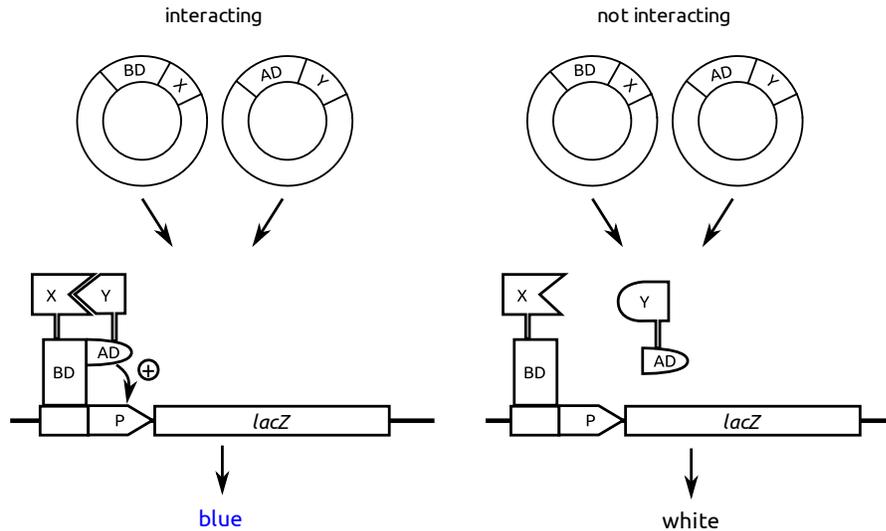
*C false*

Hermaphroditic reproduction does not have any impact on allele frequencies as long as mating is random.

*D true*

If snails mate only with snails of the same genotype, heterozygous individuals would be very rare in the population.

A yeast-two-hybrid assay (Y2H) allows to test if a protein X interacts with another protein Y. In this assay, the gene coding for X is fused to the gene of a DNA-binding domain (BD) of a transcription factor T. The gene coding for Y is fused to the gene of the activating domain (AD) of T. The resulting plasmids are transformed into a yeast strain containing the *lacZ* gene under the control of a promoter P, which is specifically recognized by BD. Plated on agar with X-gal, the colonies turn blue if they are expressing LacZ, which is only the case if BD and AD are in close proximity and hence if X and Y interact with each other.



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

- A. Y2H also works if BD alone is sufficient to activate transcription.
- B. Y2H allows studying interactions between integral plasma membrane proteins.
- C. Y2H can give false-positive results if X and Y interact indirectly via a third protein.
- D. Y2H can give false-negative results if the binding site for Y on X is situated close to the terminus at which BD is attached.

A. False B. False C. True D. True

**Original commentary**

Correct answers

A false

The assay works correctly only if BD and AD by themselves are not enough to activate transcription, but are both needed.

B false

This in vivo assay works only for soluble proteins. To study interaction of membrane proteins, the membrane proteins need to be properly folded, which is only possible if they are in lipidic environment.

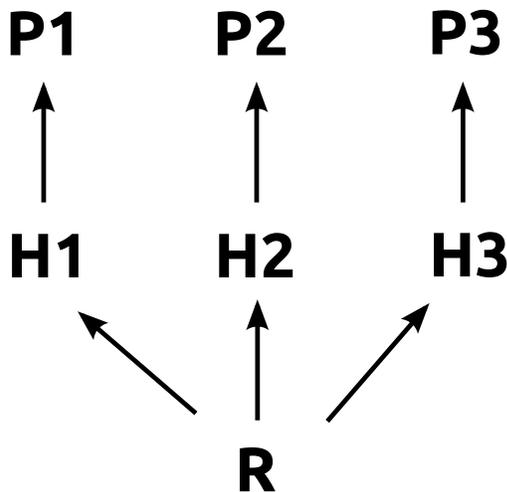
C true

If I binds to a third protein which binds to II, the assay can give positive results, even if I and II do not interact directly.

D true

The binding site can be distorted if it is too close to the junction to the transcription factor domain.

Consider a currently stable system in which three predatory insect species P1, P2 and P3, feed exclusively on three herbivore insect species H1, H2 or H3, respectively, all of which feed on the same limited plant resource R.



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

- A. If the plant resource was doubled, the abundance of P2 will increase.  
 B. If H1 is a stronger competitor than H2, removing P1 leads to a increase of P2.  
 C. If H3 was severely limited by its predator, the removal of P3 would lead a decrease in the abundance of P2.  
 D. The introduction of a top-predator feeding on P1 and P2 is likely to increase the abundance of P3.
- A. True   B. False   C. True   D. False**

**Original commentary**

Correct answers

*A true*

Doubling the resource should lead to a doubling of all abundances in the system in the long term since the interactions remain unchanged.

*B false*

Population size of predators depend on populations size of herbivores. H1 now lacking a predator will increases on cost of H2. As a consequence the abundance of P2 decreases as well. This is expected unless H2 is limited almost completely by its predator and not by competition with H1, but even in that case the abundance is expected to remain unchanged, but not increase.

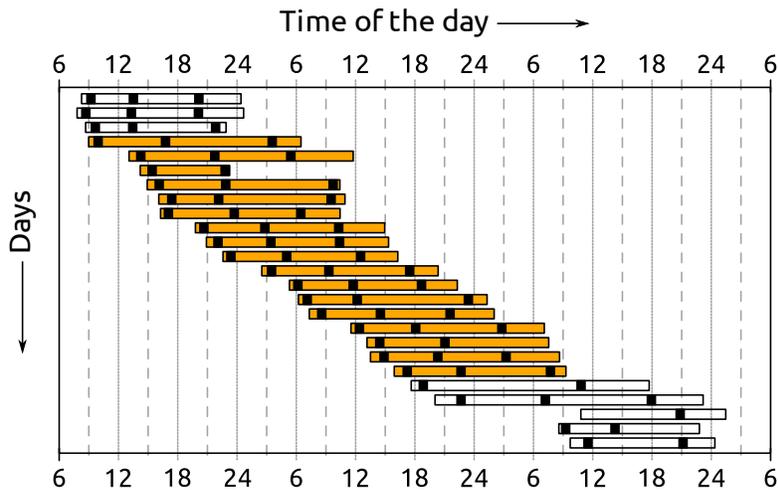
*C true*

Population size of predators depend on populations size of herbivores. H3 when having its predator removed, is able to reduce H2, P3 must be a limiting factor for H3. H2 when having its predator removed does not seem to be able to affect H3. Therefore the effect of the predator is not limiting enough to lead to significant loss of competition against H3.

*D false*

The top-predator will decrease the abundance of P1 and P2 and therefore lead to an increase of H1 and H2. As both those herbivores are in competition with H3, the abundance of H3 is likely to decrease, leading to a decrease in the abundance of P3.

The following figure illustrates the result of an experiment during which a person was alone in a room and was allowed to freely choose the awake and sleep periods by turning a bright light on and off. The consecutive time of light for each day is shown as a rectangle with times at which the person chose to eat a meal indicated by black bars. While the person had no time cues from the outside world during the days shown in orange, the room was exposed to natural light during the days shown in white.



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

- Without external cues, the person chose increasingly longer periods of light.
- The endogenous clock of this person cycles on a 28.5 h rhythm.
- These results are in agreement with bright light being a cue to delay the sleeping phase.
- These results suggest that the endogenous clock of this person can readjust completely within two days.

A. False B. False C. True D. False

#### Original commentary

Correct answers

A *false*

While the periods of light were extended in the absence of external cues, there is no indication that those periods got longer during the experiment.

B *false*

Firstly, this experiment does not measure the endogenous clock since the bright light is an effective, external cue to delay the endogenous clock. Secondly, the observed rhythm is on the order of about 26 hours (average over the 17 days).

C *true*

The person chose extended periods of light, without extending the periods of sleep much. This is an indication that the bright light resets the clock and delays the desire to go to sleep. A good example can be seen at the beginning of the experiment where the person stays up for more than 20 hours on the first two days and apparently got very tired on the third day.

D *false*

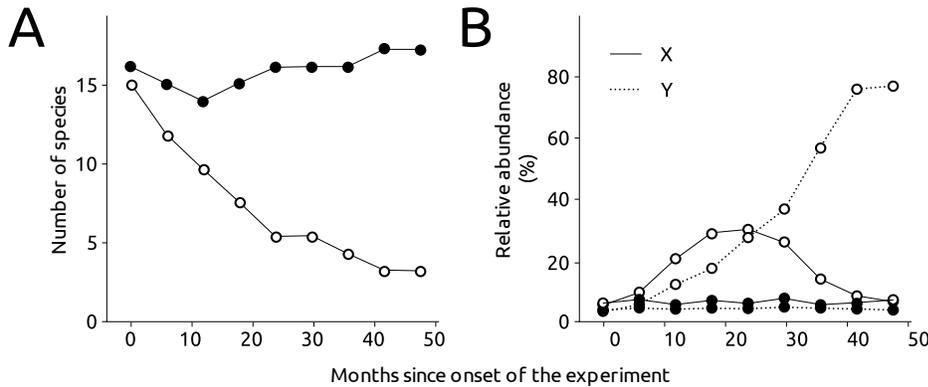
The transition back to normal conditions took the person at least four days. This can be seen best with the irregular eating times.

References

[Charles et al, Science \(1999\)](#)

A herbivorous insect H is known to exclusively feed on the seedlings of two tree species X and Y. In an experiment, patches of a forest were subjected to a treatment, or not. In the treatment, seedlings of X and Y were protected from being fed on by H (open circles). Patches in which X and Y were unprotected served as a control (filled circles). Panel A shows the average number of all species for which seedlings were found in the patches. Panel B shows the average relative abundance of seedlings of X and Y observed in the patches.

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



- A. Seedlings of species Y are weak competitors.  
 B. The regulation of this tree community involves a top-down process.  
 C. Seedlings of species X are strongly regulated by an additional herbivore.  
 D. The herbivore insect functions as a key stone species.

**A. False B. True C. False D. True**

#### Original commentary

##### Note

The two prey species must be excellent competitors, not inferior ones; otherwise they would not be able to dominate the experimental plot communities in the absence of the predator (78% vs. 27%). When community organization is regulated in this way, as opposed to the availability of nutrients — recall seedling growth was not limited by light availability — it follows a “top-down model” and not a “bottom-up model” (p. 1206). A top-down regulatory role for the predator is predicated on there being interspecific competition between prey and non-prey species for space when the prey are largely sessile, which plants are (p.1205 top of Fig. 54.17). In this way, the predator pre-empts interspecific competition among seedlings to promote local alpha diversity in the forest.

##### Correct answers

##### A false

Competition of species Y is only controlled by herbivore H. Without this control it dominates the tree seedlings in the forest within a few years. Moreover it is clearly able to outcompete species X when both species are lacking herbivore H.

##### B true

The diversity of tree species is regulated by the presence of herbivore H, a species at a higher position in the food chain. This feature qualifies a top-down process.

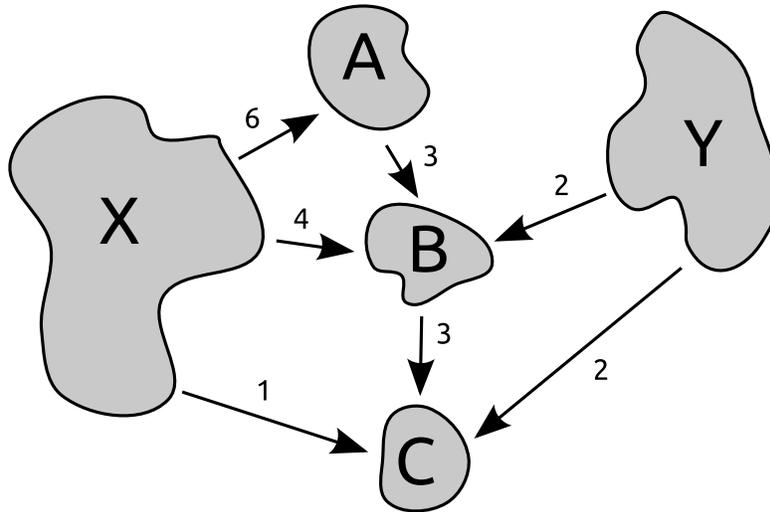
##### C false

After removing herbivore H, species X increases rapidly over two years, before diminishing again when being exceeded by species Y. This feature is best explained by competition between species X and Y. A potential regulation by another herbivore would be likely to prevent the initial strong increase of species Y.

##### D true

The predator not very abundant in the community, as both its host species only have a cumulative abundance of about 10%, but it clearly plays a pivotal ecological role in structuring the community by preventing potential dominance by prey, so it therefore qualifies as a “keystone species” (p. 1204; Campbell Biology 9th ed., 2010)

The meta-population concept describes the population size in a habitat patch as a function of birth rate, mortality and migration. Consider the hypothetical meta-population given below, consisting of two big source patches X and Y where the birth rate exceeds mortality and three sink patches (A, B and C) where reproduction does not occur. Yearly net migration (individuals) between different sub-populations is constant and indicated with arrows in the figure. In each sink patch, 6 individuals die at the end of each migration season. Individuals cannot migrate further than to the next patch within a year. The initial population sizes in the sink patches are  $A=22$ ,  $B=9$  and  $C=12$ .



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

- The subpopulation in Patch A dies out for the first time after 8 years.
- Subpopulations X and Y will be genetically isolated within few years.
- If in Patch C, 50% of the individuals (instead of 6 individuals) die each year, the Subpopulation C will not decrease below 7 individuals.
- A conservation measure to reduce mortality in A by 50% (3 individuals a year) is sufficient to preserve all subpopulations.

**A. True B. True C. False D. True**

**Original commentary**

Correct answers

*A true*

Net migration for patch A is 3. With a mortality of 6 individuals a year the sub-population declines 3 individuals each year. After 8 years, the population will reach 0.

*B true*

With the given migration and mortality, all sink population have a negative long-term trend and will die out. First, population A will die out so migration between A and B will be interrupted. Without this migration, population B and subsequently population C will die out as well. So no individual will be able any more to migrate between X and Y.

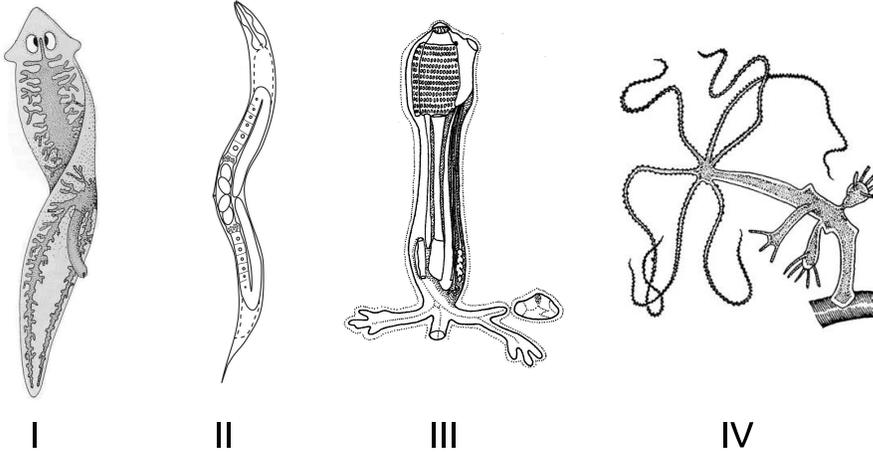
*C false*

With a constant net migration of 6 individuals into patch C, the population will fall below 7 individuals within three years, but will not fall below 6 individuals.

*D true*

This reduction in mortality prevents A from dying out. Therefore all other subpopulations will not die out either.

You are given four drawings referring to typical representatives of four major groups of metazoa.



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

- A. Organism I belongs to a taxon characterized by a digestive system with a single opening and the lack of a specialized respiratory system.
- B. Organism II belongs to a taxon characterized by a hydrostatic skeleton, a thick cuticle, a tubular digestive system with openings at both ends and often a genetically fixed number of somatic cells.
- C. Organism III belongs to a taxon characterized by a larval stage with nerves forming a neural tube and a sessile adult stage with a body surrounded by a tunic.
- D. Organism IV belongs to a taxon characterized by an endoskeleton with calcareous pads and a vascular system of fluid-filled canals used for various functions, including locomotion by tubular feet.

A. True B. True C. True D. False

**Original commentary**

Correct answers

A true

Both the drawing and the description are referring to the group of *Plathelminthes (Tubularia)*.

B true

Both the drawing and the description are referring to the group of *Nematoda*.

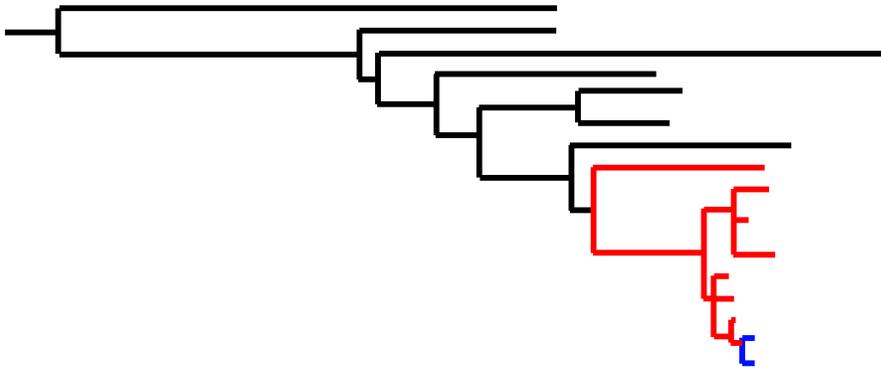
C true

Both the drawing and the description are referring to the group of *Tunicata (Chordata)*

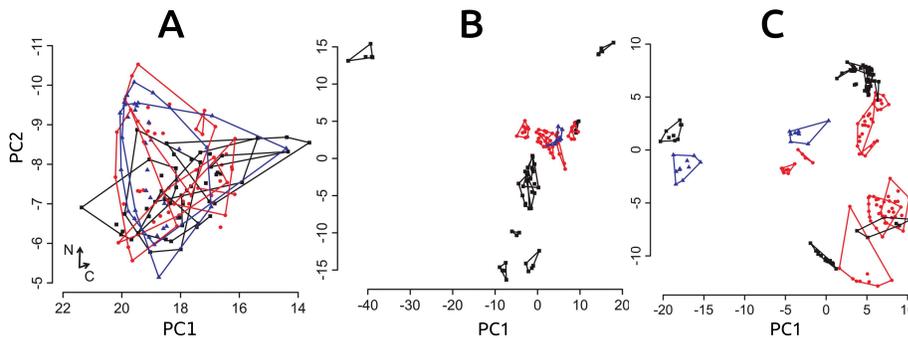
D false

The drawing shows a representative of the group of *Cnidaria (Hydra)* with typical polyps, whereas the description refers to a typical representative of the group of *Echinodermata*.

The following figure shows the phylogenetic relationship among several sympatric fish species of the family Mormyridae, which are known to use weak electric communication signals no predator is capable of sensing and the transmission of which does not depend on environmental factors.



For each species, measurements informative about the trophic level (A), body shape (B) and the shape and frequency of their electric signals (C) were determined for several individuals. The figure below shows the position of each measured fish individual in a principal components space for each of the three groups of measurements where all individuals of a species are enclosed in a polygon. The colors refer to the phylogenetic positions shown above. Principal components analysis is a statistical procedure that maximizes the variance on the first few axes.



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

- Among these species, the phylogenetic distance is highly informative about the divergence in communication systems between two taxa.
- Speciation of recently diverged sister species was likely driven by sexual selection on the communication system rather than by natural selection by ecological differences.
- The morphological variation among taxa is in agreement with an increase in habitat types at the onset of the radiation of the red and blue clade.
- Shape or frequency of communication signals in these species is strongly constrained by morphological trade-offs.

**A. False B. True C. False D. False**

**Original commentary**

Correct answers

A *false*

Recently evolved sister species are as different or even more different in their communication signals than phylogenetically distinct pairs.

B *true*

Currently diverged sister species are very distinct in their communication signals but show only limited differences in trophic ecology and morphology. Information (no predator with receptors able to track EOD's, no effect of typical ecological parameters like water turbidity and pH on communication system) given in the text make ecological driven effects responsible for the pronounced differences in signals very unlikely.

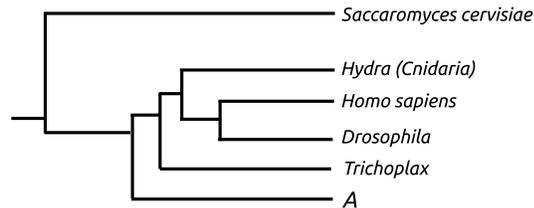
C *false*

Morphospace is mainly determined by phylogenetically very distinct taxa and therefore not created by recent changes of habitats. Recently evolved taxa do differ only marginally in body shape.

D *false*

There is no obvious correlation between body shape and electric signals of *Mormyridae*. In addition, morphologically very similar species differ heavily in their communication signals.

*Trichoplax adhaerens* is the only known animal (metazoa) of the phylum *Placozoa*. It appears as a flat disc with a very simple structure made of only very few distinct cell types. Nerves, sensory cells and muscle cells are absent. Shown below is an electron microscope image of *T. adhaerens* and a dendrogram based on molecular data indicating the phylogenetic position of *T. adhaerens* in relation to other taxa.



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

- Drosophila* is more closely related to *Trichoplax* than humans are.
- Taxa A listed in the dendrogram is more likely to be a sponge (*Porifera*) than a snail (*Mollusca*).
- Trichoplax* has no coelom and no gastric tube system.
- Trichoplax* is likely to be a representative of bilateria (animals with distinct dorsal and ventral sides as well as front and back side).

A. False B. True C. True D. False

#### Original commentary

Correct answers

A false

As *Placozoa* are a sister group of all *Eumetazoa*, they are equally related to both humans and *Drosophila*.

B true

Taxa A has a more basal position than *Cnidaria*. *Porifera* are known to be the most basal group of metazoa, whereas *Mollusca* are representatives of bilateria and therefore in the same group as humans or *Drosophila* are.

C true

Coelom and gastric tube are traits of higher *Metazoa*. *Cnidaria* do not yet have those organs, and *Placozoa* have even a more basal position than *Cnidaria*. Moreover, these organs would demand for more distinct cell types than *Placozoa* has.

D false

*Placozoa* have a more basal position than *Cnidaria*, which is a group of organisms that do not yet belong to *Bilateria*.

References

[Srivastava, Nature \(2008\)](#)

While some mammals are known for their large difference in body size between males and females, there is no apparent difference in size between sexes in other mammal species. This sexual dimorphism can often be well explained by the ecology and mating system of a species.

**Indicate if each of the following statements is true or false. A significant sexual size dimorphism with larger males is expected in ...**

- A. ... a very small antelope (< 5 kg), in which a male and a female together defend their small area (< 10 ha) with rich food resources, water and shelter.
- B. ... a seal species where males are known to travel large distances offshore to feed on dispersed food and to copulate with any oestrous female they encounter.
- C. ... an antelope species, in which males gather on a sandy lake shore during the dry season, where each of them defends a 20 m<sup>2</sup> area vigorously.
- D. ... a small carnivore (about 20 cm in length) living in a predator-rich habitat in mixed sex groups. The offspring rely heavily on parental care from both sexes and males are known for their remarkably large testicles.

**A. False B. False C. True D. False**

**Original commentary**

Correct answers

*A false*

Both sexes defend the small territory as a full time job year-round against conspecifics, therefore selection pressures are the same for both sexes.

*B false*

This particular case of fission-fusion mating selects more for agile, fast travelling males and resource-rich females than for heavily built competitive males.

*C true*

This territory is evidently too small and of bad food quality to serve as home range. Male-male interaction is permanent and highly competitive, females choose under many males - selection to show good genes and heavy bodies.

*D false*

This species is social and group members have similar functions. Male-male competition is limited since cooperation is very important to limit own mortality and to increase survival rate of offspring. In this system it is likely that females mate with several partners that cause sperm competition.

References

[Floyd, Journal of Mammology\(1998\)](#)

In ecology, two different measures of biodiversity are commonly used: alpha diversity characterizes the biodiversity at a given location and beta diversity characterizes the diversity found between habitats. A good estimate of alpha diversity is the Shannon index, which is computed as

$$H = - \sum_{i=1}^S p_i \cdot \ln(p_i)$$

where the sum runs over all species 1, ..., S present in a habitat and  $p_i$  is the relative abundance of Species i.

The table shows the abundance of adult trees of eight tree species (A through H) in four plots of a temperate ecosystem in both pristine and disturbed states.

Plot	State	A	B	C	D	E	F	G	H
1	pristine	19	0	56	332	0	76	0	0
2	pristine	3	0	12	456	0	5	0	0
3	disturbed	13	135	0	101	5	0	0	0
4	disturbed	0	143	12	178	0	4	13	7

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

- A. Alpha diversity is higher in Plot 1 than in Plot 2.
  - B. Disturbance seems to increase beta diversity in this ecosystem.
  - C. Species B is likely to be a pioneer species.
  - D. Seedlings of species D perform best in the presence of adult D trees.
- A. True B. True C. True D. True**

**Original commentary**

Correct answers

*A true*

While the number of species present is the same in both plots, their relative abundance is rather different in that species D dominates the system much more in plot 2 than plot 1, leading to a lower alpha diversity in plot 2.

*B true*

Beta diversity is much higher among plots 2 and 3 than plots 1 and 2. The students should be able to see this without calculating anything since exactly the same species are present in plots 1 and 2, but several species are restricted to either plot 3 or 4.

*C true*

Pioneer species are the first species to colonize a damaged / disturbed habitat. While other species are also present uniquely in either plots 3 and 4, none of them is present in both nor in that number, suggesting that species B.

*D true*

This is a typical characteristics of a species capable of dominating tree ecosystems, as species D is capable of doing in the pristine state. Seedling of other trees only get a chance after disturbance through external factors.