BOSWELL-BÈTA

Practice Exam 1 - VWO Biology

Date:

Time:

Number of questions: 40

Number of topics: 6

Number of multiple choice questions: 17

Number of open questions: 23

Total number of points: 74

Total number of pages: 23

Please read this thoroughly before starting, and follow the instructions:

- Write your name on each page with answers.
- Do not provide more answers (or reasons, or examples) than you are asked for.
- You will generally not be awarded any points if your answer lacks the explanation or calculation asked for in an open question.
- Write legibly and in ink. The use of correction fluid is not permitted. Pencils are allowed only for drawing images or graphs.
- You may use a Binas book, a non-graphic calculator, and drawing materials.
- All questions refer to normal situations and healthy organisms, unless stated otherwise.
- Write all of your answers on the separate paper provided, and not on the exam paper.
- Please hand in the exam paper along with your answers!

New Pancreatic Islets

Ruth is one of over 10,000 Dutch type 1 diabetes patients under the age of 25. Luckily for Ruth, this type of diabetes has not been life-threatening since the discovery of insulin. In the past, research was focussed on improving insulin quality and ways of administering it; nowadays the challenge is finding a cure for type 1 diabetes.

When Ruth was five years old, she exhibited the first symptoms of type 1 diabetes: excessive thirst and urination. Her primary care physician measured her blood glucose levels, which were elevated. Glucose was also found in her urine. Type 1 diabetes is an autoimmune disease: the immune system creates antibodies against the insulin-producing beta cells in the pancreatic islets of Langerhans.

During embryonic development the insulin gene is transcribed in the thymus. Thymus cells in children with type 1 diabetes express the insulin gene at lower levels than thymus cells in healthy children.

1 (2p) Explain why a normal production of insulin in the thymus is necessary to prevent an autoimmune response of T cells against the pancreatic beta cells.

In healthy individuals, a high blood glucose level causes a decrease in the amount of urine produced, regulated by the amount of ADH released.

2 (2p) Is the release of ADH increased or decreased in response to high blood sugar levels? As a result, is the reabsorption of water in the kidneys increased or decreased?

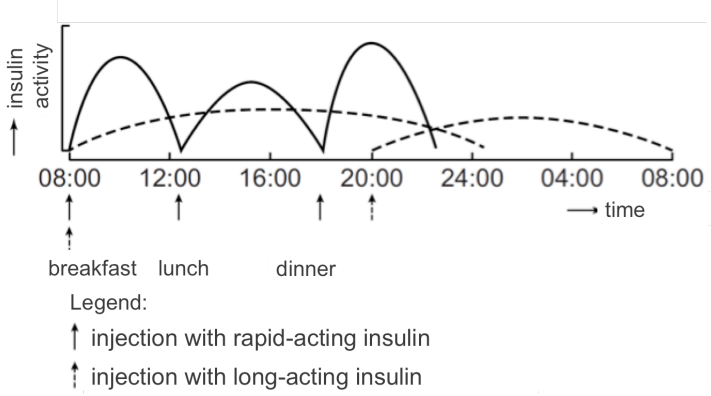
	ADH release	**water reabsorption**
A	decreases	decreases
B	decreases	increases
C	increases	decreases
D	increases	increases

If Ruth's diabetes is left untreated, she will lose weight despite the high glucose levels in her blood.

3(2p) Explain why Ruth will lose weight if she does not use insulin.

High blood glucose levels (hyperglycemia) is unhealthy because small blood vessels get damaged. This is why Ruth learned at a young age how to inject herself with rapid-acting insulin prior to each meal. In addition, she had to also administer long-acting insulin twice a day (figure 1).

figure 1



Even in patients such as Ruth who are careful about their use of insulin, blood glucose levels greatly fluctuate at times. At night, hypoglycemia (low blood glucose) may occur and in the early morning, before breakfast, blood glucose levels may increase a lot, also known as the 'dawn phenomenon'.

4(2p) How can the 'dawn phenomenon' in diabetic patients be best explained?

A Due to lower blood insulin levels, aerobic respiration decreases.

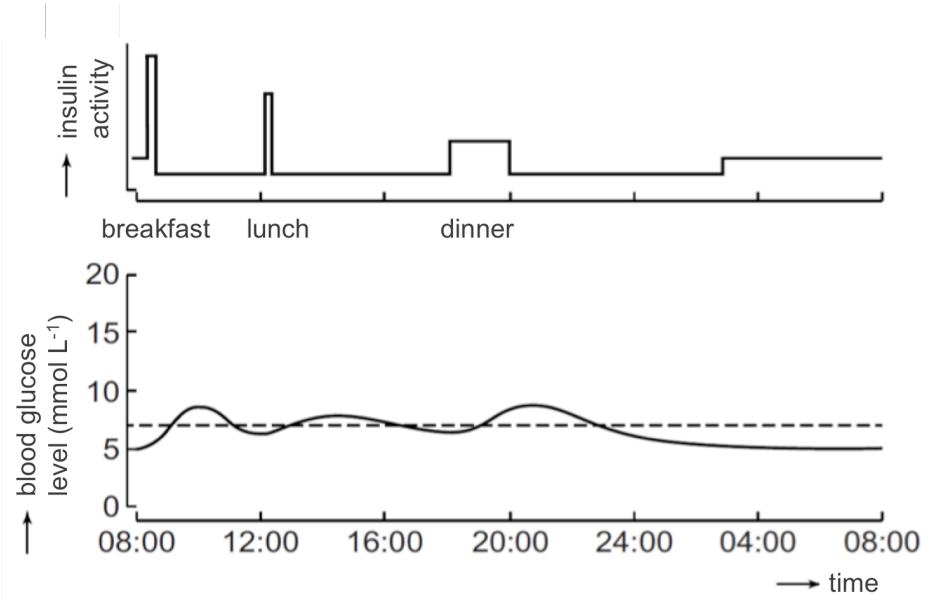
B Due to lower blood insulin levels, the liver stores less glucose.

C Due to lower blood glucose levels, the liver produces glucagon.

D During sleep less glucose is used than during the day.

Ruth has been using an insulin pump since the age of 14 (figure 2). The pump is programmed to constantly release insulin via a small needle in her belly. When Ruth eats, the pump calculates how much extra insulin is necessary (the meal bolus), based on the amount of carbohydrates she enters.
Figure 2 shows simplified diagrams of the amount of insulin administered and its effect on blood glucose levels during a 24-hour period.

figure 2



The following statements were made based on figure 2:

1 When using an insulin pump, the blood glucose levels can never be more than 10 mmol per liter.
2 The amount of insuline the pump releases at dinnertime is about half the amount that gets released at lunchtime.
3 Use of an insulin pump prevents the dawn phenomenon.

5(2p) List the numbers 1, 2 and 3 on your answer sheet and write next to them whether each statement is **true** or **false**.

There is hope of a breakthrough to cure type 1 diabetes. Researchers at the universities of Leiden, Maastricht, Utrecht and Eindhoven are collaborating on a capsule that can be implanted under the skin; a kind of tea bag made of a gelatin-like material, in which insulin-producing beta cells live. The cells are not derived from a donor, but from the patient's own stem cells. The capsule prevents an auto-immune response against these beta cells.

In order for this treatment to be successful, the capsule surrounding the beta cells needs to meet certain requirements. The pores in the capsule should not be too large, nor too small, so that certain compounds can leave but other compounds cannot enter.

6(2p) – Which compound determines the minimum size of the pores in the gel capsule?
– Which type of compound determines the maximum size of the pores?

The layer of gel surrounding the beta cells should not be too thick either. The diffusion distance would then interfere with a proper functioning of the beta cells.

7(2p) Explain why the rate of glucose diffusion through the gel layer should be as high as possible in order for the beta cells to function properly.

X Chromosome Inactivation

"Every woman is a mosaic", says Anton Grootegoed, professor at Erasmuc MC in Rotterdam. "She has groups of cells in which the X chromosome derived from her father is turned off, and groups of cells in which her mother's X chromosome is turned off." His department recently discovered the molecular switch that turns off one of the X chromosomes in female embryonic cells.

Male and female somatic cells in mammals contain a different number of X chromosomes. The expression level of X chromosomal genes is approximately the same, however, because during female embryonic development, cells randomly inactivate one of their X chromosomes permanently. Consequently, there is no transcription of genes from the inactivated X chromosome, and this inactivation is maintained in all daughter cells.

A tricolor cat (figure 3) is always female and clearly shows the effects of X chromosome inactivation. Three genes determine the coat color in these cats. Table 1 shows the combinations of alleles and the resulting phenotypes regarding these three genes.

figure 3

table 1

genes for coat color	genotypes	phenotypes
gene for a dark color (autosomal)	BB, Bb, of Bb^{l}	black coat
	bb of bb^{l}	brown coat
	$b^{l}b^{l}$	light brown coat
gene for red coloration (X chromosomal)	$X^{R}X^{R}$ of $X^{R}Y$	all black and brown coat parts turn red
	$X^{R}X^{r}$	some black and/or brown coat parts turn red
	$X^{r}X^{r}$ of $X^{r}Y$	black and/or brown coat parts do not change
gene for white spots (autosomal)	SS	many white spots
	Ss	a few white spots
	ss	hardly any or no white spots

The tricolor cat in figure 3 has black, red and white coat parts.

8(2p) Which X-chromosomal allele is **not** active in these parts?

	black parts	**red parts**	**white parts**
A	X^R	X^r	uncertain
B	X^r	X^R	uncertain
C	uncertain	X^R	X^r
D	uncertain	X^r	X^R
E	uncertain	X^R	uncertain
F	uncertain	X^r	uncertain

A tricolor cat with black, red and a few white spots mated with a completely brown male cat.

9(2p) What is the probability that the first kitten has the same coat colors as the mother cat?

Depending on the genotype of the mother cat, the probability is:

A 1/4 or 1/8
B 1/8 or 1/16
C 1/16 or 1/32
D 1/4 or 1/8 or 1/16
E 1/8 or 1/16 or 1/32

In the mother's nest, two tricolor kittens were born. Both have black, red and a few white spots, but the distribution of the spots differs between the kittens.

Regarding this difference, two statements were made:

1 It shows that the kittens cannot be identical twins.
2 It shows that the kittens do **not** have the same father.

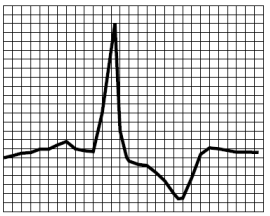
10(2p) Which of these statements is true?

A neither
B 1 only
C 2 only
D both 1 and 2

In humans, women also only have one functioning X chromosome in each cell. This can turn into a problem when in some of her somatic cells, the active X chromosome has a defective gene, such as is the case in Fabry disease. This disease is caused by a mutation in the gene coding for the enzyme α-galactosidase A. This enzyme is active in lysosomes in which waste products are broken down. When there is a lack of this enzyme, a lipid molecule called GL-3 accumulates in the lysosomes. As a result, patients with Fabry disease can get heart and vascular problems, which increases the risk of a heart attack and kidney damage.

figure 4

The heart muscle cells function improperly due to the accumulation of GL-3. Fabry patients show an aberrant electrocardiogram image (ECG, figure 4).



11 (2p) What causes the aberrant ECG?

There is an abnormality in

A the transmission of impulses through the atrioventricular node.
B the depolarisation of the atria.
C the generation of impulses through the sinus node.
D the repolarisation of the ventricles.

Because several cell types in the nephrons of a Fabry patient are impaired, kidney function deteriorates.

Some effects of Fabry disease:

1 degradation of cells in the proximal convoluted tubule
2 degradation of cells in the glomerulus
3 degradation of cells in the loop of Henle
4 constriction of afferent arterioles

Due to this, changes in the urine could be:

P protein in the urine
Q glucose in the urine
R lower creatinine excretion
S less concentrated urine

12 (2p) Which change in the urine could be caused by which nephron impairment?

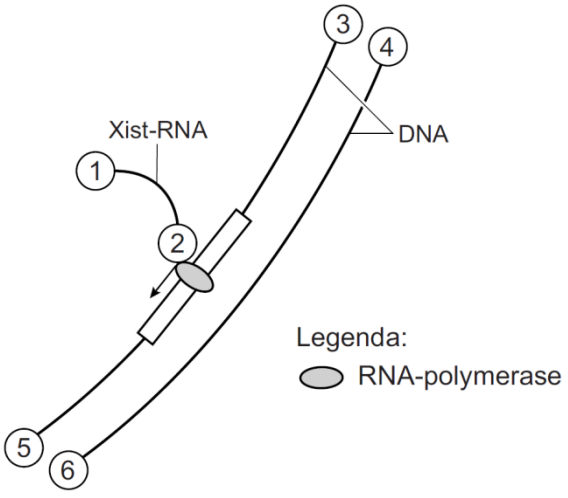
Write down numbers 1 through 4 on your answer sheet and note next to each number the corresponding letter (P, Q, R or S).

Investigations at Erasmus Medical Centre show the complexity of X chromosome inactivation:

1 There is an inactivation centre on the X chromosome: an area where the *RNF12* and *Xist* genes are located.
2 Early in embryonic development, cells of female embryos produce the RNF12 protein.
3 When concentration of RNF12 surpasses a certain threshold, transcription of Xist is stimulated.
4 The Xist RNA then covers its 'own' X chromosome, thus inactivating it.
5 The Xist RNA also inhibits production of RNF12, so that the second X chromosome does not get switched off. In 12% of the cells this happens too late and the cell dies after both X chromosomes are inactivated.

Figure 5 is a schematic representation of the two complementary DNA strands of an X chromosome, with Xist RNA in the making.

figure 5



The ends of the DNA and RNA strands are indicated with numbers 1 through 6.

13(2p) Where is the 5’ end of the Xist RNA? And where are the 5’ ends of the DNA strands?

	5’ of Xist RNA	**5’ of DNA strands**
A	location 1	location 3 and 4
B	location 1	location 3 and 6
C	location 1	location 4 and 5
D	location 2	location 3 and 6
E	location 2	location 4 and 5
F	location 2	location 5 and 6

In human embryos, transcription of RNF12 usually starts on day 8.

14(1p) Where is the human embryo when the inactivation of X chromosomes begins?

The effect on the phenotype through X chromosomal inactivation is epigenetic.

15(1p) What does ‘epigenetic’ mean?

The disease symptoms are worse in male Fabry patients than in female patients, in whom the symptoms vary greatly.

16(1p) Provide an explanation for this difference.

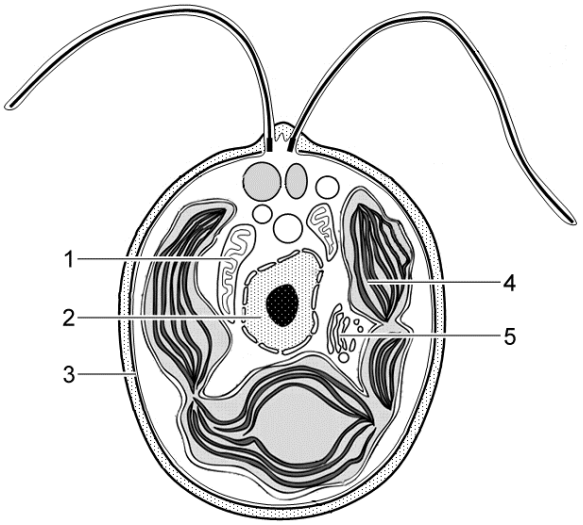
Blue Algal Blooms

‘Blooms Like It Hot’ was the title of an article in the scientific journal Science in April 2008. Researchers Hans Paerl en Jef Huisman used this title to refer to the increase of algal blooms in the oceans due to the enhanced greenhouse effect. They investigated blue algal blooms.

An increase in the average temperature on Earth has lead to an exponential growth of blue algae. Blue algal blooms consist of a layer of cyanobacteria floating on the water. They produce compounds such as microcystins and anatoxin, which are toxic for (swimming) humans and animals. Symptoms of blue algal poisoning vary from skin rashes and gastrointestinal complaints, to cramps and breathing problems.

The name blue algae is misleading, because they are in fact cyanobacteria. Based on a number of characteristics, green algae and cyanobacteria are placed in different taxonomic groups. Figure 6 shows the structure of a green algae (*Chlamydomonas*).

figure 6



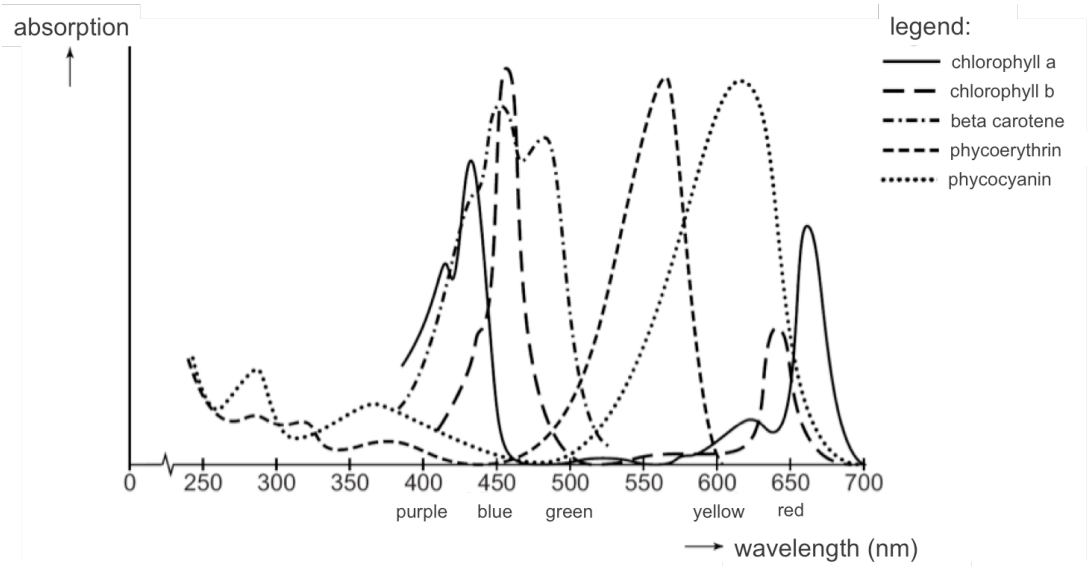
Five parts of *Chlamydomonas* are indicated with a number in figure 6.

17 (2p) In which part do the light reactions of photosynthesis take place?

A in part 1
B in part 2
C in part 3
D in part 4
E in part 5

Cyanobacteria have been floating around in water for billions of years and have contributed to the emergence of an oxygen-rich atmosphere. Cyanobacteria are also referred to as blue algae because of their blue pigment phycocyanin, which, together with other pigments such as chlorophyll-a, is involved in photosynthesis. Figure 7 shows the absorption spectrum of pigments found in cyanobacteria.

figure 7



Green algae generally do not contain the pigments phycocyanin and phycoerythrin.

18(1p) What advantage do cyanobacteria with phycocyanin and/or phycoerythrin have compared to green algae without these pigments?

19(2p) What is the role of phycocyanin in photosynthesis?

A absorbing light energy
B glucose production
C oxygen production
D ATP production
E splitting water

Due to the enhanced greenhouse effect, thermal stratification occurs in many places in the water: the layer of warm surface water is not well mixed with the deeper cold water layer.

20(2p) Explain why this stratification can contribute to the occurance of blue algal blooms.

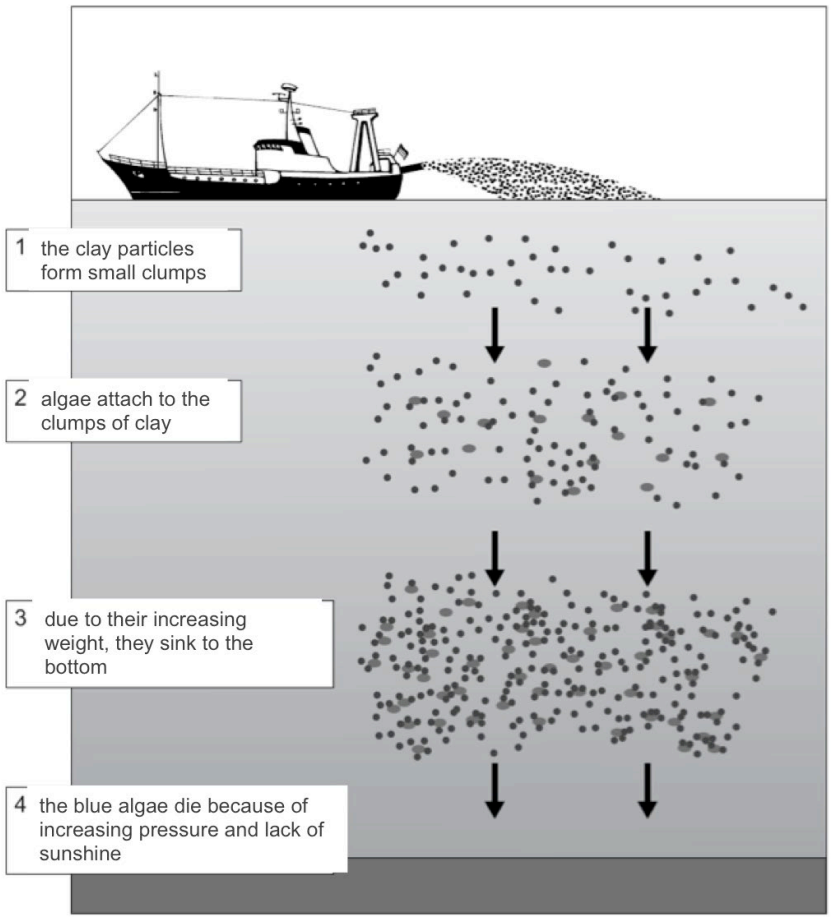
One effect of global warming is a local increase in rainfall. Paerl and Huisman predict more blue algal blooms in river estuaries (where rivers meet the sea).

21 (2p) Due to which change in the water can more rainfall on land lead to an increase in algal blooms in estuaries?

A the water becomes less turbid
B the water becomes less salty
C the water becomes more nutrient rich
D the water becomes more oxygen rich

One way to prevent blue algal blooms is by spraying clay particles on the water. Blue algae attach to the clay and sink to the bottom (see figure 8).

figure 8

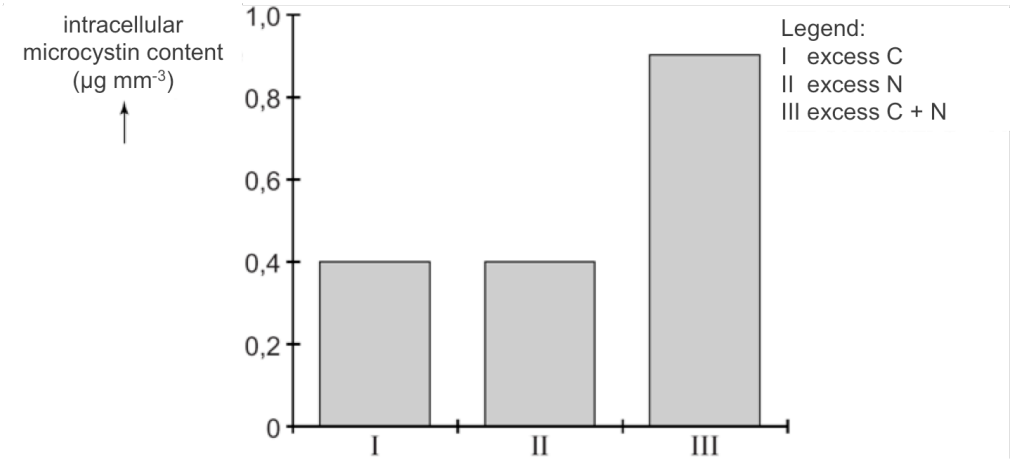


The sinking of blue algae (figure 8) helps counteract the enhanced greenhouse effect as well.

22 (2p) Explain why this method initially helps to counteract the enhanced greenhouse effect, but also why it possibly has no effect after a longer period of time.

Paerl and Huisman's research group investigated the impact of environmental conditions on the toxicity of the cyanobacteria *Microcystis aeruginosa*. In the laboratory these cyanobacteria were grown in three vessels to which were added, respectively, an excess of carbon (as CO_2), an excess of nitrogen (as NO_3^-), or an excess of both carbon and nitrogen. Afterwards, the content of the toxin microcystin was measured. The results are shown in figure 9.

figure 9



Based on these results, two conclusions are drawn:

1 In vessel I, nitrogen is a limiting factor for microcystin production by *Microcystis aeruginosa*.
2 In vessel III, light is a limiting factor for microcystin production by *Microcystis aeruginosa*.

23(2p) Which of these conclusions can be correctly drawn from the results?

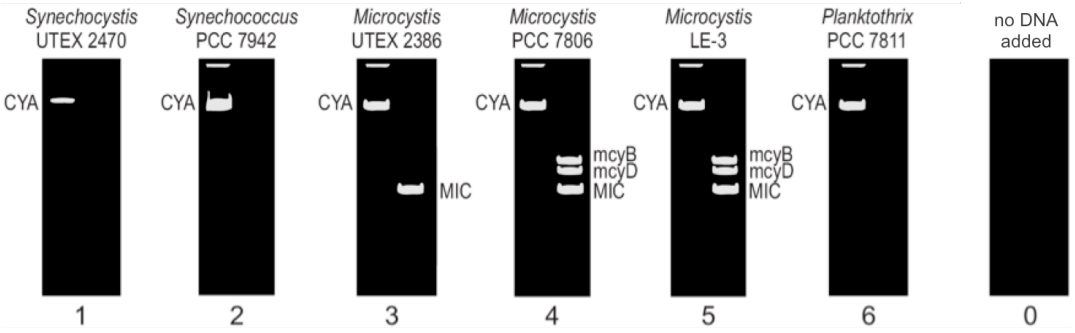
A neither
B only 1
C only 2
D both

24(3p) Explain why human-caused eutrofication combined with the emission of greenhouse gases, may increase the toxicity of *Microcystis aeruginosa* cyanobacteria.

When cyanobacteria are found in bathing water, it is important to quickly get a definitive answer as to their toxicity. This can be achieved with a genetic analysis. Only cyanobacteria with a *mcy* gene, which codes for the synthesis of microcystin, can produce microcystins.

In six different strains of cyanobacteria, the presence of the genes *mcyB* and *mcyD* were examined in the laboratory. For control genes, the investigators used the *CYA* gene that all cyanobacteria have, and the *MIC* gene that is only found in Microcystis strains.
Using Polymerase Chain Reaction (PCR), the DNA of gene fragments was multiplied. The PCR products were analysed by gel electrophoresis. The results are shown in figure 10.

figure 10



Regarding the gel electrophoresis results in figure 10, two statements are made:
1 All *Microcystis* cyanobacteria in the test are potentially toxic;
2 The Planktothrix results are unreliable because the control gene *MIC* is missing.

25(2p) Which of these statements is, or which statements are, supported by the results?

A neither
B only 1
C only 2
D both statements

When cyanobacteria are incapable of producing microcystins, it does not necessarily mean they are harmless. There are cyanobacteria that produce the dangerous and fast-acting anatoxin-a. This substance activates acetylcholine receptors in skeletal muscles. Anatoxin-a cannot be broken down by acetylcholinesterase.

26(3p)
- What happens on a cellular level when anatoxin-a is released in the synapses of motor endplates? Use the words ‘depolarisation’ and ‘repolarisation’ in your answer.
- What is the effect of this on an organ level?
- Why can this be dangerous for an organism?

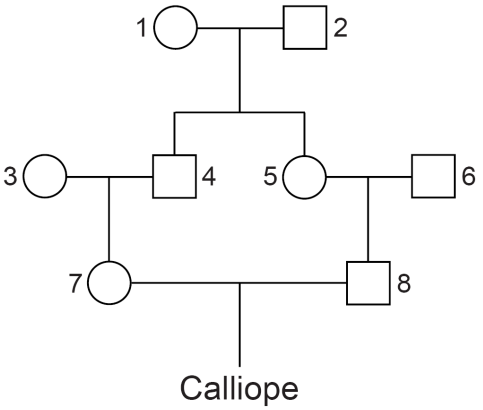
Man or Woman?

Sometimes it is unclear whether someone is a man or a woman. Oftentimes, this co-occurs with infertility.

Sometimes a genotypical boy (genotype XY) develops phenotypically into a girl who is infertile. The cause can be the extremely rare, recessive, autosomally inherited condition ARD (5-alpha reductase deficiency). Due to the missing of an enzyme, testosterone is not converted to dihydrotestosterone, which would normally stimulate the development of external sex organs.

In a different condition, AIS (Androgen Insensitivity Syndrome), there is a mutated gene on the X chromosome. Children with this syndrome have genotype XY but the receptor protein that is coded for by the mutated recessive gene is insensitive to both testosterone and dihydrotestosterone. Because of this, these children develop into a phenotypically infertile girl as well.

There is an XY-girl with ARD in a novel by Eugenides. The figure below shows her family's pedigree. Two of her grandparents (numbers 4 and 5) are brother and sister.



27(1p) Using the pedigree, explain how Calliope may have inherited ARD from her great-grandfather (number 2).

28(1p) Explain that Calliope cannot possibly have inherited AIS from her great-grandfather (number 2).

AIS affects 1 in 13,000 teenagers in the United States.

29(2p) What is the frequency of the recessive allele that is responsible for AIS in genotypically adult women in the US?

A 0
B $8.8 \cdot 10^{-3}$
C $1.5 \cdot 10^{-4}$
D $7.7 \cdot 10^{-5}$
E $2.4 \cdot 10^{-8}$

Isolation Affects the Evolution of Bacteria Populations

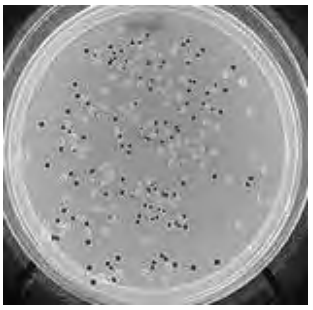
The impact of the environment on the course of evolution can be studied using bacteria. Such an experiment was carried out at Wageningen University. Bacteria were grown for several generations under different conditions. It turns out that isolation affects the evolution of *Escherichia coli* bacteria.

A simple model to study evolution consists of bacteria in an Erlenmeyer flask with a liquid growth medium. Every day, part of the bacteria population is transferred to a new flask with fresh medium. At that time, a small part of the bacteria can be frozen as well. This way, the whole process of evolution is stored in a freezer: starting with the original population, followed by samples from later flasks. The result is a kind of fossil bank, but one in which the fossils can be brought back to life.

Dr. Michelle Habets used such an experimental design with *E. coli* bacteria for her PhD research. These bacteria are facultative anaerobes: they can live in both aerobic and anaerobic conditions.
Habets investigated the effect of isolation on *E. coli* bacteria. She grew bacteria in Erlenmeyer flasks and on solid growth medium in Petri dishes (see figure 11).

figure 11

Erlenmeyer flask with bacteria in liquid growth medium



Petri dish with bacteria colonies on solid growth medium: structured (1) or mixed (2)

In the Petri dishes, too, part of the bacteria were transferred to new Petri dishes with fresh growth medium, and part of the bacteria were frozen. Two methods were used to transfer bacteria from one Petri dish to another:

1 Structured dishes: using a round patch, a print of the colonies was made every day from their original medium onto a fresh growth medium. The distribution of the bacterial colonies in the dish remained unchanged this way.
2 Mixed dishes: a few colonies were scraped off the growth medium, shaken in suspension, and smeared onto a new dish. Bacterial colonies then arose in random places in the dish.

If part of the bacteria would not regularly be transferred to a new flask or dish, the bacteria would eventually stop growing, due to lack of nutrients and space, among other reasons.

30(1p) List another reason why the bacteria would stop growing.

Growing, freezing and reactivating is fairly easy with bacteria. Because of these characteristics, bacteria are suitable for the evolution experiment.
Three other characteristics of bacteria are:

1 Bacteria have a short generation time;
2 Bacteria are easy to modify genetically;
3 Bacteria can exchange genetic information via plasmids.

31(2p) Which of these characteristics make(s) bacteria specifically suitable for the described evolution experiment?

A 1 only
B 1 and 2 only
C 1 and 3 only
D 2 and 3 only
E all three

The bacterial populations in the Erlenmeyer flasks and Petri dishes get increasingly better adapted to the conditions in the experiment.
Evolution is happening.

32(2p) Describe how this process of evolution is happening, in which the populations of bacteria are getting increasingly better adapted to the experimental conditions.

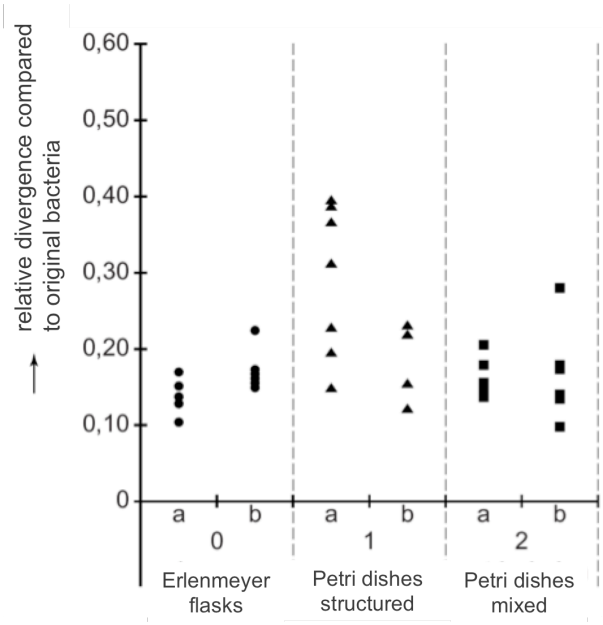
Habets investigated how different conditions affect the evolution of bacteria; one of them was the capacity to use certain carbon compounds as a source of energy. A few carbon compounds are: glucose, pyruvate, lactate and malic acid.

33(2p) Which of these carbon compounds can normally be used by bacteria as an energy source under anaerobic conditions?

A glucose only
B lactate only
C glucose and pyruvate only
D glucose, pyruvate and lactate only
E glucose, pyruvate, lactate and malic acid

Habets investigated the divergence of the bacterial populations from the three setups (group 0 = Erlenmeyer flasks, group 1 = structured dishes, group 2 = mixed dishes). She started with two identical populations of bacteria per group, a and b. They were transferred daily. After 900 days, she took a few samples of bacteria from each group. These were investigated for divergence: to what extent did these descendants differ from the original bacteria? Figure 12 shows the results.

figure 12



The results of group 1 and group 2 were compared with each other. Two statements were made explaining these results:

1 Due to the emergence of ‘islands’ on the structured plates, subpopulations arose with each their own variation in genotypes.
2 In the mixed dishes, there is strong competition between all bacterial colonies, causing selection pressure towards a limited number of genotypes.

34(2p) Which statement(s) could be correct?

A neither
B 1 only
C 2 only
D both

35(1p) Provide an explanation for the difference in divergence between the cultures of bacteria in the two Erlenmeyer groups (see figure 12).

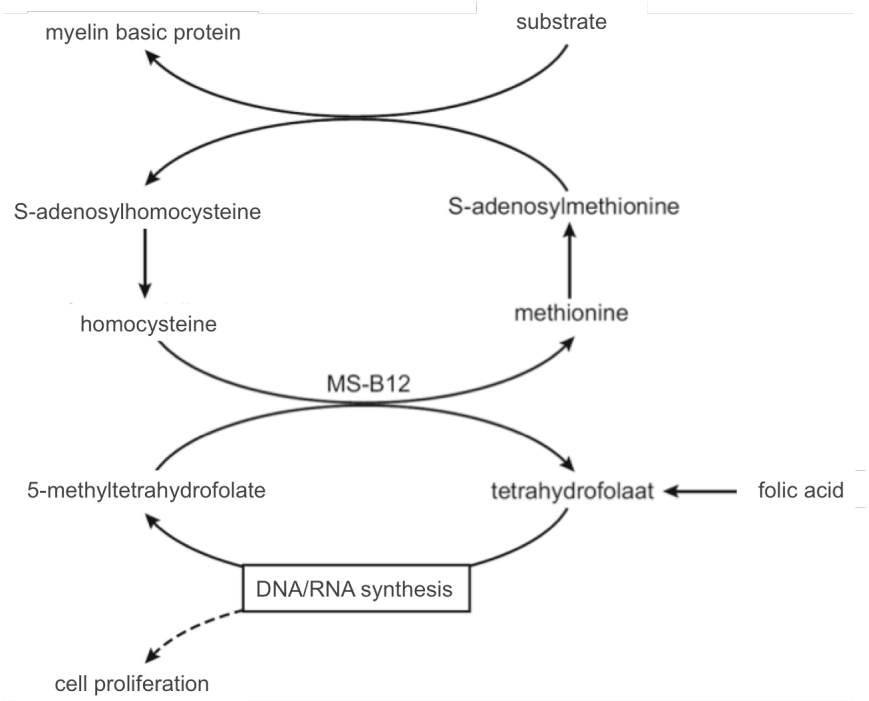
Folic Acid Enrichment Impedes Diagnosis of Nerve Damage

The Netherlands Nutrition Centre advises people to have a varied diet in order to consume sufficient vitamins. Women who wish to get pregnant are advised to take a supplement of folic acid (vitamin B11). A higher folic acid intake can, however, impede the diagnosis of nerve damage due to a vitamin B12 deficiency.

Tetrahydrofolate is a folic acid derivative and is necessary for DNA and RNA synthesis in dividing cells, such as the stem cells in bone marrow that make blood cells. Vitamin B12 is a co-factor for methionine synthase (MS-B12 complex) in the liver, and is involved in the synthesis of methionine, which is necessary for the production of myelin.

Figure 13 shows the processes in which vitamin B12 and folic acid are involved.

figure 13



Two pieces of data are:

1 Methionine is considered an essential amino acid;
2 Methionine-synthase (MS) is made in the liver.

These two pieces of data seem to be contradictory.

36(3p) – Define what is meant by an essential amino acid.
– Why is the second piece of data conflicting with the first one?
– Under what circumstance could both pieces of data be correct?

For the formation of myelin basic protein, methionine is needed as a methyl donor, meaning that methionine gives a methyl group (-CH_3) away. Methionine is also necessary in its entirety for the formation of this basic protein on the ribosomes.

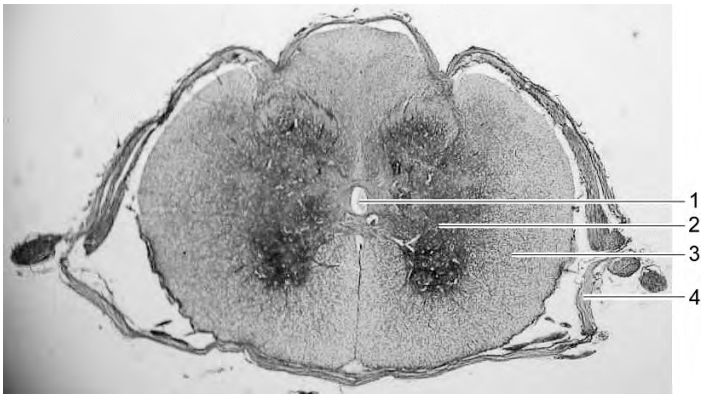
37(1p) Give an example of how methionine is needed for the formation of basic protein.

A deficiency in vitamin B12 can eventually cause nerve damage due to reduced myelin production.

38(2p) – What is the name of the cells in the nervous system that produce myelin?
– What is the effect of a reduced myelin production on neuron function?

Figure 14 shows a cross section of the spinal cord in which four parts of the central nervous system are indicated with a number.

figure 14



39(2p) In which part can most myelin-producing cells be found?

A in part 1
B in part 2
C in part 3
D in part 4

Elderly people and vegans sometimes suffer from anemia due to insufficient vitamin B12 uptake. If they regularly take a folic acid supplement, however, the anemia does not get diagnosed and there is a risk of nerve damage due to the B12 deficiency going unnoticed by the doctor.

40(2p) – Explain why anemia does not get diagnosed in these people, using the data from figure 13.
– Explain why they risk nerve damage.