BOSWELL-BÈTA

Practice Exam 2 - VWO Biology

Date:

Time:

Number of questions: 39

Number of topics: 7

Number of multiple choice questions: 16

Number of open questions: 23

Total number of points: 76

Total number of pages: 27

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

- Write your name on each page with answers.
- Write all of your answers on the separate paper provided, and not on the exam paper.
- 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 may be used 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.

Please hand in the exam paper along with your answers!

Threatened Bananas

Bananas are the most important source of food for more than 400 million people in the tropics. The global banana production is threatened by a fungus that causes Panama disease. Scientists and students from Wageningen University investigate how this banana plant disease can be prevented and treated.

The most commonly eaten banana comes from the ‘Cavendish’ variety of the banana plant *Musa acuminata*.
Until recently, this variety was unaffected by Panama disease, which is caused by the fungus *Fusarium oxysporum*.
A new strain of this fungus has now appeared, *F. oxysporum* TR4, that also affects Cavendish plants.
The fungus infects banana plants through spores in the soil, after which fungal threads grow from the roots into the transport vessels.

Wild banana plants are diploid and produce seeds.

The triploid Cavendish variety is derived from two *M. acuminata* varieties.

Cavendish plants contain two sets of chromosomes from one parent and one set from the other parent; in total there are 33 chromosomes in each cell. Cavendish bananas do not have any seeds. Figure 1 shows a Cavendish banana without seeds, and a ‘wild’ banana with seeds.

figure 1

1(2p) Explain why the triploid Cavendish **cannot** produce seeds.

Since banana plants die after flowering and there are no seeds, Cavendish growers must obtain new plants in a different way. They do this by cutting off underground stems and letting these grow into new plants.

2(2p) Explain why this propagation method can increase the spread of Panama disease.

Since Cavendish plants do not produce seeds, artificial selection to make them less susceptible to *F. oxysporum* is not possible. For this reason, Wageningen researcher Gert Kema uses genetic modification: he attempts to insert resistance genes against the fungus from a different banana variety, *M. acuminata* ssp. *malaccensis* (the Pahang banana plant), into Cavendish plants.

3(1p) Is this form of modification cisgenic or transgenic? Explain your answer.

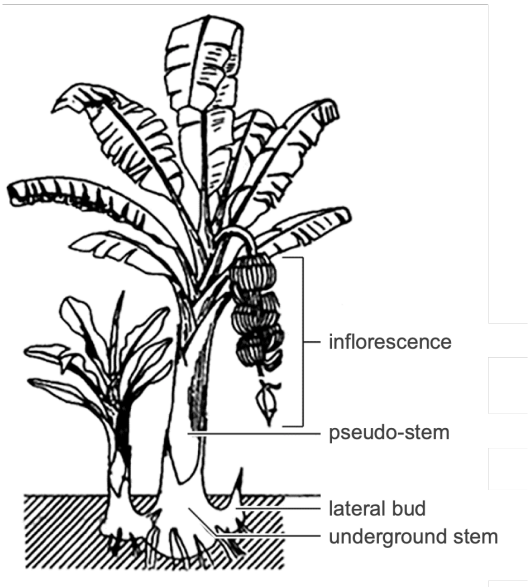
Genetic modification is cheaper and faster than changing plants through traditional plant breeding with artificial selection.

4(1p) Name another advantage of genetic modification over the traditional method of plant breeding.

Banana plants are not trees, because they do not have real trunks. The pseudo-stems actually consist of tightly folded leaves that grow from an underground stem. From the center of the pseudo-stem, a large inflorescence grows, which hangs down due to its great weight (see figure 2).

The starch-rich fruits curve up while they grow. This gives bananas their typical shape.

figure 2



F. oxysporum produces fusaric acid, a toxin used by the fungus to enter plants. The fungal threads eventually block some of the xylem vessels in the banana plant.

5 (2p) Explain how this blockage of xylem vessels indirectly reduces the plant's ability to take up CO_2, which can cause the whole plant to die.

Ripe bananas contain a lot of starch.

6(2p) The starch in a banana is made by parenchyma cells in

A the fruit.
B the leaves of the plant.
C the pseudo-stem of the plant.
D the underground stem of the plant.

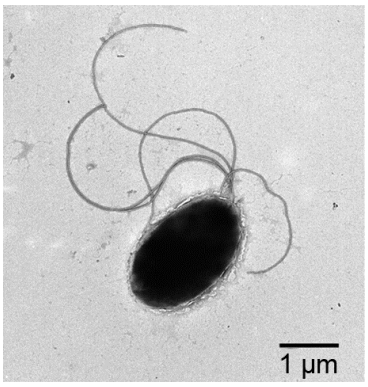
The fact that bananas curve upward while the inflorescence hangs down, may indicate an effect of gravity or an effect of light.

7(3p) – Describe how you could investigate whether the curving of bananas is influenced by light.
– Note one possible result and the conclusion you could draw from that result.

An alternative approach to treating Panama disease is aimed at making the fungus *F. oxysporum* harmless using fusaric acid-resistant and fungus-inhibiting bacteria.

A group of Wageningen students modified a fusaric acid-resistant soil bacterium *Pseudomonas putida* (figure 3) in such a way that it will only produce fungus-inhibiting molecules when there is fusaric acid in the soil. They called this bacterium 'BananaGuard'.

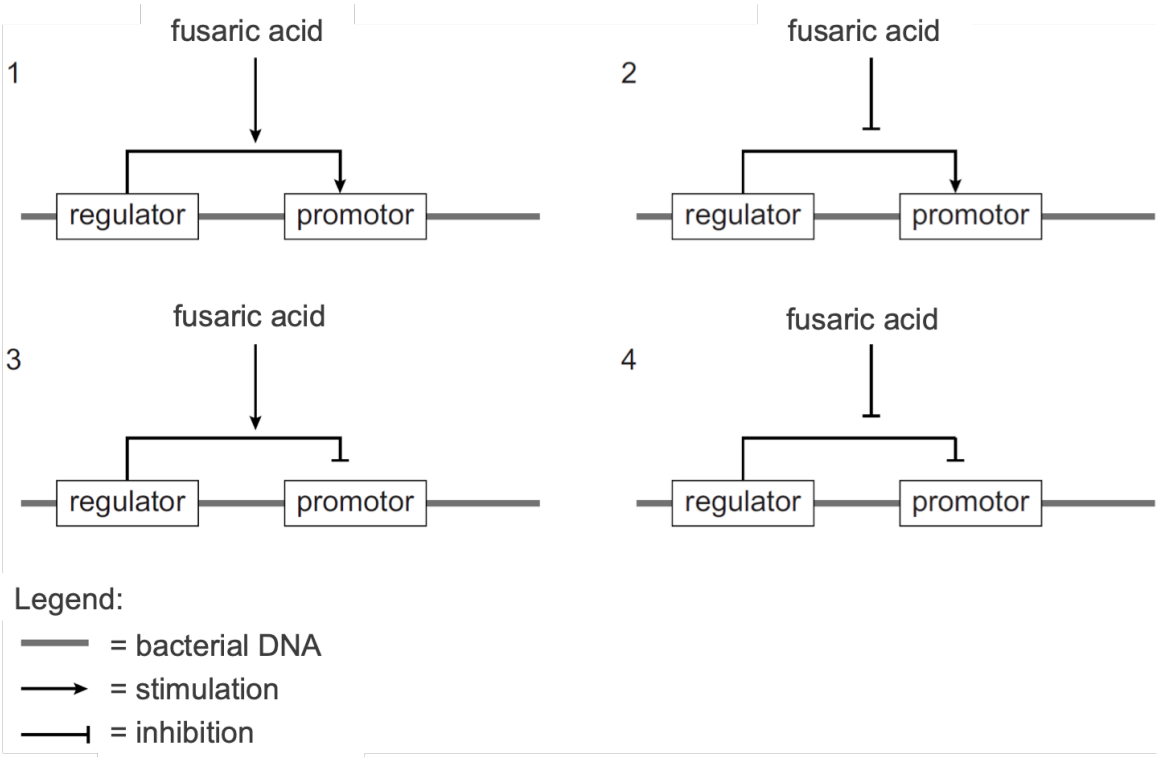
figure 3



The modified BananaGuard bacteria produce a protein that pumps fusaric acid out of the cell, but only when fusaric acid is present. The gene that codes for this protein is the fusaric acid-resistance gene.
This gene has a promotor. The transcription of the promotor (and the resistance gene) is influenced by a regulatory protein, coded for by a regulator gene.

Figure 4 shows four ways in which this promotor could be regulated.

figure 4



8(2p) Which image shows the way in which the resistance gene in BananaGuard bacteria are only activated when fusaric acid is present?

A image 1

B image 2

C image 3

D image 4

The students inserted a gene construct in *P. putida* that contains a detection unit for fusaric acid, and a few genes that code for substances that inhibit fungal growth.
The BananaGuard bacteria only produce fungal inhibitors when they detect fusaric acid in the soil.

9(2p) Explain why this delayed production of fungal inhibitors is important for an ecosystem such as a banana plantation.

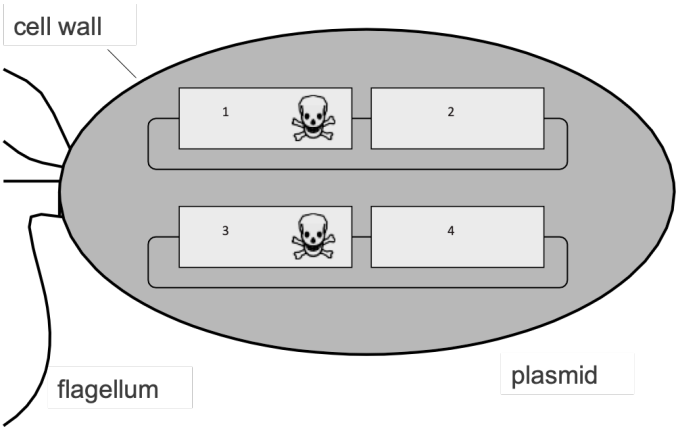
The Wageningen students want to rule out the risk that the gene construct ends up in other soil bacteria through the exchange of plasmids between bacteria.

For this reason they have designed a “toxin—anti-toxin” construct that is inserted in two separate plasmids per BananaGuard bacterium. One of these plasmids also contains the gene construct that protects against *F. oxysporum*.

They use the genes that code for the toxins *Zeta* (Z) and *Kid* (K) that are lethal to bacteria, plus a gene for an anti-toxin that neutralizes Zeta (anti-Z) and a gene for an anti-toxin against Kid (anti-K).

The four locations where these genes are inserted, are indicated with numbers in figure 5.
The genes for both anti-toxins are ‘on’, causing a repression of the expression of the corresponding toxins in the BananaGuard bacteria.

figure 5



A smart combination of the four genes, divided over two plasmids per bacterium, allows the BananaGuard bacteria to be effective against the fungi, while the risk of spreading the gene construct to other soil bacteria is minimized.

10(2p) Which of the following combinations of genes per plasmid minimizes this risk?

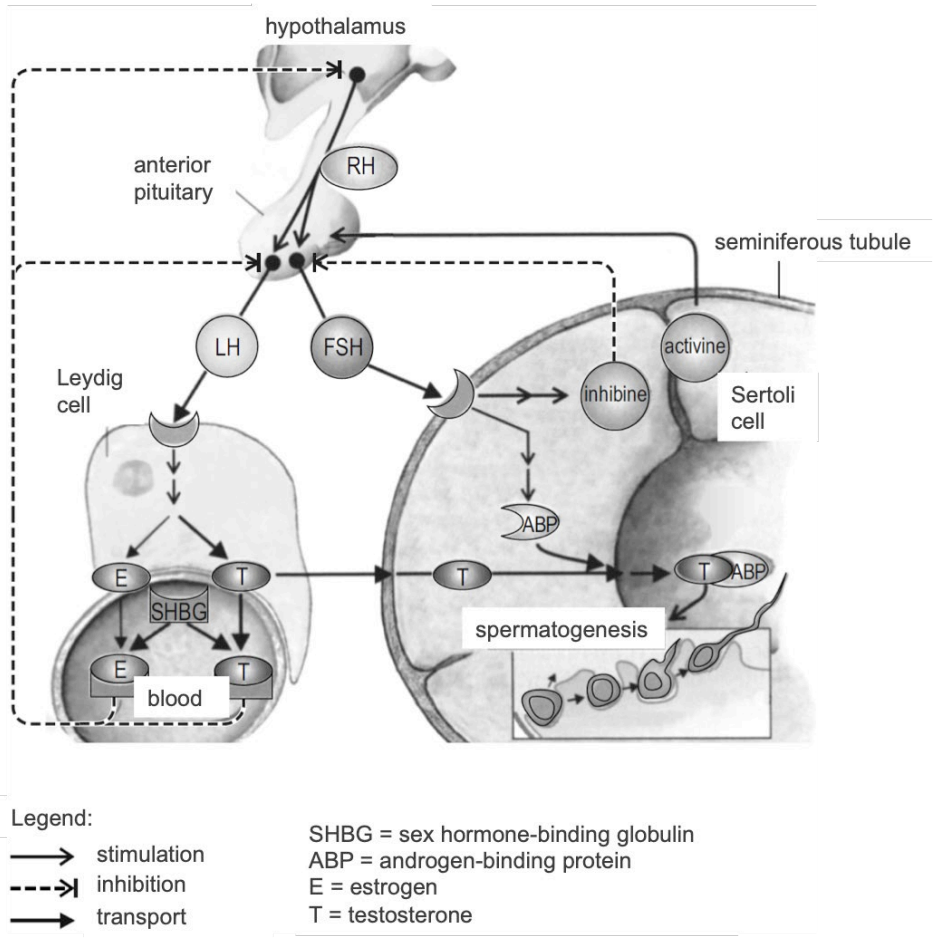
	locations 1 + 2:	**locations 3 + 4:**
A	Z + K	anti-Z + anti-K
B	Z + anti-K	K + anti-Z
C	Z + anti-Z	K + anti-K

Bone Determines Fertility

American research has shown that the cause for infertility due to insufficient spermatozoa in the semen may lie in the bones and not in the testes.

For healthy sperm cell production (spermatogenesis) a high concentration of androgens, such as testosterone, is important. Figure 6 shows how the pituitary hormones LH (sometimes called ICSH) and FSH influence spermatogenesis in the testes. Androgens bound to ABP are transported to the lumen of the seminiferous tubule and stimulate spermatogonia to divide. When a man produces too little androgens, it can lead to bone loss (osteoporosis).

figure 6



In order to preserve fertility, it is necessary for spermatogonia to divide through mitosis and not through meiosis.

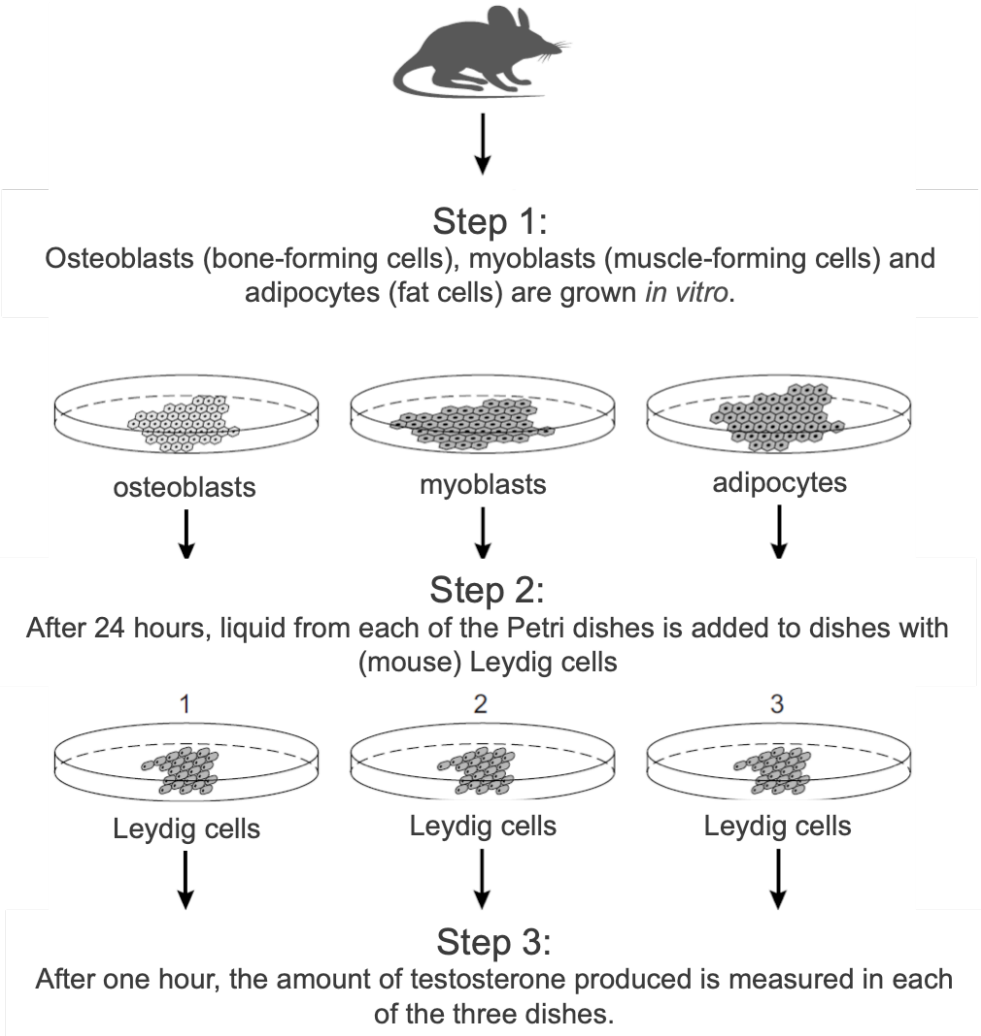
11 (2p) Explain why.

Some men use testosterone to improve bone density. This can disturb natural regulatory mechanisms, which may lead to infertility.

12(2p) Explain how extra testosterone may cause infertility in men. In your explanation, use the feedback process and its effect on Sertoli cells.

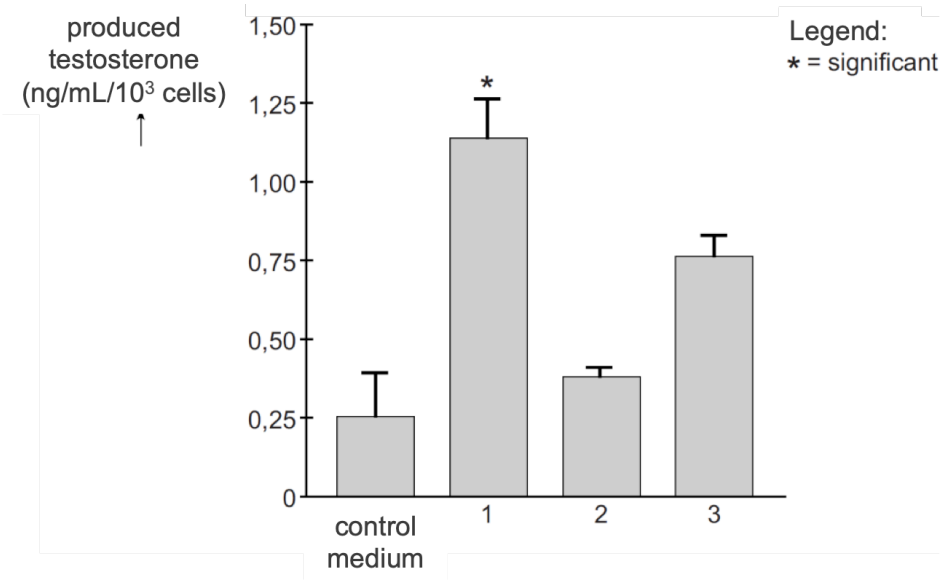
Bone hormones in turn may have an effect on the sexual organs and on fertility. A team of researchers investigated this using mouse cells. The experimental setup is depicted in figure 7.

figure 7



The results of the measurements, also from the control dish, are presented in figure 8.

figure 8



Two statements were made about the interaction between bone cells and Leydig cell in the testes:

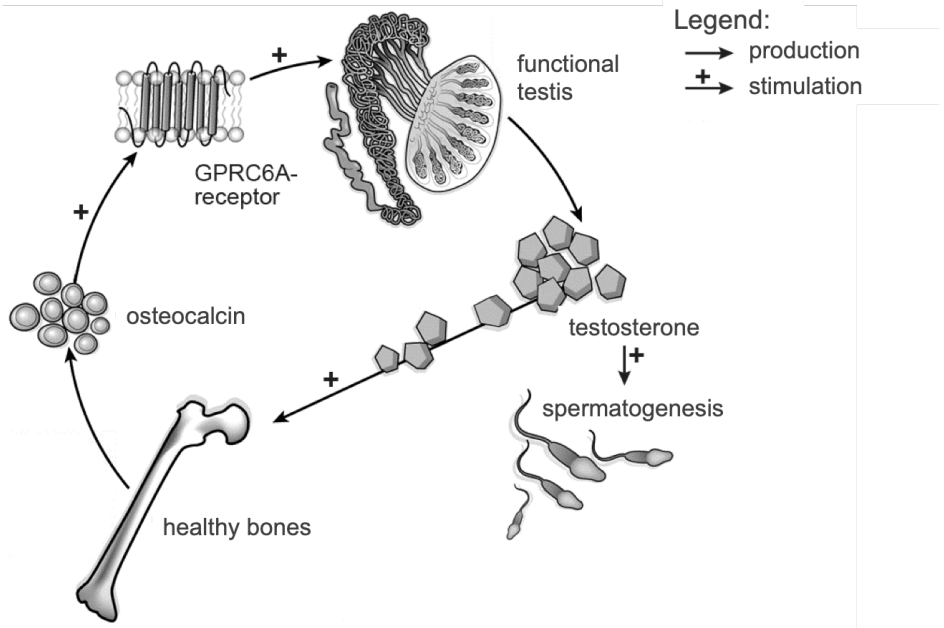
1 Leydig cells release testosterone, which stimulates osteoblasts.
2 Osteoblasts release a compound that stimulates the release of testosterone by Leydig cells.

13 (2p) Which of these statements is supported by the experiments?

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

The researchers' hypothesis is that the hormone osteocalcin, produced in the bones, affects the fertility of male mice.
Figure 9 shows the interaction between testes and bones in a simplified diagram.

figure 9



Osteocalcin affects the testes by binding to the receptor GPRC6A (see figure 9) on Leydig cells. Testosterone affects the osteoblasts in bone by binding to the testosterone receptor.

14(2p) – Is osteocalcin a peptide hormone or a steroid hormone?
– Where in the osteoblasts is the testosterone receptor located?

	osteocalcin is a	**location of testosterone receptor**
A	peptide hormone	cell membrane
B	peptide hormone	cytoplasm
C	steroid hormone	cell membrane
D	steroid hormone	cytoplasm

Testing for Sickle Cell Disease

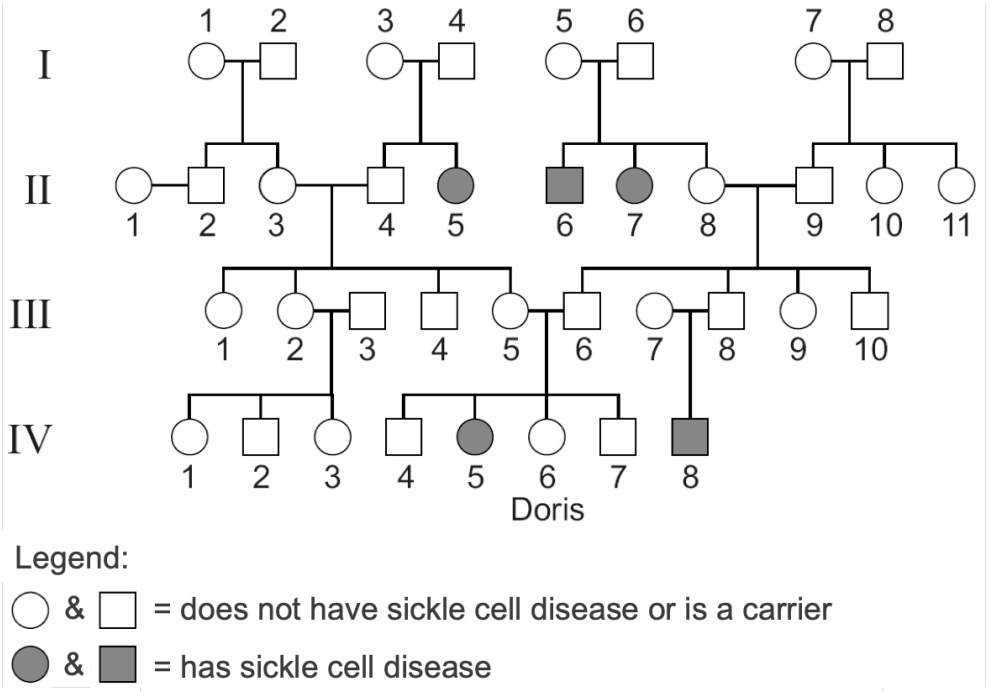
Sickle Cell Disease is a red blood cell disorder. The gene for this disease is autosomal recessive and is caused by a point mutation in the beta-globin gene.

figure 10

In the Netherlands, sickle cell disease is most common among people originating from the Antilles and from Suriname.
Expecting parents can have themselves tested to find out if they carry the gene.

In Doris' family no-one has sickle cell disease. Her family's pedigree is shown in figure 11. Doris does not have the disease, but she believes she could be a carrier.

figure 11



15(1p) How can be deduced from the pedigree that the gene for sickle cell disease is **not** located on the X chromosome?

Doris is person IV-6 in the pedigree (see figure 11).

16(2p) Based on the information shown in the pedigree, what is the probability (rounded to a whole percentage) that Doris carries the allele for sickle cell disease?

A 14%
B 25%
C 33%
D 67%
E 75%

Figure 12 shows part of the coding strand of the normal beta-globin gene, and underneath the same part of the mutated gene.

figure 12

normal beta-globin DNA	**5' GTG CAC CTG ACT CCT GAG GAG 3'**
sickle cell beta-globin DNA	**5' GTG CAC CTG ACT CCT GTG GAG 3'**

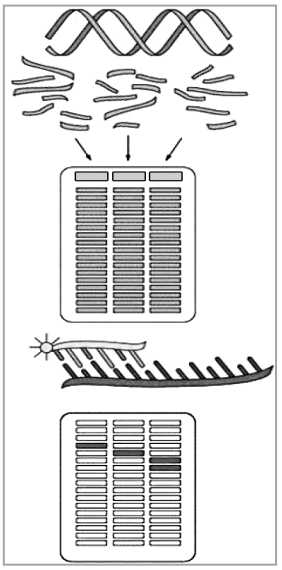
Normal hemoglobin is soluble in the cytoplasm. When there is little oxygen present, the defective hemoglobin forms long chains of insoluble hemoglobin polymers, which gives the red blood cell its distinctive sickle shape. Sickle-shaped blood cells are less flexible and can clog up capillaries in many organs. When this happens, it is called a 'crisis' and it is very painful for sickle cell patients.

A test can show whether you carry the gene for sickle cell disease. There are several kinds of tests available, such as a hemoglobin investigation (Hb phenotyping) or a DNA investigation. Sometimes DNA fragments are amplified prior to a test.

17(2p) – Why is the DNA amplified first?
– What is the name of the technique used to amplify DNA?

Doris had a DNA test done that used restriction enzymes. Restriction enzymes cut DNA at certain nucleotide sequences. Figure 13 shows how such a DNA test is done.

figure 13



1 DNA is isolated from white blood cells.

2 Restriction enzymes cut the DNA.

3 DNA fragments are separated based on their size.

4 A radioactive probe (a piece of DNA to recognize a specific DNA fragment) is added.

5 Specific fragments are made visible.

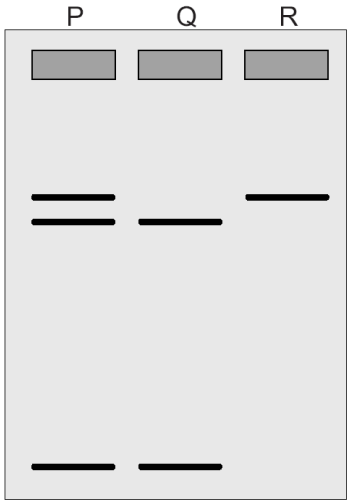
In this DNA test the restriction enzyme MstII is used.
In the mutated sickle cell beta-globin DNA, one of the MstII cutting sites is missing.

Restriction enzyme MstII recognizes the nucleotide sequence 5'-CCTNAGG-3' (where N can be any nucleotide) and cuts in between C and T within this sequence.

18(2p) Show how MstII cuts in the hemoglobin gene, by following these instructions:
- Copy the coding strand of the normal beta-globin DNA from figure 12 and add the complementary strand to this.
- Indicate, by drawing a line, how MstII cuts this DNA fragment in two.

In addition to analyzing Doris' DNA fragment, the test also uses DNA from a healthy person and from someone with sickle cell disease. Figure 14 is the test result of these three DNA samples, indicated with P, Q and R.

figure 14



The DNA test shows that Doris indeed carries the gene for sickle cell disease.

19(2p) Which pattern of bands belongs to Doris?

A pattern P
B pattern Q
C pattern R

HPV Vaccination

Cervical cancer is a type of cancer that is relatively common in women. The disease can be caused by an infection with Human Papilloma Virus (HPV). Sooner or later almost all women contract this virus. HPV is usually transmitted sexually. The infection usually does not cause any problems, but some types of HPV can cause cervical cancer. Vaccinating teenage girls against HPV is an effective way to prevent cervical cancer at a later age. Available vaccines against HPV protect against several HPV strains. HPV16 and HPV18 together cause about 70 procent of all cases of cervical cancer in Europe. In 2009, the first girls were vaccinated against HPV.

The vaccine with which the girls are injected, protects against HPV18, among other HPV strains.

20 (2p) What makes up the active component of the vaccine against HPV18?

A HPV18 RNA
B an effective immunoglobulin against HPV18
C HPV18 coat protein

21 (2p) Which cells in the immune system will respond to the vaccine by forming antibodies?

A B lymphocytes
B cytotoxic T cells
C T helper cells

It was decided that only girls will be vaccinated at first.

22 (2p) - Provide a biological argument why boys are not vaccinated against HPV.
- Provide a biological argument why it would be better to vaccinate boys too.

Carcinogenic (cancer-causing) HPV takes control of the host cell with six of its own genes. One of these genes codes for protein E6. This is a protein that inhibits the host cell's tumor suppressor genes. These tumor suppressor genes cause the cell cycle to stop and apoptosis (programmed cell death) to start, when there is DNA damage.

When a girl contracts HPV, the infection can lead to cervical cancer at a later age.

23(2p) - Explain how an HPV infection of cervical cells can lead to the development of cervical cancer.
- Provide an explanation for the fact that cervical cancer usually only develops at a later age.

The vaccine against HPV 'Cervarix' is produced in insect cells, and uses as a vector a transgenic baculovirus (with double-stranded DNA). The insect cells used for producing the vaccine must meet certain requirements.
Potential characteristics of cells are:

1 can be kept alive *in vitro* (outside the body);
2 produce antibodies *in vitro*;
3 produce antigens *in vitro*.

24(2p) Which of these characteristics should cells possess to be suitable for vaccine production?

A 1 and 2 only
B 1 and 3 only
C 2 and 3 only
D 1, 2, and 3

Heart Surgery

In the Western world, heart failure is a major health issue. Heart failure is a general term used for any disease in which the heart pump functions insufficiently. About one third of all deaths in the Netherlands are caused by cardiovascular diseases.

Certain physical symptoms, such as atherosclerosis and thrombosis, indicate an increased risk of heart failure. When a coronary artery is narrowed or clogged, bypass surgery can restore blood flow to the heart muscle tissue. Another blood vessel is then used for the bypass. Thanks to the bypass, heart tissue behind the narrowed coronary artery is again supplied with a sufficient amount of blood.

A heart attack can be caused by a combination of atherosclerosis and thrombosis.

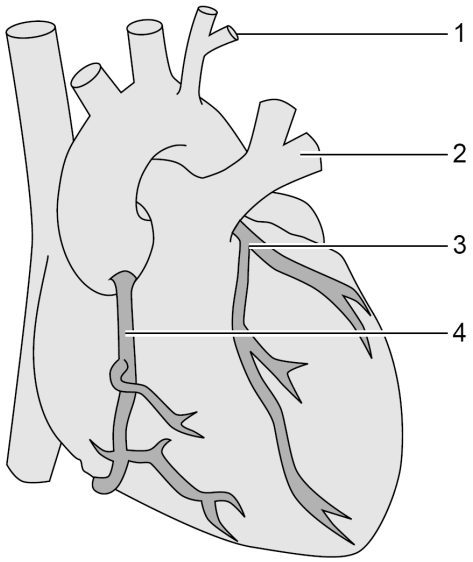
25 (3p) Describe how these risk factors together can cause a heart attack.

Different types of blood vessels are used for bypass surgery. Traditionally, leg veins were used. These days, chest wall arteries are often used. Leg veins are useful because they are very long. In addition, the vein can be easily removed from a leg. But a disadvantage is that atherosclerosis can easily develop in a bypass created from a leg vein, even when the valves are removed. For this reason, arteries (usually the left chest wall artery) started to be used as bypasses a few decades ago.

26 (1p) Name another advantage of using an artery (as opposed to a vein) as a bypass.

Figure 15 indicates four locations.

figure 15



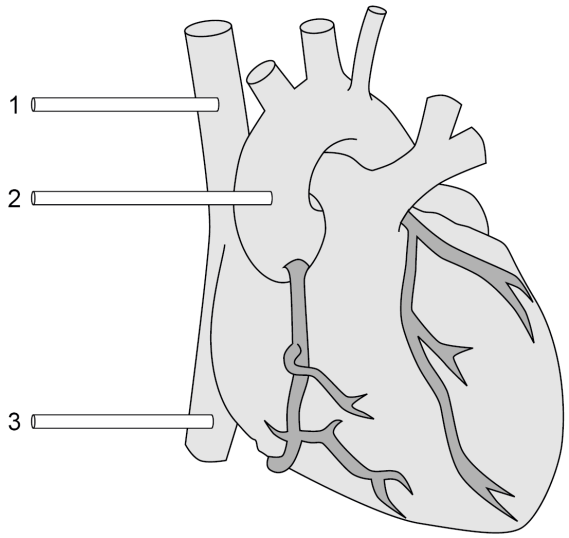
A patient with a narrowing in the upper right coronary artery gets a bypass from the left chest wall artery.

27 (2p) Between which parts is this bypass placed?

A between 1 and 2
B between 1 and 3
C between 1 and 4
D between 2 and 3
E between 2 and 4
F between 3 and 4

During bypass surgery, a patient's blood is led through a "heart and lung machine" (cardiopulmonary bypass). The machine temporarily takes over the function of the heart and lungs: a pump keeps the blood moving, blood pressure and blood temperature are maintained, and O_2 is added and CO_2 is removed. The heart is connected to the machine with three tubes. Figure 16 shows a heart with the locations of these three tubes.

figure 16



28(2p) Through which tube(s) does blood move toward the "heart and lung machine"?

A through 1 only
B through 2 only
C through 3 only
D through 1 and 2
E through 1 and 3
F through 2 and 3

When a patient is connected to a "heart and lung machine", the blood is led to and from the machine through plastic tubes. Prior to surgery, the patient is treated with heparin, a medicine that inhibits formation of the thrombokinase enzyme. After surgery, protamine is administered, which is an antagonist to heparin.

29(2p) - Why is it necessary to administer heparin?
- Why should protamine be administered immediately after surgery?

Laughing Muscles

Laughing is usually done in response to a funny situation or a joke. But reading words such as ‘laughing’ and ‘funny’ can also stimulate the laughing muscles. Conversely, when muscles are in the laughing position, a situation is more readily considered funny. Laughter therapy, which aims to reduce stress, makes use of this principle.

The most important laughing muscle is the large cheekbone muscle *Zygomaticus major* (see figure 17). When this muscle contracts, the corner of the mouth is pulled up.

figure 17

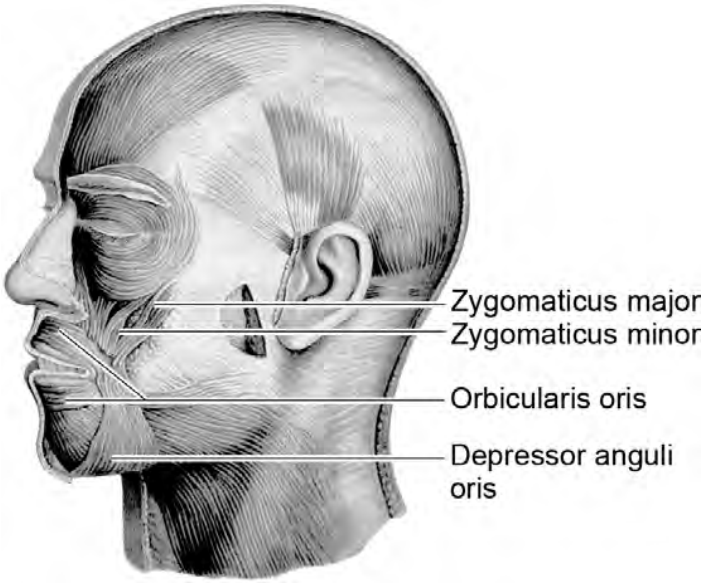


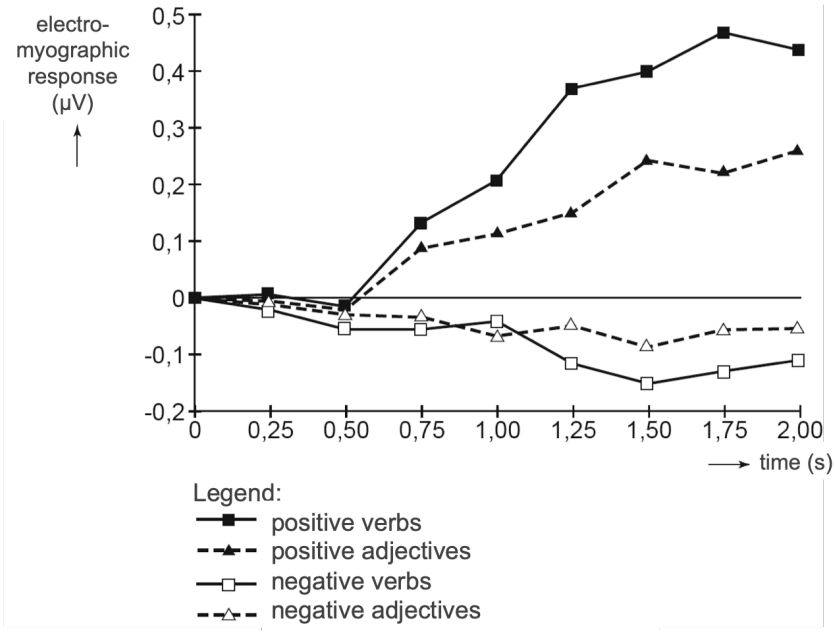
Figure 17 shows three other muscles around the mouth.

30 (2p) Which of these muscles is the antagonist of Zygomaticus major?

A Zygomaticus minor
B Orbicularis oris
C Depressor anguli oris

Social psychologists Foroni (Utrecht University) and Semin (Free University Amsterdam) had test subjects read verbs and adjectives that are related to a positive emotion (‘laughing’ or ‘happy’) or a negative emotion (‘crying’ or ‘sad’). At the same time they measured changes in the electrical activity in the Zygomaticus major muscle. The results of this investigation are shown in figure 18. At time = 0 s, the test subjects read a word.

figure 18



The investigation shows that after reading positive verbs and positive adjectives, the activity in the Zygomaticus major muscle increased.

31 (1p) Provide another conclusion you could draw from this investigation regarding **positive** words.

The Zygomaticus major muscle consists of a specific type of muscle tissue. Some characteristics of muscle tissues can be:

1 the muscle cells are fused together to form muscle fibers;
2 the muscle fibers have side branches;
3 under the microscope transverse lines (striations) are visible.

32 (2p) Which of these characteristics apply to the muscle tissue of the Zygomaticus major muscle?

A 1 and 2 only
B 1 and 3 only
C 2 and 3 only
D 1, 2 and 3

After you have had the giggles for a long time, your laughing muscles may lack oxygen. Due to the formation of lactic acid, ATP from glycolysis can be used to contract the laughing muscles despite the oxygen deficiency.

33(2p) Which process enables the formation of ATP in this situation?

A The NAD^+ deficit is resolved by reduction of lactic acid.

B The NAD^+ deficit is resolved by reduction of pyruvic acid.

C The $NADH,H^+$ deficit is resolved by oxidation of lactic acid.

D The $NADH,H^+$ deficit is resolved by oxidation of pyruvic acid.

Muscle acidification can stimulate oxygen release from the blood. There are two explanations for this:

1 When blood gets more acidic, this equilibrium $Hb + O_2 \leftrightarrows HbO_2$ moves to the left;

2 A low blood pH causes an increased breathing frequency, so more oxygen is supplied.

34(2p) Which of these explanations is correct?

A neither

B 1 only

C 2 only

D both

The slogan ‘Laugh and you’re happy’ is the basis of laughter therapy. In this kind of therapy, you consciously laugh with the aim of feeling better.

35(2p) – From which part of the cerebrum do the impulses originate that direct the laughing muscles?

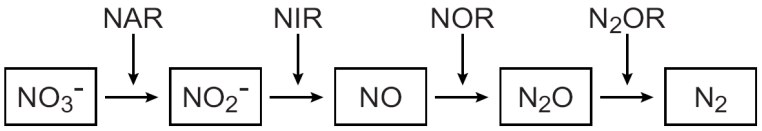
– In which part of the cerebrum do the impulses end that register that you are laughing?

Fertilizers and Bacteria

Adding fertilizer to farmland can lead to an increased emission of laughing gas (N_2O). That is harmful to both the farm and the environment, because the emitted nitrogen can no longer benefit the crops. Laughing gas is formed through denitrification by certain bacteria and fungi.

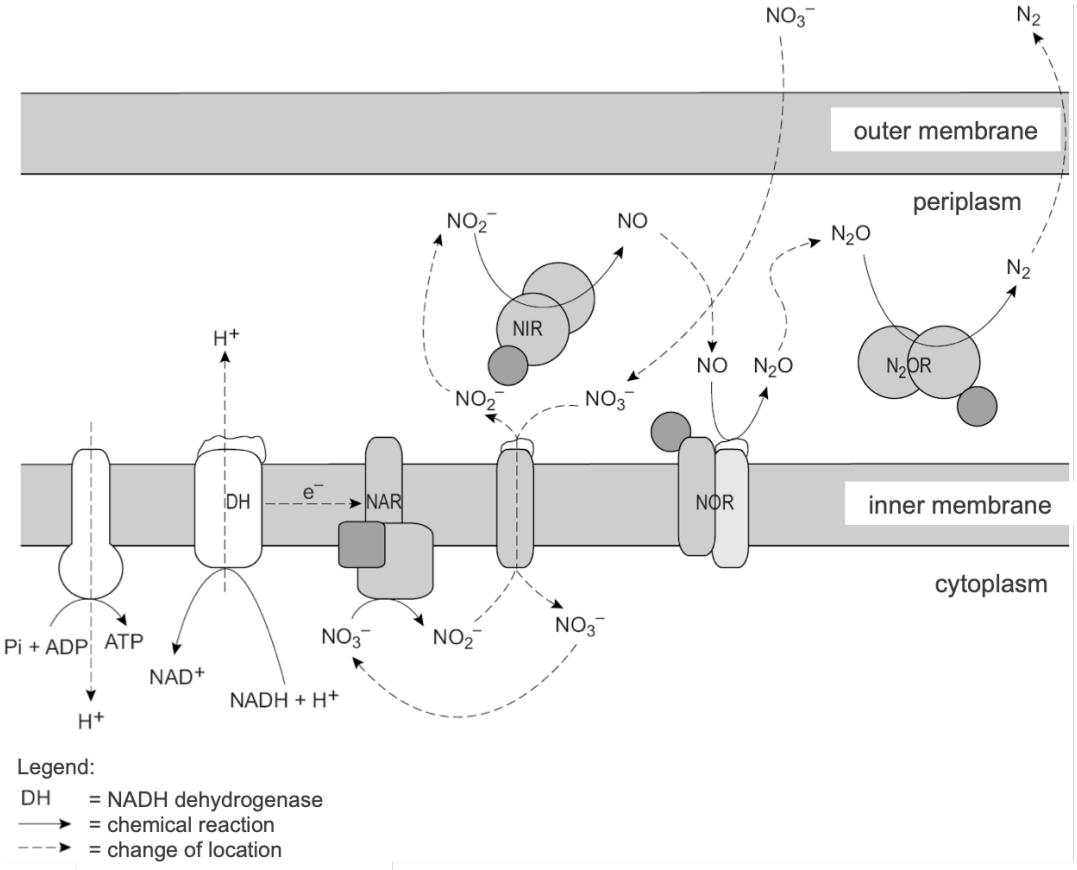
Bacteria, such as *Pseudomonas stutzeri,* can reduce nitrate to N_2, according to the reaction scheme depicted in figure 19. The chemical reactions in these bacteria are catalyzed by enzyme complexes NAR, NIR, NOR and N_2OR.

figure 19



During the reduction of nitrate by certain bacteria, electrons from NADH are passed to several enzymes. This happens on the inner cell membrane and the enzyme complex is called the ‘nitrate electron transport chain’ (see figure 20). The electrons eventually end up in N_2, in between the inner and outer membrane (periplasm) of these bacteria.

figure 20



36(2p) Explain, using figure 20, how the enzyme NADH dehydrogenase helps release energy in these bacteria.

Bacteria and fungi with a nitrate electron transport chain that lacks enzyme complex NIR, could be assisted in their energy supply by the proximity of other microorganisms.

37(2p) Which group of microorganismen could do that, and in which way would they help?

A nitrate bacteria, they convert nitrate to nitrite
B nitrate bacteria, they convert nitrite to nitrate
C nitrite bacteria, they convert nitrate to nitrite
D nitrite bacteria, they convert nitrite to nitrate

figure 21

An alternative to distributing nitrogen compounds is fertilizing farmland with green manures: leguminous plants with root nodules (see figure 21) are grown and ploughed under.
This is generally considered a more sustainable way to fertilize land.

38(2p) Explain how green manures can increase the yield on farmland.

39(1p) Why are green manures generally considered a more sustainable way to fertilize land than distributing chemical fertilizer containing nitrogen compounds?