

Maturprüfung 2019

Biologie SPF (immersiv)

Hiermit bestätige ich anhand des mir vorgelegenen Exemplars, dass die Prüfung korrekt und mit allen Unterlagen versehen, ausgefertigt ist.

Klasse / Kurs: 4e_B

Anzahl Seiten
(ohne Deckblatt): 18

6.5.19 
Datum, Unterschrift

Inhalt:

- A Respiratory organs and cell metabolism [20]
- B Blood circulatory system, lymphatic system and human organs [34]
- C Immune system and infectious diseases [14]
- D Inheritance [24]
- E Molecular genetics [23.5]
- F Evolution, systematics and ecology [21]
- G Reproduction and embryology [11]
- H Hormone system, nervous system and eye [23]

Anweisungen/ Erläuterungen: Write / draw your solutions onto the printed test sheets only if **explicitly requested**. All other answers should be written onto the supplied **blank** sheets. **Start a new page for each part of the exam (A–H)**. Please write your name and class on each of these sheets.

Prüfungszeit 13:30 to 17:30

Hilfsmittel: Pens
Pencils (for drawings only), eraser

Bewertung: The number of marks that can be obtained are indicated in square brackets in the subheadings. The grade is based on the total of marks obtained in all parts (A–H). The grade 6 does not require the maximum number of marks.

Bevor Sie mit dem Lösen der Aufgaben beginnen, kontrollieren Sie bitte, ob die Prüfung gemäss obiger Aufstellung vollständig ist. Sollten Sie der Meinung sein, dass etwas fehlt, melden Sie dies bitte **umgehend** der Aufsicht.

A Respiratory organs and cell metabolism [20]

A1 Activated sludge treatment

In sewage treatment plants, the activated sludge tanks are intensively aerated, e.g., by continuously pumping compressed air through it.

- a Why is air pumped in? In your answer, also describe the consequences for sewage treatment if the tank would not be aerated. [4]
- b With which physical process do the bacteria in activated sludge tanks absorb the oxygen? [1]
- c In most organisms, the route of oxygen from the environment to the cells in which the oxygen is consumed is more complex than in bacteria. Compare the path of oxygen from the environment to the cells between flatworms, insects and fish. Mention in your response the organs involved in oxygen transport and the physical processes required. [6]

A2 Oxygen saturation of haemoglobin

Figure A1 shows the oxygen dissociation curves of mammalian haemoglobin at two different temperatures (at 36 °C and at 40 °C).

- a Determine the oxygen saturation of haemoglobin at 40 °C and an oxygen partial pressure of 4 kPa from the graph. [1]
- b Blood that is fully (100%) saturated with oxygen carries 105 cm³ of oxygen in 1 litre of blood. Calculate the volume of oxygen released from 1 litre of blood when blood that has become 90% saturated at 36 °C reaches a part of the body where the temperature is 40 °C and the partial pressure of oxygen is 4 kPa. Show your working. [2]
- c Explain why it is beneficial for the relationship between oxygen partial pressure and oxygen saturation to be sigmoid ("S-shaped") rather than linear (cf. dashed line in figure 1A). [4]
- d Why is the effect of temperature on the oxygen dissociation curve of haemoglobin advantageous for mammals, especially during physical exercise in a cool air environment? [2]

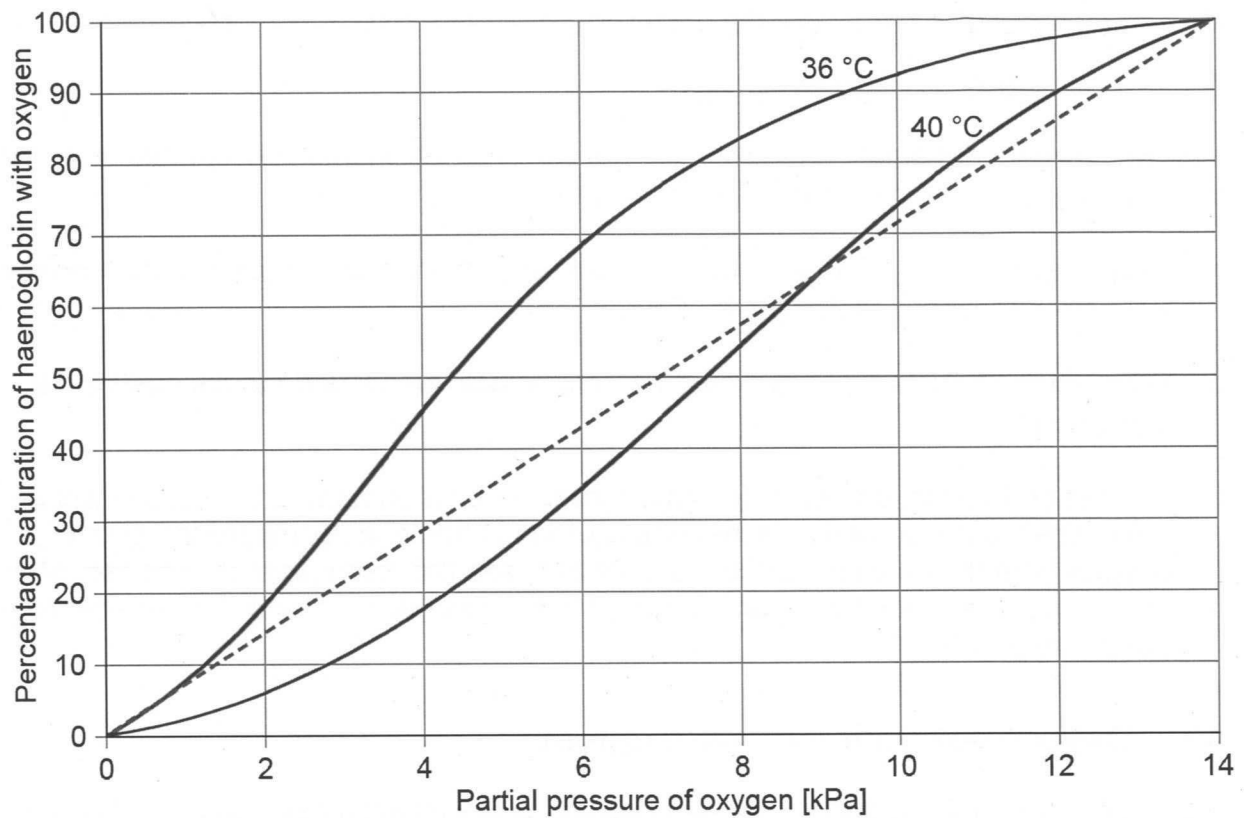


Fig. 1A Solid lines: Actual relationship between partial pressure of oxygen in the immediate surrounding and the degree of oxygenation of mammalian haemoglobin at two different temperatures.
Dashed line: hypothetical linear relationship between oxygen partial pressure and degree of oxygenation.

B Blood circulatory system, lymphatic system and human organs [34]

B1 The beating heart

- a The heart is often described as a suction pump [Saugpumpe]. Explain why this term is appropriate for the way the heart works. [2]
- b In which heart chamber is the maximum pressure higher, in the left or in the right? Briefly explain your answer. [1]
- c Which of the following statements are correct? Briefly explain the statements you have found to be correct. [3]

The systolic blood pressure ...

- 1 ... is lower than the diastolic blood pressure;
- 2 ... is higher than the diastolic blood pressure;
- 3 ... indicates the pressure in the veins close to the heart;
- 4 ... indicates the pressure in the arteries close to the heart;
- 5 ... usually gets higher in old age;
- 6 ... usually gets lower in old age.

- c Figure 1B shows processes in the left half of the human heart. The upper curves (ventricular pressure and atrial pressure) are shown correctly. What's wrong with the red curve (ventricular volume)? What needs to be changed in the graph to be correct? [1]
- e Figure 1B does not show the pressure in the aorta. Draw the course of pressure changes in the aorta (measured at the level of the aortic arch) with a pencil directly into figure 1B. Explain your curve with reference to clearly distinguishable curve sections and the transitions between them. [3]

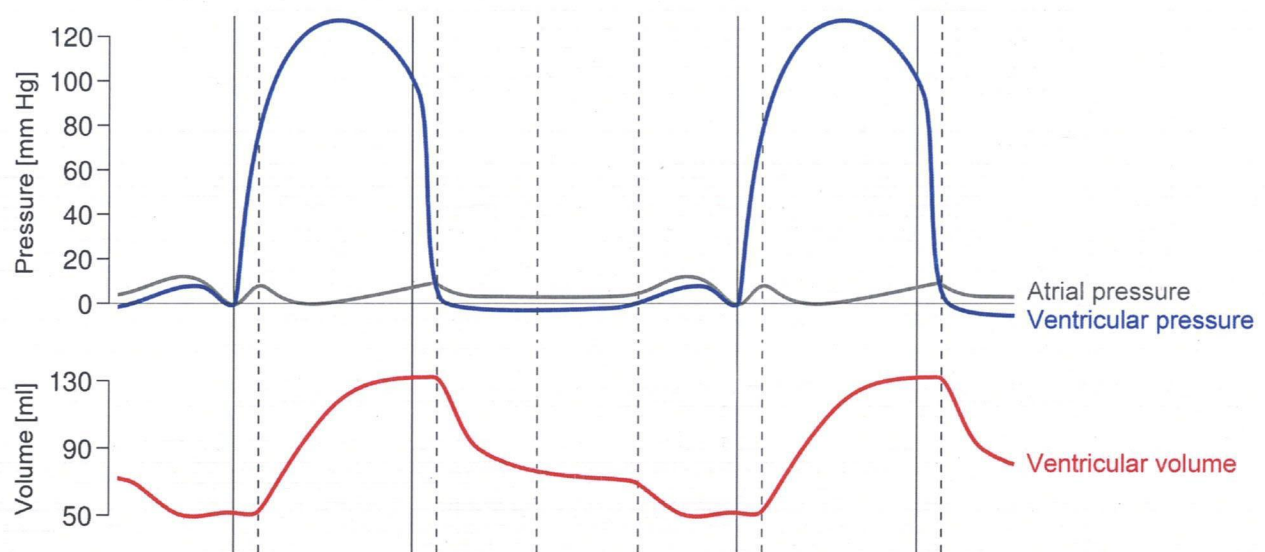


Fig. 1B Graphical representation of various processes in the left ventricle.

B2 Multiple choice questions on blood

Decide for each question, which of the five statements is the **correct or the most likely** one and enter the appropriate number in the **answer table** on the following page. [6]

- 1 What is **not** a function of the blood?
 - 1 transport of immune cells
 - 2 heat distribution
 - 3 oxygen transport
 - 4 regulation of propagation of nerve impulses
 - 5 nutrient transport
- 2 Haematocrit is the name given to ...
 - 1 the proportion of white blood cells in the blood
 - 2 the protein content of the blood
 - 3 the proportion of blood plasma in the blood
 - 4 the oxygen content of the blood
 - 5 the proportion of blood cells in the blood
- 3 Granulocytes can be recognized under the microscope by their cell nucleus which ...
 - 1 does not exist
 - 2 is round, dense and rarely indented
 - 3 is rod-shaped
 - 4 has different segments connected by bridges
 - 5 is divided into granules
- 4 After a serious accident, a patient desperately needs a blood donation at the scene of the accident. Her blood donation card only shows that she has blood type A. The doctor gives her a red blood cell concentrate with blood type ...
 - 1 AB Rh-positive
 - 2 A Rh-positive
 - 3 B Rh-negative
 - 4 O Rh-positive
 - 5 A Rh-negative
- 5 Which of the following plays **no role** in blood clotting?
 - 1 fibrinogen
 - 2 thrombokinase
 - 3 thrombocytes
 - 4 erythrocytes
 - 5 blood type
- 6 Persons with a blood type including Rh-positive possess ...
 - 1 no antigens on the erythrocytes
 - 2 antigen R on erythrocytes
 - 3 no antigen D on the erythrocytes
 - 4 the antigen D on the erythrocytes
 - 5 anti-D antibodies in the blood plasma

- 7 The formation of blood cells ...
 - 1 starts in the bone marrow and continues in the blood
 - 2 starts with the differentiation of omnipotent stem cells in the bone marrow
 - 3 runs in the spinal cord and is controlled by special hormones
 - 4 is divided into the formation of erythrocytes and lymphocytes
 - 5 takes place mostly in the bone marrow

- 8 Erythrocytes are highly specialized for oxygen transport. This is shown by the fact that
 - 1 they have a very flat nucleus
 - 2 they have the shape of biconcave disks, offering a large surface for gas exchange
 - 3 each erythrocyte can bind four oxygen molecules
 - 4 they have a large number of mitochondria
 - 5 they get only 120 days old because of their high metabolic rate

- 9 A person who has blood type O, ...
 - 1 can donate blood plasma to all other people (universal donor)
 - 2 has erythrocytes with A and B antigens on the surface
 - 3 has blood plasma containing A and B antigens
 - 4 is less common in Switzerland than persons with blood type AB
 - 5 has blood plasma with anti-A and anti-B antibodies

- 10 Blood and lymph differ in that ...
 - 1 leukocytes and antibodies are found only in blood
 - 2 only blood can clot
 - 3 there are no blood cells at all in in the lymph
 - 4 the lymph, unlike blood, contains no dissolved substances
 - 5 the lymph contains no lymphocytes

- 11 Which complication **cannot** be caused by a thrombus?
 - 1 heart attack
 - 2 pulmonary embolism
 - 3 leukaemia
 - 4 stroke
 - 5 thrombosis

- 12 The formation of new erythrocytes by the hormone EPO (erythropoietin) is **not** triggered by ...
 - 1 heavy bleeding
 - 2 anaemia
 - 3 high fluid loss in a gastrointestinal disease
 - 4 a blood donation
 - 5 a stay for several days at high altitude

Answer table for task B2:

Question	1	2	3	4	5	6	7	8	9	10	11	12
Answer												

B3 Blood vessels

- Formulate a clear, short definition of 'capillary'. [1.5]
- Many textbooks speak of a double circulatory system. Explain what this means. [1]
- Explain why the development of the double circulatory system has been beneficial for the groups of animals that have it. [2]
- Name three important differences between veins and arteries and enter these in Table B3. [3]

Table B3 Differences between veins and arteries

Veins	Arteries

- Compile a legend for figure 2B, naming the parts of the blood circulatory system as specifically as possible. [3.5]

- A
- B
- C
- D
- E
- F
- G

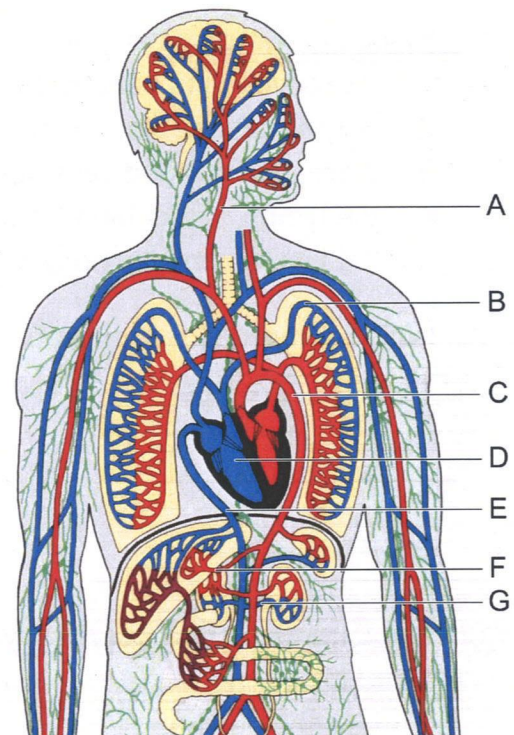


Fig. 2B Schematic representation of the human torso.

- Which organs does the portal vein connect to each other, which substances are (on average) over-represented in the portal vein compared to other blood vessels, and for which processes is the connection of the organs by the portal vein of particular importance? [4]
- Why is it important to deliver blood to the liver in two different ways? [2]
- What is wrong in the illustration of the hepatic capillary network in figure 2B? [1]

C Immune system and infectious diseases [14]

C1 Basics of immunobiology

Check the following statements for their correctness and tick (✓) accordingly the [T] (true) or the [F] (false). Correct incorrect statements by replacing **only the bold part** of the statement to make a meaningful and correct statement. A statement recognized as correct yields half a point, a recognized and correctly corrected false statement yields a whole point. Use the table below for your answers. [4.5]

- 1 Granulocytes are a kind of **leukocytes**.
- 2 All mature lymphocytes derived from the same stem cell are genetically **identical**.
- 3 In passive immunization, **attenuated [abgeschwächte] antigens** are administered.
- 4 Mast cells play a role in the **specific (adaptive)** immune response.
- 5 Without helper T cells, the body **cannot** produce antibodies.
- 6 After successful immunization, a pathogen can **no longer** invade the body and multiply there.

	corrected part of statement
1 [T] [F]	
2 [T] [F]	
3 [T] [F]	
4 [T] [F]	
5 [T] [F]	
6 [T] [F]	

C2 Active immunization (vaccination)

- a Name the two most important goals of vaccination from an epidemiological point of view. [2]
- b Describe the process of an effective vaccine against the influenza virus using the example of the B cells. Look at the contents of the vaccine, the primary immune response, and the secondary immune response, and describe how to recognize complete immunity. Use the correct technical terms. [6]
- c Under which conditions is it not possible to make effective vaccinations; in other words: what are the characteristics of pathogens of infectious diseases against which a vaccine does not make sense? Name an example. [1.5]

D Inheritance [24]

D1 Definitions

- a Explain 'homologous chromosomes' in one or two sentences. [2]
- b Explain the term 'heterozygous' using a specific example. [2]

D2 Spotted cows

A cow and a bull, both with a uniform brown fur have an offspring with spotted fur (having spots or not is a monogenic trait).

- a Which conclusions can you draw concerning the mode of inheritance and concerning the genotypes of the parent animals? [2]
- b What is the probability that another calf born to the same parent animals will be spotted? Explain your answer with the help of a Punnett square. [4]

D3 Pedigree

Figure 1D shows the pedigree of a family in which the **gonosomally** inherited disorders of red-green blindness and night blindness have occurred. Individuals 3, 9 and 15 come from families in which neither disorder has ever occurred; new mutations can be excluded.

- Determine and explain on the basis of the pedigree, how each of the two disorders is inherited (X-linked dominant, X-linked recessive or Y-linked). [5]
- Indicate the genotypes of individuals 1, 2, 4, 7, 8 and 17 using appropriate symbols. [3]
- When individual 5 has children with a partner who is neither affected nor a carrier, what is the probability that their children will be affected by red-green blindness? Explain your answer. [4]
- Only individual 17 is affected by both disorders. Which process must have occurred in which individual to be able to explain this phenotype? [2]

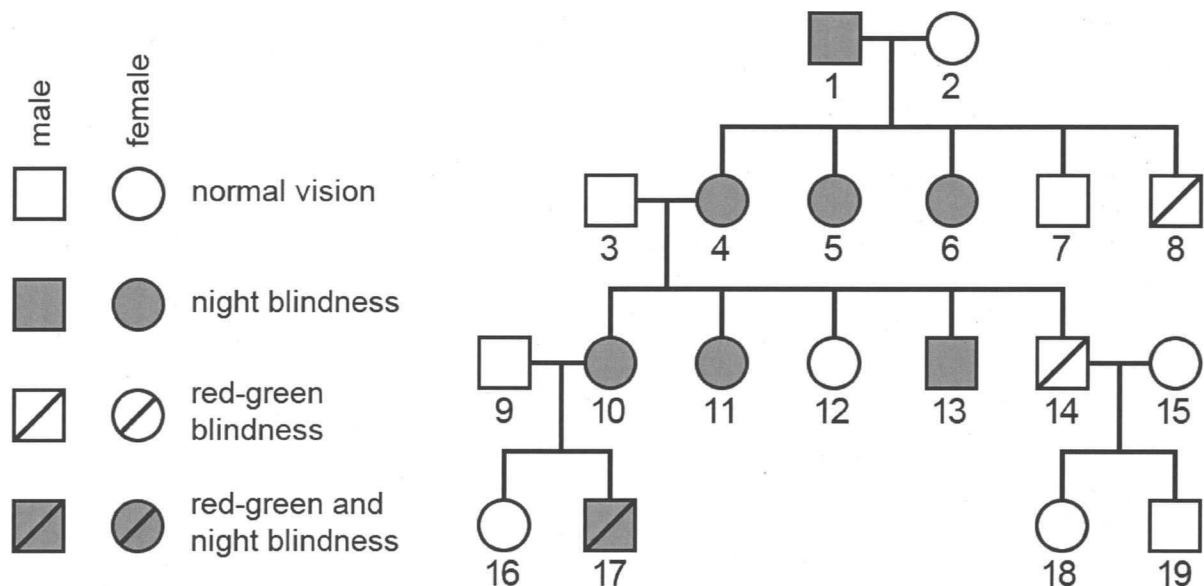


Fig. 1D Pedigree of a family with the phenotypes regarding night blindness and red-green blindness.

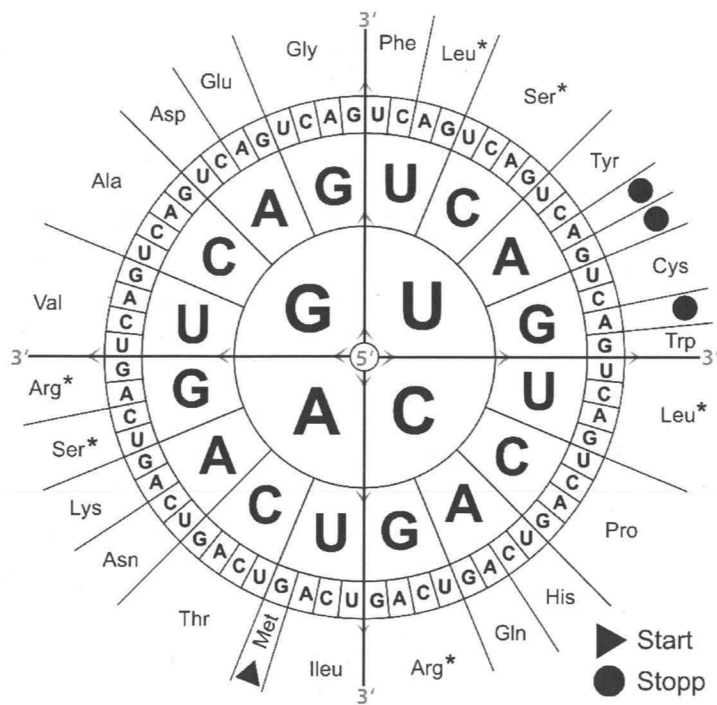


Fig. 2E Code table

E3 Mutations due to UV rays

UV rays lead to mutations in the DNA of yeast cells. Scientists wondered whether UV absorption by cytoplasmic proteins has an impact on this phenomenon. In two separate experiments, the UV absorption spectrum of DNA and that of proteins, and in a third experiment, the mutation rate in yeast cells was determined as a function of the wavelength of the UV radiation. The results of the three experiments are shown in figure 3E.

On the basis of the results, try to derive an answer to the question of the scientists and explain the result, taking into account the structure of the cells. [4]

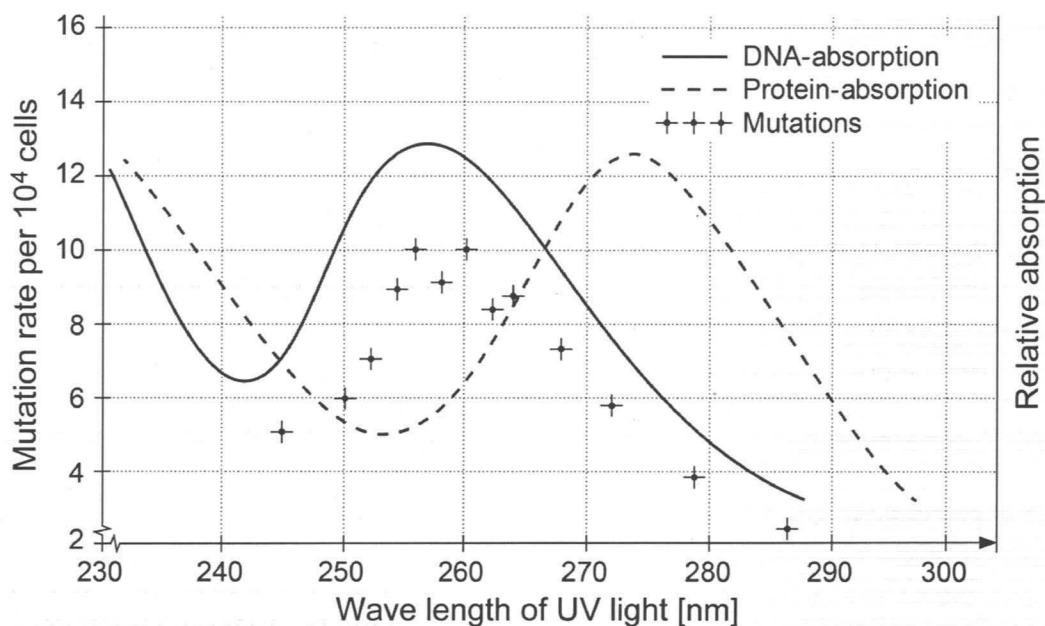


Fig. 3E Absorption of DNA and of proteins, as well as mutation rates of yeast as a function of the wavelength of the UV light.

E4 PCR (Polymerase Chain Reaction)

- a Name two important areas of application of PCR. [1]
- b In PCR, a special polymerase is used: the Taq polymerase. What is special about this polymerase and why is it used in PCR? [2]

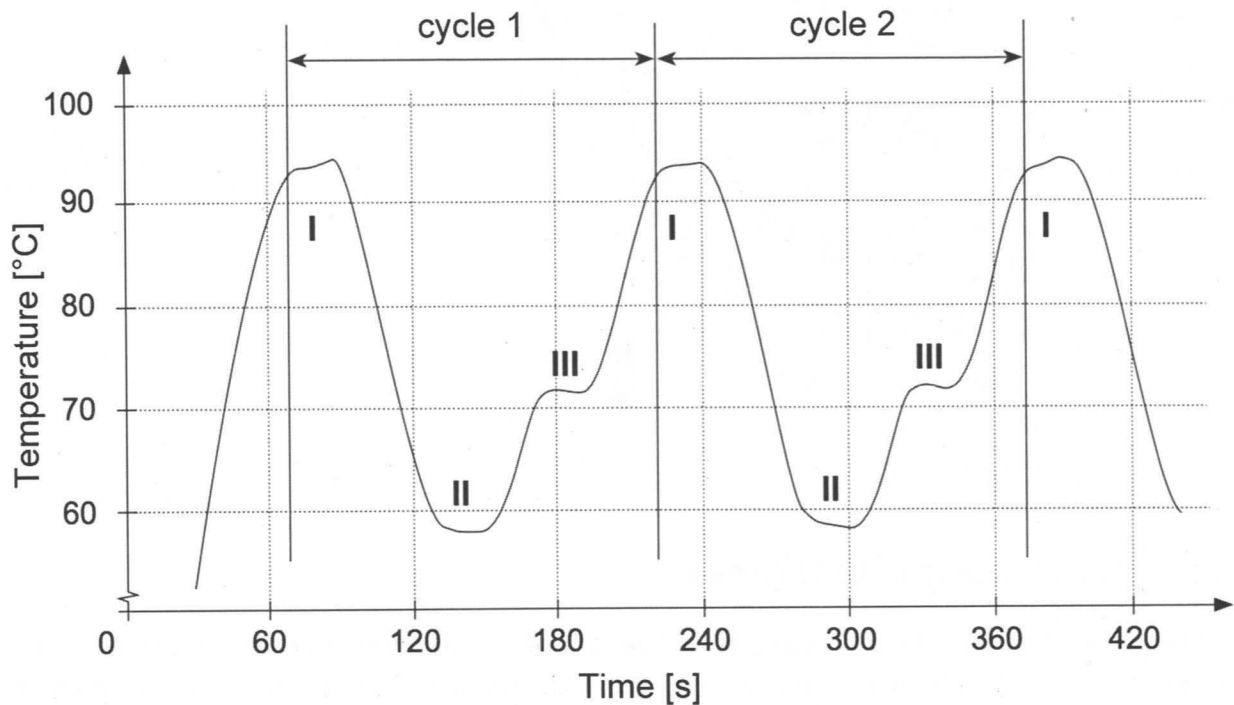


Fig. 4E Temperature changes during PCR

- c Figure 4E shows the temperature profile of a typical PCR cycle. Name the phases I, II and III of the PCR. [1.5]

Phase I:

Phase II:

Phase III:.....

- d Describe below what happens in phases II and III. [2]

Phase II:

.....

Phase III:

.....

F Evolution, systematics and ecology [21]

F1 terms

- a Define the term 'homology' (in the context of evolution) in one sentence. [1]
- b Name an example of a homologous pair of features in two distantly related vertebrates. [1]
- c Name an example of an analogous pair of features in two distantly related vertebrates. [1]

F2 The oldest insect

In 2004, American scientists assigned *Rhyniognatha hirsti*, a hitherto inaccurately determined fossil from the red sandstone of Scotland, to insects. This makes it the oldest known insect and, because of its derived characteristics that it shares with winged insects, suggests an origin of insect wings in the Devonian, more than 400 million years ago.

- a *Rhyniognatha hirsti* looks very similar to a mayfly and was assigned to the insects by the scientists because of the mandible (mouth part) structure. Name and describe the species concept this assignment is based on? [2]
- b Name 4 external characteristics of insects. [2]
- c We can assume that the early flying insects could not fly very fast. Now, there are insects such as certain large dragonflies, which can reach speeds of up to 100 km/h when hunting other insects. Explain how the dragonflies evolved the ability to fly so fast according to the theory of Lamarck, as well as according to the theory of Darwin. [4]

F3 Earless lizards in New Mexico

In a National Park in New Mexico there is a desert landscape with white gypsum dunes, the so-called White Sands, as well as scrubland [Buschland] areas with darker ground. There are two colour morphs of earless lizards, one light and one dark. The distribution of light and dark colour morphs of the earless lizards was studied in this National Park (table 1F).

	White Sands	Scrubland
Frequency of light individuals	89%	1%
Frequency of dark individuals	11%	99%

Table 1F Frequency of light and dark earless lizards in different locations

- Explain why in both sites, one of the colour morphs is much more common than the other morph. [2]
- In this National Park, it was investigated whether there is a genetic exchange between earless lizards in different locations. These were individuals trapped at five locations A to E. Seven individuals came from the White Sands (three from site A and four from site B), and eight from the scrublands (two from site C, and three from sites D and E respectively). Using a comparison of DNA sequences, a kinship [Verwandschaft] tree was drawn (figure 1F). Explain why a kinship tree can be created using DNA sequences. [2]
- Study the kinship tree and summarize how closely related the individuals are within and between sites. [3]
- Describe possible causes for the different degrees of kinship among individuals between sites A to E. [3]

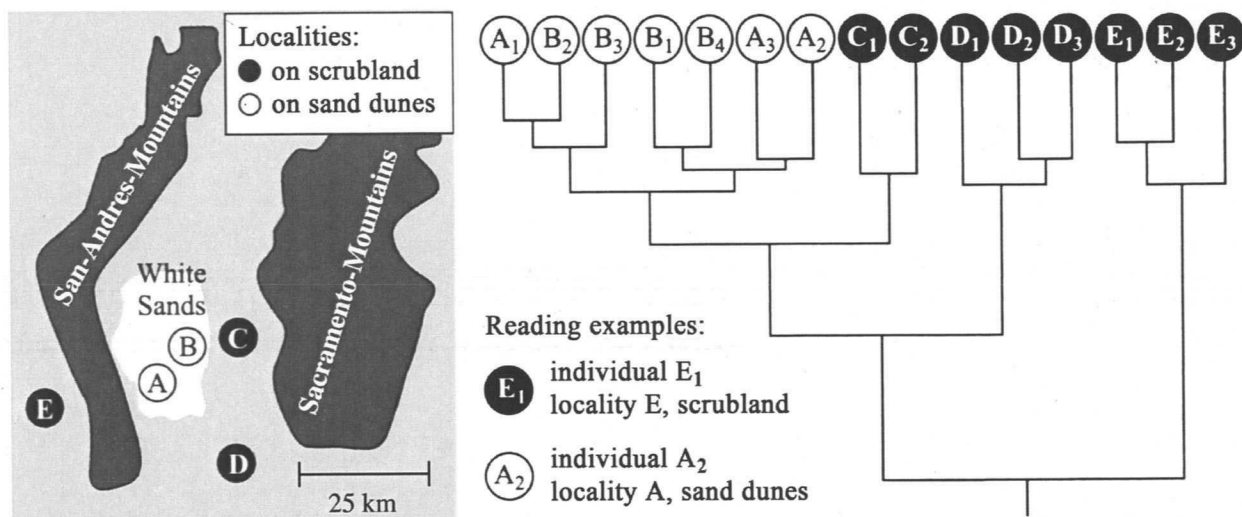


Fig. 1F Map of the study area with the locations A to E and results of the kinship analysis of 15 individuals of these locations

G Reproduction and embryology [11]

G1 Terms

Explain the following terms in 2 to 3 sentences: [3]

- a Metaphase chromosome
- b G1 phase (of the cell cycle)
- c Vegetative reproduction

G2 Mitosis and meiosis

- a Compare meiosis I with mitosis and indicate an important aspect they have in common and an important aspect in which they differ. [2]
- b How can the duration of the entire cell cycle be determined, assuming that mitosis lasts about one hour? Determine the duration of the entire cell cycle for the cells in figure 1G and explain your approach. [2]

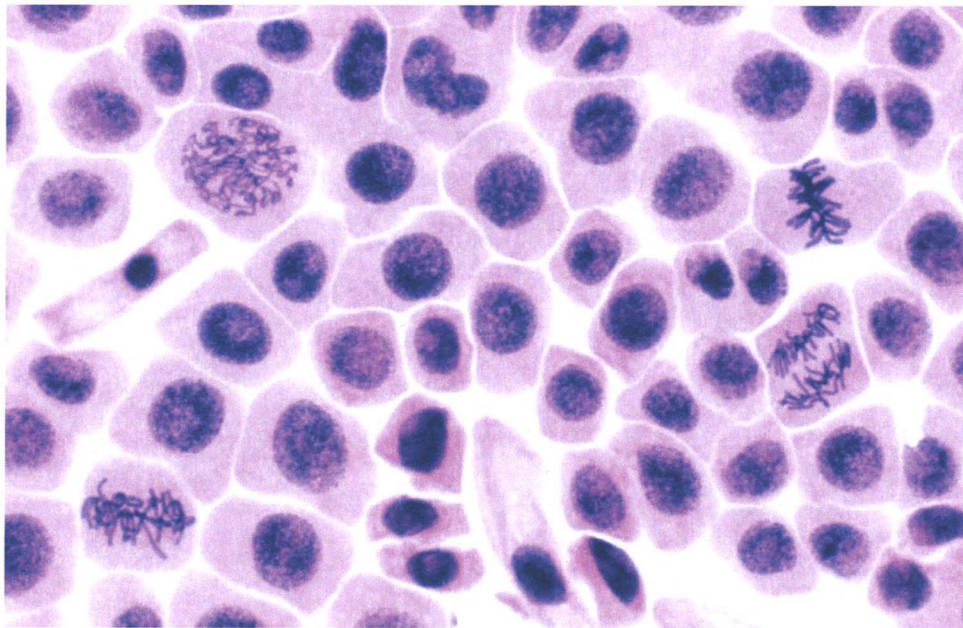


Fig. 1G Onion root cells

G3 Sperm and egg cells

- a When and how is it determined, which sex a child will have? [2]
- b In artificial insemination, an in vitro fertilized egg is transplanted to a fertile woman. At what time during the cycle is it implanted and which hormone must be administered to allow the implantation of the blastocyst and to prevent menstruation? [2]

H Hormone system, nervous system and eye [23]

H1 hormones

- a We can distinguish between two groups of hormones: those who are able to cross cell membranes and those are unable to do so. Briefly describe the cause for this difference between the two groups of hormones and name for each group one example of a hormone. [3]
- b Explain why only certain cells respond to a particular hormone. [1]
- c Explain the mechanism of action of a fictitious steroid hormone SH1 on a target cell, which in turn reacts by producing another steroid hormone SH2. Create a self-explanatory schematic drawing, label the cellular structures and name key processes. Your drawing should show a coherent chain of events from the arrival of the hormone SH1 to the release of the hormone SH2. [4]

H2 Basics of Neurobiology

Check the following statements for their correctness and tick (✓) accordingly the [T] (true) or the [F] (false). Correct incorrect statements by replacing **only the bold part** of the statement to make a meaningful and correct statement. A statement recognized as correct yields half a point, a recognized and correctly corrected false statement yields a whole point. Use the table below for your answers. [4]

- 1 In neurons, the sodium (Na^+) concentration is **higher** outside the cell than inside.
- 2 An action potential (AP) artificially stimulated with an electrode in the middle of the axon **only moves towards the axon terminal**.
- 3 The repolarization of the action potential is due to the **outflow of potassium (K^+) ions**.
- 4 The molecular equipment (channels, pumps, etc.) for the generation of an action potential is present **only at the axon hillock** in vertebrate neurons.
- 5 *Only considering chemical synapses: In all synapses*, a release of neurotransmitters is followed by a postsynaptic depolarization.

	corrected part of statement
1 [T] [F]	
2 [T] [F]	
3 [T] [F]	
4 [T] [F]	
5 [T] [F]	

- b Figure 1H shows the ion distribution across a membrane which is permeable **only** to sodium (Na^+) ions. The ion distribution shown represents the situation at equilibrium. Why are the sodium ions not distributed evenly on both sides of the membrane, even though the membrane is permeable to sodium? First, describe the relevant aspects of the situation presented, name the physical forces involved, and then answer the question. [3]

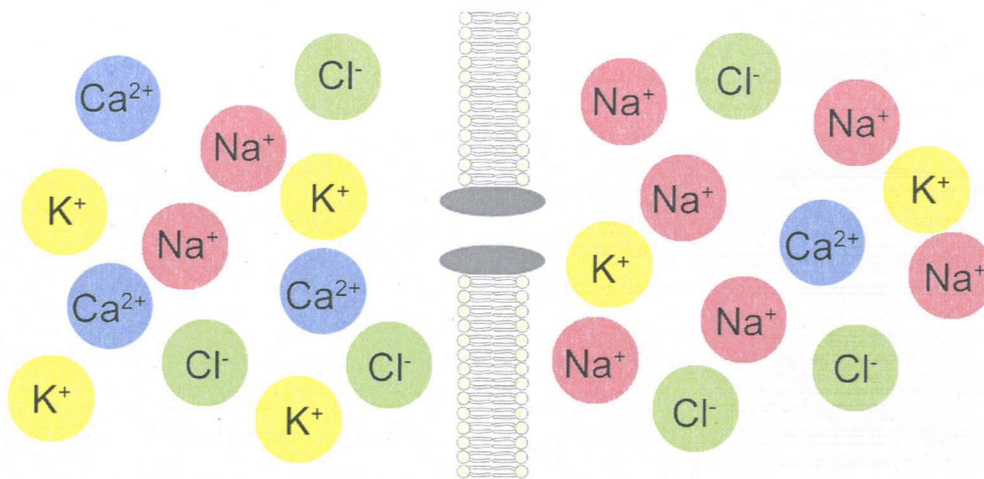


Fig. 1H Distribution of ions (not to scale)

H3 The human eye

- a Compile a legend for fig. 2H and indicate the anatomical orientation of the eye. [4]

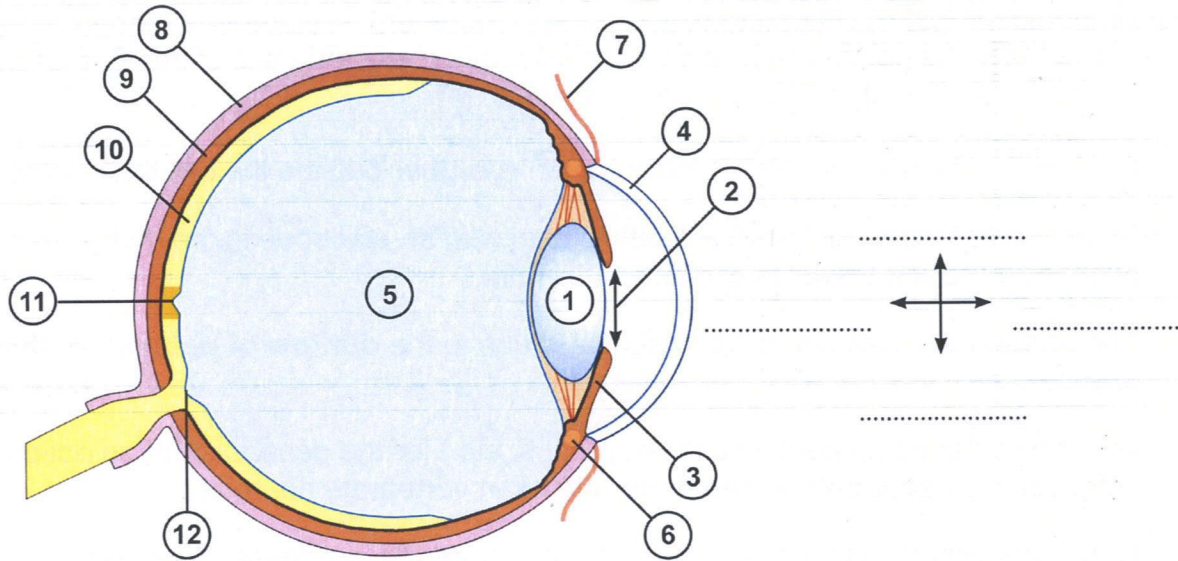


Fig. 2H Human eye in cross-section

Legend

- | | |
|---------|----------|
| 1 | 7 |
| 2 | 8 |
| 3 | 9 |
| 4 | 10 |
| 5 | 11 |
| 6 | 12 |

- b A pirate with two healthy eyes has an eyepatch on his left eye. When he goes below deck, he takes off the eyepatch. Which picture (3H, 4H) is then perceived by his right eye and his left eye respectively? [1]
- c Why does the room appear colourless, while the cannon window appears coloured? Explain the background of this phenomenon. [3]

