Final Exam

KBB032

Biochemistry and Molecular Biology

Time and location: Saturday, October 29th, 2022, afternoon session 14.00-16.00

Teacher and examiner: Michaela Wenzel 772 2074

Teacher will be available for questions by phone throughout the exam.

Aids: 2 A4 sheets (double-sided = 4 pages) of handwritten notes. See rules on next page.

Exam review: Results will be reported to Ladok within three weeks. Grading of the exam may be reviewed after agreement with Michaela Wenzel.

Points breakdown: Points for each question are indicated in parentheses.

Grading: 50% = 3; 65% = 4; 80% = 5

Read all questions carefully!

Remember that some questions may have more than one correct answer.

Please write legibly!!

Instructions for using notes:

- 2 A4 paper sheets
- can be written double-sided = 4 pages of handwritten notes
- must be physical notes on paper, no electronic notes of any kind
- must be hand-written, no printouts, no copy-pasted text, no direct copies of figures of any source
- may contain drawings, formulas, schemes, notes etc. as long as it is hand-written/hand-drawn
- may under no circumstances be shared with another student during the exam

Question 1: Definitions and concepts (10 p total)

Below is a short explanation of different expressions and phenomena used in biology. Name the concept that is described (1 p each).

a) the theory that mitochondria and chloroplasts originate from prokaryotes that has been incorporated in eukaryotes
b) a chemical reaction characterized by the gaining of electrons by an atom
c) a chemical reaction characterized by the loss of electrons from an atom
d) a group of genes that is regulated by the same regulator but <u>not</u> necessarily located close to each other on the chromosome
e) an end-product in a pathway will inhibit an enzyme in the beginning of the same pathway
f) amino acids that a given organism needs but cannot make itself and therefore must be obtained from the diet
g) the transformation of (to most organisms) inaccessible CO_2 to organic carbon compounds (e.g., glucose) by photosynthetic organisms
h) a catalytic step in a metabolic pathway that determines the reaction speed of the whole pathway
i) the transfer of a phosphate group from a substrate to ADP
j) the transfer of a phosphate group to ADP that is driven by the transmembrane proton gradient

Question 2: Nucleic acids (6 p total)

Cells have two types of nucleic acids that fulfill distinct roles in storing and using genetic information.

a) Name the individual building blocks of DNA and describe their role in DNA structure and function. (3 p)
b) Which building blocks are different in RNA? (2 p)
c) How do DNA and RNA differ in their secondary structure? (1 p)

Question 3: Replication (12 p)

In order to produce fit offspring, DNA must be replicated with high accuracy and distributed equally to the daughter cells upon cell division.

Describe or draw bacterial DNA replication. Name each involved enzyme and describe its function and localization in the replication fork, including the sequence of the individual steps. Describe what is happening with both the leading and lagging strand and include strand orientation in your description.

Question 4: Sequences (9 p total)

Translate the given sequence into the missing corresponding sequences (genetic code on next page).

Note that depending on which sequence is given there could be more than one correct answer. Mind the orientation!

(1 p per translated sequence)

DNA sequence (5'-3'): ATGAGAATAGCTGTAGATGCAATGGGAGGA

Complementary strand (5'-3'):

RNA sequence (5'-3'):

Protein sequence (N-C):

DNA sequence (5'-3'):

Complementary strand (5'-3'):

RNA sequence (5'-3'): AUGUUUAACUUACCAAAUAAAAUCACACUA

Protein sequence (N-C):

DNA sequence (5'-3'):

Complementary strand (5'-3'):

RNA sequence (5'-3'):

Protein sequence (N-C): MSSKLLRGTFVLTLGTYISR

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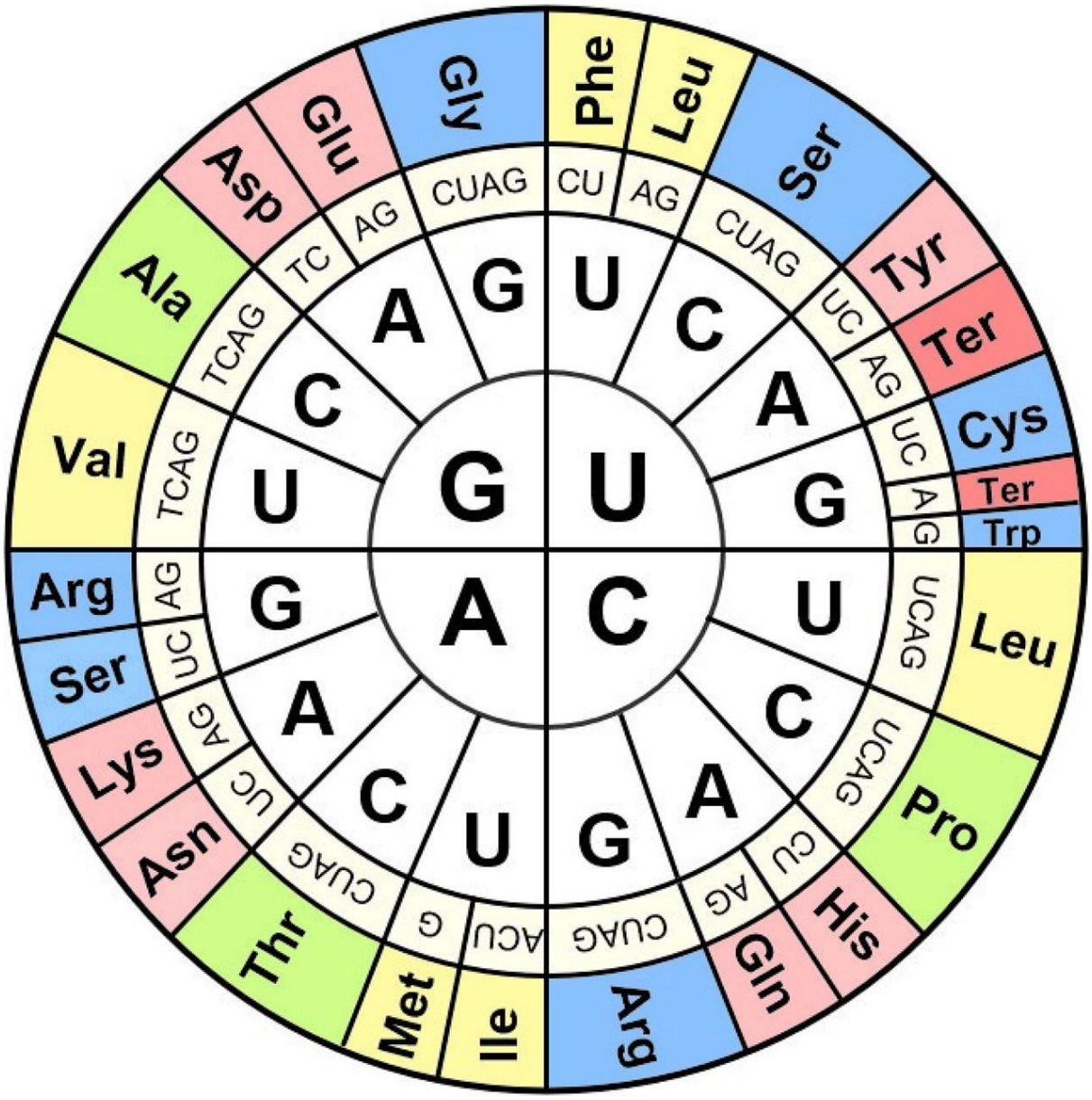
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Question 5: PCR and sequencing (16 p total)

Polymerase chain reaction and DNA sequencing are based on the same molecular principles. However, there are crucial differences that make the respective reactions possible.

a) Describe the principle of the polymerase chain reaction. Which components are needed for the reaction to be successful and what is the role of each component (2 p)? What are the individual phases and what happens in each phase (2 p)?
b) What could be a reason for a PCR not yielding any product other than forgetting to add one of the components (2 p)?
c) Describe the principle of Sanger sequencing including components and point out the four major differences to a PCR reaction (5 p).

Explain the role of each of these differences that enables sequencing (5 p).

Question 6: Carbon core metabolism (9 p total)

Energy and carbon are the most essential resources for life as we know it. Carbon and energy metabolism are closely linked with each other and connected to further cellular processes. For a eukaryotic photosynthetic organism:

a) Describe the connection between glycolysis, TCA cycle, and oxidative phosphorylation. Which metabolites are passed on from one process to the other? (3 p)
b) Describe the connection between photophosphorylation and the Calvin cycle. Which metabolites are passed on from one process to the other? (3 p)
c) Describe the connection between the processes in (a) and (b). Which metabolites are passed on between them, which ones not? (2 p)

Where does each of the aforementioned processes take place in the cell? (1 p)

Question 7: Pentose phosphate pathway (6 p total)

a) What are the three possible outcomes of the pentose phosphate pathway? (1.5 p)
b) What are the respective end products? (1.5 p)
c) What determines which of the three possible reactions is pursued in the nonoxidative phase? (1 p)
d) Which downstream process of the pentose phosphate pathway is affected by the antibiotic trimethoprim and why? (2 p)

Question 8: Oxidative stress (12 p total)

Imagine that you are working for a biotechnology company and you are tasked to optimize a bacterium for a process that results in the unwanted formation of reactive oxygen species (ROS). Your goal is to increase the resistance of your bacterium to ROS.

a) Name a metabolic pathway that you could manipulate to reach this goal and explain how it would increase ROS resistance (3 p).
b) Outside from engineering metabolic pathways, could you also reach your goal by modulating the expression of specific enzymes? If so, which ones and how would they contribute to ROS resistance (3 p)?
c) ROS can cause severe damage to DNA. Which type of DNA damage is caused by ROS and which mechanism is involved in repairing that damage (3 p)?
d) If oxidative DNA damage is not repaired, this can have serious consequences. Describe why base oxidation can lead to problems for the cells. Are there different consequences for multicellular and unicellular organisms and, if so, why (3 p)?

Question 9: Fatty acid metabolism (8 p total)

Cells can both synthesize fatty acids to produce membrane lipids (fatty acid synthesis) and degrade them (beta oxidation).

a) Name three types of fatty acids that increase membrane fluidity. What do they have in common that they all act fluidizing? (4 p)
b) How many cycles are needed to synthesize an 18 C fatty acid chain (a fatty acid chain that contains a chain of 18 carbon atoms) (1 p)?

Name three different end products of beta oxidation. For each one, name a process, in which it can be used (3 p).

Question 10: Measuring gene expression (12 p total)

Two farmers grow crops on adjacent fields. One farmer has issues with his plants frequently being eaten by caterpillars, while the other one has mostly healthy plants. Assume that there are no differences between pesticide or fertilizer usage.

Note that this question can have many different answers and that your answer to question b depends on the scenario you suggest in question a.

a) What could be possible reasons for the different susceptibilities to the caterpillar infestation? Formulate a hypothesis that could be tested with a method discussed during the course. (6 p)
b) In your chosen scenario, which method for monitoring gene expression would you choose to identify the genetic determinants underlying the different phenotypes. Justify your choice of method and explain what result you would expect, if your aforementioned hypothesis was correct. (6 p)