Final Exam

UCM010

Introduction into Cell and Molecular Biology

Time and location: Monday, May 27th 2024, 14.00, Campus Johanneberg

Teacher and examiner: Michaela Wenzel, 772 2074, wenzelm@chalmers.se

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

Aids: Dictionary

Exam review: Results will be reported to Ladok within four weeks. Graded exams can be viewed by making an appointment with Gunilla Bankel-Andersson (gunilla.bankel.andersson@chalmers.se). Grading of the exam may be reviewed in agreement with Michaela Wenzel (after consultation with the other teachers, if necessary).

Points breakdown: Total points and point breakdowns are given for each question. The exam gives 100 points in total.

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

10 bonus points can be acquired through the lab report, if it is submitted in time and approved upon first submission (that means that you could pass the course with 40 points on the exam plus 10 points from the lab report).

Read all questions carefully!

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

Questions can be answered in English or Swedish (or even a mix of both).

Please write legibly!!
We will not guess correct answers from unreadable handwriting!

Question 1: Definitions and concepts (1 point per correct answer, max. 10 points)

Below is a short explanation of different expressions and phenomena used in biology. Name the concept that is described.

a) a biomolecule class that occurs in nucleic acids, and serves as both carbon and energy source
carbohydrates
b) a method to isolate different cell components and organelles according to their size and density
differential centrifugation
c) a regulatory sequence on bacterial DNA that is bound by Sigma factors
promoter
d) the theory that DNA replicates by using each of the two DNA single strands as template for a new daughter strand
semiconservative replication
e) a class of enzymes that helps relieve tension in supercoiled DNA and decatenates circular DNA molecules
topoisomerases
f) a group of genes that is transcribed from the same promoter and translated from the same polycistronic mRNA
operon
g) an RNA sequence that changes it structure depending on the presence of a ligand resulting in a change in gene expression
riboswitch
h) the concept that mitochondria and chloroplasts originate from prokaryotes that have been incorporated into eukaryotic cells
endosymbiotic theory
i) the mitotic phase, in which the chromosomes are lined up at the middle of the cell
metaphase
j) a regulated signaling cascade leading to the intended and controlled death of a cell
apoptosis

Question 2: Cells (max. 7 points)

a) Label the missing cell components in the image below. What kind of cell is this and why? 0.5 points per correctly labeled structure, max. 7 points.

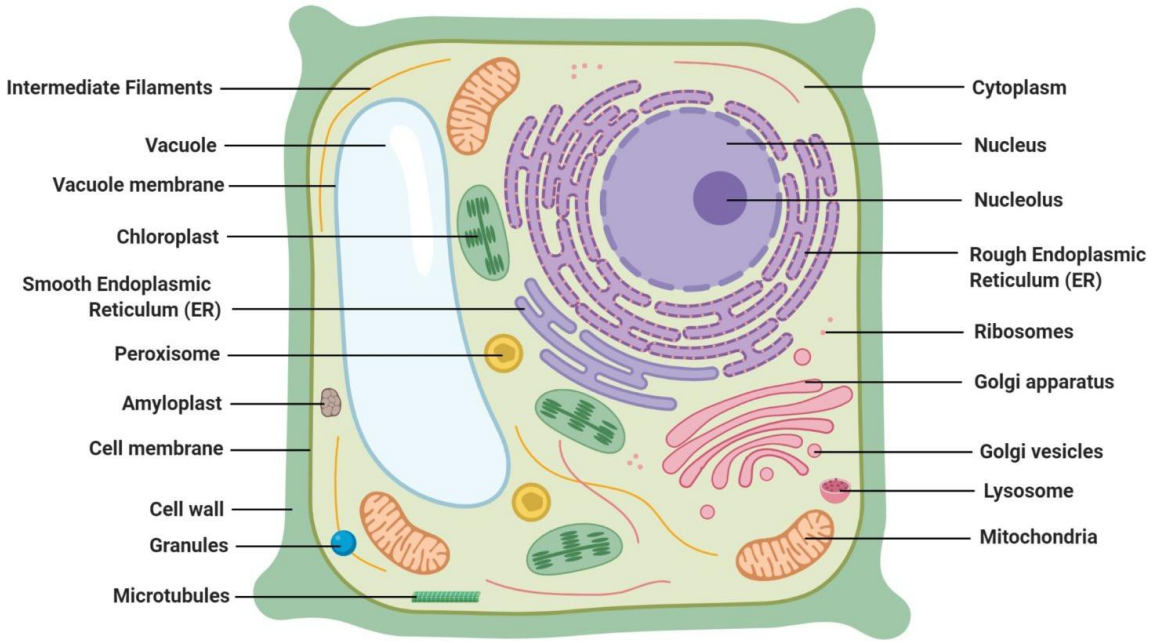
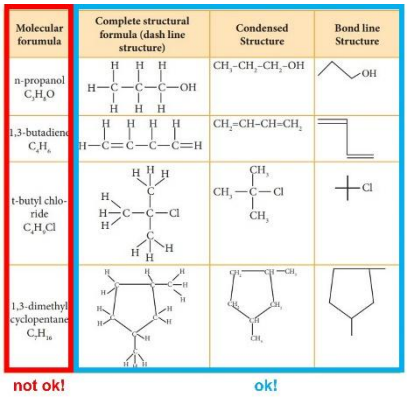


Figure: Plant Cell Structure, Image Copyright © Sagar Aryal, www.microbenotes.com

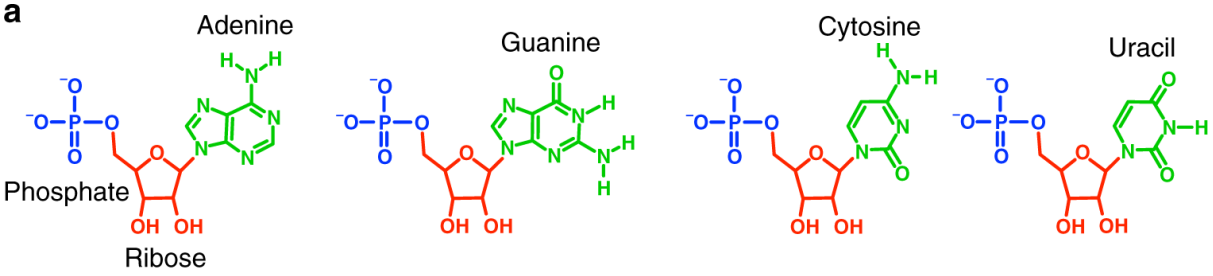
Question 3: Nucleic acids (max. 5 points)

a) Draw a single nucleotide (in any common structural formula, see image). Three points, no partial points (your nucleotide must exist in nature and occur in fully functional DNA or RNA).

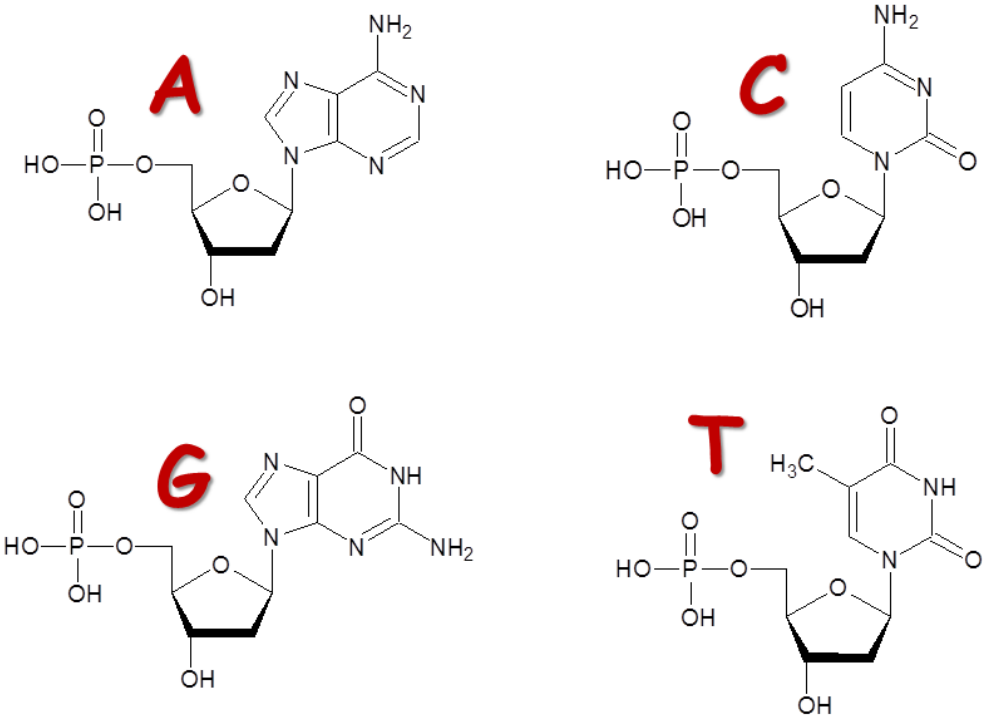


Possible RNA nucleotides:

a



Possible DNA nucleotides:



b) Did you draw a nucleotide that would occur in DNA or RNA? Which structural feature(s) determine this? One point.

Ribose in RNA, Deoxyribose in DNA (2' OH or 2'H), presence of uracil or thymine

c) Did you draw a monophosphate, diphosphate, or triphosphate version of your nucleotide? Which one of the three would be incorporated into a growing DNA/RNA strand? One point.

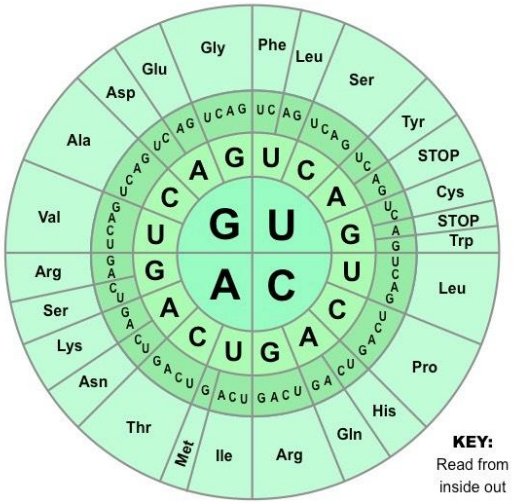
The structures above are monophosphates. Triphosphates are used as building blocks for DNA. Two phosphates are cleaved off during the reaction.

Question 4: Sequences (max. 6 points)

Translate the given sequence into the missing corresponding sequences (see genetic code to the right).

Mind the orientation!

One point per translated sequence, max. 6 points.



a)

DNA sequence (5'-3'): ATGATTCAAATCGATCCAAGAAGCTCAACA

Complementary strand (5'-3'): TGTTGAGCTTCTTGGATCGATTTGAATCAT

RNA sequence (5'-3'): AUGAUUCAAAUCGAUCCAAGAAGCUCAACA

Protein sequence (N-C): MIQIDPRSST

b)

DNA sequence (5'-3'): ATGATTGAACTGCGGCAGCTGTCAAAAGCG

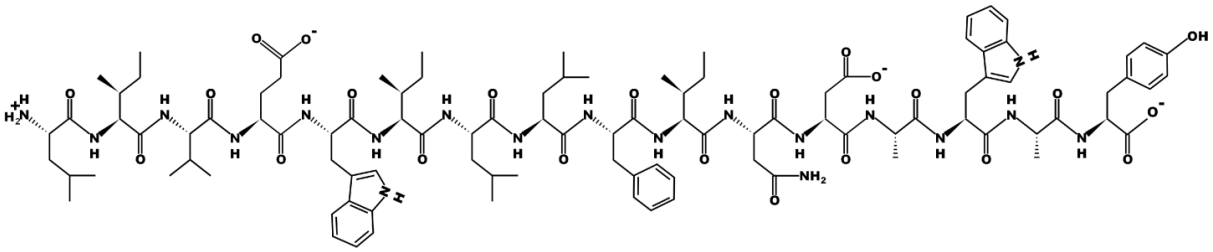
Complementary strand (5'-3'): CGCTTTTGACAGCTGCCGCAGTTCAATCAT

RNA sequence (5'-3'): AUGAUUGAACUGCGGCAGCUGUCAAAAGCG

Protein sequence (N-C): MIELRQLSKA

Question 5: Proteins (max. 25 points)

a1) Depicted below is a peptide sequence. Translated into one-letter amino acid codes, it spells a sentence. What does it say? Half a point per correct amino acid, 8 points max.



Tipp: Follow the peptide bonds to mark the peptide backbone and then identify the individual side chains!

a2) Name each individual amino acid (full names). Half a point per unique amino acid, max. 5 points.

Leucine, isoleucine, phenylalanine, glutamate, tryptophan, isoleucine, leucine, leucine, phenylalanine, asparagine, aspartate, alanine, tryptophane, alanine, tyrosine

b1) Below is a peptide sequence in three-letter codes.

Ile-Arg-Pyr-Asn-Met-Ala-Ile-Asp-Glu-Asn

How would the following amino acid substitutions affect the properties of the peptide? One point each, max. 5 points.

Ile -> Leu	hydrophobic to slightly smaller hydrophobic, small effect (similar properties and size)
Arg -> Lys	positive charge to positive charge, small effect (similar properties and size)
Asn -> Asp	hydrophilic neutral to hydrophilic negatively charged, moderate effect (similar size, both hydrophilic but charge difference)
Met -> Ala	large hydrophobic to small hydrophobic, moderate effect (large size difference, similar properties)
Glu -> Lys	negative charge to positive charge, strong effect (slight size difference, charge reversal)

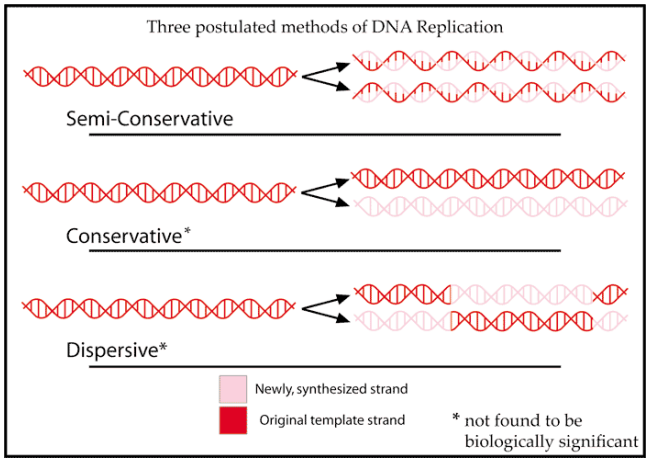
b2) Which of these substitutions would have small, moderate, or strong effects? Justify your reasoning! Half a point per answer, max. 2.5 points.
see above

b3) What does the amino acid sequence in b1 spell in one-letter code? 4.5 points.

Question 6: DNA replication (max. 12 points)

In 1958, Matthew Meselson and Franklin Stahl conducted a famous experiment that proved the concept of semi-conservative DNA replication.

a) Explain or draw the three hypothetical modes of DNA replication that were tested in this experiment (semi-conservative, conservative, dispersive). 6 points



Three hypotheses had been previously proposed for the mechanism of DNA replication:

The ***semiconservative*** hypothesis (proposed by Watson and Crick) :

the two strands of a DNA molecule separate during replication. Each strand then acts as a template for synthesis of a new strand.

The ***conservative*** hypothesis proposed that

the entire DNA molecule acted as a template for synthesis of an entirely new one.

The ***dispersive*** hypothesis proposed by Max Delbrück:

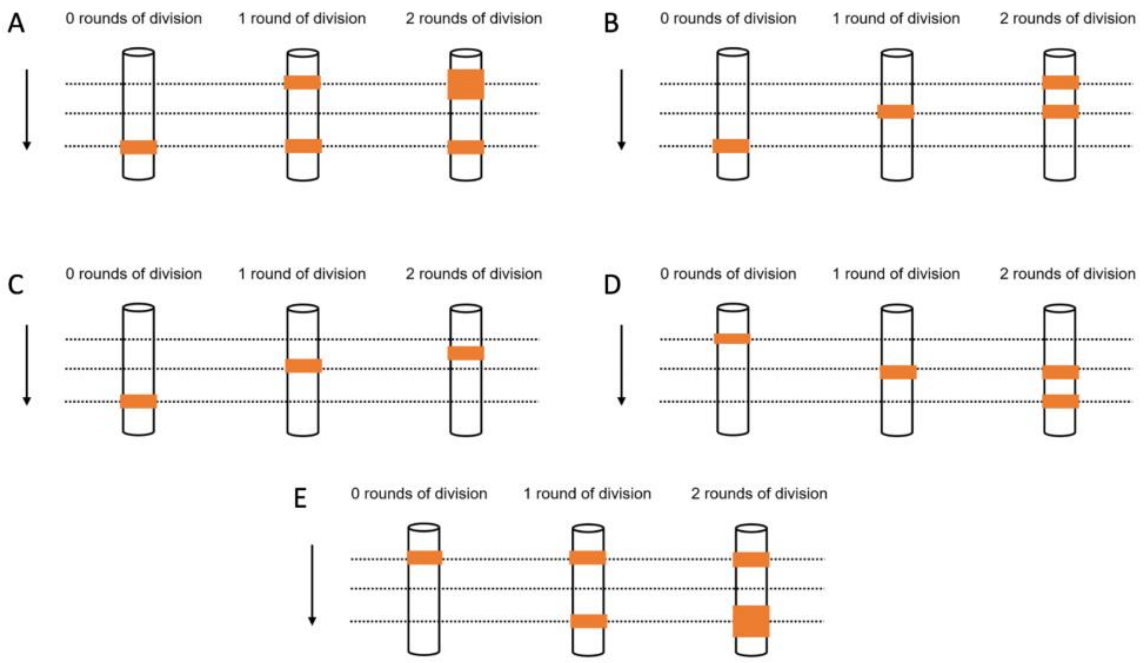
a mechanism that breaks the DNA backbone every 10 nucleotides or so, untwists the molecule, and attaches the old strand to the end of the newly synthesized one. This would synthesize the DNA in short pieces alternating from one strand to the other.

b) Explain the setup of the Meselson-Stahl experiment. Which 'trick' enabled this experiment? Which method was used? What was the model organism? 3 points

The 'trick' was labeling DNA with heavy nitrogen (15N). E. coli cultures were grown in medium containing 15N, then shifted to medium containing normal 14N. Every 20 min, the bacteria divide, equating to one round of DNA replication. By the labeling of old DNA with 15N and DNA that was newly synthesized after shifting with 14N, the proportion of old and new DNA could be measured. This was done by gradient centrifugation allowing separation of heavy and light DNA.

c) The picture below shows theoretical outcomes of the Meselson-Stahl experiment (the arrow indicates increasing density). Which one correctly depicts semi-conservative DNA replication? Motivate your answer. 3 points

B. The starting DNA is heavy. Let's assume that we start with a single DNA strand for simplicity. Then the first round of replication generates two DNA molecules with one heavy and one slight chain each, resulting one band of lighter DNA (50/50 light and heavy). The next round generates two DNA molecules with a 50/50 heavy distribution (those that use the two heavy chains as templates) and two 100% light molecules (those that use the two light chains as templates).



Question 7: Membranes (max. 10 points)

a) Name the following types of membrane components that contain: (4 points)

i. A phosphate, glycerol, and two fatty acids: phosphoglyceride
ii. A phosphate, a fatty acid, and a sphingosine: sphingolipid
iii. A fatty acid, a sugar, and a sphingosine: glycolipid
iv. A steroid ring structure and a nonpolar hydrocarbon tail: cholesterol

b) What are the three major types of active transporters? Where do these transporters get their energy from? (6 points)

Coupled transporters – electrochemical/concentration gradient

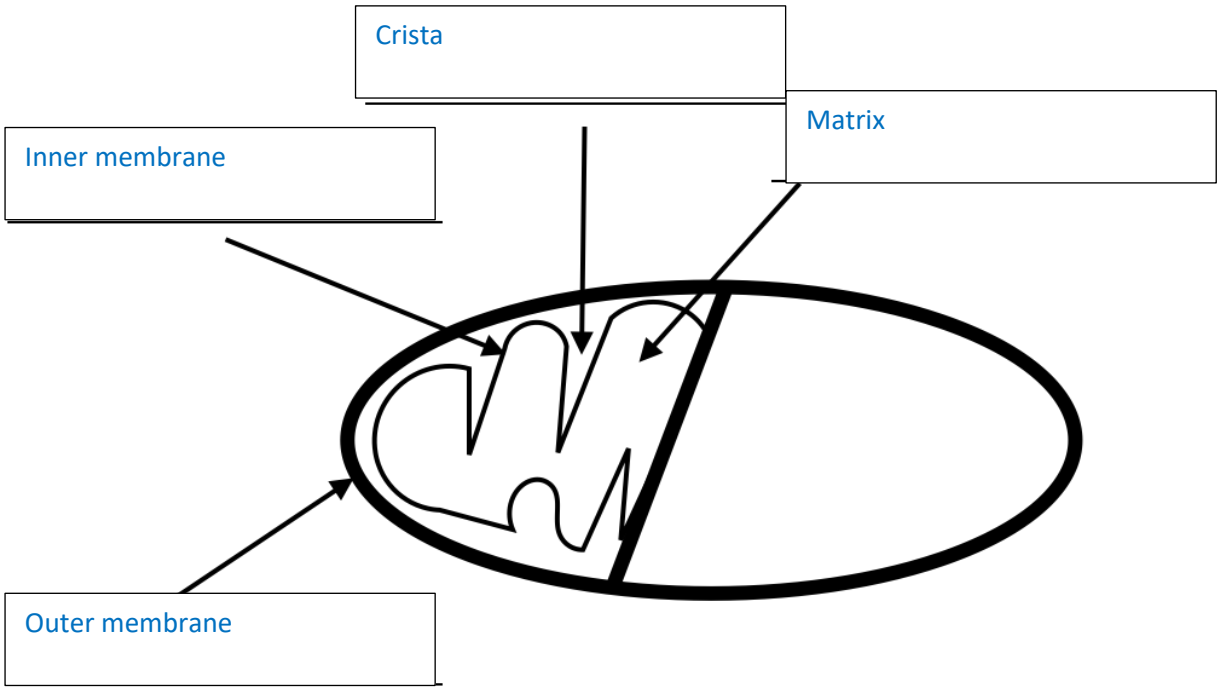
ATP-driven pumps – ATP hydrolysis (to ADP)

Light driven pumps – Light/photons

Question 8: Mitochondria (max. 11 points)

a) Use the figure below to: (6 points)

i. Name the marked four components of the mitochondria.
ii. Draw an additional arrow to the part of the mitochondria where the mitochondrial DNA is located.
Arrow should point to matrix
iii. In which of these components does the electron transport chain and ATP synthesis take place?
Inner membrane



b) In the electron transport chain,

i. Which are the three major complexes (the names, not the numbers)? (3 points)

NADH dehydrogenase, cytochrome C reductase, cytochromes C oxidase

ii. Which are the two important electron mediators that transport electrons between the complexes? (2 points)
Ubiquinone and cytochrome c

Question 9: Cytoskeleton (max. 8 points)

a) What are the two major structural components of ATP synthase? In which one are protons transported? In which one is ATP generated from ADP? (4 points)

Stator/F0 (transport), rotor/F1 (ATP generation)

b) Below, two of the three major components of the cytoskeleton are listed.

- Actin filaments
- Microtubules

For each of them, indicate:

i. Its overall structure. (2 points)
ii. One process or function in the cell, in which it is important. (2 points)

Actin filaments – helix structure of two twisted filaments – cell surface shape and cell movement

Microtubules – dimer of alpha and beta tubuline, long hollow cylinder – position of organelles, intracellular transport, mitotic spindle

Question 10: Cell cycle and reproduction (max. 6 points)

In the schematic picture of the cell cycle below…

a) Fill in the names of the different phases of the cell cycle. (3 points)

b) Indicate in what phase:

i. the nuclear DNA is duplicated (1 points): S

ii. the cell splits in two daughter cells (1 points): cytokinesis

iii. in which phase the cell commits to cell division, influenced by increased levels of cycline D. (1 points): G1