

I. Biology (35 points total)

The following questions cover some of the core concepts in biology that will be indispensable for understanding the lectures. Please be concise, but be sure to include all of the keywords in your answers.

a) Compare the structure of DNA and RNA. Keywords: nucleotides, 5 prime, 3 prime, deoxy-ribonucleotides, ribonucleotides, anti-parallel double-helix (5 points)

DNA	RNA
Deoxyribonucleotides	Ribonucleotides
Anti-parallel double helix	Normally single strand, folds into secondary, tertiary structures
Single strand DNA is directional and has a 5 prime and a 3 prime, however, because DNA forms anti-parallel double helix, a double strand DNA molecule doesn't appear to be directional.	Directional, has a 5 prime and a 3 prime

Give credit as long as the student gets the main idea.

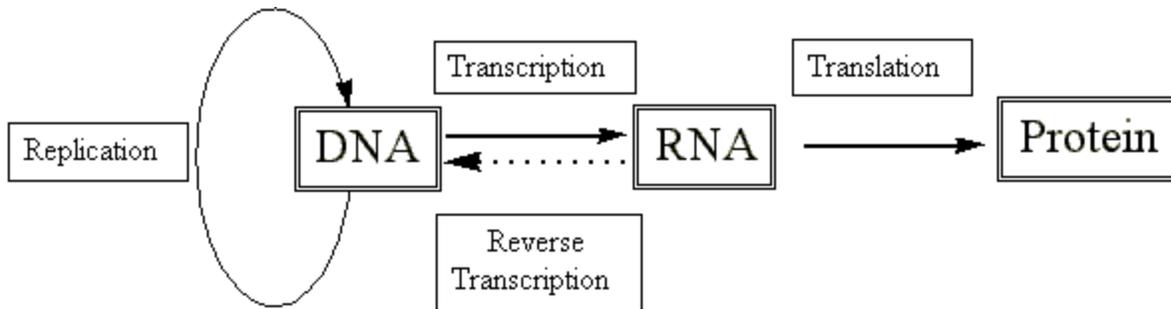
b) What's the basic subunit that's used to build a protein? Describe the 3 levels of protein structure? Keywords: amino acid, N terminus, C terminus, primary-, secondary, tertiary-structure (5 points)

primary structure: The chemical structure of the polypeptide chain or chains in a given protein - i.e., the number and sequence of amino acid residues linked together by peptide bonds. Since the peptide bonds are directional (one amino acid's $-NH_2$ is connected to the other amino acid's $-COOH$), this generates a N terminus and a C terminus.

secondary structure: Any such folding which is brought about by linking the carbonyl and imide groups of the backbone together by means of hydrogen bonds. Examples of secondary structures are alpha-helix and beta-sheet.

tertiary structure: A organization of secondary structures linked by "looser segments" of the polypeptide chain stabilized (primarily) by sidechain interactions. Disulfide bonds are included in this level.

c) Explain the Central Dogma in biology. Keywords: DNA, RNA, protein, transcription, translation (5 points)



The central dogma in biology depicts how information is transmitted between the three information molecules in biology.

The sequence in a DNA can direct its own synthesis by replication;

DNA directs the synthesis of RNA by a process called transcription, in which a gene is transcribed into a RNA, therefore passing the information from DNA to RNA;

RNA can, in some cases, be reversed transcribed into DNA. This is not a common process in organisms, and occurs mostly in some viruses. Therefore it's not the mainstream pathway of information transmission and is represented by a dotted line;

RNA directs the synthesis of protein, which is called translation and is an irreversible process, meaning that there's information loss ---- the protein translated contains less information than its RNA template and therefore the protein can't direct the synthesis of its corresponding RNA.

d) Explain what is genetic code. Keywords: translation, tri-nucleotide codon, tRNA (5 points)

DNA transfers information to mRNA in the form of a code defined by a sequence of nucleotides bases. During protein synthesis, ribosomes move along the mRNA molecule and "read" its sequence three nucleotides at a time (codon) from the 5' end to the 3' end. Each amino acid is specified by the mRNA's codon, and then pairs with a sequence of three complementary nucleotides carried by a particular tRNA (anticodon).

Since RNA is constructed from four types of nucleotides, there are 64 possible triplet sequences or codons (4x4x4). Three of these possible codons specify the termination of the polypeptide chain. They are called "stop codons". That leaves 61 codons to specify only 20 different amino acids. Therefore, most of the amino acids are represented by more than one codon. The genetic code is degenerate.

e) Compare the basic structure of eukaryotic and prokaryotic cells. Keywords: nucleus, organelle, mitochondria, ribosome (5 points)

Prokaryotic cell	Eukaryotic cell
Doesn't have nucleus	Has nucleus
70S ribosome composed of 30S and 50S subunits	80S ribosome composed of 40S and 60S subunits
Doesn't have mitochondria, use its plasma membrane for respiration	Has mitochondria
Doesn't have many complicated organelles	Have a lot of organelles such as Golgi, lysosome etc.

f) Describe the structure of a eukaryotic gene. Keywords: promoter, exon, intron (5 points)

An eukaryotic gene starts with a promoter, where various transcription factors and RNA polymerase bind to initiate transcription. It's usually upstream of the exon;

Exon is the coding sequence of the gene;

Some times, a gene has introns, which are intervening sequences between exons and are spiced out during RNA processing.

g) Describe a biological problem that you think is worth looking into using some computational methods. This could be speculation of your possible final project topic. (5 points)

Give credit as long as the student does make an effort. TFs can give suggestions concerning its novelty, practicability, etc.

Bonus: (5 points total)

a) Explain several ways in which the expression of genes can be regulated. (2 points)

This is an open question. Examples are gene silencing, gene duplication, transcriptional regulation, translational regulation, splicing regulation, post-translational regulation, RNA degradation, etc..

b) Which techniques could be utilized to look into one (or more) ways of gene regulation globally? In which of the above mentioned regulation steps could systematic quantitation and/or computational modeling be applied, and how? (3 points)

Again, this is an open question. Examples are microarray to look at transcriptional regulation, RNA degradation, etc.