

Final Examination Key

1.

- a. (10 pts) Why is the presence of active enzyme so important to whether or not a molecule is made or degraded in an organism?

Molecules are made through a sequence of chemical reactions (pathway). None of these reactions will progress fast enough to be useful unless there is a catalyst present to speed it up. Enzymes are the biological catalysts.

- b. (5 pts) In what structure (not molecule) in the cell would you find the information that tells it how to make a specific enzyme?

chromosomes

- c. (5 pts) What molecule found in that structure (see b) actually carries that information?

DNA

- d. (6 pts) Draw a schematic view of that molecule (see c) and circle the part that actually carries the information.

Show double helix: 2 strands wrapped around each other. Each strand has the backbone $\cdots\text{P-S-P-S-P}\cdots$ with one of the four bases, A,T,G,C hanging off each sugar. The 2 strands are linked with dotted hydrogen bonds so that only A \cdots T and G \cdots C pairs are formed. The A,T,G,C of one (not both) of the strands are circled.

- e. (5 pts) We must do two things with this information. We must make copies of it so that future generations can have it, and we must use it to direct the synthesis of enzymes. What is the name of the process of making an exact copy?

replication

- f. (5 pts) What is the name of the first step in the process (see e) by which it is used to direct enzyme synthesis?

transcription

- g. (15 pts) Name two substantive ways in which the two processes (see e) or products of those processes are the same and three in which they are different.

Both involve base pairing A \cdots T and G \cdots C. Both require opening up the double helix.

Transcription makes a single strand, replication makes a double strand.

Transcription makes a product that has ribose, replication makes a product that has

deoxyribose. Transcription makes a product that uses the base U, replication makes a product that uses the base T.

- h. (10 pts) For many years, the most puzzling question about the process of enzyme synthesis was that there was no clear mechanism by which the molecular structure of the information could be physically read so that the individual amino acids in solution can be put into correct position. What is the single key primary feature of the process that performs this function? Explain.

The use of transfer RNA (tRNA). On one side, it has the anticodon which reads the codon on the mRNA that carries the information identifying the next amino acid to be added to the growing protein. On the other side, it binds the amino acid that is called for by that codon.

- i. (5 pts) What geometric shape does the protein take initially as it is synthesized? Explain briefly.

Just as it is made, it takes the form of a linear chain of amino acids

- j. (16 pts) What changes in shape will you see as the protein takes its final form? Describe the various components in detail. You might use hemoglobin as an example if you wish, discussing each of the aspects of its structure.

The protein adopts its normal 3-dimensional form. In secondary structure, the backbone N-H and C=O arrange to hydrogen bond each other. In tertiary structure, the backbone folds to make the globular ball-like (or other shape) structure. In quaternary structure, the multiple single protein chains of a multi-subunit protein associate with each other and any non-protein components of the final protein are bound.

2. (10 pts) Which is more like a protein found dissolved in the watery cytoplasm of the cell, a micelle or a liposome. Explain.

The micelle is more similar. It has polar or charged groups on its surface in contact with water and non-polar groups buried in the center away from water. The liposome is different. It has charged groups in its center.

3. Let's talk about things that are different.
- a. (10 pts) In some instances the information (see question 1) is altered, and the enzyme is made incorrectly. Describe what is meant by "altered information" and describe how it would lead to the incorrect synthesis of the enzyme.

Altered information means that one of the bases of the DNA is different from normal. This would create a codon that is different from normal and code for an amino acid that is different from normal.

- b. (16 pts) Describe in words two different chemical mechanisms by which the information can be altered (see a)

In once case, a molecule with a structure very similar to that of a DNA base will, during one round of replication, pair with one base and be incorporated into a “daughter” stretch of DNA, but in a later round of replication pair with a different base which would be incorporated. After these two errors the wrong DNA base would be present and the codon changed.

- c. (30 pts) It is not uncommon for an individual human to carry different information for the synthesis of a given protein compared to that carried by most humans.
- i. In some cases this has no effect on the function of the protein. Give two ways in which this could be.

There is more than one codon for most amino acids. The change in base could create another codon for the same amino acid.

Alternatively, the change could lead to a codon for a different amino acid but one that could effectively substitute for the normal amino acid –for example a positively charged amino acid on the surface of the protein for another positively charged amino acid.

- ii. In other cases it has a significant effect on the function of the protein, leading to disease. In some of these cases, it has been shown that large populations of humans have this altered protein and are seriously ill. Why is it surprising that this altered information has become permanent and so common?

It is surprising because individuals with the serious disease would normally be less effective in reproduction; those with the error would have fewer progeny and the gene would disappear from the population.

- iii. Propose an explanation for why this type of situation does in fact exist even though one might expect that it would not. Give an example.

It may be that in addition to creating a serious illness, the altered protein leads to protection against a more serious illness, and thus those with it are, under certain circumstances, healthier than those with the normal protein. For example, sickle

cell anemia, caused by a mutation in the gene for hemoglobin, is a very serious illness but those carrying one copy of the sickle gene are protected against malaria.

4. (20 pts) The excitation of a muscle to contract depends on a number of proteins, including, acetylcholine receptor, acetylcholinesterase. and one I will incorrectly name acetylcholine synthetase
- What do you think is the primary difference between acetylcholine synthetase and acetylcholinesterase.

One catalyzes the reaction that makes acetyl choline and the other catalyzes the reaction that breaks it apart.

- what do you think is the primary difference between acetylcholinesterase and the acetylcholine receptor.

One is an enzyme and catalyzes a chemical reaction and the other is a receptor. It does not catalyze a reaction, rather it binds its ligand and that binding is a signal for other events to occur.

5. (26 pts) It is very efficient for an organism to make an enzyme only when it has use for that enzyme.
- Describe, without going into too much chemical detail, how an organism can take a nutrient such as glucose and convert it into an amino acid to be used in protein synthesis.

The organism usually converts glucose to CO₂, through a series of chemical reactions, each of which converts the product of the previous reaction into the starting material for the next reaction. Through glycolysis and Krebs cycle, all six carbons of glucose become CO₂. If, however, one of the products of one of the reactions undergoes a reaction different from the reaction that would send it further through glycolysis or Krebs, it may convert it to the starting materials for a pathway that leads to the synthesis of an amino acid.

- Is the amount of ATP that that organism can gain from metabolism of a molecule of glucose the same, less, or more when it is making amino acids than when it is not? Explain.

Less ATP would be made. The intermediate undergoing the different reaction, leading to amino acid synthesis, is not available for the usual glycolytic reactions. Thus there are fewer reactions that produce ATP directly as is done in Krebs and glycolysis, or that produce NADH or FADH₂ which would transfer their electrons and protons to the carriers of the electron transport chain to create the proton gradient leading to ATP production through oxidative phosphorylation. FADH₂

6. (100 pts) Bacteria can grow on sugars other than glucose. However, in many cases the enzymes required to metabolize one or another of those sugars are not made unless that sugar is present.

- a. What do you think would be the “signal” molecule for the production of the enzymes in a case like this? Explain.

The sugar itself. When it is not present. There is no need to activate the system that produces the enzymes to metabolize it. When the sugar is present, it can signal for the activation of the system.

- b. It has been found that cells make a class of proteins that are not receptors, enzymes, antibodies or transport proteins but rather “repressors”. These molecules bind, reversibly, to specific sections of the DNA and prevent the binding of RNA polymerase, preventing the production of mRNA for the enzymes. Describe in detail the nature of this binding:
- i. discuss the shape of the repressor in the region that will bind DNA

The DNA binding region on the surface of the receptor has a complementary shape to the DNA helix so that they can come into close contact for binding. It must be complementary to the DNA bases of the specific section to which it must bind, because the rest of the molecule is the same from one end to the other.

- ii. discuss the electronic structure of that part of the surface of the repressor.

There need to be positive charges near regions of the DNA that are negative and the reverse. There need to be groups that can hydrogen bond to parts of the DNA that can make hydrogen bonds. There must be non-polar groups near non-polar groups on the DNA.

- iii. discuss the extent to which the repressor binds to the DNA (what fraction of the DNA molecules are bound to the repressor at any given time.)

The extent of binding depends on the amount of repressor present and affinity of the repressor for the DNA stretch involved.

- iv. In what ways do your answers to the previous three questions relate to the antibody-antigen interaction?

They are the same. The antibody binds the antigen, and thus must have the complementary shape, create the appropriate electronic interactions and have a high enough concentration and affinity to bind most of the antigen present.

- v. What is the major force that works against the binding of an antibody to its appropriate antigen. Explain.

Entropy. Binding of two structures decreases the randomness of the system compared to the two structures “floating” around at independently.

- c. Explain how this protein can bind to that specific spot on the DNA (see the introduction to part b) and no other.

The binding site is designed for a specific base sequence of the DNA that signifies the repressor “binding site”.

- d. The repressor can also bind to the signal molecule in question. How can it bind both the signal molecule and also the DNA?

There are two binding sites on the repressor. One specific for the stretch of DNA in question and the other specific for the “signal molecule.”

- e. It has been found that when the signal molecule is bound to the repressor, the repressor is unable to bind to DNA. Propose an explanation.

Binding of the signal molecule to its site changes the conformation (shape) of the repressor so that the binding site for the DNA is altered and cannot bind.

- f. What do you think happens to the synthesis of the enzymes in question when the signal molecule is present? Does this make sense in terms of the control the cell wants to exert over itself?

The enzymes can be made because the RNA polymerase can bind to the DNA, produce the mRNA which then leads to protein synthesis.