BIOLOGY
SECTION II
Time—1 hour and 30 minutes

Directions: Answer all questions.

Answers must be in essay form. Outline form is not acceptable. Labeled diagrams may be used to supplement discussion, but in no case will a diagram alone suffice. It is important that you read each question completely before you begin to write. Write all your answers on the pages following the questions in the pink booklet.

1. Homeostatic maintenance of optimal blood glucose levels has been intensively studied in vertebrate organisms.
   (a) Pancreatic hormones regulate blood glucose levels. **Identify** TWO pancreatic hormones and **describe** the effect of each hormone on blood glucose levels.
   (b) For ONE of the hormones you identified in (a), **identify** ONE target cell and **discuss** the mechanism by which the hormone can alter activity in that target cell. **Include** in your discussion a description of reception, cellular transduction, and response.
   (c) **Compare** the cell-signaling mechanisms of steroid hormones and protein hormones.

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2. An experiment was conducted to measure the reaction rate of the human salivary enzyme α-amylase. Ten mL of a concentrated starch solution and 1.0 mL of α-amylase solution were placed in a test tube. The test tube was inverted several times to mix the solution and then incubated at 25°C. The amount of product (maltose) present was measured every 10 minutes for an hour. The results are given in the table below.

Time (minutes)	Maltose Concentration (μM)
0	0
10	5.1
20	8.6
30	10.4
40	11.1
50	11.2
60	11.5

   (a) **Graph** the data on the axes provided and **calculate** the rate of the reaction for the time period 0 to 30 minutes.
   (b) **Explain** why a change in the reaction rate was observed after 30 minutes.
   (c) **Draw** and **label** another line on the graph to predict the results if the concentration of α-amylase was doubled. **Explain** your predicted results.
   (d) **Identify** TWO environmental factors that can change the rate of an enzyme-mediated reaction. **Discuss** how each of those two factors would affect the reaction rate of an enzyme.

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Question 1

Homeostatic maintenance of optimal blood glucose levels has been intensively studied in vertebrate organisms. ***NOTE: Points for parts (a), (b) or (c) may be found in any part of the response**.

(a) Pancreatic hormones regulate blood glucose levels. **Identify** TWO pancreatic hormones and **describe** the effect of each hormone on blood glucose levels. **(4 points maximum)**

Identification of hormone 1 point each (2 points maximum)	**Effect of hormone on blood glucose levels 1 point each (1 point maximum per hormone)**
Insulin (humulin)	• Decreases/lowers blood glucose level.
Glucagon NOTE: A hormone name beginning with "gly-" is not acceptable.	• Increases/raises blood glucose level.
Somatostatin	• Increases/raises blood glucose level.

(b) For ONE of the hormones you identified in (a), **identify** ONE target cell and **discuss** the mechanism by which the hormone can alter activity in that target cell. **Include** in your discussion a description of reception, cellular transduction, and response. **(4 points maximum)**

• **1 point**: target cell • **1 point**: description of reception	• **1 point**: discussion of transduction • **1 point**: discussion of response of target cell

Insulin

- **Target cells**: Any cell except red blood cells, or brain cells unless specified as neuroglial cells.
- **Reception**: Insulin binds to a specific receptor (tyrosine kinase) on the cell surface.
    - Ligand binding to two adjacent monomers forms an active dimer (tyrosine kinase).
    - Dimer and other proteins become phosphorylated.
- **Transduction**: Binding of signaling molecule alters the receptor protein in some way.
    - Stimulates a cascade pathway/mediated by a second messenger/amplifies signal.
- **Response**: Transduced signal triggers a specific action by the target cell. Specify one of the following:
    - Increases/raises cellular uptake of glucose.
    - Increases formation of glycogen from glucose in liver/(skeletal) muscle cells as intracellular glucose is incorporated into glycogen (glycogenesis).
    - Increases rate of intracellular catabolism of glucose.
    - Increases fat synthesis from glucose in liver cells and adipose tissue.
    - Decreases gluconeogenesis, the conversion of amino acids and glycerol from fats to new molecules of glucose.
    - Phosphorylated transcription factors can alter gene expression.
    - Facilitated diffusion of glucose. (Glucose is phosphorylated into glucose-6-phosphate to preserve the concentration gradient so glucose will continue to enter the cell.)
    - Cells with more glucose transporters increase departure of glucose from blood.

Question 1 (continued)

Glucagon

- **Target cells**: Liver cells, (skeletal) muscle cells.
- **Reception**: Binds to a specific receptor on the cell surface (G-protein-coupled receptors on liver cells).
    - G protein-GTP activates adenylyl or guanalyl cyclase.
- **Transduction**: Binding of signaling molecule alters the receptor protein in some way. (G-protein binds to GTP and this activates other signal molecules such as adenylyl cyclase/amplifies signal.)
    - cAMP or cGMP active as second messenger/phospholipase C activation releases IP3 and DAG.
    - Kinase activation by cAMP or cGMP/phosphorylated effector proteins.
- **Response**: Transduced signal triggers the specific action by the target cell. Specify one of the following:
    - Releases glucose into the bloodstream from liver.
    - Increases breakdown (hydrolysis) of glycogen (glycogenolysis) to glucose in liver/(skeletal) muscles.
    - Increases gluconeogenesis, the conversion of amino acids and glycerol to glucose in the liver; new glucose enters the blood.
    - Decreases glucose breakdown/oxidation.
    - Increases glucose formation (gluconeogenesis).
    - Ca^{2+} release.

Somatostatin

- **Target cells**: Pancreatic cells (alpha and beta cells).
- **Reception**: Binds to a specific receptor on the cell surface (G-protein-coupled receptor).
    - G protein-GTP activates adenylyl or guanalyl cyclase.
- **Transduction**: Binding of signaling molecule alters the receptor protein in some way.
    - cAMP or cGMP active as second messenger/Phospholipase C activation releases IP_3 and DAG.
    - Kinase activation by cAMP or cGMP/phosphorylated effector proteins.
- **Response**: Transduced signal triggers the specific action by the target cell. Specify one of the following:
    - Decreases insulin secretion (from beta cells).
    - Decreases glucagon secretion (from alpha cells).
    - Ca^{2+} release.
    - Guanine nucleotide binding protein (GNAI 1) inhibits insulin.

(c) Compare the cell-signaling mechanisms of steroid hormones and protein hormones. **(4 points maximum)**

Steroid hormone (2 points maximum)

- Mechanism of action — to alter gene expression in the target cell.
- Hydrophobic/lipophilic/nonpolar/fat-soluble molecules readily cross cell or nuclear membrane.
- Acts as ligand that binds to cytosol receptors.
- Binding changes the conformation/shape of the cytosol receptor; hormone-receptor complex then enters the nucleus as the activated transcription factor.

Question 1 (continued)

- Transcription from the genes is affected:
  - Releases HDACs and recruits HATs — histone acetylases — to end chromosome repression.
  - Complex acts as a transcription factor that binds to a promoter (including HRE, hormone response element).
- Actions are slow but sustained.

Protein hormone (2 points maximum)

- Mechanism of action — to activate biochemical pathways/enzyme systems OR alter gene expression in a target cell.
- Hydrophilic/lipophobic/polar/water-soluble molecules do not readily cross cell membrane.
- Acts as ligand for membrane-bound receptors. Binds to receptor transmembrane proteins (either tyrosine kinase or G-protein receptors).
- Hormone is the ligand and the first messenger.
- Actions are brief but dramatic.