

AP[®] BIOLOGY

2010 SCORING GUIDELINES

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)	<ul style="list-style-type: none"> • Decreases/lowers blood glucose level.
Glucagon NOTE: A hormone name beginning with “gly-” is not acceptable.	<ul style="list-style-type: none"> • Increases/raises blood glucose level.
Somatostatin	<ul style="list-style-type: none"> • 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)**

<ul style="list-style-type: none"> • 1 point: target cell • 1 point: description of reception 	<ul style="list-style-type: none"> • 1 point: discussion of transduction • 1 point: discussion of response of target cell
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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.

AP[®] BIOLOGY

2010 SCORING GUIDELINES

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 guananyl 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).
 - Ca²⁺ 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 guananyl cyclase.
- **Transduction:** Binding of signaling molecule alters the receptor protein in some way.
 - 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:
 - Decreases insulin secretion (from beta cells).
 - Decreases glucagon secretion (from alpha cells).
 - Ca²⁺ 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.

AP[®] BIOLOGY
2010 SCORING GUIDELINES

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.

BIOLOGY
SECTION II

Time—1 hour and 30 minutes

1 A 1

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 this 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.

1 a) Two pancreatic hormones that regulate blood glucose levels are insulin and glucagon. Insulin is released if the glucose level is too high. The insulin allows for the glucose to be absorbed out of the bloodstream by organs/muscles such as the liver. Glucagon is released if the glucose level is too low. Glucagon breaks down glycogen allowing for more glucose to enter the bloodstream. Homeostasis is able to exist through this balance.

b) Insulin has many target cells in the body, one of which would be in the liver. The insulin sends information pertaining to the absorption of glucose to this region of the body. The message of insulin undergoes three steps: reception, cellular transduction, and response. First, during reception the ligand (binding molecule) would bind to a receptor. This would cause a conformational change that would cause a reaction within the cell. ~~with the help of~~ The signal transduction pathway would then begin. The protein

GO ON TO THE NEXT PAGE.

kinases would phosphorylate the next proteins with ATP. This would cause conformational changes that would continue until the response was completed. The reason ^{that} it would go through the signal transduction pathway would be to amplify the results.

c) Steroid hormones are able to pass through the selectively permeable membrane. They are able to go into the nucleus and actually effect the transcription of genes. ~~in the nucleus of the~~
~~protein~~ Protein hormones are unable to pass through the membrane. Therefore, ^{the ligand} ~~the~~ must bind to the surface on a receptor molecule which then undergoes a conformational change. ~~This starts a cellular transduction pathway. The protein kinases phosphorylate the next ones, until the goal is met and a response occurs.~~ Then molecules such as cAMP are activated and help to start a transduction pathway that would end in the hormone activating its desired results.

GO ON TO THE NEXT PAGE.

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A) I) Insulin regulates blood glucose levels by prompting the liver to store it as fat, or else excretes it through the kidneys; in either case, insulin lowers blood glucose levels.

II) Conversely, glucagon increases the amount of glucose in the blood by telling the liver to excrete stored glucose into the bloodstream.

b) Glucagon targets liver cells. It enters via a receptor (glucagon cannot travel through channel proteins, but a receptor protein on the surface chemically notifies a synthesizing protein on the interior of the cell membrane to produce a similar enzyme), and its counterpart inside the cell enters a positive-feedback transduction pathway,

GO ON TO THE NEXT PAGE.

ADDITIONAL PAGE FOR ANSWERING QUESTION 1

stimulating a series of enzymatic reactions which, when the product is needed, stimulates more production of the product (glucose). The response, Glucose (the product) exits the cell and enters the bloodstream, increasing blood-glucose levels.

Steroid and protein hormones both enter the cell via receptors (which create look-alikes on the other side of the cell membrane). Both can enter positive-feedback mechanisms, and both are produced in the pancreas and liver cells, as well as the rest of the endocrine system.

GO ON TO THE NEXT PAGE.

BIOLOGY
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a) Two pancreatic hormones that are produced from the pancreas are insulin and glucagon. They both ~~take~~ react as a negative feedback system. Insulin is the hormone that drops the glucose level of the blood. It allows the glucose in the blood to be stored in the liver as glycogen. The glucagon is the second hormone produced from the pancreas. Glucagon increases the ~~low~~ glucose level in the blood. It takes the glycogen in the liver back in the form of glucose in the blood.

b) Glucagon targets the liver cells. These glucagon hormones binds to the receptors of the liver cells. The ~~the~~ receptors produce signals through cellular transduction and trigger the liver cells, the liver cells will

GO ON TO THE NEXT PAGE.

respond by converting the glycogen back to glucose, therefore, this converted glucose will be released into the blood cells to increase the glucose concentration in the blood. So, the hormone, glucagon, changes the activity of liver cells to produce or convert glucose from glycogen.

c) Steroid hormones and protein hormones act as cell-signaling mechanisms, they both bind to receptors to mediate a response or produce signal. Also, they both trigger other glands or cells to produce other type of hormones. For an example, the hypothalamus produces GnRH to trigger the pituitary gland to produce FSH during the reproductive stage. It uses steroid hormones, also, the pituitary gland uses protein hormones to trigger the testicles to produce testosterone or other sex hormones.

GO ON TO THE NEXT PAGE.

AP[®] BIOLOGY

2010 SCORING COMMENTARY

Question 1

Overview

This question concerned the homeostatic maintenance of optimal levels of glucose in the blood of vertebrate organisms, and intercellular communication by hormones. In part (a) students were asked to identify two pancreatic hormones that regulate glucose levels and then to describe the specific effects of each hormone on blood glucose levels. In part (b) students were asked to identify one target cell for either of the two pancreatic hormones identified in part (a). Students were then required to discuss the mechanism by which that pancreatic hormone alters activity in the identified target cell. They were prompted to include descriptions of reception of the hormone by the target cell, the transduction of the signal by the target cell and the ultimate response of the target cell to the hormone. Part (c) moved to broader considerations in cell signaling by asking students to compare the cell-signaling mechanisms of steroid hormones and protein hormones.

Sample: 1A Score: 10

In part (a) 1 point was earned for identifying insulin and another point was earned for identifying glucagon as two pancreatic hormones that regulate blood glucose levels. One point was earned for describing how “insulin allows for the glucose to be absorbed out of the bloodstream.” A final point in part (a) was earned for the statement that “[g]lucagon breaks down glycogen allowing for more glucose to enter the bloodstream.”

Liver cells are identified in part (b) as target cells for insulin, earning 1 point. No point was earned for mentioning “ligand (binding molecule)” since a receptor location is not identified. One point in part (b) was earned for discussing the signal transduction pathway: “protein kinases would phosphorylate the next proteins.”

One point in part (c) was earned for describing steroid hormones as “able to pass through the selectively permeable membrane.” Another point was earned for steroid comparison for noting that steroid hormones “effect the transcription of genes.” A comparison point for protein hormones was earned for the statement that they “are unable to pass through the membrane.” A final comparison point in part (c) was earned for describing how protein hormones “must bind to the surface on a receptor [*sic*] molecule.” Another comparison point could have been awarded for describing the transduction pathway of protein hormones (“molecules such as cAMP are activated and help start a transduction pathway”), but the response had already earned the maximum 10 points.

Sample: 1B Score: 8

In part (a) 1 point was earned for identifying insulin as a hormone. Another point was earned for describing how insulin “lowers blood glucose levels.” One point was earned for identifying glucagon as a hormone secreted by the pancreas. A final point for part (a) was earned for describing the effect that glucagon has on blood glucose levels: “glucagon increases the amount of glucose in the blood.” In part (a) the response of the target cell “liver” is also described, but credit for this was earned in part (b).

In part (b) the response identifies the target cell for glucagon and earned a point for the statement that “[g]lucagon targets liver cells.” A point for the description of the reception was earned with the response that “glucagon cannot travel through channel proteins, but a receptor protein on the surface chemically notifies a synthesizing protein on the interior of the cell membrane.” A transduction description follows: “stimulating a series of enzymatic reactions,” which earned 1 point. A response description point was also earned for the

AP[®] BIOLOGY
2010 SCORING COMMENTARY

Question 1 (continued)

statement “stimulates more production of the product (glucose).” This response point is reinforced by the comment: “The response? Glucose (the product) exits the cell.”

No points were earned in part (c) for comparing the cell-signaling mechanisms of steroid hormones and protein hormones.

Sample: 1C
Score: 6

In part (a) 1 point was earned for identifying insulin and 1 point was earned for identifying glucagon as two pancreatic hormones that regulate blood glucose levels. Another point was earned in part (a) for describing the effect insulin has on blood glucose levels: it “drops the glucose level of the blood.” A final point was earned in part (a) for describing the effect of glucagon: it “increases the glucose level in the blood.”

Identifying liver cells as targets for glucagon earned a point for part (b). Another point was earned in part (b) for describing the response of the liver cells to glucagon: “converting the glycogen back to glucose.” No points were earned for descriptions of the mechanisms of reception and transduction in part (b).

No points were earned in part (c) for comparing the cell–signaling mechanisms of steroid hormones and protein hormones.