Name: _____ Unit 4A (Cell Communication) Study Guide

Topic 4.1: Cell Communication

Learning Objective

IST-3.A Describe the ways that cells can communicate with one another.

I can…

- ☐ describe how cells communicate with one another through direct contact
- ☐ describe how cells communicate with one another through chemical signaling over short or long distances
- ☐ describe how regulators target particular cells

1. Through what connection do sodium ions move from muscle cell to muscle cell in your heart?

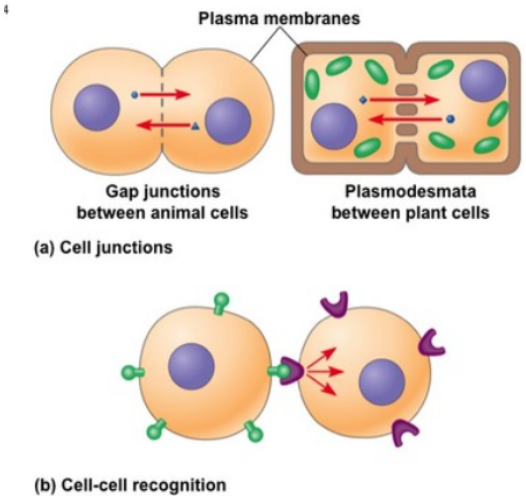
gap junctions

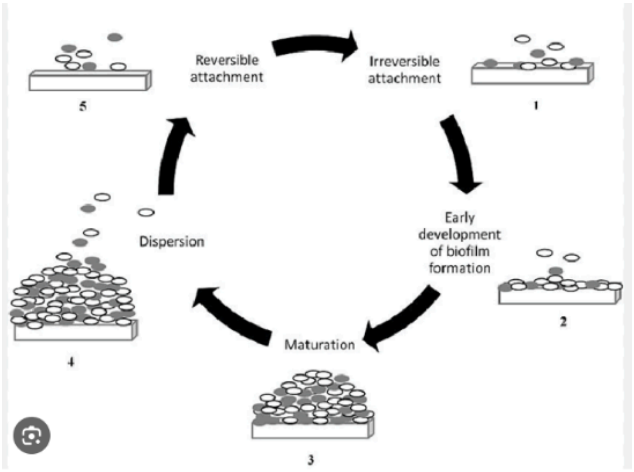
2. Through what connection do RNA molecules move from plant cell to plant cell in a daisy leaf?

plasmodesmata

3. How does a liver cell recognize another liver cell adjacent to it?

by the proteins and carbs on their surfaces (more on this later)





4. What is a biofilm? How might cell communication benefit bacteria in a biofilm?

A biofilm is a group of microorganisms (such as different species of bacteria) that work together. They are attached to a surface and are embedded in a self-produced matrix (mainly polysaccharide) that keeps them close together.

These bacteria often use quorum sensing, which is a type of cell-cell communication that allows the bacteria to share information about cell density (number of bacteria in the area). Once they determine that a critical cell density has been achieved, they may express genes that improve their survival. For example, some species of bacteria coordinate the release of toxins that will attack the host when a critical cell mass has been produced.

Here is an 18 minute video on quorum sensing. Here is a 6 minute video on how to treat bacteria.

5. List some examples of cell communication in multi-celled organisms.

Neurotransmitters are released from a neuron and affect another neuron (or a muscle cell).

Hormones are released from a gland, travel through the blood, and affect another cell.

A macrophage (a type of white blood cell) eats up a bacterial cell, digests it, and displays the bacterial proteins/carbs on the macrophage surface. A helper T cell (another type of white blood cell) recognizes these bacterial proteins and stimulates a B cell, which, in turn, produces antibodies (proteins) that attach the bacteria.

6. What is a ligand? What is a receptor? Are they specific?

A ligand is a chemical messenger. It fits with a particular receptor which is very specific. For example, insulin is a ligand that fits with insulin receptors.

7. For multi-celled organisms, what do autocrine, paracrine, neuronal and endocrine signals have in common?

All have a ligand (signaling molecule) which attaches to a specific type of receptor.

8. Long distance cell-to-cell communication (endocrine) requires what to move the signaling molecules?

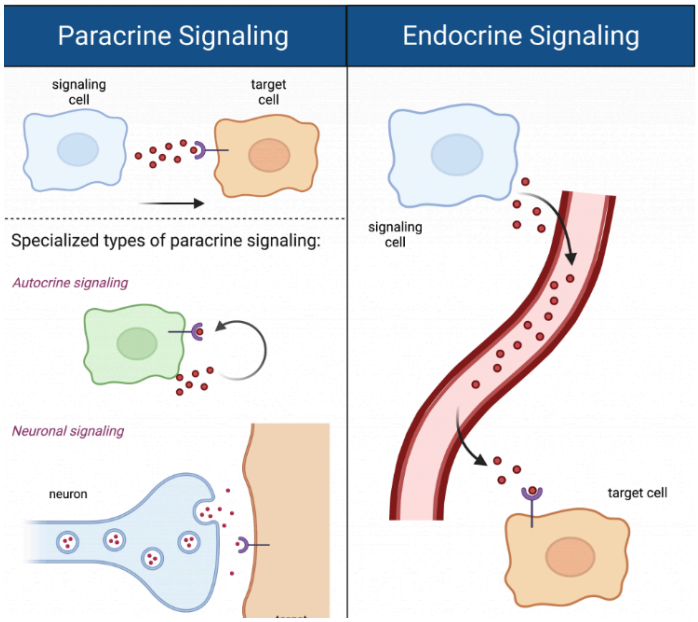
blood

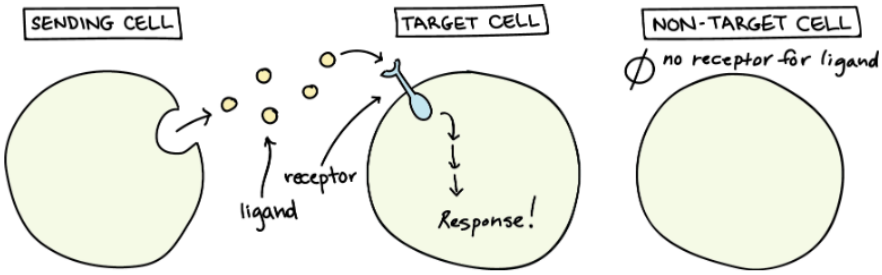
9. Do all ligands affect all cells?

No. The cell must have the correct receptor.

10. What does specificity mean?

How exact or closely matched something is. e.g. the ligand must match the receptor physically (shape) and chemically..





11. What is a target?

A target is a cell or a tissue with the right receptor for the ligand in question.

10. What best explains the fact that scientists find similarities in cell signaling between unicellular and multicellular eukaryotes?

OMG. Common Ancestor.

5. Define intracellular vs. extracellular.

Intracellular - within a cell

Extracellular - outside of a cell.

6. Why are receptors made of protein?

Because receptors have very special shapes. Proteins can form very special shapes because there are 20 different amino acids which can be arranged in various orders/sequences. The interactions of the R groups of the various amino acids are able to produce very, very specific shapes.

Topic 4.2: Introduction to Signal Transduction

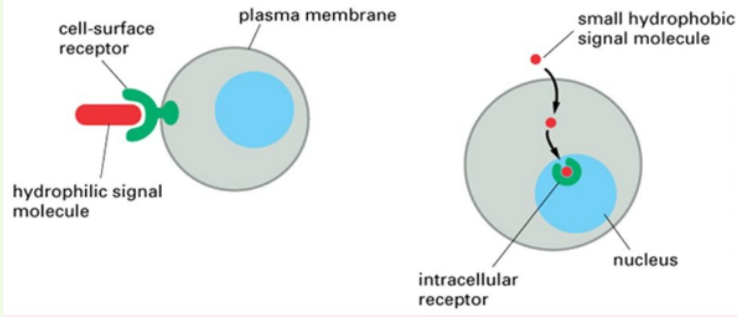
Learning Objective

IST-3.C Describe the components of a signal transduction pathway.

I can…

- ☐ describe how signal transduction pathways link signal reception with cellular responses
- ☐ describe protein modifications and phosphorylation cascades in signal transduction pathways
- ☐ describe the signal recognition (ligand to receptor protein) as a specific, one-to-one relationship
- ☐ describe how signal transduction is initiated when the intracellular domain of a receptor protein changes shape after a ligand bonds
- ☐ describe G protein-coupled receptors in eukaryotes
- ☐ describe how incoming signals can be amplified by signaling cascades
- ☐ describe how second messengers (such as cyclic AMP) relay and amplify the intracellular signal
- ☐ describe cell responses, including growth, secretion, gene expression
- ☐ describe how the binding of ligand to gated channels can cause the channel to open or close

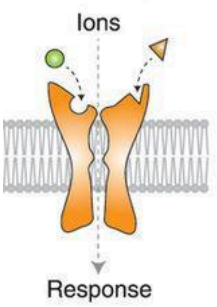
1. There are two major categories of receptors: those embedded in the plasma membrane (**plasma membrane receptors**) and those that are found inside the cell (**intracellular receptors**).



a. The ligand for which receptor is a protein? Plasma membrane receptor because proteins are usually hydrophilic and cannot move through the lipid bilayer.

b. The ligand for which receptor is a steroid? Intracellular receptors because the steroid can go right through the lipid bilayer (as both are hydrophobic).

2. When dopamine attaches to its receptor (ligand-gated ion channel), the channel opens and allows sodium ions to pass through the channel into the nerve cell.

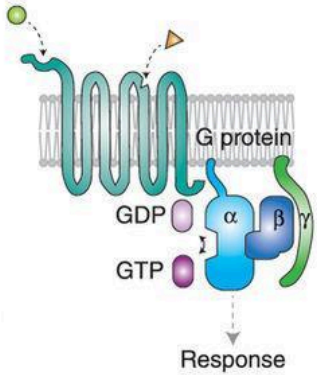


a. The dopamine is acting as what type of molecule? ligand

b. The receptor is also what type of membrane protein? transport protein/channel

c. If the sodium is moving down a concentration gradient, what type of movement is occurring? facilitated diffusion (passive transport)

d. Why is the transport of sodium ions important in our nerve cells? because ions are the electricity of our bodies. Ions moving along a nerve cell's membrane means that the neuron is firing (responding).

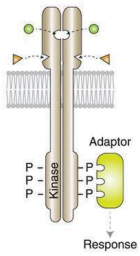


3. When a ligand attaches to a G protein coupled receptor, the receptor changes shape and interacts with GTP.

a. What is GTP? GTP is guanine triphosphate is an energy molecule, like ATP. It is acting as a second messenger (because it's not a protein, but its involved in the signal transduction cascade).

b. What does GTP do to the G protein? GTP activates the G protein by phosphorylating it.

4. When a ligand attaches to a receptor tyrosine kinase, the receptor changes shape and uses ATP to become phosphorylated.



a. what is tyrosine? it's just an amino acid that's good at getting phosphorylated.

b. What is so special about having six different phosphorylated parts?

It can start six different signal transduction pathways, thus coordinating many different activities that may need to occur at the same time.

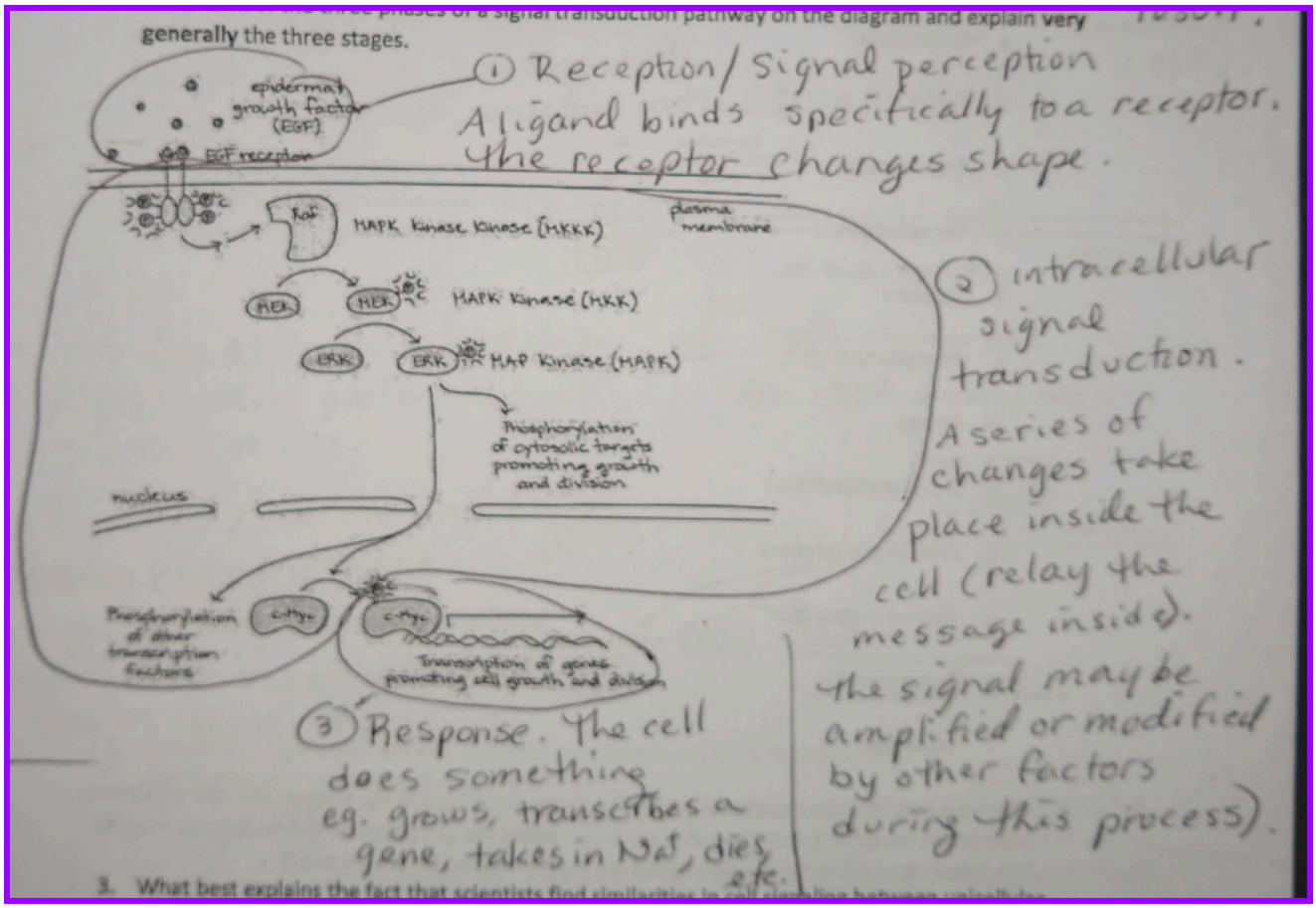
5. For the three types of receptors listed above, the ligand attachment to the extracellular domain of the receptor causes what to happen to the intracellular domain of the receptor?

a shape change!

6. What does the term transduction mean?

Transduction is the process of converting a ligand's message into a cellular response. (all the stuff between ligand attachment to receptor and the final response by the cell).

7. There are three major stages in a signal transduction pathway (signal perception, intracellular signal transduction, and cellular response). Below is a particular signal transduction pathway. Label each of the three phases of a signal transduction pathway on the diagram and explain **very generally** the three stages.



8. What is phosphorylation? Label it in the previous diagram.

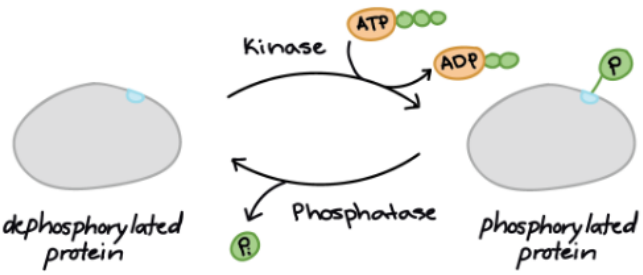
Phosphorylation is the process of adding a phosphate group (PO_4) to a molecule. You should label the inside portion of the receptor molecule, and the right side of the diagram for MEK and ERK, the C-Myc.

9. What is de-phosphorylation? Add it to the previous diagram.

Dephosphorylation is the process of removing a phosphate group (PO_4) from a molecule.

Draw arrows for MEK, ERK, and C-Myc going back to the dephosphorylated state (as well as the receptor).

10. What is a kinase? What is a protein phosphatase?

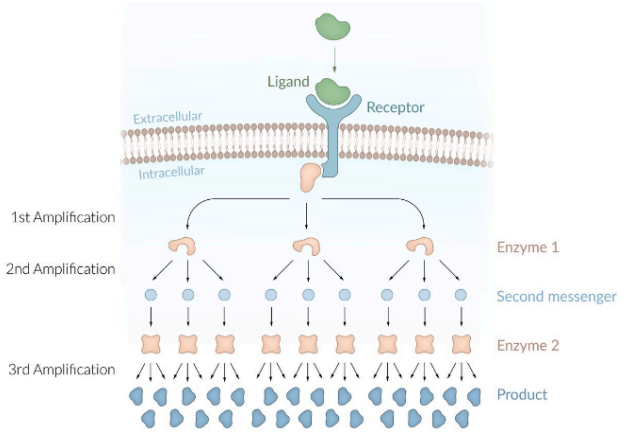


A kinase is an enzyme that phosphorylates another molecule (usually activating it)

A phosphatase is an enzyme that phosphorylates another molecule (usually inactivating it)

11. What is a cascade? Why are there so many steps to some cascades?

A cascade is a series of molecular interactions, each one activating the next. There are many steps in some cascades because it allows for more ways to regulate the process (activating or inhibiting at different steps), and/or it allows for amplification of the signal, and/or it allows for branching signals, so that one ligand can lead to several different, coordinated responses within the cell.



12. What does it mean for a signal to be amplified? Explain using this diagram.

Amplification increases the strength of the response. In the diagram, for example, one ligand produces 27 products.

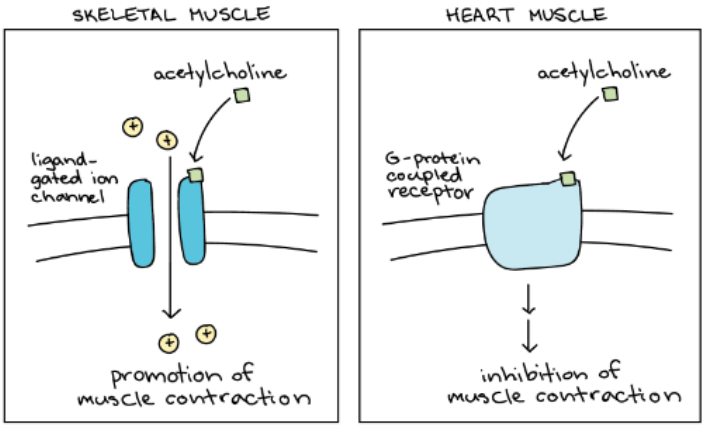
13. What is a relay protein?

Relay proteins are part of a cascade of reactions in signal transduction.

14. What is a second messenger?

A non-protein relay molecule involved in signal transduction.

15. Why would a different cell respond differently to the same chemical signal? For example, acetycholine causes skeletal muscle to contract, but causes heart muscle cells to relax. How can this be possible?



The receptors on the different cell types can be different, as long as the extracellular domain receives the same ligand.
The signal transduction cascade within different cells can also be different. Each cell type will produce

different proteins and second messengers, so the cascade can be different, resulting in different cellular responses.

Topic 4.3: Signal Transduction

Learning Objective	**IST-3.E Describe the role of the environment in eliciting a cellular response.**
I can…	□ describe how signal transduction pathways influence how the cell responds to its environment □ describe how signal transduction pathways may result in changes in gene expression and cell function □ describe how signal transduction pathways may alter phenotype (physical traits) or result in programmed cell death (apoptosis)

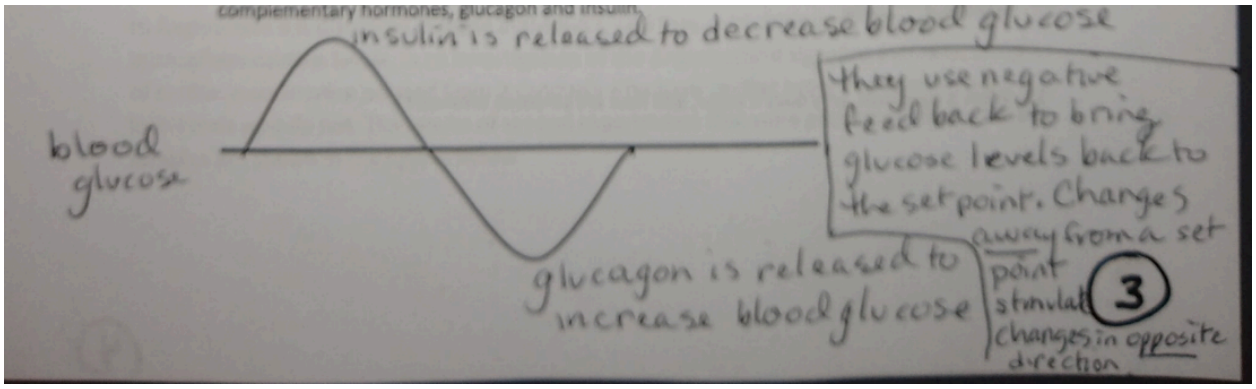
1. Explain the relationship between blood glucose levels, negative feedback, and the complementary hormones, glucagon and insulin.

Insulin is released when blood glucose levels are high. The insulin causes cells to take in glucose, lowering blood glucose levels. Once the glucose levels drop, insulin is no longer released.

Negative feedback means that changes away from a set point trigger changes in the opposite direction (to restore the set point). This is an example of negative feedback because high glucose levels trigger changes back to normal blood glucose levels. Also, the insulin level rises, but then goes back to lower levels due to negative feedback.

Glucagon is released when blood glucose levels are low. The glucagon causes cells to release glucose (from stored glycogen), raising blood glucose levels. Once the glucose levels rise sufficiently (due to eating or glucose release from cells), glucagon is no longer released.

Negative feedback means that changes away from a set point trigger changes in the opposite direction (to restore the set point). This is an example of negative feedback because low glucose levels trigger changes back to normal blood glucose levels. Also, the glucagon level rises, but then goes back to lower levels due to negative feedback.

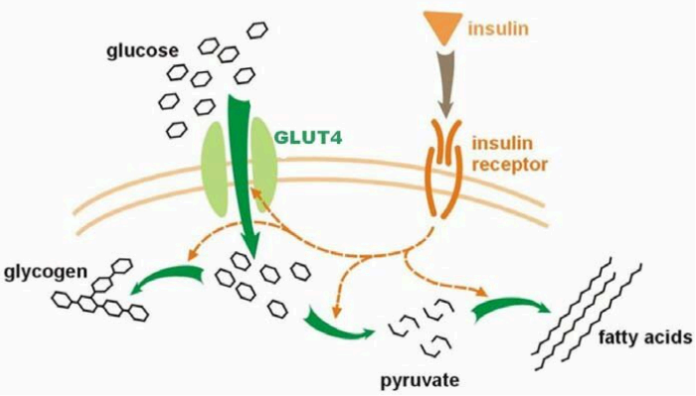


2. Distinguish between type one and type two diabetes. (You don't really need to know this, but there is so much on diabetes on the test, that it would probably make it easier for you to have some background knowledge of it).

Type 1 diabetes is an autoimmune disease. The body attacks the beta cells in the pancreas that make insulin. Thus no insulin (no ligand) is made and patients must take insulin injections or have an insulin pump.

Type 2 diabetes occurs when the body no longer responds to insulin appropriately (and also sometimes doesn't make enough insulin for body size). So type 2 diabetes is more of a signal transduction problem.

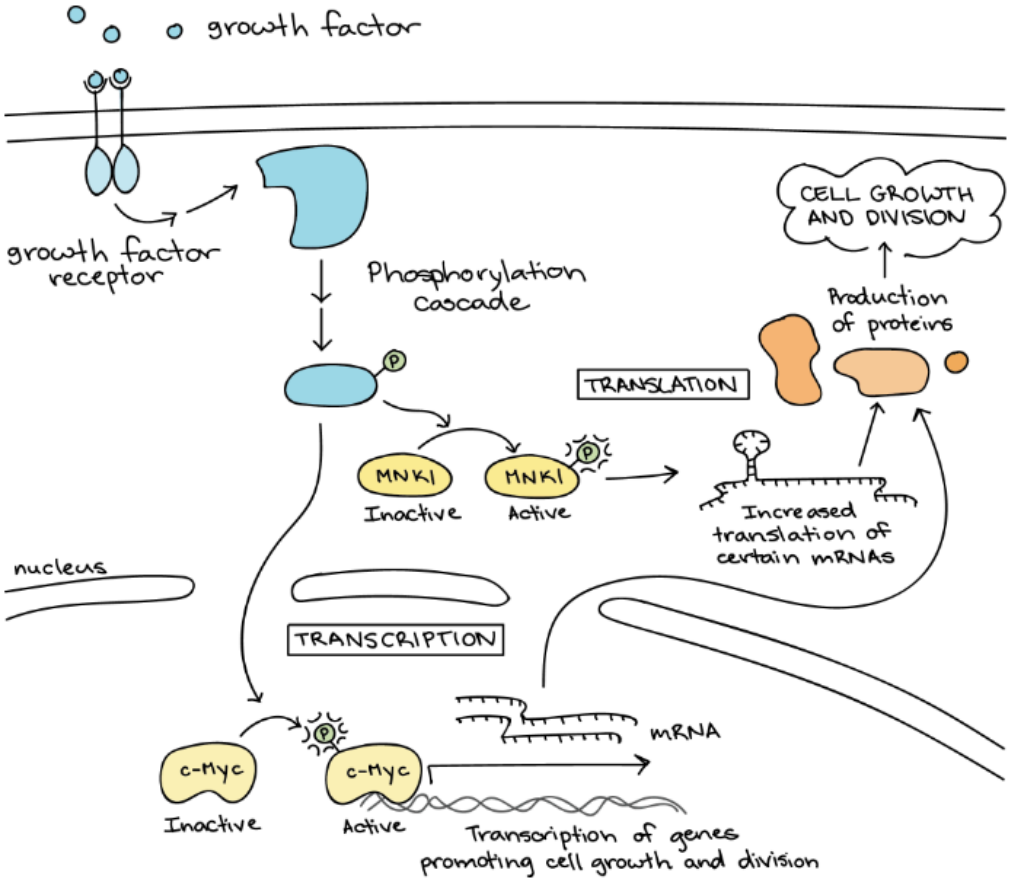
3. Eating carbs causes blood glucose levels to increase. This causes the pancreas to release insulin. Describe the cellular responses shown in the diagram to insulin's attachment to the insulin receptor.



Three cellular responses are shown:

1. glucose is taken into the cell,
2. glucose is converted to glycogen (a polysaccharide) to be stored for later use, and
3. glucose is converted to pyruvate and then to fatty acids (lipids, which store energy for a longer time).

4. The responses of the cell to growth factor are shown in a cell below. Describe the cellular responses shown in the diagram.



The cellular response is production of RNA from DNA (transcription) and increased protein synthesis (translation). These proteins are factors that stimulate the cell to grow larger and to enter mitosis (cell division)..

5. What is transcription? What is a transcription factor? (more on transcription factors in unit 6)

Transcription is the process of copying a portion of DNA into RNA (or the process of producing RNA from a gene). A transcription factor is a protein that is needed or helpful for transcription (in this case, for a particular gene). We will spend a lot more time on this in unit 6.

6. Given the diagram above, explain how a signal (like growth factor) can change the phenotype (physical characteristics) of an organism.

We'll study phenotype in unit 5 (genetics). It's the physical trait, like having brown eyes, and is often the result of a particular genotype.

Anyway, a growth factor can stimulate expression of a particular gene, which can produce a physical trait (phenotype). For example, if you have the gene to have brown eyes, you actually have to have that gene transcribed and translated in the iris cells of the eye in order to make the protein melanin which makes the eyes appear brown.

I don't love this question. But, all of your cells should have the genes necessary for growth and reproduction. You just have to turn those genes on (transcribe them) in order to actually grow and reproduce.

7. What is apoptosis? Why would a cell use apoptosis?

Apoptosis is programmed cell death. The cell doesn't just die and spill its lysosomes and digestive enzymes all over the place, hurting other cells. Instead, the cell safely (for other cells) and systematically shuts down and dies.

Our cells do this during normal development. For example, the cells between the fingers and toes need to die in order to produce individual cells. Another example in development would be a tadpole's tail, which gets reabsorbed as the tadpole becomes a froglet.

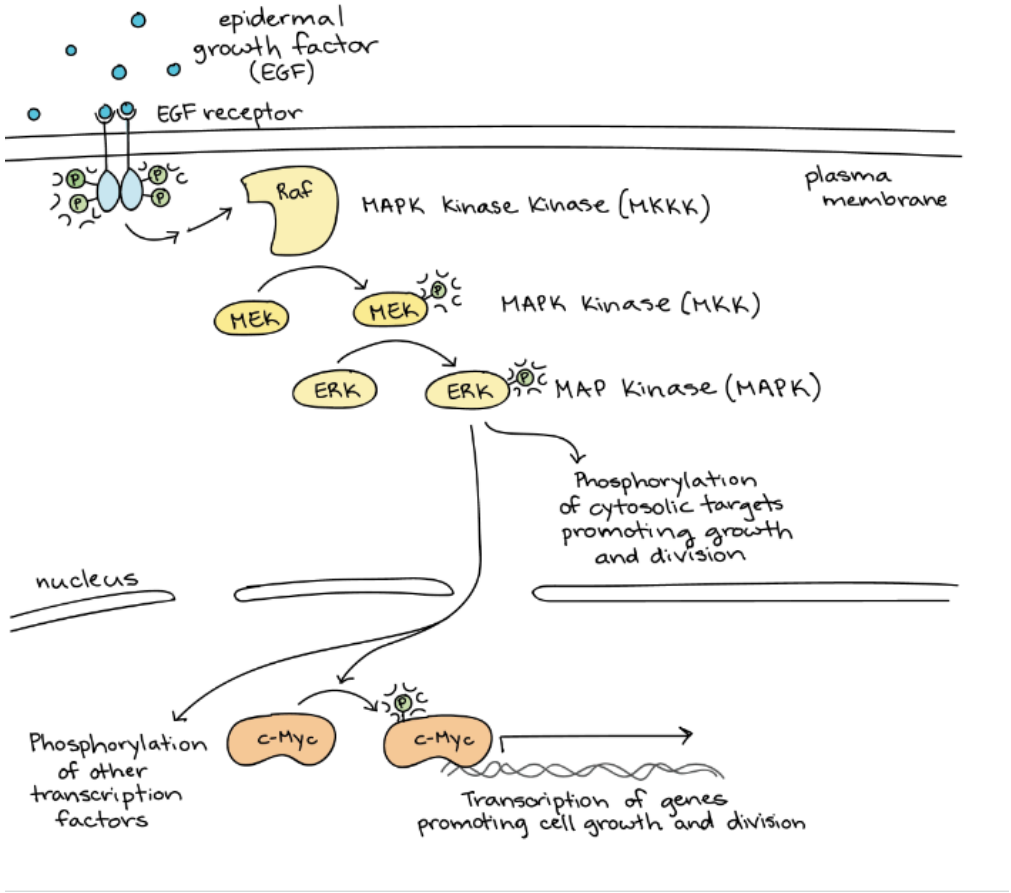
A cell will also use apoptosis when it is damaged in order to prevent cancer.

Topic 4.4: Changes in Signal Transduction Pathways

Learning Objective	**IST-3.G Explain how a change in the structure of any signaling molecule affects the activity of the signaling pathway.**
I can..	□ describe how mutations in any domain of the receptor protein or in any component of the pathway can affect the outcome of the signal □ describe how chemicals that interfere with any component of the signal transduction pathway may activate or inhibit the pathway

Use the diagram to answer questions about changes to the typical pattern shown below:

1. If the EGF receptor is mutated to <u>always</u> become phosphorylated (even in the absence of EGF), how would the cell respond?



The cell would constantly be growing and dividing (making a tumor), whether the growth factor is present or not.

2. If the EGF receptor is mutated to <u>never</u> become phosphorylated, how would the cell respond?

The cell would never grow or divide, whether the growth factor is present or not.

3. How will the cellular response change if ERK is <u>always</u> phosphorylated (even in the absence of EGF)?

The cell would constantly be growing and dividing (making a tumor), whether the growth factor is present or not.

4. How will the cellular response change if ERK can <u>never</u> be phosphorylated (even in the presence of EGF)?

The cell would never grow or divide, whether the growth factor is present or not.

5. How can a chemical that blocks EGF binding interfere with the signaling pathway?

Cell growth and division would be inhibited/slowed (or even stopped) because EGF will not be able to bind to the receptor (or not bind as frequently).

6. How can a chemical that inhibits MAP Kinase change the signaling pathway?

Target molecules will not get phosphorylated, so they will not be activated, so they will not promote growth or mitosis. So even if the growth factor (EGF) is present, cell growth and cell division will be inhibited.

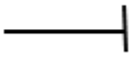
7. How can a chemical that promotes c-Myc phosphorylation change the cellular response?

Cell growth and cell division will be promoted (increased).

Topic 4.5: Feedback

Learning Objective	**ENE-3.A Describe positive and/ or negative feedback mechanisms.**
I can..	□ describe positive feedback mechanisms. □ describe negative feedback mechanisms. □ describe ways organisms use feedback mechanisms to maintain homeostasis. □ describe ways organisms respond to internal and external environmental changes.

1. What do these symbols mean?

 go or leads to  inhibit or decrease

2. Distinguish between positive feedback and negative feedback.

Positive feedback - changes away from a set point cause more changes in that same direction (away from the set point). For example, once clotting begins in the blood, the clotting factors promote other clotting factors, which speed the clotting of blood. Another example, once pepsin is activated in the stomach, more pepsin becomes activated. Another example, ethylene is a gas that promotes fruit ripening. Ripe fruit produce ethylene gas, which promotes even more fruit ripening.

Negative feedback - changes away from a set point cause changes in the opposite direction (back to the set point). Negative feedback is NOT a bad thing. Negative just means “go the other way.” For example, when we get too hot, our bodies sweat to cool us down.

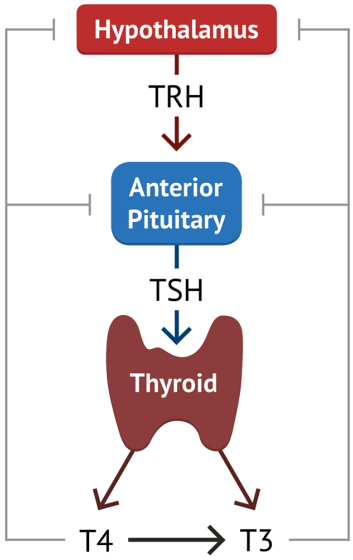
3. Which type of feedback amplifies a response?

positive feedback. (Amplify (like with music) means to increase it or to turn it up!)

4. Which type of feedback returns the body to a set point after a disturbance?

negative feedback

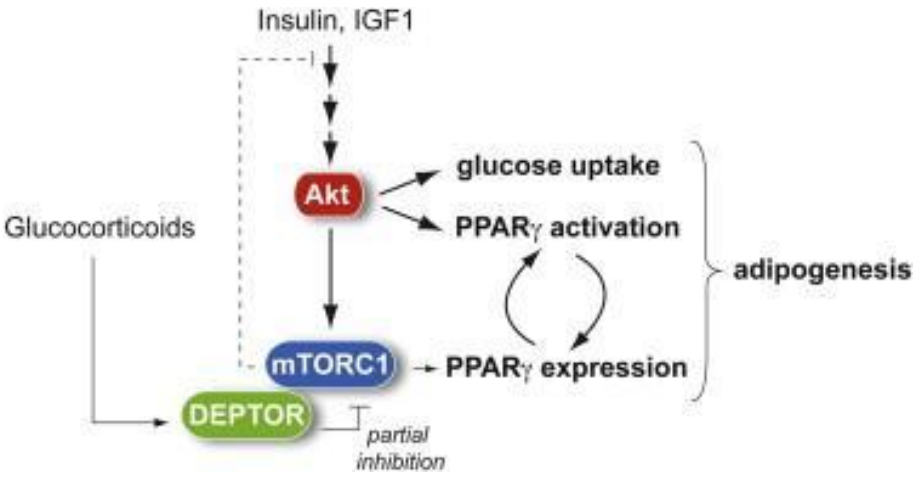
5. Explain the effect of high levels of T3 and T4 on TRH and TSH. Use the term “negative feedback” in your description.



The hypothalamus produces the hormone TRH which stimulates the anterior pituitary gland to produce TSH. TSH is a hormone that stimulates the thyroid gland to produce T3 and T4. Once we have high levels of T3 and T4, these inhibit the hypothalamus, so it makes less TRH. High levels of T3 and T4 also inhibit the anterior pituitary gland, so it makes less TSH.

So, high levels of T3 and T4 reduce TRH and TSH levels. This is negative feedback because the high T3 and T4 will reduce TRH and TSH, and low levels of these will stop stimulating the thyroid, producing less T3 and T4, thus keeping levels of T3 and T4 at a fairly stable level. (changes away from a set point - producing lots of T3 and T4 - trigger changes in the opposite direction - producing less T3 and T4)

When we have low T3 T4, then we stop inhibiting. Which means that we’ll start making more TRH and TSH (which will then stimulate the production of T3 and T4)..



6. Adipogenesis is the formation of fat cells from a particular type of stem cell. You don’t need to know anything about it (yay). Study the diagram.

a. Does insulin stimulate or inhibit adipogenesis?

b. Do glucocorticoids stimulate or inhibit adipogenesis?

7. What is apoptosis?

SORRY FOR THE REPEAT QUESTION. CROSS IT OUT, IF YOU WANT.

Apoptosis is programmed cell death. The cell doesn’t just die and spill its lysosomes and digestive enzymes all over the place, hurting other cells. Instead, the cell safely (for other cells) and systematically shuts down and dies.

8. What are stem cells?

Stem cells are undifferentiated cells that can differentiate into specialized cells.

BACKGROUND WITH VOCAB THAT YOU DON'T NEED:

Totipotent cells can form all the cell types in a body, plus the extraembryonic, or placental, cells. (Very early embryonic cells).

Pluripotent cells can give rise to all of the cell types that make up the body (but not placenta)

Multipotent cells can develop into more than one cell type, for example, adult bone marrow cells can differentiate into red blood cells, any of the many types of white blood cells, and platelets.

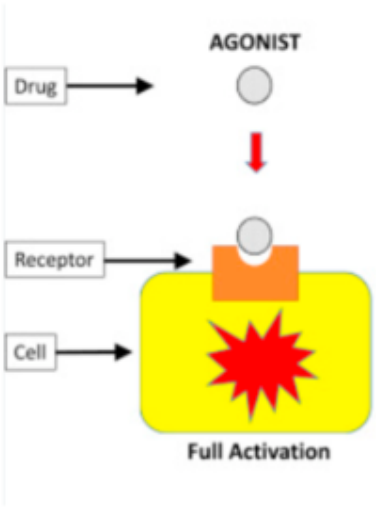
9. Pharmaceuticals (drugs) are developed and produced to help treat various diseases. Some of these drugs work great and some don't. You might see the term "efficacy" used to describe this. Please define efficacy.

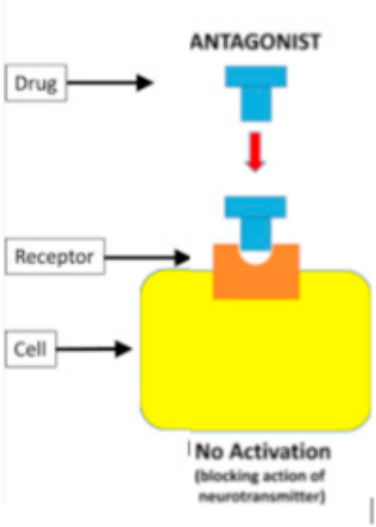
Efficacy is effectiveness. So if a drug has high efficacy, it works really well, producing the desired result (making you well again).

10. Explain how the drugs (agonist or antagonist) in each of the examples here work.

An agonist is a drug that mimics a ligand (or it is a natural ligand). The agonist activates the receptor.

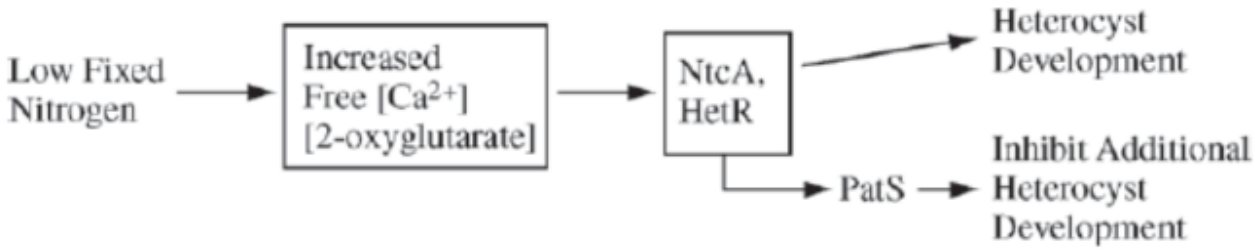
An antagonist blocks the ligand, stopping it from working (opposite of the agonist). The antagonist stops the receptor from activating.





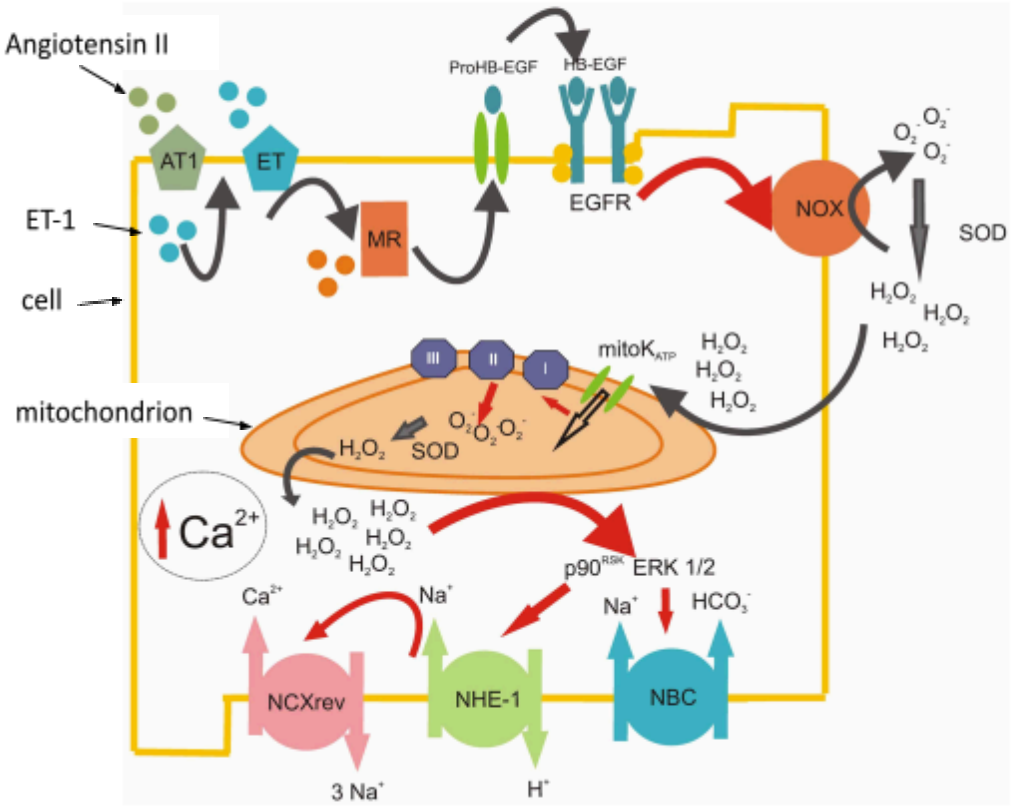
11. Anabaena is a simple multicellular photosynthetic cyanobacterium. In the absence of fixed nitrogen, certain newly developing cells along a filament express genes that code for nitrogen-fixing enzymes and become non-photosynthetic heterocysts. The specialization is advantageous because some nitrogen-fixing enzymes function best in the absence of oxygen. Heterocysts do not carry out photosynthesis but instead provide adjacent cells with fixed nitrogen, in exchange receiving fixed carbon and reduced energy carriers. When there is low fixed nitrogen in the environment, an increase in the concentration of free calcium ions and 2-oxyglutarate stimulates the expression of genes that produce two transcription factors (NtcA and HetR) that promote the expression of genes responsible for heterocyst development. HetR also causes production of a signal, PatS, that prevents adjacent (nearby) cells from developing as heterocysts.

In a low fixed nitrogen environment, explain how treating cells with a calcium binding compound would affect heterocyst development.



In an environment with low fixed nitrogen, treating the Anabaena cells with a calcium-binding compound should prevent heterocyst differentiation.

Practice for the Cell Signaling Test



Angiotensin II (a small peptide) stimulates AT1 receptors. This induces the release of intracellular ET-1, which, in turn, acts on ET receptors. This leads to the activation of the mineralocorticoid receptor (MR), which causes the release of membrane heparin-bound EGF (HB-EGF). HB-EGF then stimulates EGFR receptors. The stimulation of the EGFR leads to the activation of the NADPH oxidase (NOX), which produces superoxide anion (O_2^-) and quickly is converted to hydrogen peroxide (H_2O_2) by superoxide dismutase (SOD). This molecule produces the opening of mitochondrial ATP-dependent potassium channels (mitoK$_{ATP}$) with the subsequent enhanced production of mitochondrial O_2^-. These mitochondrial O_2^- are converted to H_2O_2 and released to the cytosol, where they stimulate MAPkinases (ERK 1/2 and p90^{RSK}), which, in turn, activate NHE-1 and NBC, pH regulation transporters that induce the increase in intracellular Na^+. Finally, this cytosolic Na^+ increase favors the operation of the reverse mode of NCX, promoting the influx of Ca^{2+} into the cell. The enhancement of intracellular Ca^{2+} in a cardiac muscle cell increases the strength of muscle contraction (Summary of research paper found here: https://www.researchgate.net/publication/237098431_Mitochondrial_reactive_oxygen_species_ROS_as_signaling_molecules_of_intracellular_pathways_triggered_by_the_cardiac_renin-angiotensin_II-aldosterone_system_RAAS).

(Note: I am making up most of the stuff that follows, to give you practice in interpreting graphs).

In cardiac hypertrophy, the heart enlarges and outgrows is blood supply. The cellular response to Angiotensin II is disrupted in these individuals, and they cannot properly regulate intracellular calcium levels. In an investigation of the Angiotensin II signaling pathway, samples of cardiac muscle were isolated from individuals who have cardiac hypertrophy and from individuals who do not. The results of several experiments that were performed on the muscle samples are shown in the figures below.

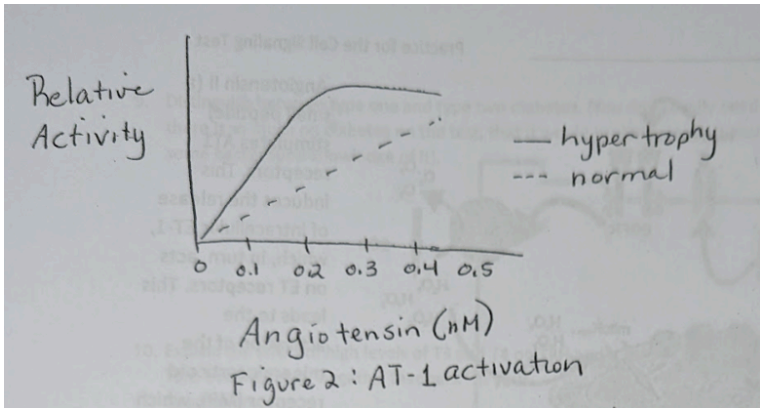


Figure 2 : AT-1 activation

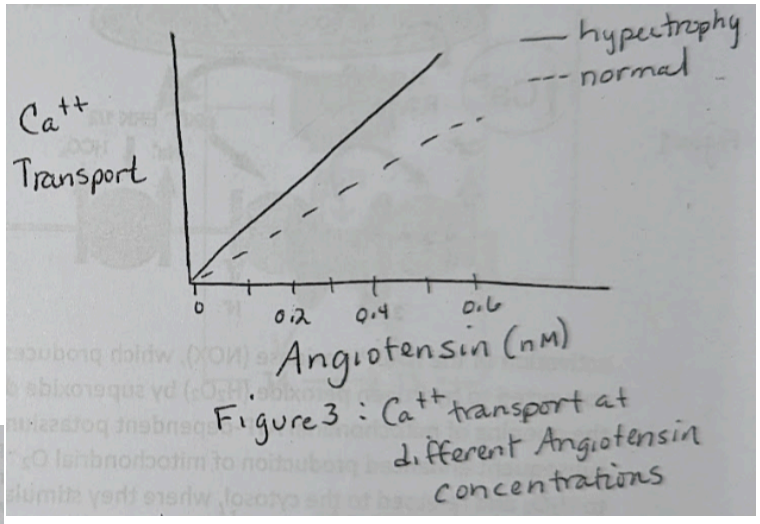


Figure 3 : Ca^{++} transport at different Angiotensin concentrations

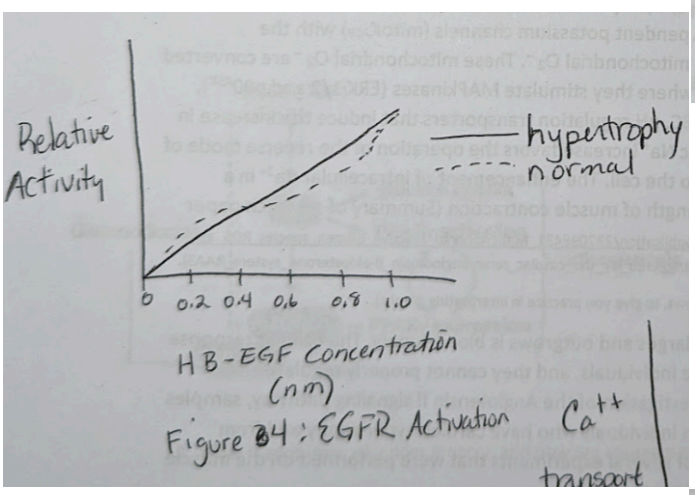


Figure 4 : EGFR Activation

Ca^{++} transport

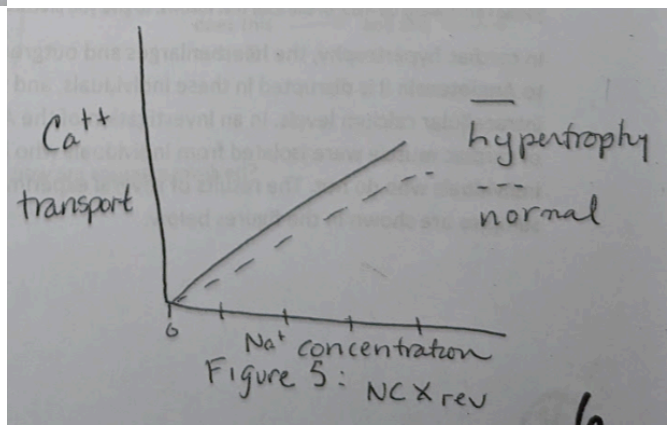


Figure 5 : NCX rev

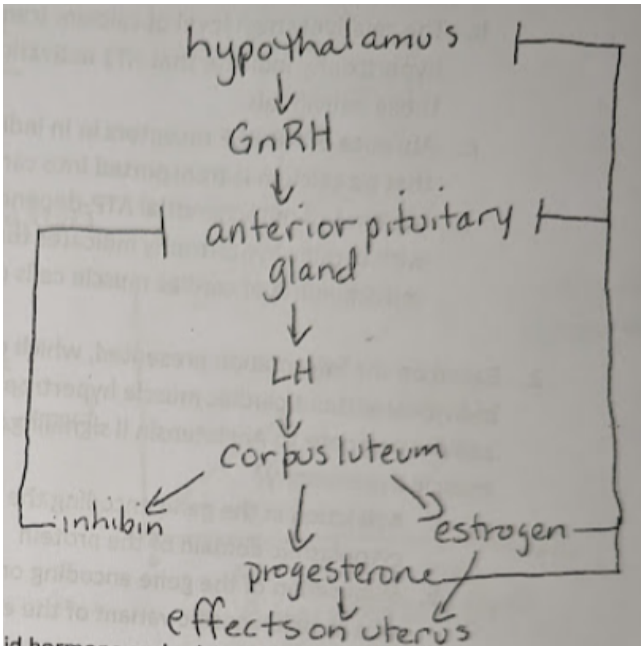
1. Which of the following is a valid interpretation of the experimental results that explains how individuals with cardiac hypertrophy differ from individuals without cardiac hypertrophy?
    a. The relatively high level of calcium transport in individuals with cardiac hypertrophy indicate that no angiotensin is received by cardiac muscle cells of those individuals
    b. The relatively high level of calcium transport in individuals with cardiac hypertrophy indicate that AT1 activation is increased in cardiac muscle cells of those individuals
    c. Absence of HB-EGF receptors in in individuals with cardiac hypertrophy indicates that no calcium is transported into cardiac muscle cells of these individuals
    d. Absence of mitochondrial ATP-dependent potassium channels in in individuals with cardiac hypertrophy indicates that no potassium is transported into mitochondria of cardiac muscle cells of these individuals

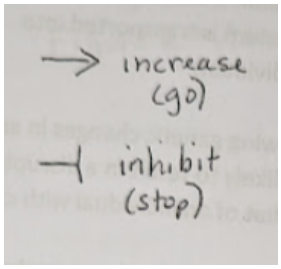
2. Based on the information presented, which of the following genetic changes in an individual without cardiac muscle hypertrophy is most likely to result in a disrupted cellular response to Angiotensin II signaling similar to that of an individual with cardiac muscle hypertrophy?
    a. A deletion in the gene encoding the EGFR receptor that removes only the cytoplasmic domain of the protein
    b. Duplication of the gene encoding one of the MAPkinases that results in synthesis of a muscle-specific variant of the enzyme in liver cells as well as in cardiac muscle cells.
    c. A mutation in the gene encoding AT1 that causes the protein to be inactive in cardiac muscle cells even in the absence of angiotensin II.
    d. Insertion of a small segment of DNA into the promoter of the NCX_{rev} gene that results in increased synthesis of NCX_{rev} proteins in cardiac muscle cells

3. Based on the experimental results, which of the following describes the most likely defect in cardiac muscle cells of patients with cardiac hypertrophy?
    a. NCXrev blocks calcium from entering the cells
    b. Angiotensin over activates the AT1 receptor
    c. The ET receptor is inactivated at high angiotensin concentrations
    d. Hydrogen peroxide does not activate mitochondrial ATP-dependent potassium channels

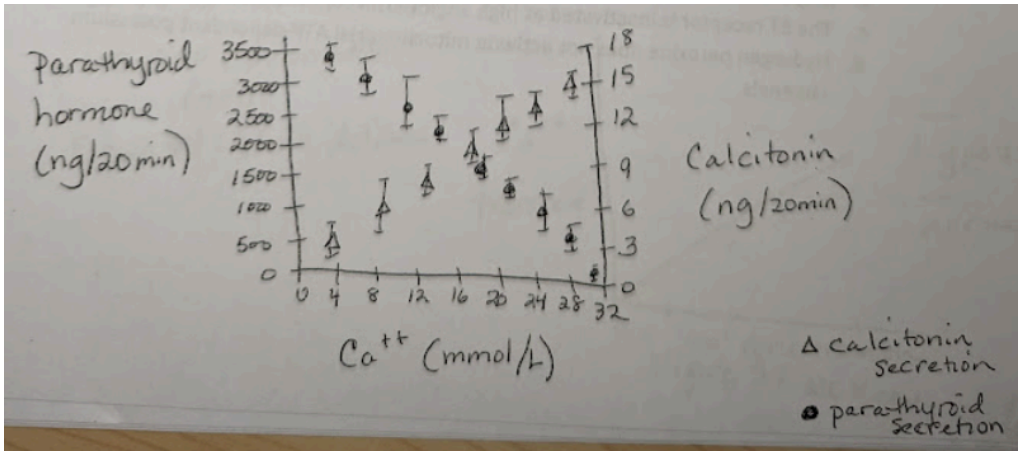
4. Regulation of estrogen is required for maintenance of a healthy uterus in mammals, as summarized in the figure. Several compounds in plastics mimic the action of estrogen when they are absorbed into the body, which can occur when food or water is stored in plastic. Assuming that these mimics function in the same way as naturally occurring estrogen, it is most likely that these mimics would

A. decrease natural estrogen production
B. stimulate LH secretion
C. stimulate progesterone production
D. stimulate inhibin secretion





5. The graph below shows changes in parathyroid hormone and calcitonin secretions at different concentrations of blood calcium levels. Which of the following feedback mechanisms is best supported by the data?
    a. A low parathyroid level causes a rise in calcitonin level, which maintains equal amounts of both hormones in the blood.
    b. A high parathyroid level causes a rise in calcitonin level, which maintains equal amounts of both hormones in the blood.
    c. A high calcium level causes the release of parathyroid hormone, which stimulates the release of more calcium from bones
    d. A high calcium level causes the release of calcitonin, which inhibits the release of calcium from bones



6. Thyroxin is a hormone that increases metabolic activities within various tissue targets. Low levels of circulating thyroxin trigger the secretion of thyroid-stimulating hormone (TSH) from the anterior pituitary. TSH secretion then stimulates thyroxin production and release by the thyroid gland. The increased level of circulating thyroxin inhibits further secretion of TSH from the anterior pituitary. Based on the information provided, which of the following can most likely be concluded about the TSH-thyroxin loop?
A. A person taking thyroxin to supplement low thyroxin secretion will produce more TSH.
B. Increased thyroxin production would cause elevated ribosomal activity in the anterior pituitary.
C. The structure of the loop would lead to elevated thyroid and tissue activity due to positive feedback.
D. The feedback mechanism would maintain relatively constant levels of thyroxin throughout tissue targets.

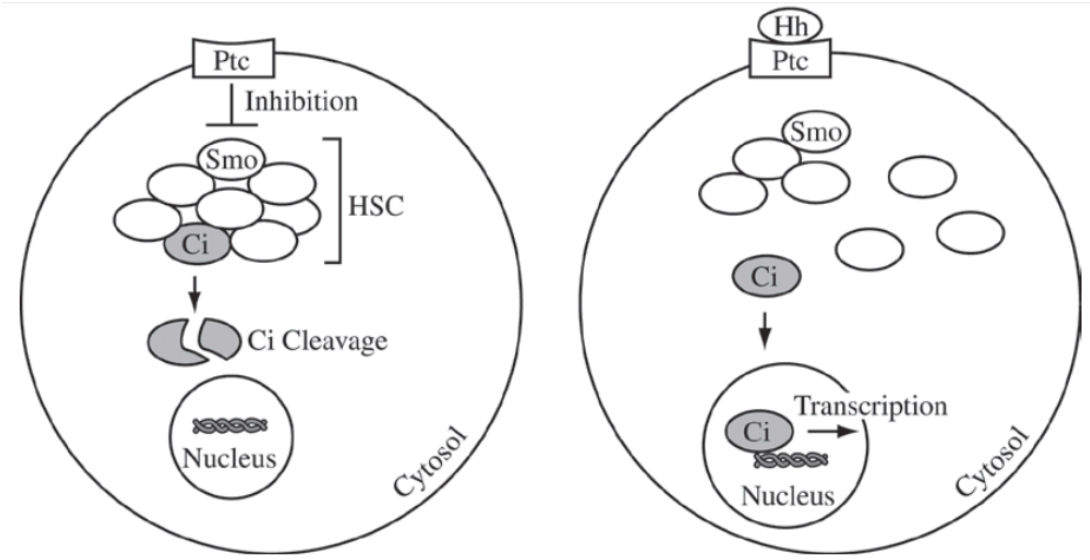
7. Type 1 diabetes results from the destruction of insulin-producing cells in the pancreas. Individuals with type 1 diabetes produce insufficient amounts of insulin, a hormone that regulates the concentration of glucose in the blood.
Which of the following best explains how treatment with a drug that stimulates the production of insulin receptors on target cells will affect the insulin signaling pathway in an individual with type 1 diabetes?
A. The drug will have little or no effect on the signaling pathway because the receptors will not be activated in the absence of insulin.
B. The drug will have little or no effect on the signaling pathway because insulin receptors will not be allowed to enter the cells.
C. The drug will restore the function of the signaling pathway because insulin levels will return to normal.
D. The drug will restore the function of the signaling pathway because nonpancreatic cells will begin to produce insulin receptors.

8. The mechanism of action of many common medications involves interfering with the normal pathways that cells use to respond to hormone signals. Which of the following best describes a drug interaction that directly interferes with a signal transduction pathway?
A. A medication causes the cell to absorb more of a particular mineral, eventually poisoning the cell.
B. A medication enters the target cell and inhibits an enzyme that normally synthesizes a second messenger.
C. A medication enters the target cell's nucleus and acts as a mutagen.
D. A medication interrupts the transcription of ribosomal RNA genes.

9. Ethylene gas is an organic molecule that serves many cell signaling roles in flowering plants. Which of the following best explains how a positive feedback mechanism involving ethylene works?
A. Cells of ripening fruit produce ethylene, which activates the ripening response in other fruit cells.
B. Low water stress causes cells to produce ethylene, which binds to root cells and initiates cell division.
C. Cells damaged by leaf-eating insects produce ethylene, which is released into the air, and repels insects.
D. Fertilized ovules produce ethylene, which initiates apoptosis in flower petal cells.

10. The Hedgehog protein (Hh) plays a critical role during a certain period of embryo development, but it normally has no role in adults except for the maintenance of adult stem cells. However, the Hedgehog

protein has been detected in 70 percent of pancreatic cancer cell samples. As illustrated in the figures below, the Hedgehog protein binds to an integral membrane protein receptor known as Patched (Ptc), thus initiating a pathway of gene expression. When Hedgehog is absent, Ptc inhibits another protein known as Smoothened (Smo), which, in turn, blocks the activation of a group of proteins collectively known as the Hedgehog signaling complex (HSC). The inactivation is the result of proteolytic cleavage of one component of the HSC complex, a transcription factor known as Cubitus interruptus (Ci). When Hedgehog is present, it binds to Ptc, which prevents the inhibition of Smo by Ptc. The result is that Ci remains intact and can enter the nucleus, where it binds to and activates certain genes.



One approach to treating patients with pancreatic cancer and other cancers in which the Hedgehog protein is detected is to modify the Hedgehog signaling pathway.

Which of the following is the most useful approach?

A. Treating patients with a molecule that is structurally similar to Hedgehog and that will bind to and interact with Ptc in the same fashion as Hedgehog

B. Injecting patients with embryonic cells so that Hedgehog will bind to those cells instead of the cancer cells

C. Treating patients with a membrane-soluble compound that can bind to Smo and block its activity

D. Injecting patients with a preparation of purified membrane-soluble Ci that will enter the nuclei of the cancer cells and induce gene transcription

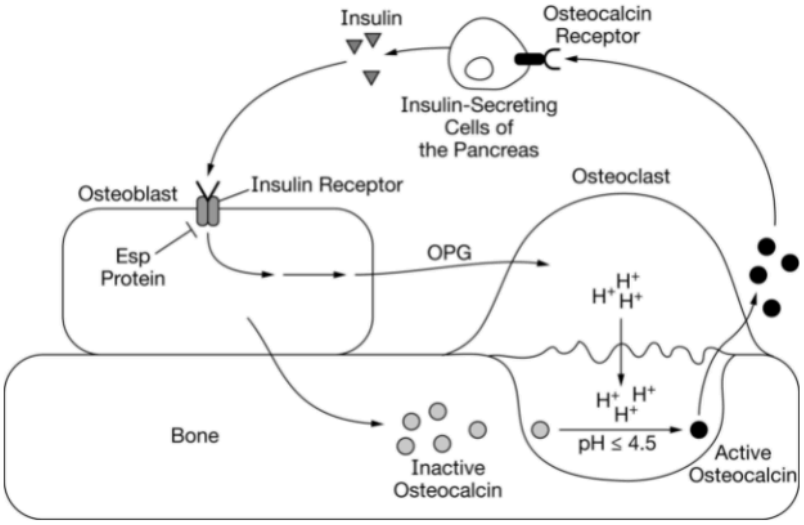
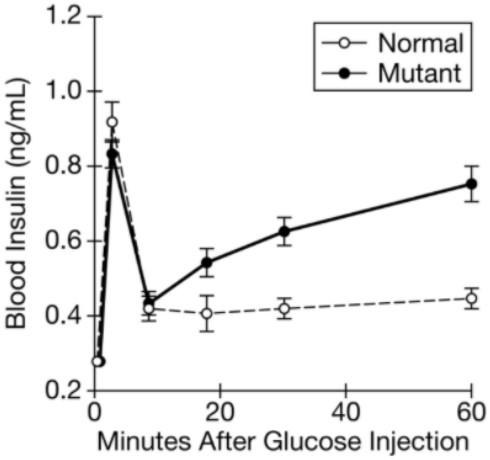


Figure 1. Pathway activated by insulin binding to the insulin receptor

Hormones are chemical signals that are released by cells in one part of the body that travel through the bloodstream to signal cells in another part of the body. Insulin is a hormone that is released by the pancreas that

induces the uptake of glucose molecules from the bloodstream into cells. In this way, insulin lowers the overall blood glucose levels of the body. Osteoblasts and osteoclasts are two types of bone cells that play a role in regulating blood glucose levels (Figure 1).



Binding of insulin to the insulin receptor on osteoblasts activates a signaling pathway that results in osteoblasts releasing a molecule, OPG, that binds to neighboring osteoclasts. In response, the osteoclasts release protons (H+) and create an area of lower pH outside the cell. This low pH activates osteocalcin, a protein secreted in an inactive form by osteoblasts.

Figure 2: Blood insulin levels in normal mice and Esp mutant mice after exposure to glucose

The Esp gene encodes a protein that alters the structure of the insulin receptor on osteoblasts and interferes with the binding of insulin to the receptor. A researcher created a group of osteoblasts with an Esp mutation that prevented the production of a functional Esp product (mutant). The researcher then exposed the mutant strain and a normal strain that expresses Esp to glucose and compared the levels of insulin in the blood near the osteoblasts (Figure 2).

11. Based on the information provided, which of the following best justifies the claim that osteocalcin is a hormone?
A. The phosphorylation of the insulin receptor causes a response in osteoblast bone cells.
B. The osteoblasts in the bone secrete osteocalcin, which causes cells in the pancreas to change their activity.
C. The change in expression of Esp changes the insulin receptor activity of the osteoblast.
D. The activation of the osteocalcin by a bone cell is pH dependent.

12. Scientists compared the chemical structure of several molecules that various bacterial species use for quorum sensing. Quorum sensing is an ability some bacteria have to detect the number of related cells nearby. The chemical structure of some of these molecules found in certain species of bacteria are shown in Figure 1.

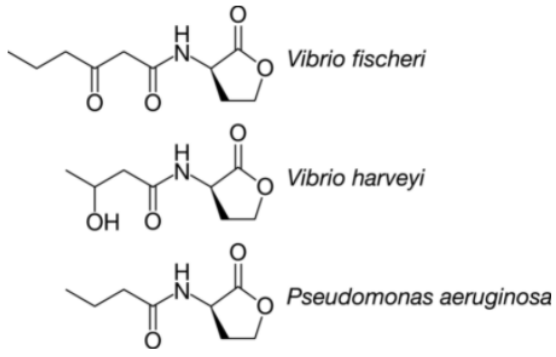
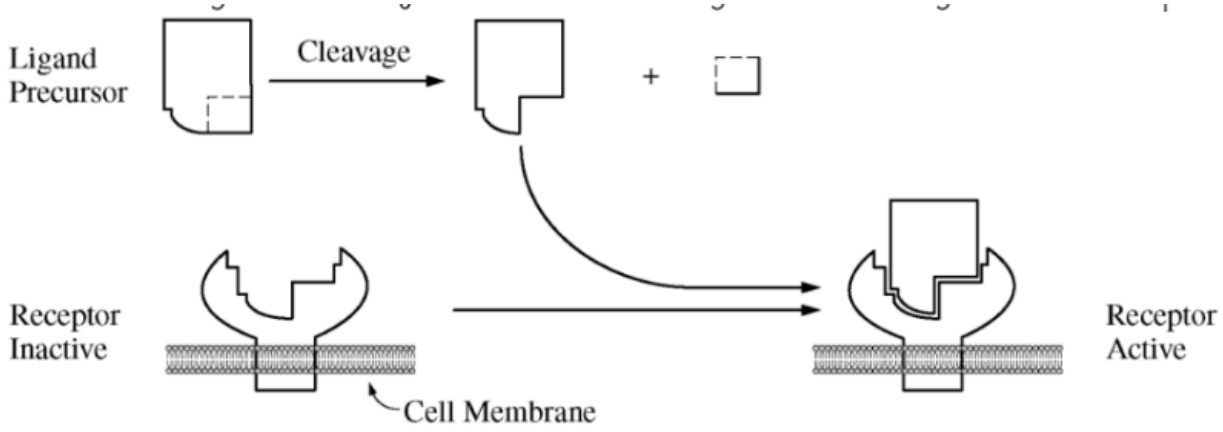


Figure 1. The chemical structure of several molecules used for quorum sensing in three species of bacteria

Which of the following research questions would best guide an investigation of the link between the structure of the signaling molecules and the evolution of quorum sensing?
A. Do these molecules require the same receptors in each bacteria species to generate a response?

B. Did these species evolve from a common ancestor that used a similar signaling molecule?
C. Do these species all perform the same action when the concentration of the signaling molecules is high enough?
D. Did these species evolve from the same common ancestor that is still living today and uses the same receptors?

13. The figure below shows a model of a ligand precursor being cleaved to produce an active ligand that binds to a specific receptor. Which of the following is most likely to reduce the binding of the active ligand to its receptor?



A. A change in the cytoskeletal attachment of transmembrane proteins
B. The presence of a large amount of the precursor form of the ligand
C. An increase in the ratio of the number of unsaturated to the number of saturated fatty acid tails of the membrane lipids
D. A mutation in the receptor gene that causes a substitution of a charged amino acid for a nonpolar amino acid in the ligand binding site of the receptor