

# Actions of Hormones on Target Cells

Graphics are used with permission of:  
Pearson Education Inc., publishing as Benjamin Cummings (<http://www.aw-bc.com>)

## Page 1. Actions of Hormones on Target Cells

- Hormones influence their target cells by binding to specific receptors.
- The hormone-receptor interaction initiates the process of transforming the chemical message into a cell response.

## Page 2. Goals/ What You Need to Know

### Goals

- To learn about hormone receptors.
- To describe common second messenger systems and transcription factors.
- To review insulin.
- To understand that hormones induce changes in cellular metabolism.

### What You Need to Know

- That changing the shape of a molecule can activate or inactivate it.
- The terminology of carbohydrate, lipid and protein metabolism.
- The difference between the absorptive and postabsorptive states of the body.

## Page 3. Target Cell Responses to Hormones

- Hormones bind with **receptors** to initiate the cellular response to a chemical signal.
- Target cells **convert** the signal into a biochemical change inside the cell.
  - Via second messenger systems.
  - Via direct gene activation.
- Cells **respond** to this stimulus in several different ways:
  1. Cause contraction of muscle tissue.
  2. Secretion of cellular products.
  3. Effecting ion exchange through channels.
  4. Cause synthesis of new peptides and proteins.
  5. Cause breakdown of storage molecules.
- Receptors are complex proteins that only respond to specific hormones.
  - Receptors for water-soluble hormones are found on the plasma membrane.
  - Receptors for lipid-soluble hormones are found in the cytoplasm or the nucleus.
- Receptors will **down-regulate** and decrease sensitivity when there is prolonged exposure to high levels of a hormone.
- Receptors have the ability to **up-regulate** and increase sensitivity in response to sustained low levels of a hormone.
- Not all cells have receptors for all hormones and some cell respond differently to different concentrations of hormone.

### **\*\*Now is a good time to go to the quiz question #1.**

- Click the quiz button on the left side of the screen.
- Click on the scrolling page list at the top of the screen and complete question 1.
- When you are finished you can click the return from link button on the left side of the screen to return to the topic.

## Page 4. Water-soluble Hormones and Receptor Responses

- The water soluble hormones are the peptide and catecholamines.
- They bind to receptors on the outside surface of the cell.
- Two common classes of membrane bound receptors are:
  - Receptors that activate G-proteins.
  - Receptors that activate protein kinases.
- 1. G-protein moderated second messenger systems
  - cAMP second messenger.**
    - Hormone (first messenger) binds to receptor on outside of cell membrane.
    - Receptor changes shape and activates G-protein on inside of cell membrane.
    - GTP binds to G-protein and causes it to activate **adenylate cyclase**.
    - Adenylate cyclase converts ATP into cyclic AMP (**cAMP**).
    - cAMP acts as a second messenger and phosphorylates kinases inside the cell.
    - The kinases can activate or inhibit activities of the cell.
    - The process continues as long as long as the G-protein is active.
    - **Phosphodiesterase** degrades cAMP and stops the process.

- **Amplification** – greatly increases the effect that single hormone molecule has on the activity of a cell.

### **DAG and IP<sub>3</sub> second messengers.**

- Diacylglycerol (DAG) and inositol triphosphate (IP<sub>3</sub>) are other G-protein moderated second messengers.
- Hormone binds to receptor on outside of cell membrane which changes shape and stimulates the G-protein.
- Activated G-protein binds to **phospholipase C** on inside of cell membrane.
- Phospholipase C converts membrane phospholipids into DAG and IP<sub>3</sub>.
- DAG remains in the cell membrane and activates protein kinase C which influences cell response.
- IP<sub>3</sub> causes the endoplasmic reticulum to release Ca<sup>++</sup>, which acts like a second messenger.
- Ca<sup>++</sup> can bind to the protein calmodulin and enhance the response of the cell.

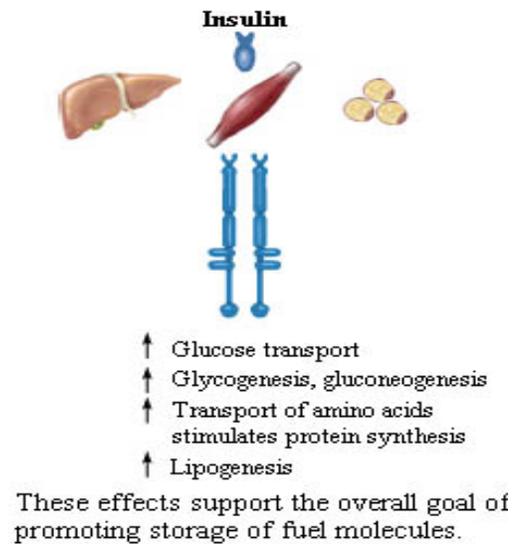
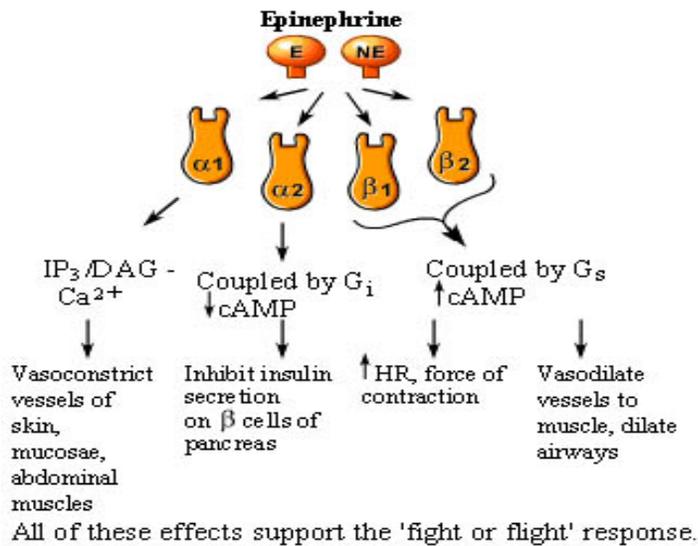
### **\*\*Now is a good time to go to the quiz question #2.**

- Click the quiz button on the left side of the screen.
- Click on the scrolling page list at the top of the screen and complete question 2.
- When you are finished you can click the return from link button on the left side of the screen to return to the topic.

### 2. Receptors that activate protein kinases.

- Some hormones bind with tyrosine kinase receptors on the outside of the cell membrane.
- When two receptors are bound their interior surfaces intertwine which causes the phosphorylation of neighboring phosphate groups on the receptor.
- The active phosphate sites provide a docking site for intracellular relay proteins.
- The relay protein phosphorylates other kinases within the cell that causes the cellular response.

- Catecholamines and insulin are water-soluble hormones that bind to plasma membrane receptors and are good examples of how hormones can have multiple and varied effects on their target tissues.



### Now is a good time to go to the quiz question #3.

- Click the quiz button on the left side of the screen.
- Click on the scrolling page list at the top of the screen and complete question 3.
- When you are finished you can click the return from link button on the left side of the screen to return to the topic.

### Page 5. Insulin Review

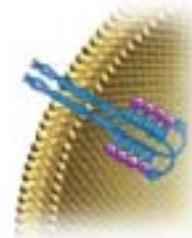
**\*Be sure to view all the steps in the animation on this page and make notes in the space provided below.**



SECRETION



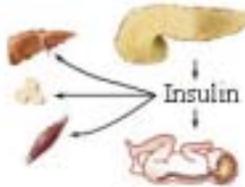
TRANSPORT



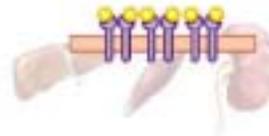
CELLULAR MECHANISM  
OF ACTION



SYNTHESIS



FUNCTIONS



BREAKDOWN

- Secretion
- Transport
- Cellular Mechanism of Action
- Synthesis
- Functions
- Breakdown

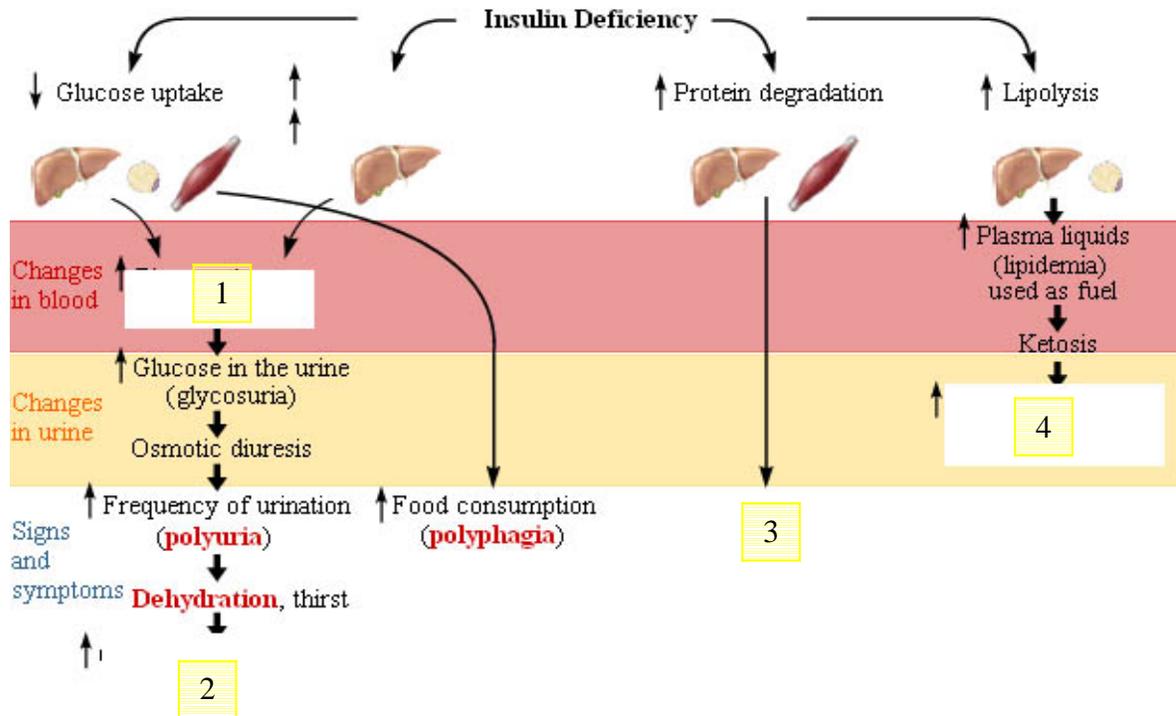
**\*\* Now is a good time to go to the quiz question #4.**

- Click the quiz button on the left side of the screen.
- Click on the scrolling page list at the top of the screen and complete question 4.
- When you are finished you can click the return from link button on the left side of the screen to return to the topic.

**Page 6. Diabetes Mellitus**

- There are two types of diabetes mellitus:
  1. Type 1 – characterized by insulin deficiency or absence.
  2. Type 2 – characterized by normal or elevated insulin levels, but resistance of target cells to insulin.

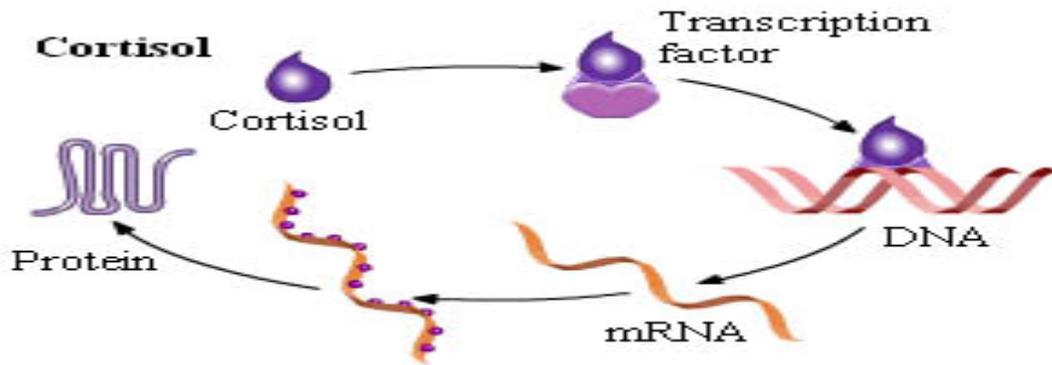
- Complete the table exercise and then fill in the blanks in the copy of the same chart below.



- Be sure to also click on the muscle and adipose tissue to see other ways in which insulin secretion can be affected.

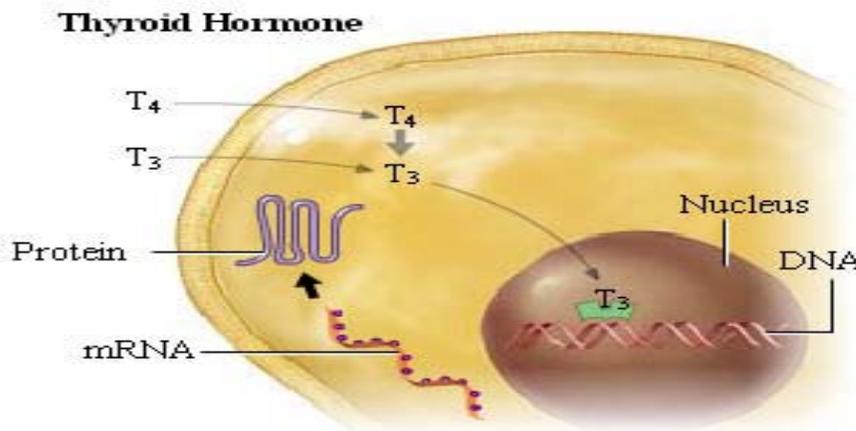
### Page 7. Lipid-soluble Hormones

- The lipid-soluble hormones are steroids and TH.
  - Receptors are located inside cells, typically inside the nucleus.
  - Each receptor has a site that binds to the hormone and a site that binds to DNA.
  - The DNA site is covered by a chaperone molecule when no hormone is present.
  - When a hormone binds the chaperone is released and the hormone receptor complex binds to DNA and acts as a **transcription factor**.
  - The hormone receptor complex can trigger the synthesis of mRNA and stimulate or it can inhibit gene activity.
  - If mRNA is stimulated then new proteins will be synthesized.
- Cortisol**



Cortisol acts to maintain high levels of fuel molecules, maintain blood pressure, and modulate body defenses, all necessary for the stress response.

- Cortisol binds with receptors in the nucleus.
- The hormone-receptor complex acts as a transcription factor.



Thyroid hormone is the main regulator of metabolic rate in the body.

- **Thyroid Hormone**
  - T<sub>4</sub> is converted into T<sub>3</sub> inside cells.
  - T<sub>3</sub> receptors are located on the DNA in the nucleus.

**Now is a good time to go to the quiz question #5.**

- Click the quiz button on the left side of the screen.
- Click on the scrolling page list at the top of the screen and complete question 5.
- When you are finished you can click the return from link button on the left side of the screen to return to the topic.

**Page 8: Summary**

- Hormone receptors are proteins located in the plasma membrane or the interior of the cell.
- Water-soluble hormones bind to plasma membrane receptors, and lipid-soluble hormones typically bind to intracellular receptors.
- Receptor activation engages cellular machinery that leads to the response of the cell.
- The effects of a single molecule of hormone are amplified by the cellular machinery.

- All about insulin, diabetes mellitus, and the causes and consequences of hypersecretion of insulin.

### **Notes on Quiz Questions:**

#### **Quiz Question #1: Hormone Receptors**

- The first part of this question requires you to place hormone receptors in their correct positions on the cell membrane or inside the cell.
- The second part of this question asks you to pick which receptors are for water-soluble hormones and which receptors are for lipid-soluble hormones.

#### **Quiz Question #2: Second Messenger Systems**

- This question requires you to put the events that lead to a cell response in the correct chronological order. Be sure to review the action of plasma membrane receptors before answering this question.

#### **Quiz Question #3: Insulin**

- This question requires you to put the events that occur when insulin binds with its receptors in the correct order.

#### **Quiz Question #4: Insulin vs. Glucagon**

- You must complete a table that contrasts the antagonistic effects of insulin and glucagon.
- Take note that there are two pages to this table.

#### **Quiz Question #5: Steroid Hormones**

- You must put the elements of a steroid based hormone response in the correct sequence.

### **Study Questions on Action of Hormones and Hormone Receptors**

1. (Page 1.) How do hormones influence their target cells?
2. (Page 3.) What are the two ways in which the chemical message of a hormone is converted into a cell response inside the cell?
3. (Page 3.) List the 5 ways in which cells respond to activation by hormones.
  - a.
  - b.
  - c.
  - d.
  - e.
4. (Page 3.) Receptors for water-soluble hormones are found on the \_\_\_\_\_ of target cells, while receptors for lipid-soluble hormones are found in the \_\_\_\_\_ or \_\_\_\_\_ of cells.
5. (Page 3.) Target cells tend to \_\_\_\_\_ the number of their receptors when there are sustained high levels of hormone present.

6. (Page 3.) True or False: All cells have receptors for all hormones.
7. (Page 4.) Put the steps of the cAMP second messenger system in the correct chronological sequence.
1. G-protein binds to adenylate cyclase which converts ATP into cAMP.
  2. Activated protein kinases elicit the cell response.
  3. Hormone binds with Receptor.
  4. cAMP phosphorylates protein kinases.
  5. Receptor changes shape and activates G-protein.
8. (Page 4.) \_\_\_\_\_ is the process whereby a single hormone can elicit the response of many second messengers within single target cell.
9. (Page 4.) Complete this sequence:  
hormone → receptor → G-protein → \_\_\_\_\_ → IP<sub>3</sub> and \_\_\_\_\_.
10. (Page 4.) When insulin binds to a tyrosine kinase receptor on its target cell what is the main result?
11. (Page 5.) List the main stimuli for insulin secretion.
- a.
  - b.
  - c.
  - d.
12. (Page 5.) How is insulin transported through the blood?
13. (Page 5.) What are the two major functions of insulin?
14. (Page 6.) \_\_\_\_\_ diabetes is characterized by insulin absence or deficiency, while \_\_\_\_\_ diabetes is caused by resistance of target cells to the action of insulin.
15. (Page 6.) Excess glucose in the urine is known as \_\_\_\_\_
16. (Page 7) When a lipid soluble hormone binds to its receptor molecule it acts as a
17. (Page 7) Put these events in the correct chronological sequence.
1. mRNA is transcribed.
  2. New protein is synthesized in the cell.
  3. Cortisol binds to receptor-chaperone complex.
  4. Hormone-receptor complex binds to DNA.
  5. Cell response is initiated.