Biochemistry, Secretion, and Transport of Hormones

Page 1. Biochemistry, Secretion, and Transport of Hormones

- Hormones can be classified according to their chemical structure.
- The functionality of a hormone is dependent upon its chemical structure.
- The control of secretion of a hormone is dependent upon its function.

Page 2. Goals/ What You Need to Know

Goals

- To recognize the chemical classes and solubility properties of hormones.
- To observe how a single member of each class of hormones it synthesized.
- To know that secretion of hormones depends on release, synthesis or both.
- To learn that neural, hormonal, or humoral stimuli control secretion of hormones.

What You Need to Know

- The structures of amino acids, proteins, and steroids.
- The difference between water-soluble and lipid-soluble.
- The concept of negative feedback systems and how they work.
- The synthesis of complex molecules proceeds along pathways, each step requiring a specific enzyme.
- The anatomy and neurotransmitters of the autonomic nervous system.

Page 3. Chemical Structure of Hormones

- **Peptide Hormones**
  - Composed of chains of amino acids that range from 3-20 amino acids in length.
  - Most hormones are peptides.
  - Most peptides are water-soluble.
- **Amine Hormones**
  - Contain the amino acid tyrosine.
  - The catecholamines are epinephrine, norepinephrine, and dopamine and they are water-soluble.
  - Thyroid hormone is created as iodine is added to tyrosine and is lipid-soluble.
- **Steroid Hormones.**
  - Derived from cholesterol.
  - They are lipid-soluble.

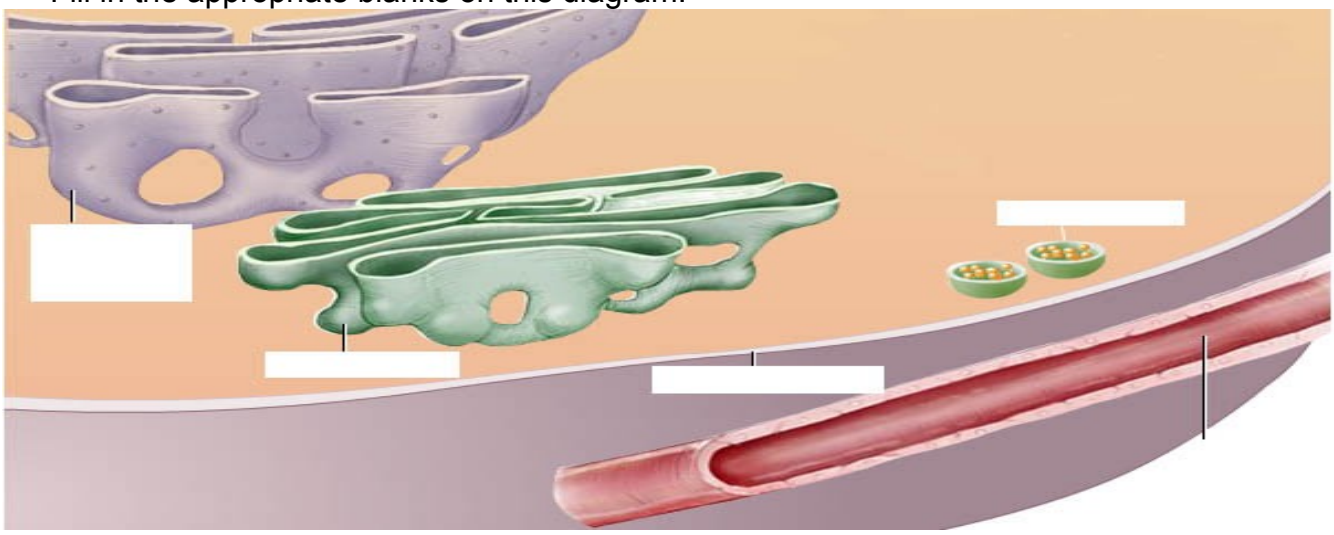
**** Now is a good time to go to the quiz question #1.**

- 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. Peptide Hormones: Insulin

***Be sure to view all the steps in the animation detailing the synthesis of insulin.**

- Prohormones are formed by ribosomes of the rough ER.
- They are packaged in vesicles and sent to the Golgi apparatus for processing.
- The Golgi apparatus releases secretory vesicles filled with the prohormone.
- Activation to the active form of the hormone often takes place inside the secretory vesicles.
- The insulin is stored until needed in the secretory vesicles.
- Once stimulated it can be released in the blood stream very quickly by exocytosis.
- Peptides are water-soluble and travel in the blood as dissolved particles.
- Fill in the appropriate blanks on this diagram.



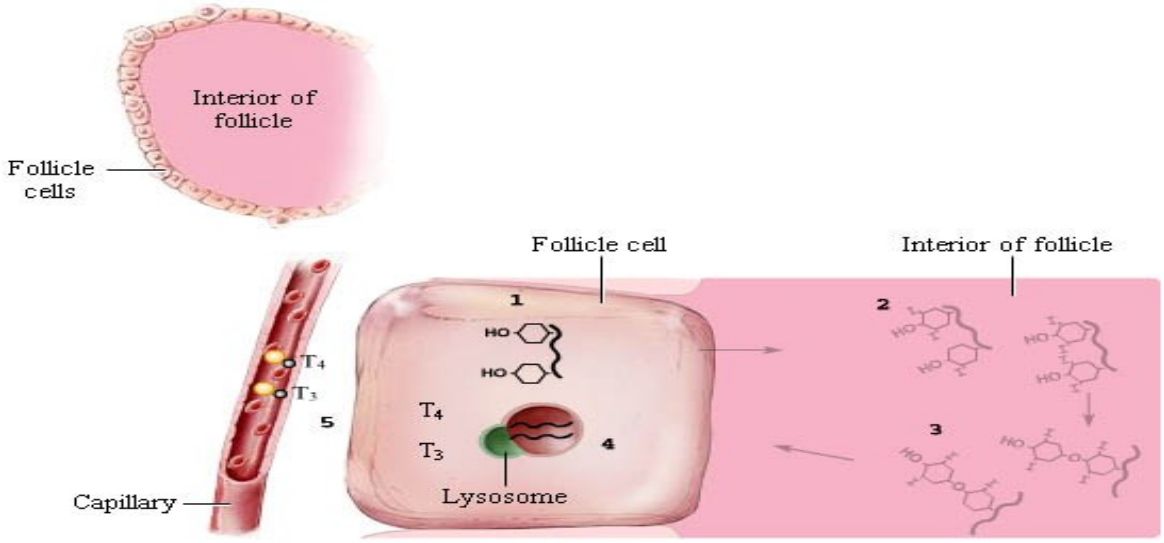
Page 5 Amine Hormones: Epinephrine

- Synthesized in the medulla of the adrenal gland.
- Cells of the adrenal medulla are modified postganglionic sympathetic neurons.
  - Mechanism of secretion is that same as for any neuron.
- Synthesis is an enzymatic process that follows this pathway:
  - Tyrosine→dopamine→NE→Epinephrine
  - Epinephrine is produced in ratio of 4:1 to NE.
  - NE is produced inside secretory vesicles, released into cytoplasm, converted to epinephrine and then absorbed back into vesicle for storage.
- Secretory vesicles act as stores for epinephrine and NE so they can be released quickly and they prevent break down of the hormones by enzymes.
- Catecholamines are water-soluble so they travel in the blood as dissolved particles.

Page 6 Amine Hormones: Thyroid Hormone

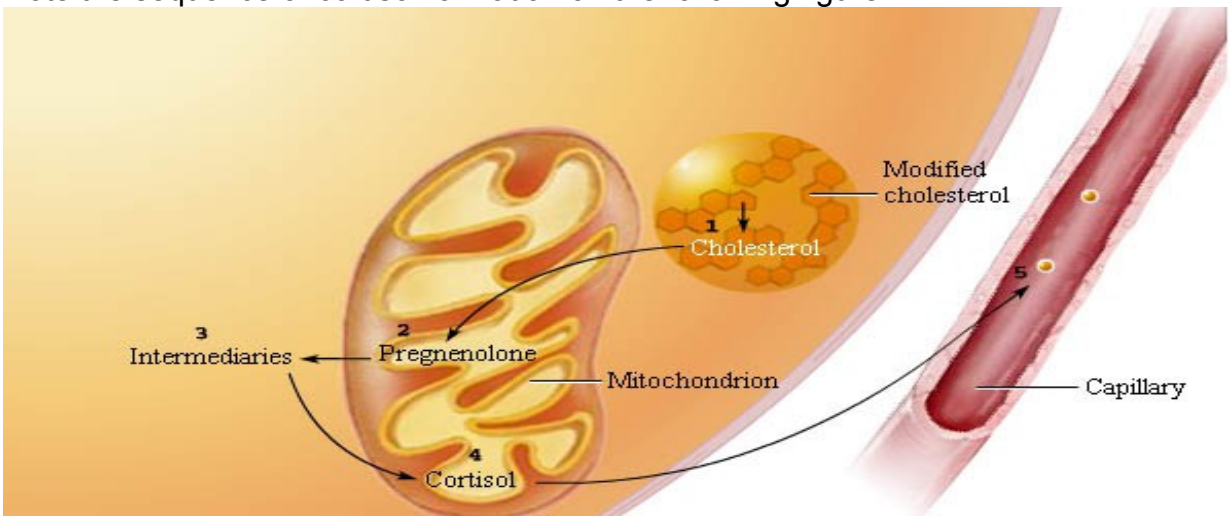
- The mechanism of thyroid hormone (TH) production is unique in the body.
- TH is lipid-soluble.
- Two to three months worth of TH can be stored in the follicles of the thyroid gland.
- TH synthesis takes place in the follicular cells.
  1. Follicles synthesize thyroglobulin and secrete it into the lumen of the follicle along with tyrosine.
  2. Iodine is added to the tyrosine, two variants exist t_3 and t_4, which reflects the number of iodine bound to each tyrosine.
  3. The thymoglobulin-TH complex is stored in the follicle until needed.
  4. Upon secretion enzymes cleave TH from the thyroglobulin and make it active.
  5. TH is bound to plasma proteins for transport through the blood.

- Note the numbers on the diagram to see the sequence of TH synthesis



Page 7: Steroid Hormones: Cortisol

- Synthesis of steroids from cholesterol in the adrenal cortex creates a large family of related hormones.
- The precursor molecule pregnenolone is essential to cortisol formation.
- Cortisol is lipid–soluble and is transported in the blood bound to plasma proteins.
- Note the sequence of cortisol formation on the following figure:



- Remember the formation of cortisol is enzymatically driven as it is with all hormones.
- Steroids are formed on an "as needed" basis and are not stored like TH or some catecholamines.

Page 8 Control of Hormone Secretion

- Control of secretion is in the form of neural, hormonal, or humoral stimuli.
  1. Neural
     - The adrenal medulla is directly stimulated by the sympathetic nervous system.
     - Epinephrine and NE reinforce the actions of the sympathetic nervous system.

  2. Hormonal

- Occurs when hormones from one endocrine gland stimulate the secretion of hormones from another endocrine gland.
- E.g. TRH→TSH →TH
- E.g. CRH →ACTH→Cortisol
- These routes of secretion are usually controlled in a negative feedback manner.

3. Humoral
   - Occurs when substances other than hormones control the secretion of endocrine glands.
   - E.g. Insulin secretion by the pancreas is determined by several factors.
     - Rise in glucose after a meal triggers insulin secretion.
     - Rise in amino acids after a meal triggers insulin secretion.
     - In addition hormonal and neural stimuli also play a role in insulin secretion.

**** Now is a good time to go to the quiz questions #2 and 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 questions 2 and 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 9 Blood Levels of Hormones

- Blood levels of a given hormone can vary widely over the course of a day.
- Hormone levels are determined by their secretion.
- Some hormones exhibit a daily rise and fall as part of the body's normal circadian rhythms.
  - Stressful stimuli can further enhance secretion patterns.
- TH is unique because increased secretion does not affect blood levels of TH significantly due to the large reserves of TH held in your body.
- Hormones are metabolized and excreted mainly by the liver and kidneys.
- Water-soluble hormones are easily degraded by enzymes in the blood stream and are also excreted very quickly from the kidneys.
  - E.g. insulin has a half-life of about 10 minutes in the body.
  - E.g. Epinephrine has a half-life of about 10 seconds in the body.
- Lipid-soluble hormones are bound to plasma proteins and are less easily metabolized and excreted from the body.
  - E.g. TH has a half-life of several days.
  - E.g. Cortisol has a half-life of about 90 minutes.

**** Now is a good time to go to the quiz questions #4 and 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 questions 4 and 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 10 Summary

- The chemical of a hormone determines its solubility properties.
- The synthesis of hormones involves moving of precursor molecules between organelles, often several times during their synthesis.
- Families of related hormones are produced when the metabolic pathway involves the sequential modification of a basic starting molecule.
- The hormone produced by a given cell depends upon the enzymatic makeup of that cell.
- Hormones that are not soluble in water are transported on carrier proteins (protein bound).

- Blood levels of most hormones vary widely throughout the day.

Notes on Quiz Questions:

Quiz Question #1: Molecular structure of hormones/Hormone properties

- The first part of this question is a puzzle that requires you to match the molecular structure of each hormone to its name in the puzzle piece.
- The second part of the question requires you to create a table of water-soluble and lipid-soluble hormones. Utilizing those basic properties you should be able complete the rest of the table.

Quiz Question #2: Stimuli of hormone secretion

- For this question you are required to choose only those stimuli that **DO NOT** directly affect hormone secretion. Be sure to think through each stimuli completely as some stimuli are related to more than just one hormone.

Quiz Question #3: Insulin: Control of secretion / Feedforward mechanisms

- You must choose all the stimuli that control the secretion of insulin.
- In the second part of this question you must select the stimuli that act as a feedforward mechanism that allows the body to anticipate the need for insulin.

Quiz Question #4: Half-life of hormones

- For this question you must place hormones from the list into the chart based upon the duration of their half-lives. Those with the shortest half-lives go at the top of the list.
- Make sure you watch the time pass on the clock and the calendar when you correctly place each hormone in the table.

Quiz Question #5: Hormone degradation

- Click on the two organs that are primarily responsible for the degradation and excretion of hormones.

Study Questions: Biochemistry, Secretion and Transport of Hormones

1. (Page 1.) How are hormones classified?

2. (Page 3.) The following are the chemical structures of hormones:
   1. Amine
   2. Peptide/protein
   3. Steroid

   Place the correct number (s) in the blanks below.
   a. water soluble
   b. main ingredient is tyrosine
   c. derived from cholesterol
   d. lipid-soluble.

3. (Page 3.) Which class of amine hormone is lipid-soluble?

4. (Page 4.) How does insulin travel through the blood?

5. (Page 5.) What composes the cells of the adrenal medulla?

6. (page 5.) Place the following molecules in the correct sequence from earliest derivative to the complete hormone: dopamine, epinephrine, NE, tyrosine.

7. (Page 5.) Are catecholamines water or lipid soluble?

8. (Page 6.) What are the two major ingredients necessary for the synthesis of TH?

9. (Page 6.) Place the steps of TH synthesis in the correct order:
    1. Lysosomal enzymes cleave TH from the thyroglobulin and make it active.
    2. Iodine is added to the tyrosine residues, two variants exist, t_3 and t_4, which reflects the number of iodine bound to each tyrosine.
    3. Follicle cells synthesize tyrosine-containing thyroglobulin molecules and secrete them into the lumen of the follice.
    4. The thymoglobulin-TH complex is stored in the follicle until needed.
    5. TH is bound to plasma proteins for transport through the blood.

10. (Page 7.) Steroid hormones are all derived from this cell membrane molecule: _____.

11. (Page 7.) Are steroid hormones stored for long periods of time like insulin and TH?

12. (Page 8.) The control of the thyroid gland secretion by the anterior pituitary is an example of _____ control.

13. (Page 8.) What class of hormones in the body is primarily under neural control?

14. (Page 9.) Place these hormones in order according to length of their half-lives: testosterone, insulin, TH, epinephrine.