## Course learning goals

**Students should be able to:**

1. Demonstrate/illustrate how the homeostatic model applies to every endocrine system in normal physiology and disease.

2. Demonstrate/illustrate how every aspect of our physiology and behavior is directly controlled or modified by hormones using reproduction, growth, development, stress, and metabolism as examples.

3. Demonstrate/illustrate that the same biochemical and cellular processes of chemical communication are involved in endocrinology as they are in any other biological systems; i.e., all chemical communicators (hormones, neurocrines, cytocrines, etc.) work in essentially the same manner.

4. Demonstrate/illustrate the concept of cross talk between physiological systems and within target cells between signaling pathways; i.e., how many hormones affect the secretion and actions of other hormones.

5. Demonstrate/illustrate how endocrine systems can be disrupted with respect to synthesis, secretion, transport, receptors, mechanisms of action, and metabolism/excretion.

6. Develop an appreciation of an evolutionary perspective that explains why mammalian endocrine systems work the way they do.

7. Demonstrate your understanding of endocrine pathways by designing tests that will help to diagnose a condition.

8. Develop students to be self-learners through the promotion of active study techniques such as abstracting, re-organizing, or connecting lecture notes into a version that's convenient to the students, taking notes while reading, attending recitations, asking questions during lecture, and using the provided study questions as modes of self-assessment.

**TOPIC LEARNING GOALS**

## Introduction to Endocrine Systems

**Readings:**

- Chapter 1: An Overview of Chemical Bioregulation in Vertebrates
- Chapter 2: Methods to Study Bioregulation

**Students should be able to:**

*Categories and Functions of Bioregulators*

1. If given an example of how a bioregulator works (source, mode of transportation, sites of action), identify to which category (hormones, neurocrines, cytocrines, and intracrines) and which subcategory it belongs.

2. Describe an example of how a single bioregulator can have overlapping functional roles.

3. Based on the chemistry of a bioregulator, predict how it is synthesized, secreted, transported, metabolized, and its mode of action.

*Special Features*

4. Given a novel, experimental or clinical situation, identify the type of feedback that is operating and explain why it's appropriate for that situation.
    - *Student misconception: If it inhibits something, it must be negative feedback.*

5. Given a disruption of a feedback system, predict the physiological outcome.

6. Describe what makes a cell a target cell.

7. Describe or predict what physiological or cellular factors contribute to the shape of a given dose-response curve.

8. Explain the difficulty in interpreting results obtained from a study involving the injection of a single dose of a hormone.

9. Design an experiment using the appropriate techniques to solve an endocrine problem. Justify your design by describing what the technique will tell you and how it will help solve the problem.

## Molecular Aspects

**Readings:**

- Chapter 3: Synthesis, Metabolism, and Actions of Bioregulators

**Students should be able to:**

1. Compare and contrast the synthesis, secretion, transport, and general metabolism (degradation) for protein/peptide, biogenic amines, steroids, eicosanoids, and thyroid hormones.

2. Explain why hormones are regulated at so many levels.

3. Explain why most actions of steroid hormones are slower than peptide hormones.

4. Describe the post-transcriptional/post-translational processing of protein/peptide hormone synthesis.

5. Predict the biological effect of a novel steroid based on the chemical structure (e.g., number of carbons, position of double bonds, attached groups).

6. Diagram the synthesis of testosterone, E2, DHT, aldosterone and corticosterone starting from acetyl CoA. Indicate all of the key intermediates and the essential enzymes and inhibitors. Do NOT draw the structures of the steroids. Use either the common names or the accepted abbreviations for all steroids.

7. Describe interaction of $\Delta 4$ and $\Delta 5$ pathways.

8. Predict the potential outcomes and/or side effects of adding a hormone or enzyme or inhibiting an enzyme in the steroidogenesis pathway. -- OR -- Given clinical data predict where the defect in the steroidogenesis pathway occurred and propose a viable treatment option.

*Receptors*

9. Compare and contrast the various types (subtypes) of membrane and intracellular bioregulator receptors with respect to their structure (domains), location, and how each generally produces a measurable effect (genomic vs. non-genomic) in a target cell.

10. Predict what would happen to the signal transduction pathway if you administer a drug that selectively inhibits the following G-proteins: Gs (including alpha, beta/gamma subunits), Gi, or Gq.

11. Predict what would happen to the biological effect of steroid hormone receptors if you administer drugs that selectively inhibit different domains of the steroid hormone receptor.

12. Describe the mechanisms and predict the consequences of upregulation, downregulation, and recycling of the receptor.

13. Diagram the intracellular events caused by any bioregulator after binding with each of the various types of cell membrane-bound receptors discussed in class. Provide a brief word description of each event.

14. Diagram the sequence of events in the activation of ligand-activated nuclear receptors. Include in your diagram: ligand binding, dimer formation, domains, exposure of Zn fingers, dissociation of Hsps, phosphorylation, transportosome formation, binding to coregulators, and binding to transcription apparatus.

15. Predict the physiological consequences of steroid administration taking into account cytoplasmic conversion.

16. Hypothesize how activation of one pathway could influence the activation of another pathway (cross talk).

*The Second Messenger Concept*

17. Compare and contrast cAMP and IP3 signal transduction pathways.

18. Predict how other bioregulators or pharmacological agents could alter cAMP or IP3 pathways induced by a specific bioregulator.

19. (Optional): Be able to chemically name a steroid if given a drawing if its structure. Be able to draw a steroid if given its chemical name.

## Hypothalamo-Hypophysial Axes

**Readings:**

- Chapter 4: Organization of the Mammalian Hypothalamus-Pituitary Axes

**Students should be able to:**

1. Describe the advantage of the portal circulation over the regular circulation.

2. Describe the anatomy (including hypothalamic nuclei, subdivisions of the pituitary, vascular connections, and cell types) and related function of the mammalian hypothalamic-pituitary system and be able to provide a generalized diagram of this system in mammals.

3. Distinguish among the different classes of tropic hormones based on chemistry and function.

4. Compare the similarities and differences in hypothalamic regulation for the release of tropic hormones. Include all regulators and their sources. Be sure to include feedback effects too. You might use an annotated diagram, a table, or both.

5. Distinguish the nonapeptides of the pars nervosa based on their chemical structure and function.

6. Differentiate the sites of synthesis and release of the nonapeptides of the pars nervosa.

7. Describe the processing of POMC into hormones of the pars distalis and the pars intermedia.

*Clinical Aspects of the Neuroendocrine System*

8. Given certain symptoms of a clinical disease or manipulation, predict the endocrine cause of the disorder.

*The Pineal Gland*

9. Describe the regulation of the pineal gland and its relation to the light-dark cycle.

*10.* Optional: Explain the role of the pineal gland in regulating the secretion of tropic hormones at the level the hypothalamus and pituitary.

## Thyroid Gland

**Readings:**

- Chapter 6: The Hypothalamus-Pituitary-Thyroid (HPT) Axis of Mammals

**Students should be able to:**

*Synthesis, Secretion, Action, and Metabolism of Thyroid Hormones*

1. Diagram the hypothalamo-pituitary-thyroid (HPT) system (Chapter 4). Include targets as well as all endogenous factors that might stimulate or inhibit responsiveness of the system at every level.

2. Diagram the processes and locations of thyroid hormone synthesis. Include the following components: pendrin, NIS, iodide, T4, T3, TPO, thyroglobulin (TGB), basal membrane, apical membrane, endosome, endolysosome, endoplasmic reticulum, microvilli, deiodinase, lumen.

3. Predict how the process of thyroid hormone synthesis and/or its regulation would be altered if a specific components were disrupted. Include sites of actions of various natural and synthetic compounds that can affect normal thyroid function (e.g., goitrogens).

4. List the types of deiodinases, where are they found (liver, kidney, thyroid gland, brain, pituitary, placenta, skin, gut), and their roles. Predict what happens to thyroid parameters if one of the deiodinases is lost.

5. Optional: Compare and contrast physiological consequences of different types of thyroidectomies (chemical, radiological, surgical).

6. Given hypothetical pathological conditions, predict whether you will find hypo- or hyper-thyroid goiters.

7. Describe physiological consequences of thyroid deficiencies and/or excess on: metabolism/thermoregulation, nervous system development/function, growth and differentiation, and reproduction.

8. Design appropriate diagnostic tests to determine a potential mechanism leading to hyper- or hypothyroidism.

## Adrenal Gland

**Readings:**

- Chapter 8: The Mammalian Adrenal Glands: Cortical and Chromaffin Cells

**Students should be able to:**

1. Diagram the hypothalamo-pituitary-adrenal (HPA) system (Chapter 4). Include targets (e.g., muscle, liver, adipose) as well as all endogenous factors that might stimulate or inhibit responsiveness of the system at every level.

*The Mammalian Adrenal Gland*

2. Diagram the adult adrenal gland indicating major anatomical regions and the functions of each region. Indicate all the physiological factors that might influence secretion by each region, including how hormones from one layer can influence the function of other layers.

3. Describe the developmental changes in structure and function of the adrenal gland from gestation to adulthood. (Figure 8-3)

*Secretion and Actions of Corticosteroids*

4. Compare the physiological and pharmacological actions of glucocorticoids in humans.

*Aldosterone and the Renin-Angiotensin System*

5. Describe the molecular and physiological actions of aldosterone.

6. Explain the synthesis (including anatomical sources) and functions of the renin-angiotensin system.

7. Describe the factors that regulate the activity of renin-angiotensin system and the control of ionic and osmotic balance.

8. Under the conditions of chronic hypertension, predict the changes in the renin-angiotensin system as well as atrial natriuretic peptide (ANP).

9. Predict how changes in the renin-angiotensin system contribute to chronic hypertension, hypotension, and high salt intake.

*Stress response / Pathologies of the Adrenal Axis*

10. Predict the physiological consequences of chronic elevation of glucocorticoids.

11. Describe the major clinical disorders associated with the topics of chapter 8 (Addison's disease, Cushing's disease, Cushing's syndrome, hyperaldosteronism, congenital adrenal hyperplasia).

## Reproduction

**Readings:**

- Chapter 10: The Endocrinology of Mammalian Reproduction

**Students should be able to:**

*General Features of Mammalian Reproduction*

1. Diagram the hypothalamo-pituitary-gonadal (HPG) system (Chapter 4). Include targets (e.g., mammary glands, prostate, etc.) as well as all endogenous factors that might stimulate or inhibit responsiveness of the system at every level.

2. Anatomy review: Diagram the adult male and female sex organs indicating major anatomical regions, cell types, and the functions of each organ.

3. Describe the roles of gonadal genes in sex determination and gonadal hormones in sexual differentiation of reproductive tracts and external genitalia.

4. Describe how reproduction in humans is influenced by thyroid and adrenal functions.

5. (Optional): Describe the various ways that EDCs affect reproduction.

6. Review: Compare and contrast gametogenesis in males and females.

*Endocrine Regulation in Females*

7. Describe and explain (diagram) the hormonal changes during different phases of the ovarian cycle assuming pregnancy does not occur.

8. Describe the mechanism of ovulation and leuteolysis at the level of the ovary.

9. Describe the coordinated events of the uterine and ovarian cycles.

10. Describe the endocrine and anatomical changes that take place to begin a pregnancy cycle in the human female.

11. Describe the specific endocrine roles of the placenta, fetus, and mom necessary to maintain pregnancy in humans.

12. Describe the specific roles of the placenta, fetus, and mom in the birth process in humans.

13. (Optional): Describe the endocrine regulation of lactation.

*Endocrine Regulation in Males*

14. Describe the hormonal regulation of steroid hormone production in males.

## Regulation of Metabolism

**Readings:**

- Chapter 12: Bioregulation of Feeding, Digestion, and Metabolism

**Students should be able to:**

*Bioregulation of Metabolism*

1. Review: Describe how proteins, fats, and complex carbohydrates all lead to ATP synthesis.

*Hormones Regulating Mammalian Metabolism*

2. Describe the effects of hormones on the following metabolic processes (lipogenesis, lipolysis, liponeogenesis, glycogenesis, glycogenolysis, gluconeogenesis, protein anabolism and protein catabolism) within skeletal muscle, liver, brain, and adipose tissues.

3. Diagram and describe how different hormones interact with insulin to regulate metabolism.

4. Predict the physiological consequence of overproduction/deficiency of bioregulators involved in feeding.

*Effects of Acute and Chronic Stress on Metabolism*

5. Predict the effects of prolonged excessive food intake, semi-starvation (e.g., forced or voluntary dieting), total starvation, or chronic stress on metabolic processes and hormones. Note, prolonged or chronic conditions do not achieve death in these cases. How might excessive food intake or chronic stress lead to diabetes mellitus?