

SECTION 4 - THE ENDOCRINE SYSTEM

EXERCISE 4.1 HISTOLOGY OF THE ENDOCRINE GLANDS

Approximate Time for Completion: 1-2 hours

Introduction

This exercise is designed to introduce students to various selected glands of the endocrine system and to a variety of hormones produced by these glands. The endocrine system works closely with the nervous system to maintain homeostasis and therefore is very important in the physiology of all body systems. Students will benefit from early discussion of the embryonic derivation of glandular epithelium and from the procedures featuring the histological slides of representative endocrine glands. It should be emphasized that hormones can be secreted by other tissues of the body that are not included in this list of endocrine organs. Also, a discussion of the role of hormone receptors and target cell response might be appropriate at this time, using the microscopic anatomy to visualize the physiology.

Materials

1. Microscopes
2. Prepared histological slides

Textbook Correlations: Chapter 11 – Pituitary Gland; Adrenal Glands; Thyroid and Parathyroid Glands; Pancreas and Other Endocrine Glands

Answers to Questions

- | | | |
|------|------|------|
| 1. g | 4. d | 7. i |
| 2. e | 5. f | 8. h |
| 3. b | 6. c | 9. a |
-
10. antrum
 11. seminiferous tubules; spermatogenesis
 12. thyroxine (T_4); thyroid
 13. adrenal medulla (sympathetic ganglion); posterior pituitary (neurohypophysis)
 14. antidiuretic hormone (ADH); posterior pituitary
 15. Exocrine glands secrete the products into ducts leading to an external surface, whereas endocrine glands secrete hormones into the blood and circulatory system. For example, the exocrine acini of the pancreas secrete pancreatic digestive juice into the pancreatic duct leading to the duodenum, whereas the pancreatic islets secrete insulin and glucagon hormones that are released into the blood.
 16. Vasopressin and oxytocin are manufactured in cell bodies of hypothalamic neurons and packaged into vesicles that travel down the axons of these neurons in the hypothalamus to the posterior pituitary (hypothalamo-hypophyseal tract). As a storage organ, the posterior pituitary responds to neuroendocrine reflexes by releasing the appropriate hormone.
 17. Adrenocorticotrophic hormone (ACTH) is produced in the anterior pituitary. It stimulates the adrenal cortex to secrete the glucocorticoids, such as hydrocortisone (cortisol). ACTH has an additional supportive or “trophic” effect on the adrenal cortex. Its secretion is inhibited partially by the negative feedback of corticosteroids released from the adrenal cortex and stimulated by corticotropin-releasing hormone (CRH) released from the hypothalamus and transported along the hypothalamo-hypophyseal portal system.
 18. The anterior pituitary is sometimes called the “master gland” because its many trophic hormones control other endocrine glands. This term is misleading, however, because the anterior pituitary is controlled primarily by another master—the hypothalamus. The concept of a master gland (even the hypothalamus) is misleading in any case, because the secretions of the hypothalamus and anterior pituitary are ultimately controlled by the target glands and circulating hormones and neurotransmitters through complex negative feedback loops.

19. Ligation of the vas deferens would have no effect on the blood testosterone concentration. This is because the Leydig cells secrete testosterone into the blood (endocrine), not into the duct system of the seminiferous tubules (exocrine). The sperm and semen constitute an exocrine secretion, because they are carried by a duct system to the outside of the body, whereas endocrine glands secrete their hormones into the blood.
20. Glucocorticoids are steroid hormones produced by the adrenal cortex that help regulate the metabolism of glucose and other organic molecules. One cause of excessive glucocorticoids secretion would be over secretion of ACTH from the anterior pituitary gland (see question 17). Another cause would be the result of a tumor of the adrenal cortex. The third possible cause of glucocorticoids secretion is in response to undue stress on the body, resulting in an increased ACTH secretion.

EXERCISE 4.2 THIN-LAYER CHROMATOGRAPHY OF STEROID HORMONES

Approximate Time for Completion: 2 hours

Introduction

This exercise is designed to introduce students to the steroid hormones synthesized and secreted by the adrenal cortex and the gonads. In this exercise, students use thin-layer chromatography to compare the solubility characteristics of different steroid hormones as a means of identifying unknown steroids in a mixture. When performing the thin-layer chromatography, students need to be sure that their steroid solution spots are above the level of the solvent cocktail when the TLC plates are placed in the developing chamber. Remind students to mark the leading edge of their solution *before* drying the plates or they will not be able to find it. Also, discuss the potential hazards of looking directly at the UV light source. Students enjoy the task more if you suggest that your unknown sample may have been obtained from athletes participating in a steroid abuse drug-testing program that was monitoring some important athletic event near or on your campus.

Materials

1. Thin-layer plates (silica gel, F-254), chromatography developing chambers, capillary tubes (F= fluorescent)
2. Driers (chromatography or hair driers), ultraviolet viewing box (short wavelength), rulers or spotting template (optional)
3. Steroid solutions in absolute methanol, final concentration is 1.0 mg/ml for the hormones: testosterone, hydrocortisone, cortisone, corticosterone, and deoxycorticosterone; and 5 mg/ml of estradiol
4. Unknown steroid solution containing any two (or 3?) of the steroids previously described
5. Developing solvent: 60 ml toluene plus 10 ml ethyl acetate plus 10 ml acetone or a volume containing a comparable 6:1:1 ratio of solvents
6. Fume hood to prepare developing solutions and to maintain developing chambers

Textbook Correlations: Chapter 11 – Chemical Classification of Hormones; Mechanism of Steroid Hormone Action; Functions of the Adrenal Cortex; Gonads and Placenta

Answers to Questions

1. estradiol; ovary
2. testosterone; testes (interstitial cells of Leydig)
3. adrenal androgen; the adrenal cortex
4. ovary (corpus luteum); placenta
5. aldosterone; zona glomerulosa layer of the adrenal cortex
6. hydrocortisone; cortisol; zona fasciculata and zona reticularis of the adrenal cortex
7.
 - a. estrogens (estradiol)
 - b. testosterone
 - c. progesterone; corticosteroids

8. Steroids that have twenty-one carbons:
 Progesterone (female sex steroid, secreted by the corpus luteum and placenta)
 Corticosteroids (secreted by the adrenal cortex - mineralocorticoids and glucocorticoids):
 Mineralocorticoids (regulate electrolyte balance, such as aldosterone)
 Glucocorticoids (regulate glucose metabolism, such as hydrocortisone)
- Steroids that have nineteen carbons:
 Androgens, primarily testosterone (stimulate male secondary sex characteristics and maintain male sex accessory organs; secreted primarily by the testes)
- Steroids that have eighteen carbons:
 Estrogens, secreted by the ovaries, stimulate female secondary sexual characteristics and maintain female sex accessory glands
9. Testosterone and deoxycorticosterone have the highest R_f values and therefore are the most soluble in the solvent. The glucocorticoids (corticosterone, hydrocortisone, and cortisone) have the lowest R_f values and thus are the least soluble. Estradiol is intermediate between these extremes.
10. Any drug that inhibits the action of the enzyme 5α -reductase would result in symptoms of androgen deficiency since this enzyme converts the prehormone, testosterone into the more active product, dihydrotestosterone (DHT). Lacking the normal stimulatory and trophic effects of DHT, the prostate gland would atrophy and become less productive.
11. The conclusion is that male-pattern baldness is due to the hair loss activity of DHT in the target cells of the follicles. Any drug that inhibits the action of the enzyme 5α -reductase in the hair follicle, then should prevent hair loss and hopefully restore the original hair.
12. During pregnancy the placenta secretes the estrogens estriol and estetriol. These placental estrogens are more polar and therefore more water-soluble than estradiol. Since the solvent is non-polar (6 toluene:1 ethyl acetate:1 acetone) the more polar placental estrogens would be less soluble, migrate a shorter distance up the plate, and have a lower R_f value than estradiol.

EXERCISE 4.3 INSULIN SHOCK

Approximate Time for Completion: 30 minutes

Introduction

This exercise provides an excellent introduction to the actions of insulin and to the discussion of the disease states, hypoglycemia and diabetes mellitus. One should have a few fish on hand, because the response to insulin is variable. Often the full 30 minutes must be allowed to observe an effect. When it goes “belly up,” the ailing fish must be removed immediately from the insulin solution and placed into the 5% glucose solution if the fish is to be revived successfully.

Materials

1. Large beaker filled with water, another beaker with 5% glucose solution
2. Guppy, goldfish, or another fish of comparable size
3. Insulin (insulin, zinc-100 IU), 5% glucose solution (5 g glucose per 100 ml water)

Textbook Correlations: Chapter 11 – Pancreatic Islets

Chapter 19 – Energy Regulation by the Pancreatic Islets; Diabetes Mellitus and Hypoglycemia

Answers to Questions

1. beta; islets of Langerhans
2. transport of glucose from the blood into the muscle, liver, and adipose tissue, thus lowering the blood glucose concentration
3. lowers
4. hyperglycemia; hypoglycemia
5. diabetes mellitus
6. glucosuria
7. Insulin shock can occur in persons with type I diabetes mellitus if too much insulin is injected. The blood sugar falls below normal resulting in inadequate energy nutrients (glucose) for neurons of the brain. The loss of central nervous system energy could cause this person to lose consciousness and possibly lapse into a coma.
8. The person with diabetes mellitus lacks insulin and therefore is unable to use glucose for cellular respiration and the continuous demand for energy. Tissues then turn to the metabolism of fat for energy, thereby producing ketone bodies as a byproduct of fat catabolism. Acetone is one type of ketone body that is volatile and therefore detectable as a “fruity” odor on the breath of such people. The excretion of the extra ketone bodies as well as the unused glucose molecules in the urine is accompanied by the osmotic diuresis of large amounts of water, causing dehydration.
9. A type 1 diabetic can lose weight rapidly because glucose metabolism as a source of energy is no longer able to meet the demands of the body. Consequently, there is an increase in fat metabolism that is accompanied by a decrease in fat stores (adipose tissue) and weight loss. Dehydration also contributes to this rapid weight loss.
10. A person with type 2 diabetes mellitus, the most common type, still exhibits hyperglycemia despite the fact that the beta cells of the pancreas continue to secrete normal, if not even above normal, amounts of insulin. This is possible if the normal target tissues for insulin become less responsive to the hormone, becoming insulin resistant. In this case, glucose uptake by normal target tissues would be decreased and blood levels of glucose would rise (hyperglycemia). Obesity is known to decrease insulin sensitivity of target tissues (raise insulin resistance), whereas exercise (and weight loss) increases insulin sensitivity. This is especially true of “apple-shape” obesity that is characterized by enlarged adipose cells located particularly in the abdominal region. The smaller adipocytes that are more commonly seen in the “pear-shape” obese are not as resistant to insulin and can therefore help keep blood glucose levels within normal limits.