Endocrine System Physiology

PhysioEx tm 9.0, Exercise # 4, Activities 1 and 2

Materials:

Group Supplies

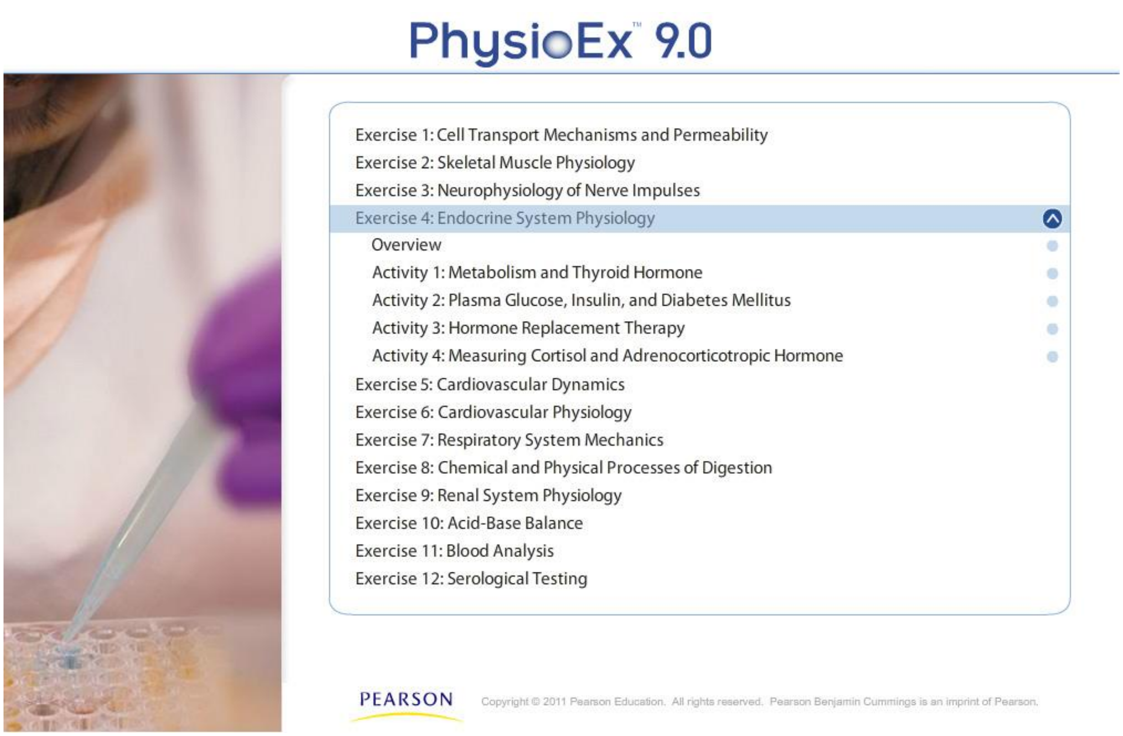
Computer with PEX9 installed.

Methods:

Double click the shortcut named PEx to select PhysioEx 9.0: an application for simulating physiology experiments.

Select: "Access PhysioEx 9.0 to get started!"

Select: "Exercise 4: Endocrine Physiology" (and then **Activities 1 and 2**.)



Select: “**Activity 1: Metabolism and Thyroid Hormone**”

Read the Objectives and Introduction.

Objectives:

1. To understand the terms metabolism, basal metabolic rate (BMR), thyroid-stimulating hormone (TSH), thyroxine, goiter, hypothyroidism, hyperthyroidism, thyroidectomized, hyophysectomized.
2. To observe how negative feedback mechanisms regulate hormone release.
3. To understand thyroxine’s role in maintaining the basal metabolic rate
4. To understand the effect of TSH on the basal metabolic rate.
5. To understand the role of the hypothalamus in regulating secretion of thyroxine and TSH

Introduction

Metabolism is the broad range of biochemical reactions occurring in the body. Metabolism includes anabolism and catabolism. Anabolism is the building up of small molecules into larger, more-complex molecules via enzymatic reactions. Energy is stored in the chemical bonds formed when larger, more-complex molecules are formed.

Catabolism is the breakdown of large, complex molecules into smaller molecules via enzymatic reactions. The breaking of chemical bonds in catabolism releases energy that the cell can use to perform various activities, such as forming ATP. The cell does not use all the energy released by bond breaking. Much of the energy is released as heat to maintain a fixed body temperature, especially in humans. Humans are homeothermic organisms that need to maintain a fixed body temperature to maintain the activity of the various metabolic pathways in the body.

The most important hormone for maintaining metabolism and body heat is thyroxine (thyroid hormone), also known as tetraiodothyronine, or T4. Thyroxine is secreted by the thyroid gland, located in the neck (view Figure 4.3).

The production of thyroxine is controlled by the pituitary gland, or hypophysis, which secretes thyroid-stimulating hormone (TSH). The blood carries TSH to its target tissue, the thyroid gland. TSH causes the thyroid gland to increase in size and secrete thyroxine into the general circulation. If TSH levels are too high, the thyroid gland enlarges. The resulting glandular swelling in the neck is called a goiter.

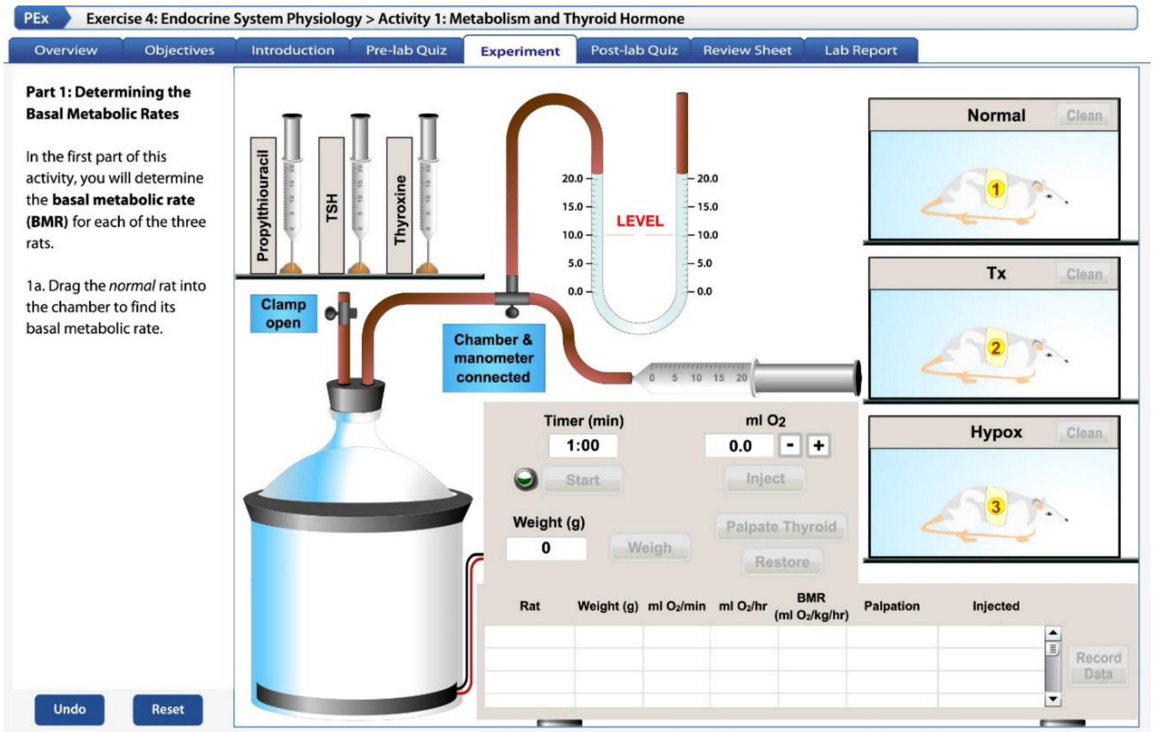
The hypothalamus in the brain is also a vital participant in thyroxine and TSH production. It is a primary endocrine gland that secretes several hormones that affect the pituitary gland, or hypophysis, which is also located in the brain. The Thyrotropin-releasing hormone (TRH) is directly linked to thyroxine and TSH secretion. TRH from the hypothalamus stimulates the anterior pituitary to produce TSH, which then stimulates the thyroid to produce thyroxine.

These events are part of a classic negative feedback mechanism. When circulation levels of thyroxine are low, the hypothalamus secretes more TRH to stimulate the pituitary gland to secrete more TSH. The increase in TSH further stimulates the secretion of thyroxine from the thyroid gland. The increased levels of thyroxine will then influence the hypothalamus to reduce its production of TRH.

TRH travels from the hypothalamus to the pituitary gland via the hypothalamic-pituitary portal system. This specialized arrangement of blood vessels consists of a single portal vein that connects two capillary beds. The hypothalamic-pituitary portal system transports many other hormones from the hypothalamus to the pituitary gland. The hypothalamus primarily secretes tropic hormones, which stimulate the secretion of other hormones. TRH is an example of a tropic hormone because it stimulates the release of TSH from the pituitary gland. TSH itself is also an example of a tropic hormone because it stimulates production of thyroxine (view Figure 4.4).

In this activity you will investigate the effects of thyroxine and TSH on a rat's metabolic rate. The metabolic rate will be indicated by the amount of oxygen the rat consumes per time per body mass. View the BMR Measurement wet-lab video to see the measurement of a rat's basal metabolic rate. You will perform four experiments on three rats: a normal rat, a thyroidectomized rat (a rat whose thyroid gland has been surgically removed and a hypophysectomized rat (a rat whose pituitary gland has been surgically removed). You will determine (1) the rat's basal metabolic rate, (2) its metabolic rate after it has been injected with thyroxine, (3) its metabolic rate after it has been injected with TSH, and (4) its metabolic rate after it has been injected with propylthiouracil, a drug that inhibits the production of thyroxine.

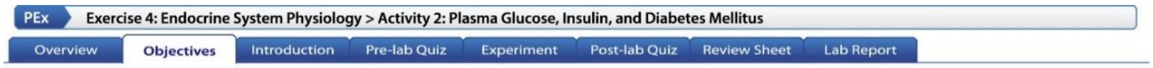
Do the Pre-Lab Quiz, Experiment, and Post-Lab Quiz.



Select: “**Activity 2: Plasma Glucose, Insulin and Diabetes Mellitus**”

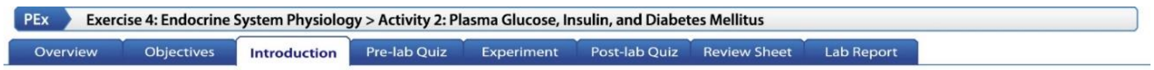
Read the Objectives and Introduction.

Objectives:



1. To understand the use of the terms insulin, type 1 diabetes mellitus, type 2 diabetes mellitus, and glucose standard curve.
2. To understand how fasting plasma glucose levels are used to diagnose diabetes mellitus.
3. To understand the assay that is used to measure plasma glucose.

Introduction:



Insulin is a hormone produced by the beta cells of the endocrine portion of the pancreas. This hormone is vital to the regulation of plasma glucose levels, or "blood sugar," because the hormone enables our cells to absorb glucose from the bloodstream. Glucose absorbed from the blood is either used as fuel for metabolism or stored as glycogen (also known as animal starch), which is most notable in liver and muscle cells. About 75% of glucose consumed during a meal is stored as glycogen. As humans do not feed continuously (we are considered "discontinuous feeders"), the production of glycogen from a meal ensures that a supply of glucose will be available for several hours after a meal.

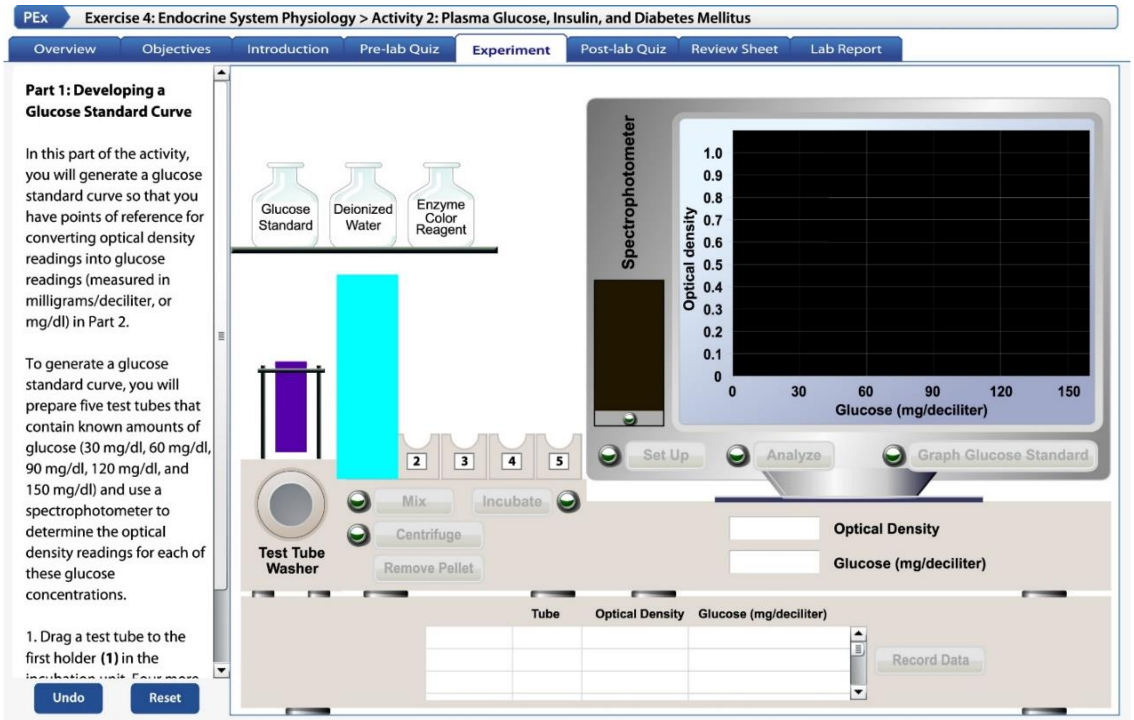
Furthermore, the body has to maintain a certain level of plasma glucose to continuously serve nerve cells because these cell types use only glucose for metabolic fuel. When glucose levels in the plasma fall below a certain value, the alpha cells of the pancreas are stimulated to release the hormone glucagon. Glucagon stimulates the breakdown of stored glycogen into glucose, which is then released back into the blood (view Figure 4.5a and Figure 4.5b).

When the pancreas does not produce enough insulin, type 1 diabetes mellitus results. When the pancreas produces sufficient insulin but the body fails to respond to it, type 2 diabetes mellitus results. In either case, glucose remains in the bloodstream, and the body's cells are unable to take it up to serve as the primary fuel for metabolism. The kidneys then filter the excess glucose out of the plasma. Because the reabsorption of filtered glucose involves a finite number of transporters in kidney tubule cells, some of the excess glucose is not reabsorbed into the circulation. Instead, it passes out of the body in urine (hence sweet urine, as the name diabetes mellitus suggests).

The inability of body cells to take up glucose from the blood also results in skeletal muscle cells undergoing protein catabolism to free up amino acids to be used in forming glucose in the liver. This action puts the body into a negative nitrogen balance from the resulting protein depletion and tissue wasting. Other associated problems include poor wound healing and poor resistance to infections.

This activity is divided into two parts. In Part 1, you will generate a glucose standard curve, which will be explained in the experiment. In Part 2, you will use the glucose standard curve to measure the fasting plasma glucose (FPG) levels from several patients to diagnose the presence or absence of diabetes mellitus. A patient with FPG values greater than or equal to 126 mg/dL in two FPG tests is diagnosed with diabetes. FPG values between 110 and 126 mg/dL indicate impairment or borderline impairment of insulin-mediated glucose uptake by cells. FPG values less than 110 mg/di are considered normal. (Update – FPG between 100 and 128 mg/dL is considered prediabetic.)

Do the Pre-Lab Quiz, Experiment, and Post-Lab Quiz.



Discussion:

Activity 1: Metabolism and Thyroid Hormone

1. Explain the role of Thyroxine from the thyroid in maintaining basal metabolic rate.
2. Explain the role of TRH from the hypothalamus and TSH (Thyrotropin) from the anterior pituitary, in the control of Thyroxine from the thyroid.
3. Explain the role of Thyroxine from the thyroid in providing negative feedback control of TRH from the hypothalamus.
4. Explain how excess TSH can cause a goiter.

Activity 2: Plasma Glucose, Insulin and Diabetes Mellitus

5. Explain the role of Insulin and Glucagon from the pancreas in the control of blood glucose.
6. Explain the difference between type1 and type 2 diabetes mellitus.
7. Explain the significance of fasting blood glucose in diagnosing diabetes mellitus,
8. Explain why high blood glucose often means that cells are unable to get adequate glucose for metabolism.