Chapter 13

Endocrine System – Part II

Before we continue looking at the rest of the endocrine system, let's take a quick look back on the chart we studied last week:

Gland/Organ	Hormone(s) produced
Anterior lobe (pituitary)	Thyroid-stimulating hormone (TSH) Adrenocorticotropic hormone (ACTH) Follicle-stimulating hormone (FSH) Lutenizing hormone (LH) Prolactin (PRL) Growth hormone (GH)
Posterior lobe (pituitary)	Antidiuretic hormone (ADH) Oxytocin
Thyroid	Thyroxine (T_4) Triiodothyronine (T_3) Calcitonin (CT)
Parathyroids (4)	Parathyroid hormone (PTH)
Adrenal (cortex)	Mineralocorticoids (Aldosterone) Glucocorticoids (Cortisol)
Adrenal (medulla)	Epinephrine (adrenaline) Norepinephrine (noradrenaline)
Pancreas	Insulin Glucagon
Thymus	Thymosins
Pineal	Melatonin
Ovaries	Estrogens Progesterone
Testes	Testosterone Inhibin

Now it's time to continue our journey through the endocrine system with an exploration of the...

Thyroid and Parathyroid glands

The **thyroid gland** is located in the neck and is in front of (anterior) to the *trachea* (aka – the windpipe). It is a large gland weighing an average 1.2 ounces (34 grams) as compared to the pituitary gland which weighs in at 0.02 ounces (0.5 grams).

The thyroid gland stores the hormones it creates in spherical sacs called **follicles**. Three important hormones are secreted by this gland which is known as:

Thyroxine (T_4), Triiodothyronine (T_3), and Calcitonin (CT)

Although T_3 and T_4 have similar functions, differences exist within their chemical structures as T_3 contains only three atoms of iodine while T_4 has four. Of the two, T_4 is produced in greater volume accounting for nearly 90% of all manufactured hormones by the thyroid.

Triiodothyronine (T_3) and Thyroxine (T_4)
Target cells for this hormone = Nearly all cells throughout the body

The entire body depends upon these two hormones for its survival because:

The primary functions of T_3 and T_4 are to increase the rate in which cells use oxygen and food to produce energy!

In addition to this vital function, these two hormones also perform the following tasks within the human body:

- Increases the heart rate and forces the contraction of heart muscle
- Assists in the regulation of oxygen and carbon dioxide levels in the blood
- Stimulates the formation of red blood cells to enhance oxygen delivery
- Supports the growth of bones in developing children

It may be easy to think of these glands as separate entities, each performing their own functions independently of each other; however, this is definitely not the case! If you recall from the last chapter, the thyroid is controlled by a particular hormone (TSH) which is produced by another gland – the pituitary gland! Don't ever forget:

Everything in your body is connected together.

The thyroid is not exception to this rule, but the following story may help you to understand how it performs within the human body:

The thyroid gland is much like a car - it's where the fuel goes in, combusts, and provides the power for everything else to work. A car is run by an engine which relies on fuel as well. In a similar way, the thyroid gland takes in a different type of fuel – the element iodine, and turns it into T_3 and T_4 hormones which influence how energy gets transmitted to the body's tissues. FYI - We normally receive our daily amount of iodine from the iodized salt in our diet.

What about the other thyroid hormone - calcitonin?

Calcitonin (CT):
Target cells for this hormone = Bone tissue

In addition to stimulating bone growth, **calcitonin** helps to regulate the amount of calcium found in the blood. When calcium levels are increased, calcitonin is released to lower this concentration to a safer level.

That is about all there is to say about the thyroid gland for now. Let's take a look at its counterpart...

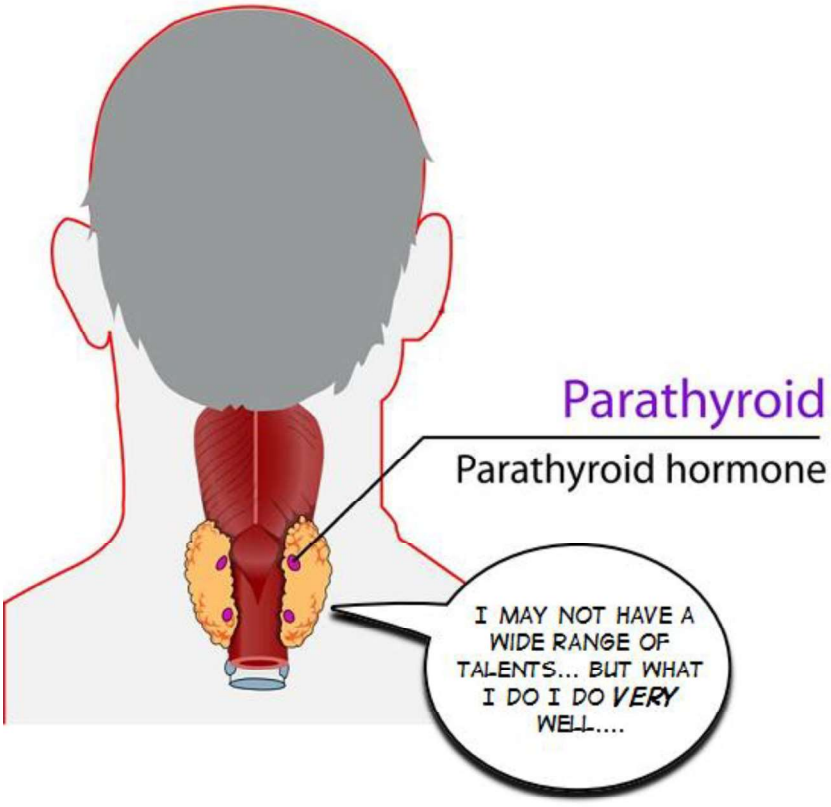
Parathyroid glands

There are four **parathyroid glands** found on each side of the back (posterior) surface of the thyroid gland. These glands are very small, pea-sized organs weighing only around 0.015 ounces (0.4 grams) each. The main function of these glands is to produce the hormone called **parathyroid hormone (PTH).**

Parathyroid hormone (PTH):
Target cells for this hormone = Bone tissue and kidneys

The main function of PTH is to increase the levels of calcium (for bones) in the blood which it accomplishes in a variety of ways:

- PTH stimulates osteoclasts to break down bone tissue and release calcium from the bone into the blood. (Check back in Chapter 4 for a review of this process!)
- PTH blocks the action of osteoblasts from absorbing calcium in the blood during the process of bone development.
- PTH encourages the absorption of calcium and phosphorus from the small intestine into the bloodstream during digestion.
- PTH lowers the amount of calcium lost in our urine by assisting the kidneys in reabsorbing this element back into the blood stream.



How does PTH and calcitonin help to promote homeostasis?

When the concentration of calcium within the blood is too high, the thyroid gland secretes calcitonin to remove this element from the blood. There is no way for the thyroid to know when to stop secreting calcitonin. So, when the amount of calcium begins to fall below safe levels, the parathyroid starts to release PTH until the blood calcium levels increases to its normal value.

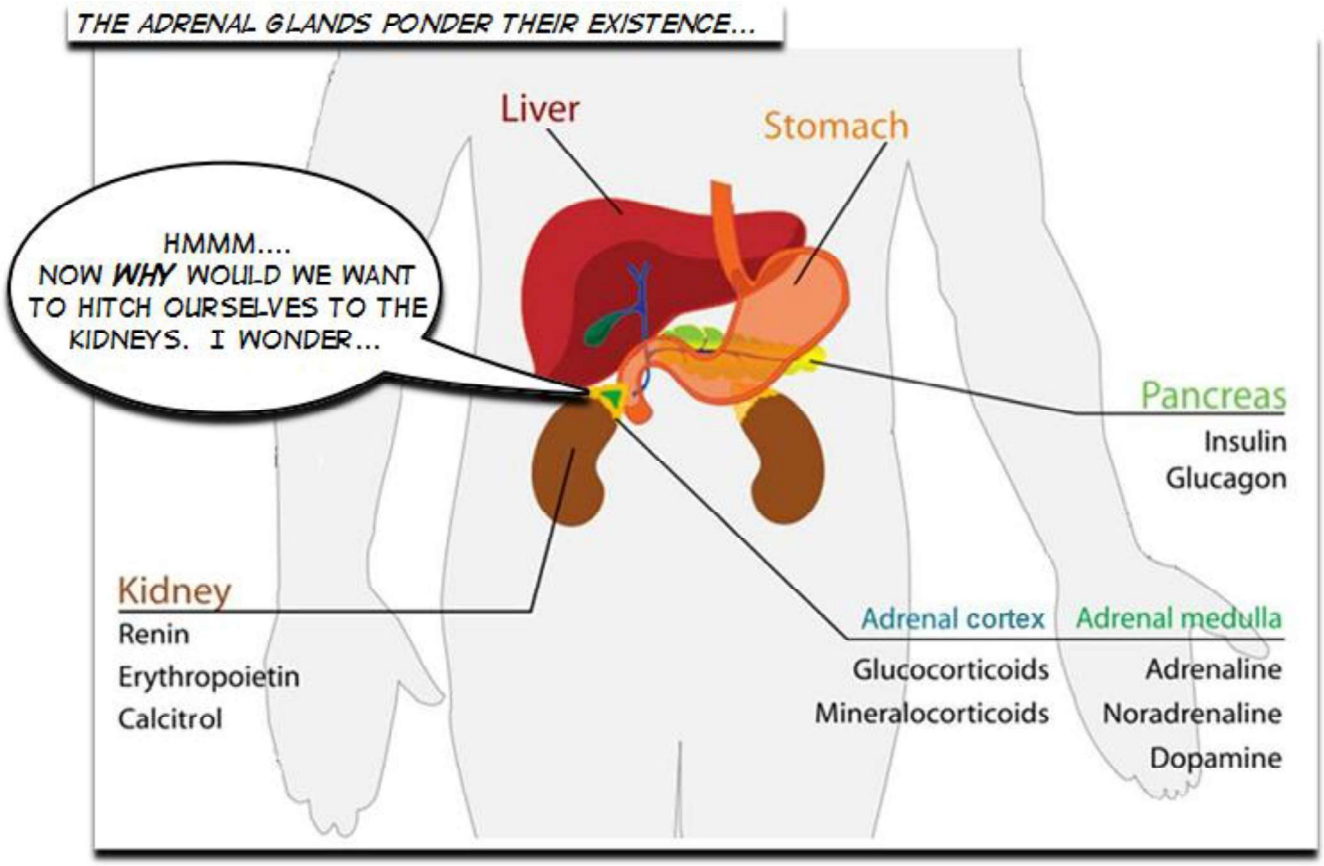
It's like a never-ending ride on a see-saw with both ends constantly in motion!

We've been talking a little about our kidneys and you may have picked up on a few hints about the function of this important organ. Simply put, both of your kidneys filter the bloodstream in order to get all of the toxins out of your blood, and they also regulate the amount of water within the blood as well. We will spend a considerable amount of time in future chapters discussing this organ.

Until that time, we are still not done exploring the endocrine system. So, let's look at two more glands that are found <u>on top</u> of the kidney...

The Adrenal Glands

The **adrenal glands** can be found on top of each kidney. Each of these yellow-colored glands weighs close to 0.19 ounces (7.5 grams) and has a pyramid shape. Each adrenal gland is constructed of two separate glands themselves. The tiny, innermost section of the adrenal gland is a separate gland known as the **adrenal medulla.** This organ is surrounded by a much larger gland known as the **adrenal cortex**. Of the two, the adrenal cortex makes up approximately 90 percent of the mass of entire adrenal gland.



Let's look at each of these glands separately!

Adrenal cortex

The adrenal cortex secretes more than two dozen different hormones called **corticosteroids** each serving a unique purpose. Most of these hormones can be grouped into two main categories:

Mineralcorticoids and Glucocorticoids

Mineralocorticoids

The primary mineralocorticoid is the hormone called **aldosterone**. This hormone is responsible for increasing the amount of sodium into the blood by removing it from the urine. In addition, aldosterone also helps to remove the element potassium from the blood into the urine. Why would it do these things?

Homeostasis

Simply put, aldosterone is released when the amount of sodium in our blood is too low or when the amount of potassium is too high.

Glucocorticoids
The primary glucocorticoid is the hormone **cortisol**. This hormone is released when our blood contains a low amount of sugar. The presence of cortisol triggers a series of actions which result in the release of sugar into the bloodstream.

That's right! This is another example of homeostasis in action!

In addition to the release of sugar, cortisol also stimulates the breakdown of fats and proteins which can be used as energy sources.

Adrenal medulla

The adrenal medulla produces the hormones **epinephrine** (also known as **adrenaline**) and **norepinephrine.** The production of these two hormones is regulated by the nervous system. By far, the main hormone that is produced by the adrenal medulla is epinephrine.

You learned back in Chapter 10 that the sympathetic nervous system increases your alertness and generally prepares your body to deal with stress and emergencies. Both hormones secreted by the adrenal medulla regulate this **"fight or flight"** system in your body. These hormones affects nearly all body tissues both directly and indirectly as their main function at times of stress is to elevate the heart rate, thus increasing the blood flow throughout the body.

Now let's look at the longest of the glands we will be studying...

The Pancreas

The **pancreas** is an elongated organ which is about 6 inches (~15cm) long and can be found between your stomach and small intestine. There are several different types of cells which make up the pancreas, each of which produce different types of hormones. However, the two most important of these has to be the following:

Insulin and Glucagon

Much like the hormone cortisol, **glucagon** stimulates the *liver* (you will learn more about this organ in future chapters) to convert a particular type of sugar known as **glycogen** within your body into a more usable sugar called **glucose**. This simple sugar is used to generate the compound ATP (adenosine triphosphate) which is the chemical fuel needed for most bodily processes. You first learned about this important chemical back in Chapter 7. As you may have guessed, glucagon is released when the blood glucose levels in our body fall below normal levels which, in turn, trigger the eventual release of ATP into the bloodstream.

So what controls glucagon from producing too much sugar into the bloodstream?

This is when **insulin** gets to work! Insulin is secreted when blood sugar levels rise above normal values. Insulin does a very good job at helping cells absorb as much sugar (glucose) out of the bloodstream. In addition, insulin also helps to convert glucose back into glycogen which can be easily stored by the liver for use when blood glucose levels drop once again.

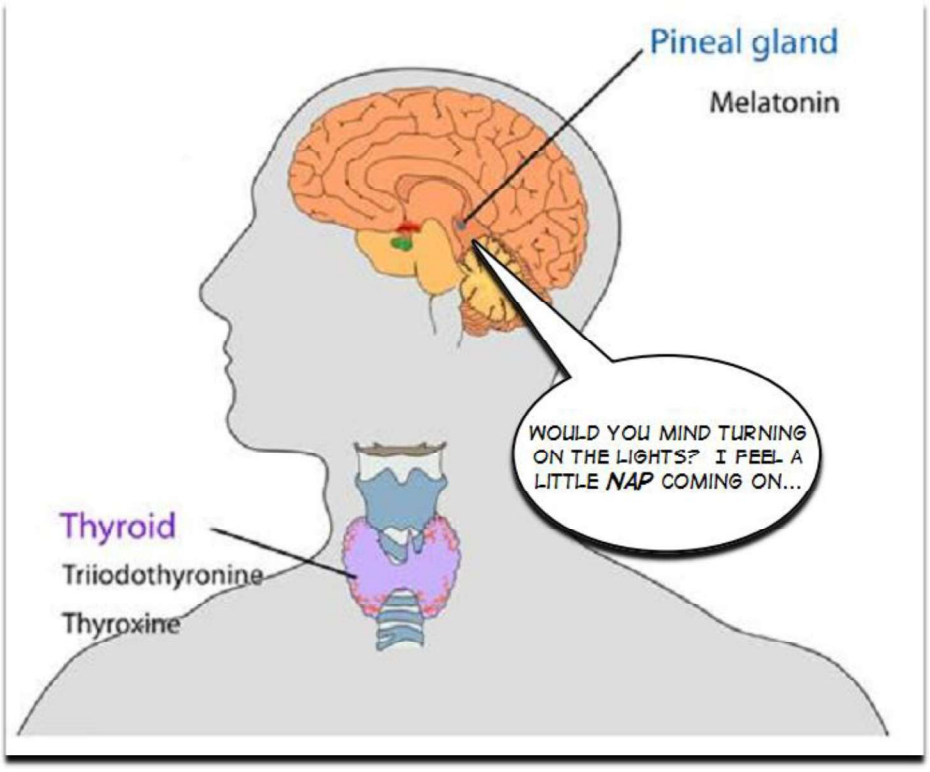
Two more glands worth mentioning include the:

Thymus gland and the Pineal gland

The **thymus gland** can be found directly between the lungs and ranges from 0.17-1.2 grams (5-35 grams) depending upon the age of the individual. Unlike most glands, the thymus continues to grow until the individual reaches **puberty** (a period of time in which a series of physical and chemical changes in a child's body matures into an adult body). Upon the end of puberty, the thymus gland begins to shrink in size throughout the life of the individual.

The thymus gland produces several hormones, called **thymosins**, which help the immune system by assisting in the production of **T cells**. These immune cells attack foreign substances as they enter our body.

The tiny **pineal gland** can be found near the center of the brain, between the two hemispheres. This gland is roughly the size of a grain of rice and seems to control at least one pattern within our body. The pineal gland secretes the hormone **melatonin** during periods of darkness and acts to regulate our sleep-wake cycle. This cycle, also known as a **circadian rhythm** (as it repeats every 24 hours), can be controlled by the level of melatonin released into our bodies which induces drowsiness. Melatonin's production is directly linked to our bodies exposure to bright light.



Our last stop within our study of the endocrine system deals with our ability to reproduce. These last two glands are known as:

The Ovaries and Testes

You learned about these two glands previously during our discussion on the follicle-stimulating (FSH) and lutenizing (LH) hormones. The ovaries (female reproductive organs) and the testes (male reproductive organs) are the target cells for these two hormones. Both of these organs are responsible for secreting their own unique hormones as well:

Ovaries

Hormones produced: Estrogen and Progesterone

Although both **estrogen** and **progesterone** are found in men and women and stimulate a long list of functions, it is women who carry a larger volume of these hormones. Their primary functions in women involve the preparation and maintenance of their bodies before and during pregnancy. This includes the regulation of the organs and tissues within the reproductive system of women.

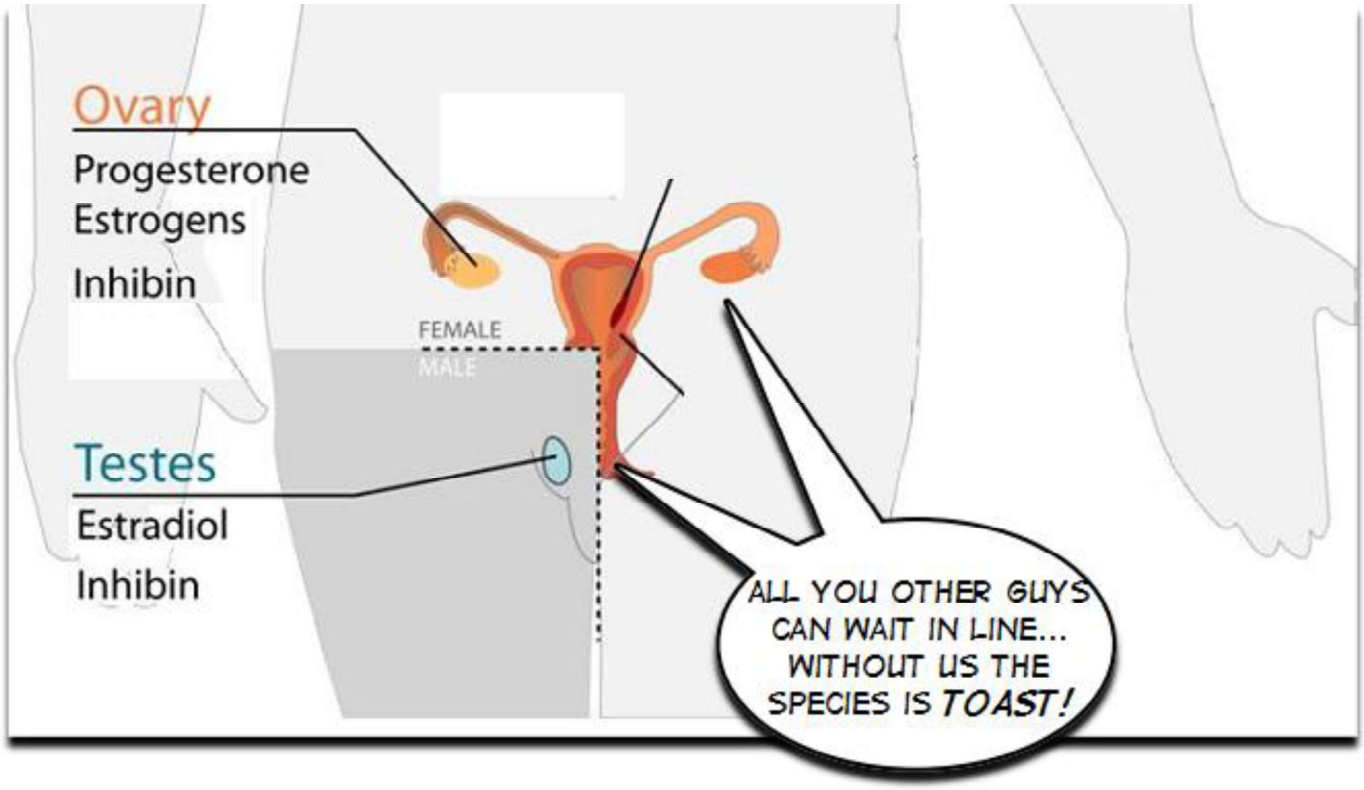
Testes

Hormones produced: Testosterone and Inhibin

By far, the hormone **testosterone** is the most important male hormone secreted by the testes. Much like progesterone and estrogen, testosterone is created in the reproductive organs of both males and females; however, it is typically found in greater quantities within males as it stimulates the growth of male reproductive tissues, bones, muscles, and body hair at the beginning of puberty. And, it also plays a vital role (along with estrogen) to stop the growth of new cells along the epiphyseal plates at the end of puberty, thereby regulating the height of an individual. In addition, testosterone also acts upon the respiratory system to cause a deepening of the voice.

In addition to testosterone, the testes also produce a hormone called **inhibin** which acts to lower the amount of FSH secreted into the bloodstream.

Yep! Homeostasis in action once again!



Anatomy & Physiology - Connections

How the following body systems affect the endocrine system		How the endocrine system affects the following body systems	
Integumentary	Protection of endocrine organs; synthesis of vitamin D	Testosterone stimulates the growth of body hair; PRL develops mammary glands; corticosteroids affect blood flow within skin	**Integumentary**
Skeletal	Additional protection for endocrine organs	Multiple hormones regulate bone growth and development; calcium levels managed by PTH and calcitonin	**Skeletal**
Muscular	Additional protection for endocrine organs	Multiple hormones oversee muscle growth and development; calcium levels managed by PTH and calcitonin	**Muscular**
Nervous	Hypothalamus regulates pituitary gland secretions; nervous system controls the adrenal medulla	Hormones regulate fluid and nutrient concentrations for nerve impulses	**Nervous**

Match the following vocabulary terms with their correct definition:

adrenal cortex	**glucagon**	**pineal gland**
adrenal glands	**glucocorticoids**	**progesterone**
adrenal medulla	**glucose**	**puberty**
aldosterone	**glycogen**	**T cells**
calcitonin	**inhibin**	**testosterone**
circadian rhythm	**insulin**	**thymosins**
corticosteroid	**melatonin**	**thymus gland**
cortisol	**mineralocorticoid**	**thyroid gland**
epinephrine	**norepinephrine**	**thyroxine (T_4)**
estrogen	**pancreas**	**triiodothyronine (T_3)**
fight or flight response	**parathyroid glands**	
	parathyroid hormone	

1)	_____	a complex sugar stored by the liver for use when blood sugar levels increase or decrease
2)	_____	a gland which is located in the neck and is in front of (anterior) to the trachea ; secretes the hormones thyroxine, triiodothyronine, and calcitonin
3)	_____	a glucocorticoid hormone secreted by the adrenal cortex responsible for increasing the level of sugar within the blood
4)	_____	a mineralocorticoid hormone secreted by the adrenal cortex; responsible for increasing the amount of sodium (and water) into the blood and to remove potassium from the blood into the urine
5)	_____	a series of physical changes in which a child's body matures into an adult body
6)	_____	a simple sugar created from glycogen within the liver; used as fuel for most cellular functions within the body

7)	_____	an elongated organ 6in (15+cm) found between the stomach and small intestine; responsible for producing several hormones, the most important being insulin and glucagon
8)	_____	comprises ~90% of the adrenal gland; secretes 2+ dozen corticosteroid hormones
9)	_____	four glands found on each side of the back(posterior) surface of the thyroid gland ; responsible for producing the hormone parathyroid hormone (PTH)
10)	_____	gland found directly between the lungs; secretes thymosin hormones which help the immune system produce T cells
11)	_____	gland found near the center of the brain; regulates the sleep-wake cycle of humans through the secretion of the hormone melatonin
12)	_____	hormonal response to emergency situations; regulated by epinephrine which elevates the heart rate, thereby increasing both blood and oxygen flow throughout the body
13)	_____	hormone produced by the thyroid gland which stimulates bone growth and helps to regulate the amount of calcium found in the blood
14)	_____	hormone released from the parathyroid glands; responsible for increasing the levels of calcium (for bones) and phosphorus (for cell membranes) found within the blood
15)	_____	hormone responsible for lowering the amount of follicle stimulating hormone within the blood stream
16)	_____	hormone secreted by the adrenal medulla; works with epinephrine to regulate the fight or flight response in humans during times of stress
17)	_____	hormone secreted by the adrenal medulla; works with norepinephrine to regulate the fight or flight response in humans during times of stress

18)	_____	hormone secreted by the ovaries which works along with estrogen to prepare and maintain women before and during pregnancy
19)	_____	hormone secreted by the ovaries which works along with progesterone to prepare and maintain women before and during pregnancy
20)	_____	hormone secreted by the pancreas which helps cells to absorb sugar from the bloodstream
21)	_____	hormone secreted by the pancreas which stimulates the liver to produce an increased amount of glucose to be released into the bloodstream
22)	_____	hormone secreted by the pineal gland; regulates the circadian rhythm of humans
23)	_____	hormone secreted by the thyroid gland which contains four atoms of iodine and regulates the rate in which cells use oxygen and food to produce energy
24)	_____	hormone secreted by the thyroid gland which contains three atoms of iodine and regulates the rate in which cells use oxygen and food to produce energy
25)	_____	hormone which stimulates the growth of male reproductive tissues, bones, muscles, body hair, and the deepening of one's voice
26)	_____	hormones produced by the thymus gland
27)	_____	immune cells which attack foreign substances as they enter our body
28)	_____	one class of corticosteroid secreted by the adrenal cortex; the primary hormone being aldosterone
29)	_____	one class of corticosteroid secreted by the adrenal cortex; the primary hormone being cortisol
30)	_____	one of 2+ dozen hormones secreted by the adrenal cortex
31)	_____	sleep-wake cycle of humans; controlled by the hormone melatonin secreted by the pineal gland

32)	_____	small section of the adrenal gland responsible for producing the hormones epinephrine (also known as adrenaline) and norepinephrine
33)	_____	two glands which sit on top of each kidney and separated into two sections known as the medulla and the cortex

Choose the correct answer from the following questions:

1) Which of these hormones is released by the adrenal medulla:

A) sex hormones
B) aldosterone
C) glucocorticoids
D) epinephrine

2) Rising blood levels of aldosterone results in the removal of _____ from the urine.

A) calcium
B) sodium
C) iodine
D) potassium
E) hydrogen

3) The hormone that appears to help regulate our sleep-awake cycles is:

A) melatonin
B) thyroxine
C) progesterone
D) inhibin
E) glucagon

4) Estrogens do all of the following EXCEPT:

A) stimulate menstruation in preparation for fertilization
B) help maintain pregnancy
C) stimulate growth of facial hair
D) prepare the uterus to receive a fertilized egg during reproduction

5) Insulin causes:

A) a decrease in the concentration of blood glucose
B) an increase in blood pressure
C) an increase in the production of glucagon
D) an increase in the concentration of blood glucose

6) _____ is controlled by and regulates the function of insulin within the blood stream.

A) oxytocin
B) glucagon
C) testosterone
D) thyroid hormone

Application Question:

How is the hormone calcitonin controlled by a negative feedback mechanism, and what effect does calcitonin have on blood calcium levels?