- Nervous system
  - sense organs (the 5 senses)
  - reflex arc

A reflex action is the simplest type of behavior produced by an organism in response to a stimulus. It is a rapid, automatic, inborn response that does not require any conscious thought.

Information from a stimulus is detected by sensory receptors and transmitted to the Central Nervous System (brain and spinal cord). The CNS produces a response by sending nerve impulses to the appropriate effector organs.

Reflexes are rapid because there is a direct circuitry of neurons connecting the receptor and the effector. This is known as the Reflex Arc.

An example of a reflex arc is shown in the diagram below.

- feedback loops (feedback inhibition, negative feedback)

Homeostasis is a dynamic, active process, not a static one. A Feedback Loop is one way to illustrate this active process:
To help you visualize this diagram, pretend that Any System is a bucket half full of water. The bucket has a hole in it where water is flowing out---this is Output. You are holding the bucket under a running faucet--this is Input. If the amount of water flowing out of the hole is the same as the amount entering from the faucet, the system is in balance. In this situation, the sensor is your eyesight. The feedback system is your hand on the faucet, which can turn the faucet to increase or decrease the flow based on what your eyes are telling you.

Feedback corrects the Input. Think of the time when you finally learned to ride a bicycle; when you learned to balance. Homeostasis happens without thinking--we just do it. Here are two stages of this process as feedback loops:
In Figure One, you are just starting to lose your balance. If you don't correct it you will fall. Homeostasis is the process of correcting imbalances. Figure Two takes place about three seconds after Figure One.
Another way to think of homeostasis is that living systems try to maintain a constant internal environment. The adjustments that organisms make to keep their interior environments stable are responses to changes in the environment outside their bodies. Homeostasis is 'the wisdom of the body'; there is no thinking required. The result of this continual balancing act is sometimes called a "dynamic equilibrium."

The most familiar regulation our own bodies do is temperature regulation. In humans, normal body temperature is about 98.6 F.

A rise in body temperature means we need to dump heat. We sweat and we breathe faster, two regulatory processes that lower the body temperature. To get rid of heat, we also reduce activity, and expand our capillaries so more blood can dump its heat near the surface of the skin. Our skin is an efficient heat-exchanger when the air around it is cooler than the body.

A decrease in body temperature, say from a chilly winter walk, leads to increased heat-producing activity such as increased metabolism or the muscular contractions of shivering. Heat loss is also reduced by decreased circulation to the skin; the capillaries shrink. Below is a feedback loop showing a response to cold:
Feedback loops are used by living systems to regulate a large number of internal conditions.

- **Waste:** From protozoans to worms to insects to mammals, the organ systems that get rid of unusable and excess substances work to maintain the balance between inside and outside. The principal function of the excretory system of animals is homeostasis.
- **Saltiness:** Most animals regulate the salt content of their internal fluids. The blood of most ocean fishes, for example is not nearly as salty as the ocean itself—if it were the fish would die. So they must continuously adjust their blood to keep dissolved mineral salts out. Freshwater fishes have the opposite problem: their blood requires a higher salt content than is found in fresh water. So they must continually regulate to retain dissolved mineral salts. In both cases, the kidneys accomplish this job.
- **Temperature:** Land animals regulate their temperatures; the salt and sugar content of their blood (fluid and electrolyte balance); and their metabolisms (energy production and use).
- **Sugar:** Most animals regulate the sugar content of their blood; in turn the sugar content helps determine metabolism.
- **Hormones:** The activity of endocrine glands (hormone producers) are regulated by feedback loops in the circulatory system.
- **Enzymes:** Many enzymes are regulated by feedback loops within individual cells, and others by feedback loops in larger systems.
**Closed Loops:** These regulatory feedback loops are "closed" feedback loops. A change in the outside is sensed, which triggers a response which opposes or corrects the change. Closed feedback loops are often called negative feedback loops, which is a misleading name, because their action is toward the good of the living system.

**Open Loops:** "Open" feedback loops (often called positive feedback loops) are very different. They are often destructive. The response in an open loop says "Great! More! More!" So the change in the outside is reinforced instead of corrected. Positive feedback loops accelerate change, which can lead to death. But some situations require open feedback loops.

If you cut yourself, your blood tries to clot to stop blood loss. The more the blood tries to clot, the more it does clot. This is a positive feedback loop in action, but when the bleeding ends, it stops, and a closed feedback loop takes over. If the positive feedback loop continued its "runaway" clotting, all the blood in your body would coagulate and you would die.

In economics, open feedback loops are often described as spirals. Inflation of a money supply is good example, bankruptcy is another. The "upward spiral of inflation" and the "downward spiral of debt" are common phrases in newspapers.

- nerve impulses
  - An action potential.
- action potential
  - The potential difference produced across the plasma membrane of nerve or muscle cells when they are stimulated.
- sodium-potassium pump
The concentration differences between $K^+$ and $Na^+$ across cell membranes create an electrochemical gradient known as the membrane potential. Adenosine triphosphate (ATP) provides the energy to pump 3 Na$^+$ ions out of the cell in exchange for 2 K$^+$ ions, thus maintaining the membrane potential.

- **Active transport**
  Carrier proteins are used in active transport to pick up ions or molecules from near the cell membrane, carry them across the membrane, and release them on the other side. Active transport requires energy.

- **Neurotransmitters**
  - A chemical liberated from an axon terminal of a neuron which transmits a neuronal signal across a synapse to another neuron or a muscle fiber. Released by pre-synaptic neuron, interacts with receptors on membrane of post-synaptic neuron. Examples: Noradrenaline, acetylcholine.

- **Synapse**
  - The point of communication between one nerve cell and another or between a nerve cell and its non-neuronal target (e.g. muscle fiber). The neuronal message is carried across the synapse by a chemical transmitter.
## Parts of a Neuron

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Axon</strong></td>
<td>The long extension of a neuron that carries nerve impulses away from the body of the cell.</td>
</tr>
<tr>
<td><strong>Axon Terminals</strong></td>
<td>The hair-like ends of the axon</td>
</tr>
<tr>
<td><strong>Cell Body</strong></td>
<td>The cell body of the neuron; it contains the nucleus (also called the soma)</td>
</tr>
<tr>
<td><strong>Dendrites</strong></td>
<td>The branching structure of a neuron that receives messages (attached to the cell body)</td>
</tr>
<tr>
<td><strong>Myelin Sheath</strong></td>
<td>The fatty substance that surrounds and protects some nerve fibers.</td>
</tr>
<tr>
<td><strong>Node of Ranvier</strong></td>
<td>One of the many gaps in the myelin sheath - this is where the action potential occurs during saltatory conduction along the axon</td>
</tr>
<tr>
<td><strong>Nucleus</strong></td>
<td>The organelle in the cell body of the neuron that contains the genetic material of the cell</td>
</tr>
<tr>
<td><strong>Schwann's Cells</strong></td>
<td>Cells that produce myelin - they are located within the myelin sheath.</td>
</tr>
</tbody>
</table>

- **gray and white matter**
  - Grey matter is where all the processing is done and white matter is responsible for communicating between regions of grey matter and between the grey matter and the rest of the body.
- **differences between sensory neurons, interneurons, and motor neurons**
  - **Sensory Neuron:** A nerve cell concerned with carrying impulses from sensory receptor organs to the CNS.
  - **Interneuron (or Association Neuron):** A small neuron within the grey matter of the CNS, interposed between sensory and motor neurons in a reflex arc.
  - **Motor Neuron:** A nerve cell that carries impulses away from the CNS to an effector organ.

- **Endocrine system**
  - **types and functions of hormones**

  The endocrine system is the internal system of the body that deals with chemical communication by means of hormones, the ductless glands that secrete the hormones, and those target cells that respond to hormones. The endocrine system functions in maintaining the basic functions of the body ranging from metabolism to growth. **The endocrine system functions in long term behavior and works in conjunction with the nervous system in regulating internal functions and maintaining homeostasis.**

### Hormones

Hormones are the chemical messengers released by specialized endocrine cells or specialized nerve cells called neurosecretory cells. Hormones are released by the endocrine system glands into the body’s fluids, most often into the blood and transported throughout the body. Hormones are specified by their different chemical structures which can be classified into four categories…

**Amines:** are small molecules originating from amino acids. Examples of this are epineprine and thyroid hormones.

**Prostaglandins:** are cyclic unsaturated hydroxy fatty acids synthesized in membranes from 20 carbon fatty acid chains

**Steroid hormones:** are cyclic hydrocarbon derivatives synthesized in all instances from the precursor steroid cholesterol. Examples of this are testosterone and estrogen.

**Peptide and Protein hormones:** are the largest and most complex hormone. Example of this is insulin.

Hormones drive the endocrine system and without them the body could not function. Hormones are the communicators of the endocrine system and are
responsible for maintaining and controlling cellular activity.

Hormones function

Hormones regulate bodily functions and are specific in what responses they elicit. As hormones are released into the bloodstream they can only initiate responses in target cells, which are specifically equipped to respond. Each hormone due to its chemical structure is recognized by those target cells with receptors compatible with their structure. Once a hormone is released, the first step is the specific binding of the chemical signal to a hormone receptor, a protein within the target cell or built into the plasma membrane. The receptor molecule is essential to a hormone's function. The receptor molecule translates the hormone and enables the target cell to respond to the hormone's chemical signal. The meeting of the hormone with the receptor cell initiates responses from the target cell. These responses vary according to target cell and lipid solubility.

Hormones are either lipid-soluble or lipid-insoluble, depending on their biochemical structure. The lipid solubility of the hormone determines the mechanism by which it can affect its target cell.

Lipid-soluble hormones are able to penetrate through the cell membrane and bind to receptors located inside the cell. Such hormones diffuse across the plasma membrane and target those receptor cells found within the cytoplasm. Lipid-soluble hormones target the cytoplasmic receptors which readily diffuse into the nucleus and act on the DNA, inhibiting and stimulating certain proteins. DNA function is of great influence over the cellular activities of the body and therefore such hormonal-DNA interaction can have effects as long as hours and in some cases days. Two known types of lipid soluble hormones are steroids and thyroid hormones. Both travel over long courses of time via the bloodstream and both directly effect DNA functions.

Those hormones which are lipid-insoluble are unable to penetrate through the plasma membrane and function with their target cells in a much different and complex manner. Lipid-insoluble hormones must bind with cell-surface receptors which follow a different path involving a second messenger. The hormone's inability to penetrate the membrane requires a second messenger which translates the outer message and functions within the cell.

Once a lipid-insoluble hormone binds with a cell surface receptor, its’ signal is translated into the cell by specific secondary messengers. There are three known and accepted secondary messengers which vary in structure and function, but all three carry out the external signal internally. The three known secondary messengers are (1) cyclic nucleotide compounds (cNMPs), cAMP, and cGMP; (2) inositol phospholipids; and (3) Ca2+ ions. After a hormone binds with a receptor molecule it via a transducer protein sends the
hormones signal through the membrane. The protein receptor initiates the formation of a second messenger, whether it be cAMP or an inositol phospholipid, which then binds to an internal regulator. The internal regulator controls the target cells’ response to the hormone's signal.

Each different type of secondary messenger evokes different responses by those cells they affect. cAMP has wide range of tissues it targets and those responses it elicits. cAMP pathways can increase the heart rate and force a contraction in a heart, it can decrease lipid breakdown in fat cells, and it can stimulate resorption of water in a kidney. An inositol phospholipid pathway can initiate breakdown of liver glycogen and DNA synthesis in fibroblasts. Ca2+ pathways are linked to initiating responses in striated muscles most notably contraction. These responses, however, are short lived responses; much shorter then those by lipid soluble affected cells. Although the cellular mechanisms of hormones vary according to solubility and first and second messengers, such hormones function in eliciting responses from their target cells.

Hormones more or less function as a stimulant, promoting an action in a target cell which can be magnified in stimulating organs or even systems. Hormone stimulation varies from growth and metabolic functions to ova and sperm production.

**Signals transmitted by the endocrine system**

There are two ways in which the endocrine system affects the rest of the organism. The first method of transmission, is called local signaling. This is when regulators are released by a gland or cell into the interstitial fluids and are absorbed by nearby cells. The second method of transmission is called long distance signaling. Long distance signaling takes place when an endocrine cell or neurosecretory cell releases hormones into the bloodstream. Once in the bloodstream the hormones travel to the receptor cell. When they reach their destination the receptor cell integrates the signal and reacts to its design.

**Growth factors in the endocrine system**

Growth factors affect the development of new cells. There are specific hormones that correspond with the development of specific cells. For example, epidermal growth factor is required to grow epithelial cells. The rate of growth can also be affected, for example an experiment on fetal mice was done to see if rate of growth of skin would change with an influx of hormones. It was found that by injecting the fetal mice with EGF that skin developed faster.
The role of the hypothalamus and pituitary gland

The hypothalamus and pituitary gland are two parts of the brain that have important roles in integrating the nervous and endocrine system. The hypothalamus is found in the lower part of the brain in the midbrain where it functions in receiving messages from nerves and integrating that into endocrine gland responses. The hypothalamus is more or less the communication link between the nervous system and the endocrine system. The hypothalamus regulates the secretion of various hormones by controlling the main hormonal gland the pituitary gland.

The pituitary gland releases hormones that control many of the endocrine system's functions. The pituitary gland releases hormones when signaled by the hypothalamus. The pituitary gland has numerous functions which are performed by its two parts. Pituitary’s two separate parts are essential to the production of many hormones but, their function in relation to the hypothalamus and endocrine system vary greatly.

The posterior pituitary is an extension of the brain and secretes two types of hormones, oxytocin and antidiuretic hormone (ADH), both of which are produced by the hypothalamus and released into the posterior pituitary. Neurosecretory cells in the hypothalamus produce oxytocin and ADH and are transported down an axon to the posterior pituitary where it is stored. The posterior pituitary releases these hormones when needed via the bloodstream and bind to their target cells. The posterior pituitaries hormones elicit specific responses from the kidneys, by means of ADH, and the mammary glands, by means of oxytocin. ADH acts directly on the ability of the kidneys to reabsorb water, whereas oxytocin causes mammary glands to release milk.

The anterior pituitary also relies on the hypothalamus to control and regulate its hormonal release, but in a less direct manner. The release of hormones by the anterior pituitary is driven by neurosecretory cells located in the hypothalamus. When the hypothalamus receives a signal for the need of a hormone produced by the anterior pituitary, it sends releasing hormones through short portal vessels and into a second capillary network within the anterior pituitary, where it acts on a specific hormone. Besides releasing stimulatory hormones the hypothalamus also releases inhibiting hormones which prevent the release of certain hormones from the anterior pituitary. The anterior pituitary produces and releases several different hormones with many different functions. Its hormones range from growth hormones that act on bones, to prolactin which stimulates mammary glands. A unique function of those hormones released by the anterior posterior, is that some of them act on other endocrine glands and signal them to produce and release other hormones. Tropic hormones are responsible for this, such as thyroid stimulating hormone which stimulates the thyroid and its production of
Pheromones and their function

Pheromones are chemical signals that function as external communicators whereas hormones are internal. Pheromones communicate between separate individuals, not within one individual as hormones do. Pheromones are communicating chemicals that act between animals of the same species. Pheromones are dispersed into the environment and are used in attraction, defense, and marking territories. Pheromones play a great role in the insect world, but their importance in human interaction is disputed. Some scientists question the presence of chemical influence on human behavior while an entire industry, the fragrance industry, bases its existence on the appreciation for external scents. Pheromones most likely play a hidden role in the interaction of humans with each other.

The Endocrine System related to the Nervous System

The nervous and endocrine systems are related in three main areas, structure, chemical, and function. The endocrine and nervous system work parallel with each other and in conjunction function in maintaining homeostasis, development and reproduction. Both systems are the communication links of the body and aid the body’s life systems to function correctly and in relation to each other.

Structurally many of the endocrine systems glands and tissues are rooted in the nervous system. Such glands as the hypothalamus and posterior pituitary are examples of nerve tissues that influence the function of a gland and its secretion of hormones. Not only does the hypothalamus secrete hormones into the bloodstream, but it regulates the release of hormones in the posterior pituitary gland. Those that are not made of nervous tissue once were. The adrenal medulla is derived from the same cells that produce certain ganglia.

Chemically both the endocrine and nervous system function in communication by means of the same transmitters but use them in different ways. Hormones are utilized by both systems in signaling an example of this can be seen in the use of Norepinephrine. Norepinephrine functions as a neurotransmitter in the nervous system and as an adrenal hormone in the endocrine system.

Functionally the nervous and endocrine system work hand in hand acting in communicating and driving hormonal changes. They work in maintaining homeostasis and respond to changes inside and outside the body. Besides functioning in similar manners they work in conjunction. An example of this can be seen in a mother’s release of milk. When a baby sucks the nipple of its mother, sensory cells in the nipple sends signals to the hypothalamus, which
then responds by releasing oxytocin from the posterior pituitary. The oxytocin is released into the bloodstream where it moves to its’ target cell, a mammary gland. The mammary gland then responds to the hormones signal by releasing milk through the nipple. Besides working in conjunction with each other, both systems affect one another. The adrenal medulla is under control the control of nerve cells, but the nervous systems development is under the control of the endocrine system.

**Growth hormone**

Growth hormone (GH) is a peptide hormone produced by the anterior lobe of the pituitary gland in response to GH-releasing hormone from the hypothalamus. Release of growth hormone is inhibited by somatostatin, which also is produced by the hypothalamus. GH enhances the metabolism of fats for energy. It also enhances amino acid uptake and protein synthesis, which help in growth of cartilage and bone. Secretion of growth hormone is increased by exercise, stress, lowered blood glucose, and by insulin.

**The hormones that influence our attitudes and behaviors**

There are many hormones that in one way or another effect attitude and behavior, but in the interest of time and space, this section will mostly discuss the gonadal, placenta, and thyroid hormones.

A variety of hormones are produced by the gonads and placenta. Estrogens, such as estradiol, function in the development and maintenance of the female reproductive tract, in the simulation of the mammary glands, in the development of secondary sex characteristics, and in the regulation of behavior. Androgens, such as testosterone, influence the development and maintenance of the male reproductive tract, secondary sex characteristics, and behavior.

There has been a great deal of interest in the relationship between hormones and behavior and it has been found that the natural variation in the amount of hormones present is correlated with variation in behavior. For example, during the female menstrual period the "average" female shows a decreased body temperature, decrease in food and water intake, decrease in body weight, and she becomes sexually receptive. These variations within the body cause the females behavior to change. It's been found that it can result in changing of mood, performance in cognitive tasks, sensory sensitivity, and sexual activity. Unfortunately, due to the possible implications of gender issues this research is controversial. The same can happen with males. Research has shown that there is some suggestion of a relationship between androgens, like testosterone, and dominance-related behavior. For example, men with high levels of testosterone are prone to be more competitive and
have a higher level of aggression.

Thyroid hormones can also influence a person's mood due to the changes in the thyroid's activity. Little is known about the mechanisms by which thyroid hormones elevate mood, but it has a connection to the neural functions in the brain, which have influence over hormone releasal.

Many psychological disorder are directly related to certain impairments of brain functioning (chemical and hormonal imbalances), while others are more behaviorally orientated. Affective Disorders, for example, are those in which there is a disturbance of mood. One form of this disorder is depression which has been related to a number of hormones like melatonin and thyroid hormones.

Headaches, which can dramatically make a person irritable, snappy, and emotional can be another consequence of a hormone. During the female menstrual period, around ovulation time, estrogen rises to a peak. When estrogen is high a message goes out to produce a hormone called serotonin. This hormone makes the blood vessels in the brain narrow. This doesn't cause any pain, but when the estrogen, and hence serotonin, levels drop, blood vessels in the head begin to expand and put pressure on nerves. This causes the pain you feel when you have a headache.

**What is Seasonal Affective Disorder, and how is it that one hormone can make some people's winter mood less than pleasant?**

Seasonal Affective Disorder(SAD) is a seasonal disruption of mood that occurs during the winter months. Symptoms of it usually begin in the fall when the day light hours begin to shorten and last until the day light hours begin to lengthen again in the spring. Some symptoms of SAD are depression, tiredness, increased appetite (which can lead to weight gain), and irritability. The direct cause for this disorder is in connection to the hormone melatonin.

The pineal gland, which is located in the center of the brain, releases a hormone called melatonin. This hormone can accumulate in the hypothalamus where it can have an effect on long-term releasing factors influencing growth and reproductive development and also on circannual rhythms (seasonal timing). SAD is influenced by the latter of those. Very little melatonin is secreted in the daytime (light) and a great deal is produced at night (dark). Because the winter months have longer nights there is an extra production of melatonin. Therefore, the level of melatonin in the body increases. This production of melatonin influences our overall mood and causes SAD. Unfortunately, there isn't any concrete information on the exact reasoning to how or why this happens, but there are plenty of ways in which
people try to cure it. For example, artificial lighting.

There have been several experiments that demonstrate that changes in the level of melatonin in the bodies of seasonally breeding animals affect their reproductive cycle. Artificial lighting can prolong this breeding activity due to the decrease in melatonin.

Special Topic Paper: Osteoporosis - Prevention and Post-Diagnosis Treatment (by Bobby Bailey)

When we think of the disease osteoporosis, we often attribute it to getting old. Osteoporosis, however, is much more complex. Physiologically, the body undergoes a lot of changes through the process of aging that relate to it, but it is these processes that allow the world of medicine to find means to prevent and even sometimes treat osteoporosis.

Osteoporosis is a condition of aging in which the density of bones in the body begins to decrease. Although many people view bones as rather inactive tissues, they actually are constantly in a flux known as turnover. This is the process by which the bone is continually remodeled to produce new bone (Snow-Harter, 1993). Constant muscular and weight bearing strain on the surface of the bone causes tiny stresses. These stresses get attacked by osteoclasts, which bore into the stress on the surface of the bone. This begins the process of resorption, during which the small hole almost triples in size. The next phase is the beginning of reformation of the bone matrix. This occurs when osteoblasts migrate to the cavity caused by resorption. The osteoblasts are responsible for producing the matrix that composes the structure of the bone. Osteoblastic activity also triggers calcium formation, which completes the formation of the bone. If this continual process occurs under the right conditions, the bone can actually increase in mass and density (Snow-Hartet, 1993). If conditions are not right, osteoporosis is the end result. Improper conditions, which will be discussed later, lead to an imbalance of osteoclastic and osteoblastic activity. If the resorption of bone is greater than the reformation of the bone matrix, bone density decreases leading to the increased susceptibility to fractures and other bone related injuries. (Snow-Hartet, 1993)

Better knowledge of the causes of osteoporosis leads to better treatment and prevention. The medicinal treatments will be discussed but prevention is by far the most cost effective (Wood, 1992). The easiest method of osteoporosis prevention is by a continual and progressive regiment of weight bearing exercise. Among pre-menopausal women, exercise is a fantastic way to promote bone and overall health of the body. As was discussed before, the continual stress on the bone surface can lead to increased osteoblastic reformation of the bone matrix. Exercise can also help women who have gone through menopause. A study of 22 healthy post-menopausal women showed
that those receiving estrogen therapy actually increased bone density and mass after 22 months of exercise. Lumbar spine bone density actually increased by 6.1%. Women that were not put on a workout plan showed a loss of bone (Wood, 1992).

Calcium consumption above the RDA value of 800 mg for adults is recommended to prevent the onset of osteoporosis. This is increasingly important for elderly, post-menopausal women because they have a less efficient calcium uptake mechanism due to aging. More supplemental calcium is required to improve absorption of the mineral (Wood, 1992). Calcium can also be used for treatment after the onset of osteoporosis. It was observed that post-menopausal osteoporosis patients who received 1000 mg of supplemental calcium a day showed a 50% decrease in non-vertebral bone loss (Wood, 1992). Some evidence suggests that calcium supplementation can only benefit a female post-menopausal osteoporosis patient if she is already undergoing estrogen therapy because estrogen helps control the absorption of calcium. This argument continues but it is known that estrogen therapy for osteoporosis patients is an effective treatment for the crippling disease.

There is powerful evidence that estrogen replacement maintains bone mass and reduces the fracture risk of post-menopausal women (Snow-Harter, 1993). Supplemental estrogen during the early years of menopause is effective in decreasing osteoporosis-related injuries by upwards of 50% (Wood, 1992). This treatment also has been noted to work well for women who have well-established osteoporosis. Results show that it can increase bone mass by 3% by decreasing resorption and shifting the balance to the side of the more favorable reformation (Wood, 1992).

Another anti-resorptive hormone that aids in decreasing the adverse effects of osteoporosis is calcitonin. No evidence currently exists stating why the drug works well, but trials do suggest that it is an effective agent in ceasing bone loss in patients with high bone turnover. Unfortunately, the evidence of this drug’s effects is unclear plus it is a very expensive form of therapy.

Other drugs known for their anti-resorptive properties are bisphosphonates. These drugs bind to hydroxyapatite crystals in the bones and remain in the bone for many years (Wood, 1992). These drugs seem to be effective at inhibiting resorption. This is done when they get released from the bone surface, bind to the osteoclasts, and interfere with resorption of the bone. The downside of these drugs is that they cause irritation in the digestive system.

Other methods of treatment actually support the formation of bone instead of protecting them from degradation. Sodium fluoride has been shown to increase bone density in the spine by 8 percent/year and by 4 percent/year in the femur (Wood, 1992). Unfortunately there is no evidence proving that this
increased density is the same as bone strength. The increased bone growth can be abnormal in structure and lead to mass that is not strong.

Growth Factors such as insulin growth factors I and II are being related to the increased success of osteoblasts. This increase in osteoblast efficiency leads to increased rates of bone formation. Unfortunately, like most new drugs, these growth factors have adverse side effects. One issue that is raised is the ability for the factor to couple with a bone-seeking compound that will successfully deliver the treatment to the site (Wood, 1992).

The nice thing about knowing how a disease attacks the body is being able to take steps to prevent it, and there are a lot of ways to deter osteoporosis. Science has shown that exercise is the cheapest and one of the most effective ways to prevent osteoporosis. If this is coupled with proper diet, calcium supplementation, and estrogen therapy, the characteristic loss of bone mass and density from osteoporosis can actually be reversed. The same theories that make prevention possible are being proven to make treatment possible. Supplements like estrogen and calcium are sometimes very effective in stopping resorption, which leads to bone loss. Other drugs like sodium fluoride are able to promote the formation of new bone matrix. However, many of the treatments are experimental and unproven to be reliable in a broad range of cases. There is hope though, and science and medicine is well on its way to developing treatments to ease the pain of over 1.5 million Americans a year (Wood, 1992). On the other hand, even if foolproof treatments did exist, the only way that they could be effective is if people were educated about the disease. Education and self responsibility is the key to catching this disease before it attacks and for fighting it off if it does.

Information provided by: http://academics.smcvt.edu

- endocrine glands

The major glands that make up the human endocrine system include the:

- hypothalamus
- pituitary gland
- thyroid
- parathyroids
- adrenal glands
- pineal body
- reproductive glands (which include the ovaries and testes)

The **hypothalamus** (pronounced: hi-po-tha-luh-mus), a collection of specialized cells that is located in the lower central part of the brain, is the main link between the endocrine and nervous systems. Nerve cells in the hypothalamus control the pituitary
gland by producing chemicals that either stimulate or suppress hormone secretions from the pituitary.

Although it is no bigger than a pea, the pituitary (pronounced: puh-too-uh-ter-ee) gland, located at the base of the brain just beneath the hypothalamus, is considered the most important part of the endocrine system. It's often called the "master gland" because it makes hormones that control several other endocrine glands. The production and secretion of pituitary hormones can be influenced by factors such as emotions and changes in the seasons. To accomplish this, the hypothalamus provides information sensed by the brain (such as environmental temperature, light exposure patterns, and feelings) to the pituitary.

The tiny pituitary is divided into two parts: the anterior lobe and the posterior lobe. The anterior lobe regulates the activity of the thyroid, adrenals, and reproductive glands. The anterior lobe produces hormones such as:

- **growth hormone**, which stimulates the growth of bone and other body tissues and plays a role in the body's handling of nutrients and minerals
- **prolactin** (pronounced: pro-lak-tin), which activates milk production in women who are breastfeeding
- **thyrotropin** (pronounced: thy-ruh-tro-pin), which stimulates the thyroid gland to produce thyroid hormones
- **corticotropin** (pronounced: kor-tih-ko-tro-pin), which stimulates the adrenal gland to produce certain hormones

The pituitary also secretes endorphins (pronounced: en-dor-fin), chemicals that act on the nervous system and reduce feelings of pain. In addition, the pituitary secretes hormones that signal the reproductive organs to make sex hormones. The pituitary gland also controls ovulation and the menstrual cycle in women.

The posterior lobe of the pituitary releases antidiuretic (pronounced: an-ty-dy-uh-reek-tik) hormone, which helps control the balance of water in the body. Antidiuretic hormone also affects the production of oxytocin (pronounced: ahk-see-toe-sin), which triggers the contractions of the uterus in a woman having a baby.

The thyroid (pronounced: thy-royd), located in the front part of the lower neck, is shaped like a bow tie or butterfly and produces the thyroid hormones thyroxine (pronounced: thy-rahk-seen) and triiodothyronine (pronounced: try-eye-uh-doe-thy-ruh-neen). These hormones control the rate at which cells burn fuels from food to produce energy. The production and release of thyroid hormones is controlled by thyrotropin (pronounced: thigh-ruh-tro-pin), which is secreted by the pituitary gland. The more thyroid hormone there is in a person's bloodstream, the faster chemical reactions occur in the body.

Why are thyroid hormones so important? There are several reasons - for example, they help kids and teens develop strong bones, and they also play a role in the development of the brain and nervous system in kids.

Attached to the thyroid are four tiny glands that function together called the parathyroids (pronounced: par-uh-thyroydz). They release parathyroid hormone, which regulates the level of calcium in the blood with the help of calcitonin (pronounced: kal-suh-toe-sin), which is produced in the thyroid.
The body also has two triangular adrenal (pronounced: uh-dree-nul) glands, one on top of each kidney. The adrenal glands have two parts, each of which produces a set of hormones and has a different function. The outer part, the adrenal cortex, produces hormones called corticosteroids (pronounced: kor-tih-ko-ster-oydz) that influence or regulate salt and water balance in the body, the body's response to stress, metabolism, the immune system, and sexual development and function. The inner part, the adrenal medulla (pronounced: muh-duh-luh), produces catecholamines (pronounced: kah-tuh-ko-luh-menz), such as epinephrine (pronounced: eh-puh-neh-frun). Also called adrenaline, epinephrine increases blood pressure and heart rate when the body experiences stress.

The pineal (pronounced: pih-nee-ul) body, also called the pineal gland, is located in the middle of the brain. It secretes melatonin (pronounced: meh-luh-toe-nin), a hormone that may help regulate when you sleep at night and when you wake in the morning.

The gonads are the main source of sex hormones. Most people don't realize it, but both guys and girls have gonads. In guys the male gonads, or testes (pronounced: tes-teez), are located in the scrotum. They secrete hormones called androgens (pronounced: an-druh-junz), the most important of which is testosterone (pronounced: teh-stass-tuh-ron). These hormones tell a guy's body when it's time to make the changes associated with puberty, like penis and height growth, deepening voice, and growth in facial and pubic hair. Working with hormones from the pituitary gland, testosterone also tells a guy's body when it's time to produce sperm in the testes.

A girl's gonads, the ovaries (pronounced: oh-vuh-reez), are located in her pelvis. They produce eggs and secrete the female hormones estrogen (pronounced: es-truh-jen) and progesterone (pronounced: pro-jes-tuh-ron). Estrogen is involved when a girl begins to go through puberty. During puberty, a girl will experience breast growth, will begin to accumulate body fat around the hips and thighs, and will have a growth spurt. Estrogen and progesterone are also involved in the regulation of a girl's menstrual cycle. These hormones also play a role in pregnancy.

Although the endocrine glands are the body's main hormone producers, some other organs not in the endocrine system - such as the brain, heart, lungs, kidneys, liver, and skin - also produce and release hormones. The pancreas (pronounced: pan-kree-us) is also part of the body's hormone-secreting system, even though it is also associated with the digestive system because it produces and secretes digestive enzymes. The pancreas produces (in addition to others) two important hormones, insulin (pronounced: in-suh-lin) and glucagon (pronounced: gloo-kuh-gawn). They work together to maintain a steady level of glucose, or sugar, in the blood and to keep the body supplied with fuel to produce and maintain stores of energy.

**What Does the Endocrine System Do?**

Once a hormone is secreted, it travels from the endocrine gland that produced it through the bloodstream to the cells designed to receive its message. These cells are called target cells. Along the way to the target cells, special proteins bind to some of the hormones. These proteins act as carriers that control the amount of hormone that is available for the cells to use. The target cells have receptors that latch onto only specific hormones, and each hormone has its own receptor, so that each hormone will communicate only with specific target cells that have receptors for that hormone. When the hormone reaches its
target cell, it locks onto the cell's specific receptors and these hormone-receptor combinations transmit chemical instructions to the inner workings of the cell. When hormone levels reach a certain normal amount, the endocrine system helps the body to keep that level of hormone in the blood. For example, if the thyroid gland has secreted the right amount of thyroid hormones into the blood, the pituitary gland senses the normal levels of thyroid hormone in the bloodstream. Then the pituitary gland adjusts its release of thyrotropin, the hormone that stimulates the thyroid gland to produce thyroid hormones.

Another example of this process is parathyroid hormone. Parathyroid hormone increases the level of calcium in the blood. When the blood calcium level rises, the parathyroid glands sense the change and reduce their secretion of parathyroid hormone. This turnoff process is called a negative feedback system.

**Things That Can Go Wrong With the Endocrine System**

Too much or too little of any hormone can be harmful to your body. For example, if the pituitary gland produces too much growth hormone, a teen may grow excessively tall. If it produces too little, a teen may be unusually short. Doctors can often treat problems with the endocrine system by controlling the production of hormones or replacing certain hormones with medication. Some endocrine problems that affect teens include:

- **Adrenal insufficiency.** This condition occurs when the adrenal glands don't work properly or don't produce enough corticosteroids. The symptoms of adrenal insufficiency may include weakness, fatigue, abdominal pain, nausea, dehydration, and skin changes. Doctors treat adrenal insufficiency with medications to replace corticosteroid hormones.

- **Type 1 diabetes.** When the pancreas fails to produce enough insulin, type 1 diabetes (pronounced: dy-uh-bee-teez and previously known as juvenile diabetes) occurs. In kids and teens, type 1 diabetes is usually an autoimmune disorder, which means that some parts of the body's immune system attack and destroy the cells of the pancreas that produce insulin. To control their blood sugar levels and reduce the risk of developing diabetes problems, kids and teens with this condition need regular injections of insulin.

- **Type 2 diabetes.** Unlike type 1 diabetes, in which the body can't produce normal amounts of insulin, in type 2 diabetes the body can't respond to insulin normally. Kids and teens with the condition tend to be overweight. Some kids and teens can control their blood sugar level with dietary changes, exercise, and oral medications, but many will need to take insulin injections like people with type 1 diabetes.

- **Growth hormone problems.** Too much growth hormone in kids and teens who are still growing will make their bones and other body parts grow excessively. This rare condition (sometimes called gigantism) is usually caused by a pituitary tumor and can be treated by removing the tumor. The opposite can happen when a kid or teen has a pituitary gland that doesn't produce enough growth hormone. Doctors may treat these growth problems with medication.

- **Hyperthyroidism.** Hyperthyroidism (pronounced: hi-per-thy-roy-dih-zum) is a condition in which the levels of thyroid hormones in the blood are very high. In kids and teens, the condition is usually caused by Graves' disease, an immune system problem that causes the thyroid gland to become very active. Doctors may treat hyperthyroidism with medications, surgery, or radiation treatments.

- **Hypothyroidism.** Hypothyroidism (pronounced: hi-po-thy-roy-dih-zum) is a condition in which the levels of thyroid hormones in the blood are very low. Thyroid hormone
deficiency slows body processes and may lead to fatigue, a slow heart rate, dry skin, weight gain, constipation. Kids and teens with this condition may also grow more slowly and reach puberty at a later age. Hashimoto's thyroiditis is an immune system problem that often causes problems with the thyroid and blocks the production of thyroid hormone. Doctors often treat this problem with medication.

**Precocious puberty.** If the pituitary glands release hormones that stimulate the gonads to produce sex hormones too early, some kids may begin to go through puberty at a very young age. This condition is called precocious puberty. Kids and teens who are affected by precocious puberty can be treated with medication that will help them develop at a normal rate.

Updated and reviewed by: Wayne Ho, MD, and Steven Dowshen, MD
Date reviewed: February 2004
Originally reviewed by: Steven Dowshen, MD

- feedback loops (feedback inhibition, negative feedback)
  - same as above
- Immune system
  - vaccines and antibiotics
    - Antibiotics and vaccines can work on meningitis. Some reasons why is because its caused by a virus or a bacteria. It could also be caused by a fungal disease. That is why an antibiotic or a vaccine could work.
      
      Antibiotics can help cure different diseases; however, they can't cure viral infections because they are made to help cure bacterial infections. An antibiotic is a chemical that you take to destroy a disease inside you. So as you can see antibiotics are very helpful to us.

Other than antibiotics, vaccines are of good use to people. A vaccine is a substance that tells the body to produce chemicals to destroy the virus or bacteria in your body. That is what a vaccine does.

A vaccine consist of weaken or dead pathogens of a particular disease. It then sparks the immune system to produce memory cells and antibiotics specifically for that disease. A vaccine also produces active immunity. Active immunity is when you get vaccinated and your immune system makes memory cells. Then the memory cells recognize the disease and destroy it quicker the next time it enters your body. That is how vaccines work.

Antibiotics and vaccines differ from each other in many ways. Antibiotics only help your symptoms go away. Vaccines can create
active immunity to a certain disease while you don't even know you have it. Though antibiotics and vaccines differ in many ways they both help people a lot. Now you know what antibiotics and vaccines are and how they work.

- compromises of the immune system (e.g. HIV/AIDS)
- parts of the immune system
- antibodies
  - specialized protein that helps destroy disease-causing organisms
- antigens
  - an antigen is a molecule that acts to stimulate the body’s immune system and trigger an immune response.
- history of vaccine use (Edward Jenner, Louis Pasteur, Jonas Salk, and Albert B. Sabin)

**Edward Jenner and the Discovery of Vaccination**

originally exhibited spring 1996
Thomas Cooper Library, University of South Carolina

text by Patrick Scott
hypertext by Jason A. Pierce

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**Introduction**

The year 1996 marked the two hundredth anniversary of Edward Jenner's first experimental vaccination—that is, inoculation with the related cow-pox virus to build immunity against the deadly scourge of smallpox.

Edward Jenner (1749-1823), after training in London and a period as an army surgeon, spent his whole career as a country doctor in his native county of Gloucestershire in the West of England. His research was based on careful case-studies and clinical observation more than a hundred years before scientists could explain the viruses themselves. So successful did his innovation prove that by 1840 the British government had banned alternative preventive treatments against smallpox. "Vaccination," the word Jenner invented for his treatment (from the Latin *vacca*, a cow), was adopted by Pasteur for immunization against any disease.

In the eighteenth century, before Jenner, smallpox was a killer disease, as widespread as cancer or heart disease in the twentieth century but with the difference that the majority of its victims were infants and young children. In 1980, as a result of Jenner's discovery, the World Health Assembly officially declared "the world and its peoples" free from endemic smallpox.
Louis Pasteur was born on December 27, 1822 in Dole, in the region of Jura, France. His discovery that most infectious diseases are caused by germs, known as the "germ theory of disease", is one of the most important in medical history. His work became the foundation for the science of microbiology, and a cornerstone of modern medicine.

Profile: Jonas Salk, M.D.
Developer of Polio Vaccine

The Calling to Find a Cure

"We were told in one lecture that it was possible to immunize against diphtheria and tetanus by the use of chemically treated toxins, or toxoids. And the following lecture, we were told that for immunization against a virus disease, you have to experience the infection, and that you could not induce immunity with the so-called "killed" or inactivated, chemically treated virus preparation. Well, somehow, that struck me. What struck me was that both statements couldn't be true. And I asked why this was so, and the answer that was given was in a sense, "Because." There was no satisfactory answer."

Jonas Salk was still a student when he began to look for a better answer to his classroom question, and the answer he found led to one of the most dramatic breakthroughs in the history of medicine.

In America in the 1950s, summertime was a time of fear and anxiety for many parents; this was the season when children by the thousands became infected with the crippling disease poliomyelitis, or polio. That burden of fear was lifted forever when it was announced that Dr. Jonas Salk had developed a vaccine against the disease. Salk became world-famous overnight, but his discovery was the result of many years of painstaking research.

Salk went on to found the Jonas Salk Institute for Biological Studies in La Jolla, California, where he continued his research into the causes, prevention and cure of diseases such as cancer and AIDS. Dr. Salk never patented his polio vaccine, but distributed the formula freely, so the whole world could benefit from his discovery.

Albert B. Sabin, M.D.

(1906 - 1993) Video Clip
Dr. Albert Sabin, developer of the oral, live virus polio vaccine, began his career in biomedical research in 1926 while still a student at New York University where he received his M.D. degree. He worked at the Rockefeller Institute for Medical Research from 1935-1939. From 1939 through 1969, Dr. Sabin was successively Associate Professor of Pediatrics, Professor of Research Pediatrics, and Distinguished Service Professor at the University of Cincinnati College of Medicine and The Children's Hospital Research Foundation. A Lieutenant Colonel, he served in the U.S. Army Medical Corps as a member of the Epidemiological Board from February 1943 to September 1945. His work included studies on sandfly fever, and the development of vaccines against dengue fever and Japanese B encephalitis. From 1970, he served successively as President of the Weizmann Institute of Science (1970-72), full-time expert consultant of the U.S. National Cancer Institute (1974), Distinguished Research Professor of Biomedicine at the Medical University of South Carolina (1974-82), and Senior Expert Consultant at the Fogarty International Center for Advanced Studies in the Health Sciences of the National Institutes of Health (1984-86).

In 1960, after extensive, worldwide preliminary trials, Dr. Sabin's oral polio vaccine was first used in about 100 million children in Europe. While it was approved for use in the U.S. in late 1960, it was not until 1962-64 that about 100 million persons of all ages received the vaccine in the U.S. It is estimated that from 1965-66, worldwide use of the vaccine prevented about 5 million cases of paralytic polio and 500,000 deaths. In 1972, in an unprecedented humanitarian gesture, he donated the strains of the polio virus to World Health Organization to increase their availability to developing countries.

In 1966, poor health and increasing physical disability forced Dr. Sabin into complete retirement.

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Before going to Cincinnati in 1939, Dr. Sabin was noted for his work of fundamental studies on poliomyelitis and other viruses causing diseases of the nervous system, the protozoan parasite toxoplasma, and arthritis. During
the 30 years in Cincinnati, his work on human poliomyelitis and the complex properties of the polio viruses had the greatest practical impact. He also worked on arthropod-borne viruses and the human diseases they cause, such as dengue, sandfly fever, and Japanese B Encephalitis. He also worked on the genetics of natural resistance to certain viruses and the discovery of the unique dye test for toxoplasma antibody that greatly elucidated the role of this parasite in human disease.

Dr. Sabin served on many advisory committees on medical research, including those of the National Institutes of Health, U.S. Armed Forces, World Health Organization, and Pan American Health Organization. He was a member of the National Academy of Sciences (elected in 1951), American Academy of Arts and Sciences, Association of the American Physicians, American Pediatric Society, and many other professional societies in the U.S. and abroad, including the U.S.S.R. Academy of Medical Sciences.

Dr. Sabin received forty-six honorary degrees from U.S. and foreign universities. His numerous awards include the U.S. National Medal of Science (1970), Presidential Medal of Freedom (1986), Medal of Liberty (1986), Order of Friendship among Peoples awarded by the President of the Supreme Soviet of the U.S.S.R. (1986), and from the President of Brasil, the Ordem Cruzeiro do Sul, Grande Oficial (1986) and Gran Cruz Ordem do Rio Branco (1991).

When the National Medal of Science was presented to Dr. Sabin in 1970 by the President of the United States, the citation read, "For numerous fundamental contributions to the understanding of viruses and viral diseases, culminating in the development of the vaccine which has eliminated poliomyelitis as a major threat to human health."

When the definitive history of the twentieth century is written, the achievements of medicine will occupy a significant place, and within that history Dr. Albert B. Sabin will occupy a preeminent position. Throughout the world he is one of the most recognizable and revered names in medical sciences. In the 1960s, Dr. John R. Paul, Professor Emeritus of Preventive Medicine and Epidemiology at Yale University, wrote about Albert Sabin in his history of poliomyelitis, "No man has ever contributed so much effective information and so continuously over so many years to so many aspects of poliomyelitis as Sabin."

Dr. Sabin continued into his eighties to have a powerful and significant impact on the international scientific community in his capacity as medical statesman, consultant, and lecturer. His contributions were not just in the scientific realm but included a more global perspective of humanitarianism. He became a "courier of peace" and fought the diseases of ignorance and
poverty by espousing the same strategies of mutual trust and international cooperation which led to the conquest of poliomyelitis.

Dr. Sabin died in 1993, and is buried in Arlington National Cemetery.

- o viruses and bacteria