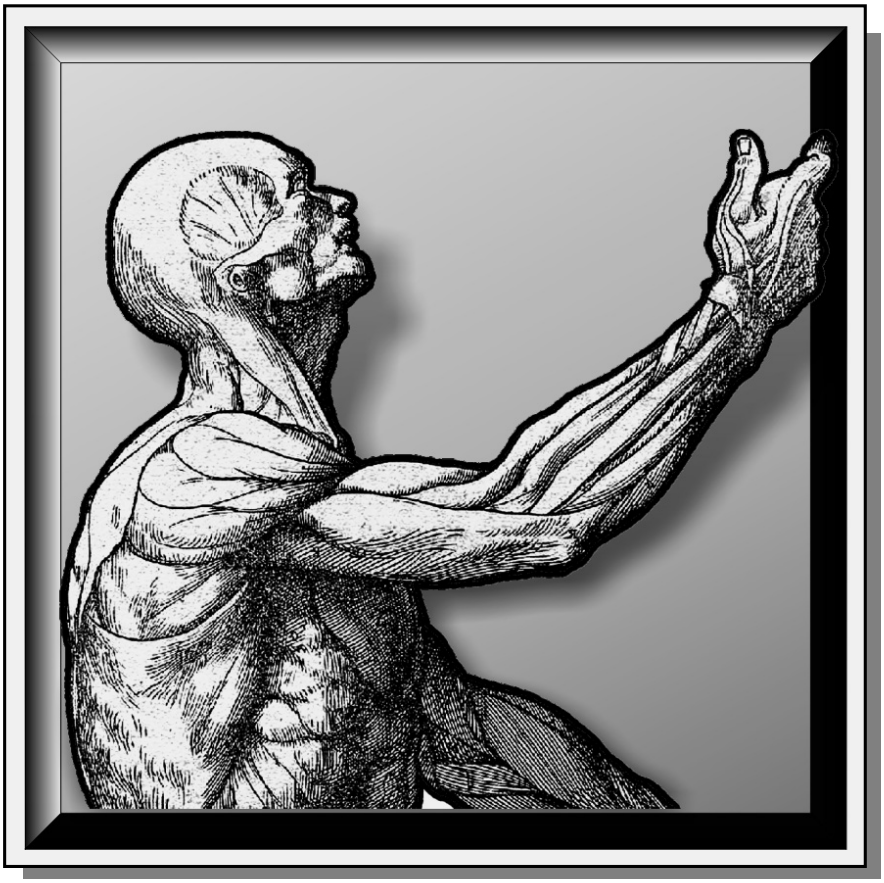
Precepts of Anatomy & Physiology

This chapter requires a companion activity book in which students respond to questions on text content. Answers are found in the *Teacher's Resource Kit*.



Chapter 1

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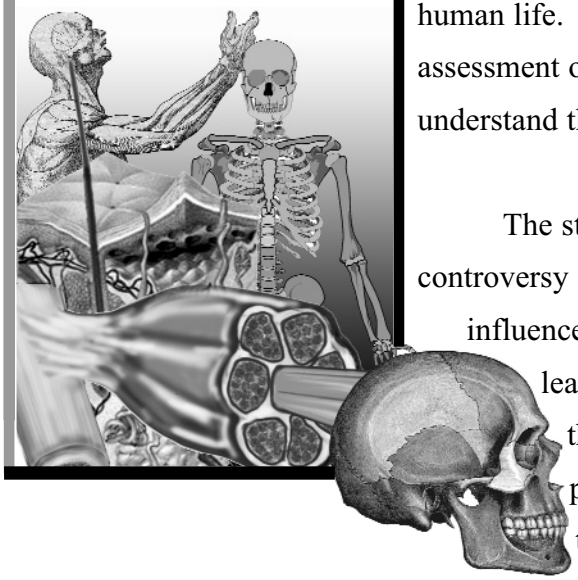
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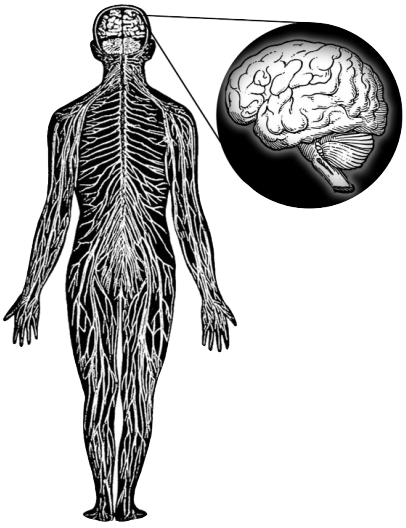
Precepts of Anatomy & Physiology
INTRODUCTION



Like other sciences, the study of Anatomy & Physiology is humanity's quest to understand human life. Organisms, living and dead, are considered in assessment of humans, plants and animals in an effort to understand the past, occupy the present and project the future.

The study of Anatomy & Physiology is not without controversy among scientists whose personal belief systems influence interpretation of data. This course allows you to learn about the marvelous structure and functions of the incredible human body through lessons presented with consideration of various scientific theories regarding human design, development, and evolution. A combination of text and graphics helps you to appreciate the interdependency of body systems which function harmoniously among bone, tissue, and organs.

When you complete this unit study of human anatomy, you will have gained a comprehensive perspective of your body—how it functions and why it deserves your best efforts to keep it healthy. Additionally, the course equips you to challenge theories, discuss precepts, question principles, and engage in open dialog about human anatomy and physiology.







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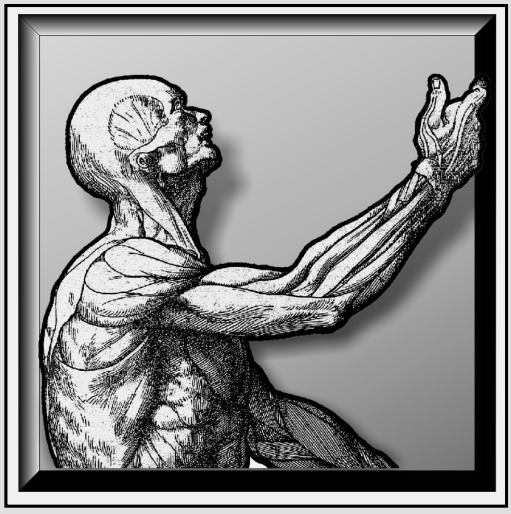


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Anatomy and physiology is the study of the structure, function and relationships of your marvelous bodily components. Your task is to use these resources wisely.

—Nancy S. Johnson





The Human Body

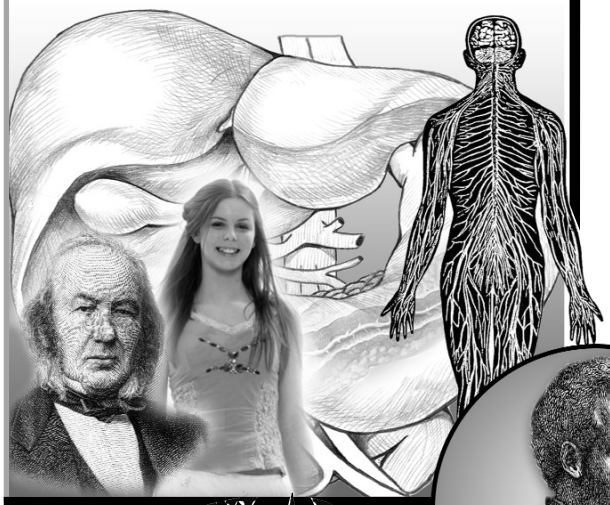
Lesson 1

Chapter 1

THE HUMAN BODY: ORGANIZATION

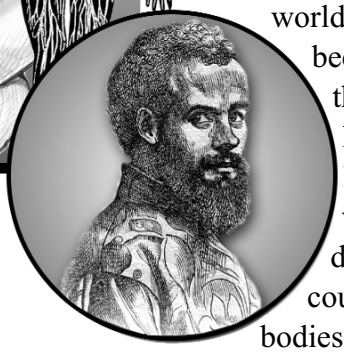
Section 1

Lessons 1-5

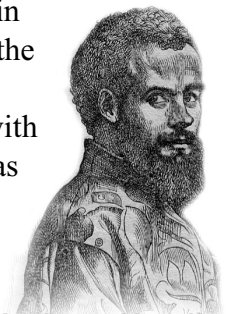


Studies of the human body, its workings and its origins, have fascinated scientists for thousands of years. Both biology and ***anatomy*** are rooted in the healing arts. The founder of anatomy as a scientific discipline was a Greek surgeon named Herophilus in the first part of the third century B.C., who pioneered the study of human ***dissection*** using hundreds of corpses. He also founded a school of anatomy.

A hundred years later Rome ruled the world, and another Greek named Galen became the most important physician in the Roman Empire. Rome, however, had harsh laws against dissection of human corpses. Although fatally wounded gladiators or other nearly-dead victims of the Roman arena could be ***vivisectioned***; once dead, the bodies could not be cut. Therefore, Galen performed most of his experiments on apes and other animals.



For various reasons, dissection of ***cadavers*** in the study of human anatomy was not allowed until the time of Andreas Vesalius (1514-1564). Vesalius, a Flemish physician, was a devout Roman Catholic with a tremendous respect and awe for the human body as a product of creation. Vesalius developed a great interest in anatomy by studying the body parts of human cadavers. After completing a medical degree at age 22, Vesalius taught younger medical students by performing dissections during medical lectures. Although his methods were considered radical for his time, at the age of 28 Vesalius was able to write the most accurate and comprehensive book on human anatomy ever written up to that time. The 600-page work was lavishly illustrated with 300 detailed, hand-made engravings. His book boldly challenged contemporary medical teachings on how the human body operates. Galen's works, which contained many



Andreas Vesalius

VOCABULARY

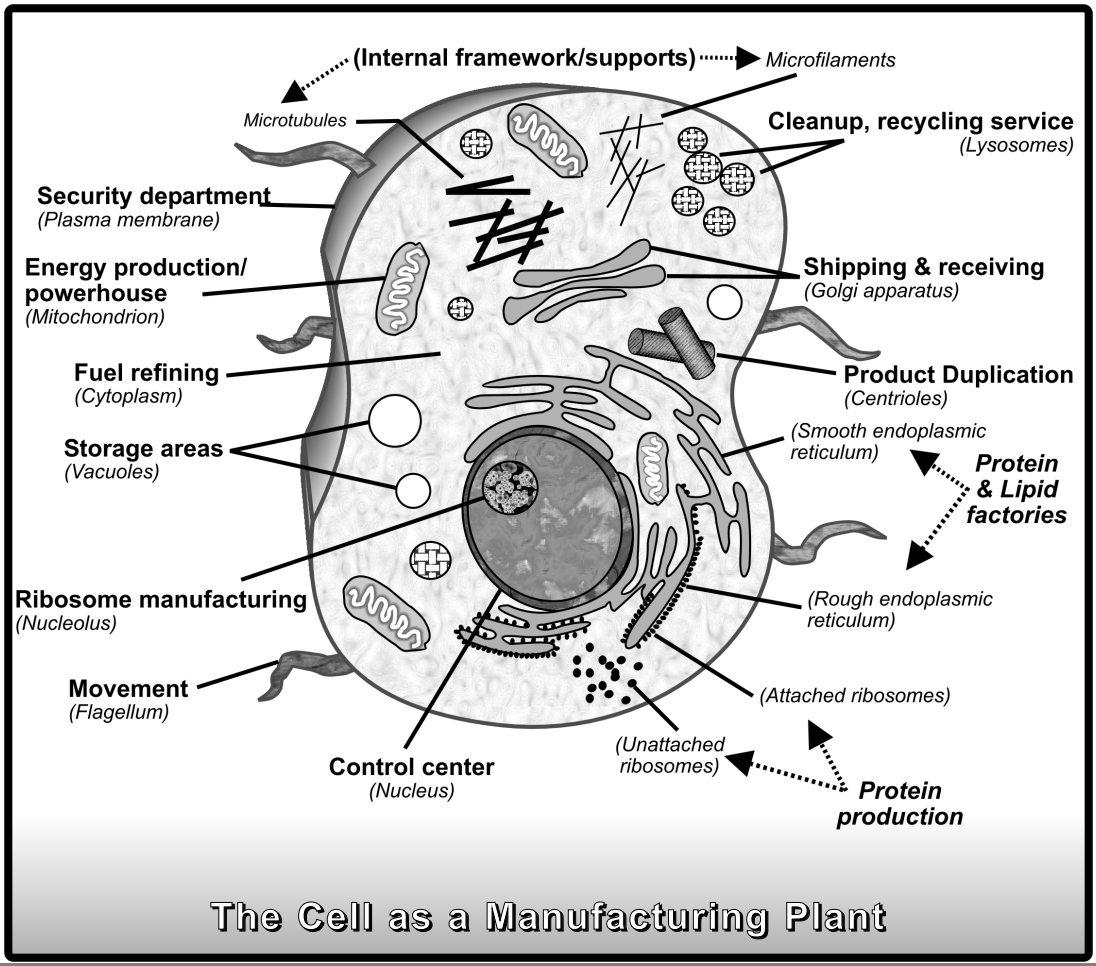
Anatomy: from Greek words meaning "to cut" or "to dissect"
Dissection: the cutting up of a dead body into sections for scientific study
Vivisection: to cut or section, to operate on a living body
Cadaver: a dead body; specifically one intended for dissection
Tissue: mass of similar cells that performs a specific function
Organ: a group of tissues that work together to perform a specific function
Organ system: a group of organs that perform closely related functions

errors, had been the standard medical reference for nearly 1500 years. Many traditional anatomists who revered Galen attacked Vesalius' book, but were not able to refute Vesalius' arguments. His text and the vivid drawings were verified by meticulous dissection of human cadavers.

Hundreds of years ago, before the advent of advanced technology, Vesalius firmly believed humans were the product of a master designer. Today, scientists are still awed by the incredible human body. Webster's dictionary defines design as a plan, a scheme, a project or a purpose with intention or aim. The evident design of human beings is causing many to question the theory of human evolution. Biologists are recognizing that human beings reflect the ultimate in anatomical precision.

Levels of Organization

The human body consists of an estimated 30 to 100 trillion cells, depending on the size of the individual. Each of these cells has a purpose of its own, but each is also part of something much larger. Among Earth's over six billion people, every person is an individual. However, most people associate in groups. The most basic of these groups is the family. Communities, counties, states and nations form groups of people who work together to organize and operate governments. Because human beings are complex creatures, they reflect many organizational levels that keep societies running properly. The human body functions in a similar way, constructed according to levels of cell organization that increases in size and complexity.



The Cell as a Manufacturing Plant

Cells form the basic structural and functional units of life; they are the smallest living parts of our bodies. The trillions of human body cells are nearly alike, chemically speaking, but "are as different as animals in a zoo" in terms of appearance and function. The remarkable complexity and organization within each cell operates much like the operation of a manufacturing plant.

Groups of cells are programmed to come together to form ***tissues***. Your body contains many tissues. Five basic types of tissues are: *epithelial*, *connective*, *nerve, bone* and *muscle tissues*. *Epithelial tissue* covers interior and exterior body surfaces. *Connective tissue* provides support for the body and connects all its parts. *Nerve tissues* transmit nerve impulses throughout the body. *Bone tissue* provides body framework, strength and freedom of movement. *Muscle tissues* connect with bones to enable the body to move efficiently.

Organs

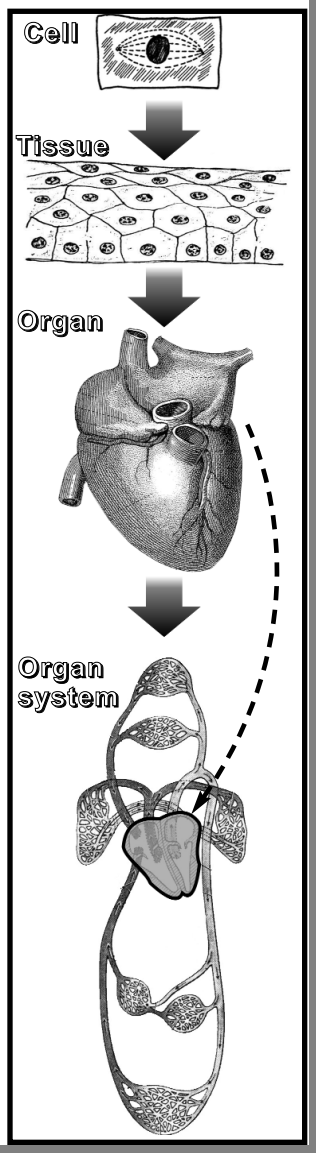
A group of tissues united together to perform a single function is called an ***organ***. The eye is an organ made up of epithelial tissue, nerve tissue, muscle tissue and connective tissue. Even though these tissues are very different, they all work together to perform a single function.

Organ Systems

Two or more organs, along with their associated structures, join forces to perform certain vital functions, such as digestion or reproduction. A group of organs working together is called an ***organ system***. For example, the eye is one of the organs of the nervous system which gathers information about the outside world and uses it to control many of the body's functions.

The human body consists of eleven marvelous organ systems, each with its own job but all highly interdependent. Unfortunately, when these systems operate well, we tend to take them for granted—scarcely giving them a passing, grateful thought.

The main job of the *skeletal system* is to protect our inward parts and to support us. Muscles of the *muscular system* help us move and respond to external stimuli. The task of the *endocrine system* is to maintain order among the body's trillions of cells. Both the *digestive* and the *respiratory systems* provide raw materials to sustain daily functions and to enhance growth. Both systems also help discard wastes. The *circulatory system* transports nutrient and oxygen-rich blood throughout the body. The *excretory system* rids our body of liquid and solid wastes. The *nervous system* interprets and responds to stimuli from outside, as well as from inside the body. The job of the *reproductive system* is to ensure survival of mankind. The *integumentary system* is the skin that fits us like a "seamless body stocking", holding the whole body together and helping protect us from invading



bacteria. The *immune system* (includes the *lymphatic system*) fights off invading germs and provides protection from diseases and parasites.

The intricate organization of cells, tissues and organs combine to make human life rich with stimulating experiences, such as the skillful hand of a pianist, the eye and brain focus required in reading this text, or the muscle coordination of a world-class gymnast. No other creature in the animal kingdom performs the diverse talents and skills operative in human beings.

A bird may sing, but it cannot lead an orchestra. A flock of geese may fly in a wedge formation, but a goose cannot design an airplane. A chimpanzee may crack a nut, but it cannot operate a pecan farm or design an orchard. A dog may play with a ball, but it cannot write a poem or send an e-mail to a friend. Only humans have the intelligence for these and countless other activities.

In the next lesson, we will examine the communication and control within the human body.

LIFE PRINCIPLE



"The great thing in this world is not so much where we are, but in what direction we are moving."

—Oliver Wendell Holmes (1809-1894), American physician and writer



The Human Body

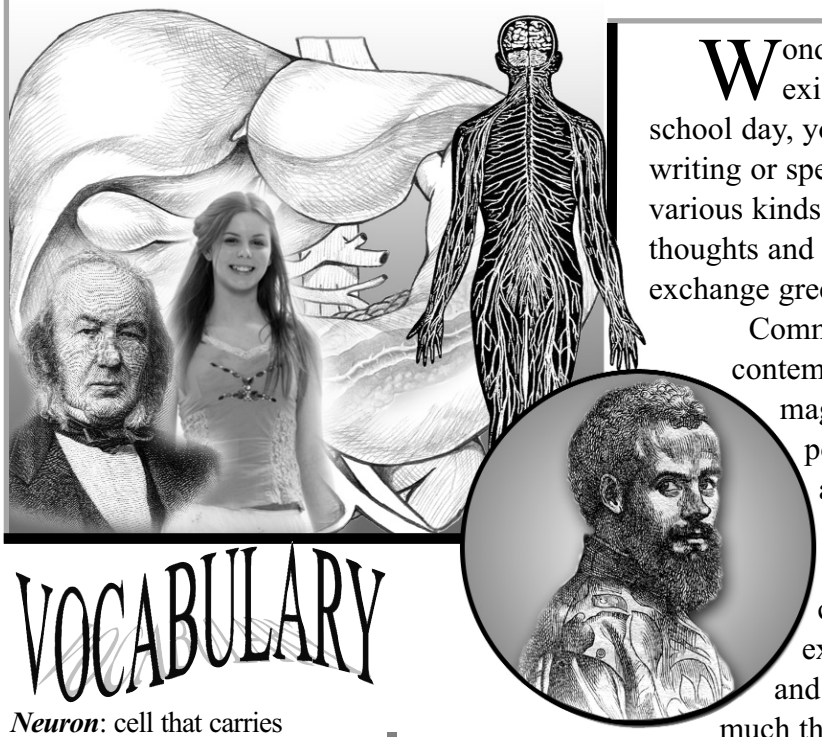
Lesson 2

Chapter 1

THE HUMAN BODY: COMMUNICATION AND CONTROL

Section 1

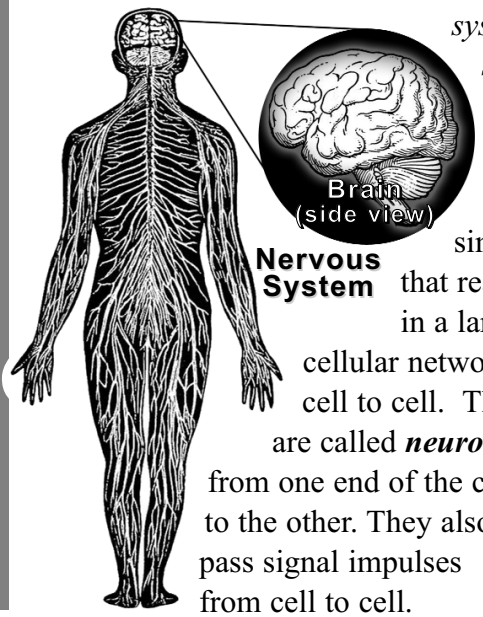
Lessons 1-5



Wonderful forms of communication exist among human societies. Every school day, you communicate with others by writing or speaking with them. You use various kinds of communication to express thoughts and ideas, to ask questions and to exchange greetings.

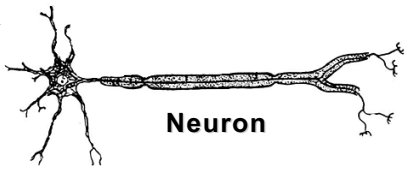
Communication is very important in contemporary societies. Newspapers, magazines, the Internet, radio, I-pods, cell phones and television are used to spread news. Communication systems bind the people of a society together with common experiences and exposure to a broad range of ideas and facts. The human body works in much the same way. Cells, tissues, organs and organ systems communicate in harmony.

Two organ systems are responsible for maintaining communication within the body—the *nervous system* and the *endocrine system*.



NERVOUS SYSTEM

The nervous system is similar to a telephone network that reaches every home and office in a large city. The body contains a cellular network that carries messages from cell to cell. These message-carrying cells are called ***neurons***. Neurons relay signals from one end of the cell to the other. They also pass signal impulses from cell to cell.



VOCABULARY

Neuron: cell that carries impulses throughout the nervous system

Hormones: chemical messengers that travel throughout the bloodstream; affects behavior of other cells

Receptor: specific chemical binding site for a particular hormone

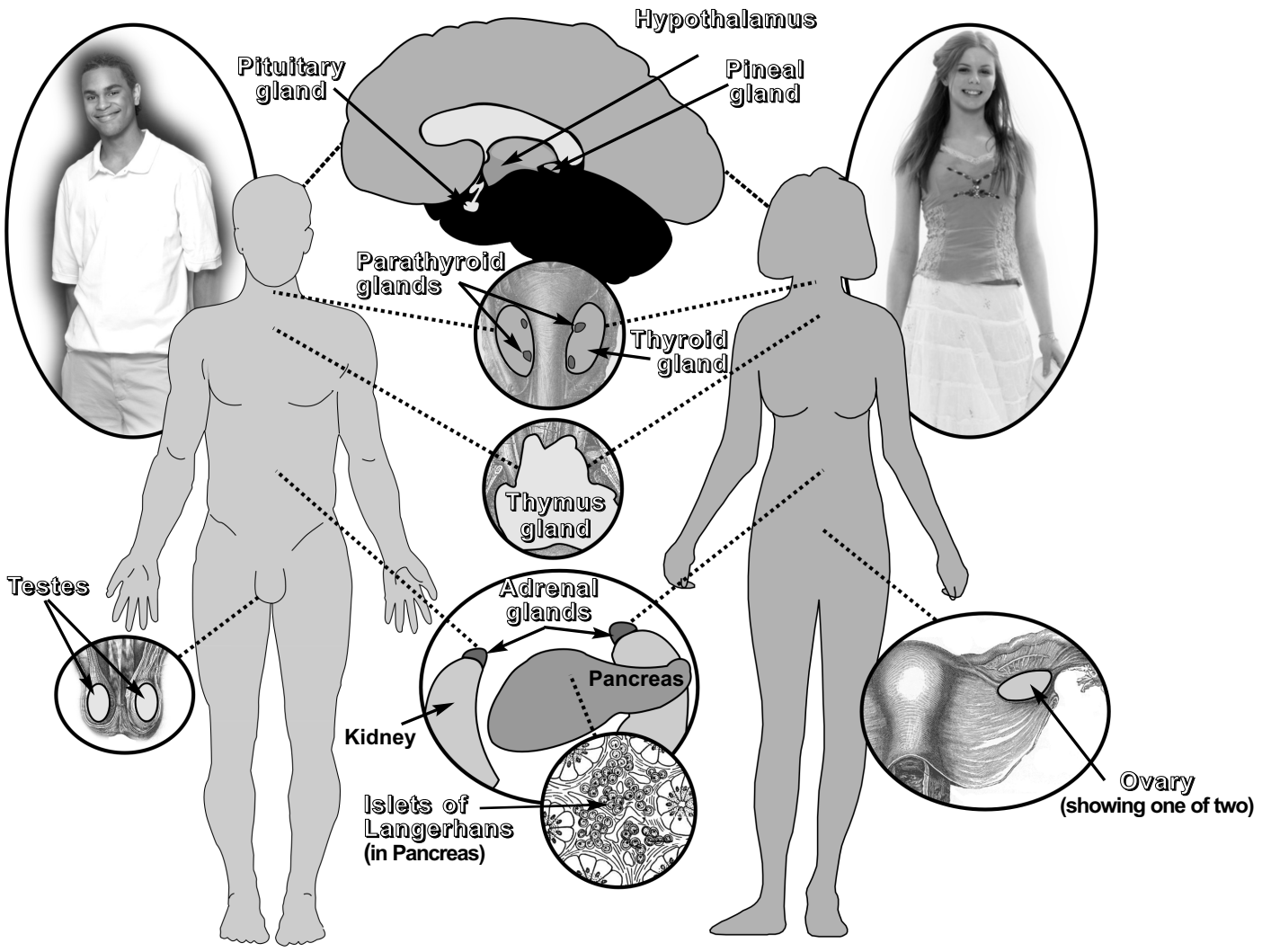
Target cell: a cell that has receptors for a particular hormone or other chemical substance

Homeostasis: the steady-state physiological condition of the body; the constant balancing of chemical conditions in living organisms

Neurons are like tiny electronic wires in a large communications network. They gather information from every area of the body and relay it to a central location. Here, the information can be analyzed and sent as instructions to organs located throughout the body. The center of this network of nerves is the brain, where impulses arrive from every part of the body. The brain analyzes each impulse to determine its operational response. Information is stored and retrieved as needed to activate appropriate responses to be sent back through the network.

Endocrine System

The endocrine system acts as a broadcasting network that can send messages to millions of cells simultaneously. The endocrine system is made up of a series of glands located throughout the body. Glands are organs that produce and release chemicals. These chemicals, called ***hormones***, are generally released directly into the bloodstream in response to certain stages in life such as puberty. Hormones are also released in response to your emotional state at any given time. Good thoughts produce good emotions which trigger beneficial hormones and good



Main Endocrine Glands of the Body

health. Toxic thoughts release hormones that destabilize your physical and emotional health. Hormones are powerful chemical messengers which affect the behavior of specific cells, positively or negatively. ***Target cells*** have specific chemical binding sites, called ***receptors***, each of which responds to a particular hormone or other chemical substances, such as antihistamines.

Hormones are very important in maintaining the human body's equilibrium in a steady-state known as ***homeostasis***. The concept of homeostasis is based upon feedback that prevents small changes from becoming too large and harmful. An example of homeostasis is the way in which the body releases two hormones, called *insulin* and *glucagon*, to regulate sugar levels in the blood. *Insulin* is normally released when sugar levels begin to get too high. *Insulin* decreases the blood glucose concentration by accelerating the movement of glucose out of the blood and through the cell membranes of working cells. *Glucagon* works in the opposite fashion. This hormone is released when blood sugar levels get too low. *Glucagon* converts glycogen to glucose, thereby raising the blood sugar level.

We will be discussing the endocrine system in more detail in the next few lessons.

LIFE PRINCIPLE



"A wise man will hear, and will increase learning; and a man of understanding shall attain unto wise counsels."

—Ancient Hebrew Proverb


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The Human Body

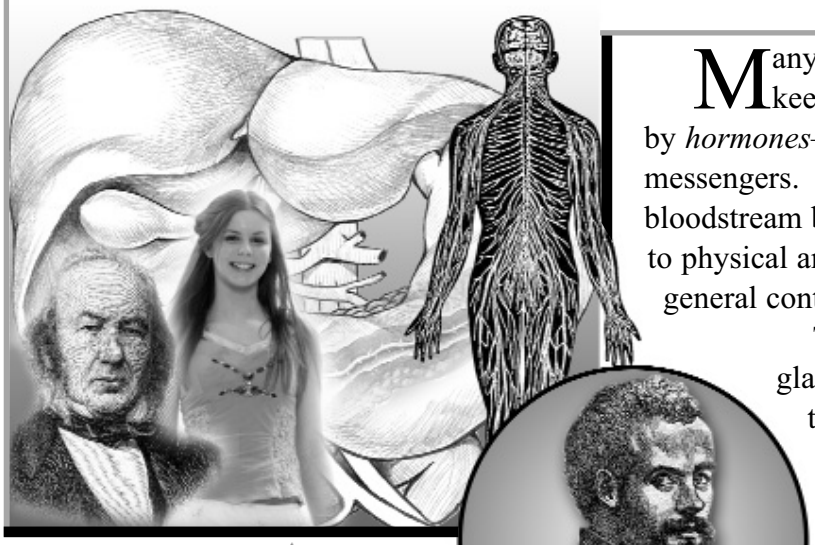
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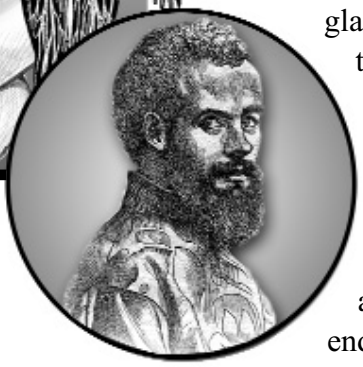
Chapter 1

THE HUMAN BODY: THE ENDOCRINE SYSTEM—HORMONES AND HOMEOSTASIS

Section 1

Lessons 1-5

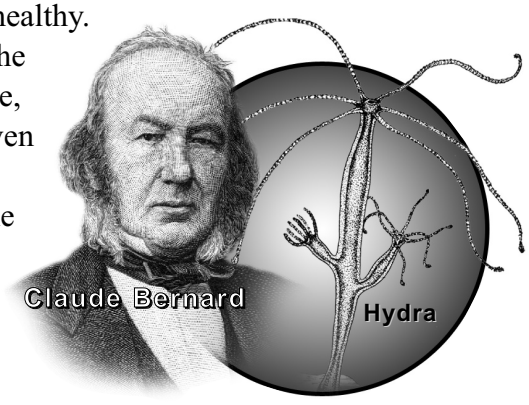




Many of the chemical controls that keep us healthy and fit are controlled by *hormones*—very powerful chemical messengers. Hormones are released into the bloodstream by endocrine ***glands*** in response to physical and emotional stimuli and exert general control over vital bodily activities.

The ***endocrine system*** consists of glands tucked into various areas in the body. Some are close to the organs they influence; others are located at a distance. Endocrine glands include the *pituitary*, *adrenal*, *thyroid*, *parathyroid*, *pineal*, *thymus*, *pancreas*, *testes* and *ovaries*. Although the endocrine message and control system operates much more slowly than the nervous system, the signals are very accurate and last much longer. The effects from hormones may last from minutes to months. Hormones may affect many organs, not just one, as do nerves. The endocrine system operates differently as children grow into adults. On the other hand, the nervous system works in a routine manner throughout growth and life stages.

Physicians have long recognized that the body must be in chemical balance to stay healthy. If one chemical variable in the human body is out of balance, then disorder, ***disease*** and even death can result. Hormones play a key role in keeping the body balanced. Although ancient philosophers believed the human body maintained some sort of



VOCABULARY

Gland: an organ that prepares and secretes a substance (such as hormones, saliva, sweat) for further use in, or discharge from, the body

Endocrine system: the internal system of chemical communication involving hormones; ductless glands that secrete hormones and molecular receptors on or in target cells that respond to hormones; functions in concert with the nervous system to effect internal regulation and maintain homeostasis

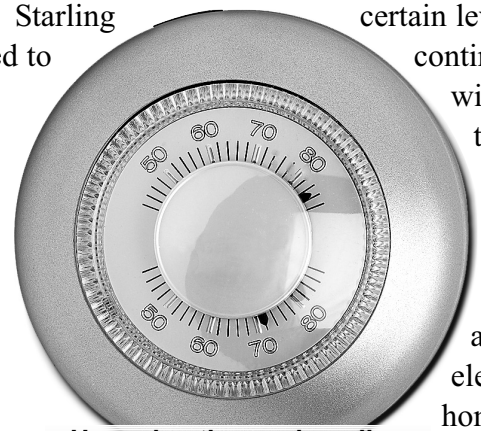
Disease: not being at ease; not being free from pain or discomfort

chemical balance, a French physiologist named Claude Bernard developed a clear idea of chemical balance during the 19th century. He recognized the power of many animals to maintain a relatively constant condition in their internal chemical environments, even when the external chemical surroundings changed. Bernard observed that a pond-dwelling hydra was powerless to change the temperature of the surrounding water. However, the hydra's body could maintain its internal temperature at 37°C. Bernard referred to this body balance as "constant internal milieu."

In 1902, British physiologist Ernest Starling discovered hormones. Starling observed that hormones seemed to give the body "wisdom from within." Starling marveled at the coordinated communication and feedback among cells as they continued to keep the conditions of life constant. This is the steady-state known as *homeostasis*, which we discussed in the previous lesson. Although homeostasis applies to all organisms, our studies will focus on the steady-state in the human body. The mechanism of homeostasis is found in all 11 body systems.

The word homeostasis comes from two Greek terms, *homeo* (alike or the same) and *stasis* (standing or remaining). Thus, the word means "remaining the same". Walter B. Cannon coined the term "homeostasis" in 1932 in a book entitled The *Wisdom of the Body*. His book recognizes the marvelous interdependent features of organisms. Living organisms appear to be *engineered* to sustain life through homeostatic mechanisms. Cannon pictured the body as a large community constantly seeking the most favorable conditions for itself. The body automatically corrects imbalances in fluids and salts, mobilizes to heal itself, and deploys resources on demand.

Technically, homeostasis applies to living systems only, but some man-made engineered systems exhibit a form of homeostasis. Examples would include thermostatically-controlled home heating and cooling systems. When the temperature drops below the desired level in the house, the thermostat turns on the furnace. The furnace is turned off when the thermostat indicates that the temperature has reached a certain level. If the temperature continues to rise, the thermostat will "tell" the air conditioner to turn on. With these controls, the temperature of a house can be kept within a narrow range all year. Both heat and cold are regulated by a kind of electro-mechanical homeostasis.



Home heating and cooling systems reflect a simplified, man-engineered homeostasis.

Within the human body, the many trillions of cells are all trying to maintain a balance, just like a home heating and cooling system. Of course, homeostasis in living organisms is far more complex than simple temperature controls in a building. Whether it is internal temperature control, water balance, electrolyte balance, pH balance (acid-alkaline balance) or a myriad of other balancing acts, the human body is constantly working as though some huge computer were controlling all functions. The intricate system of checks and balances is truly an engineering marvel.

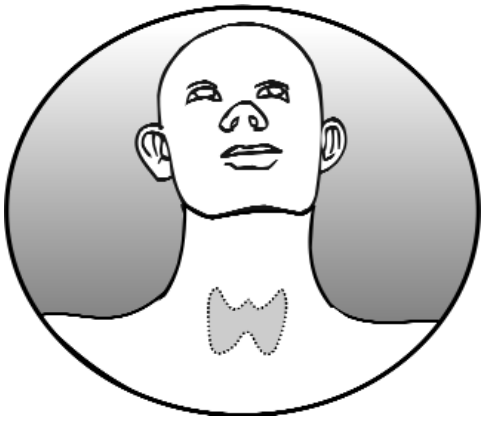
We will continue our study of the endocrine system in the next lesson.

LIFE PRINCIPLE



"If there were an eleventh commandment, it would be 'Thou shalt have balance!'"

—Bill Gothard
Founder, Institute in Basic Life Principles





The Human Body

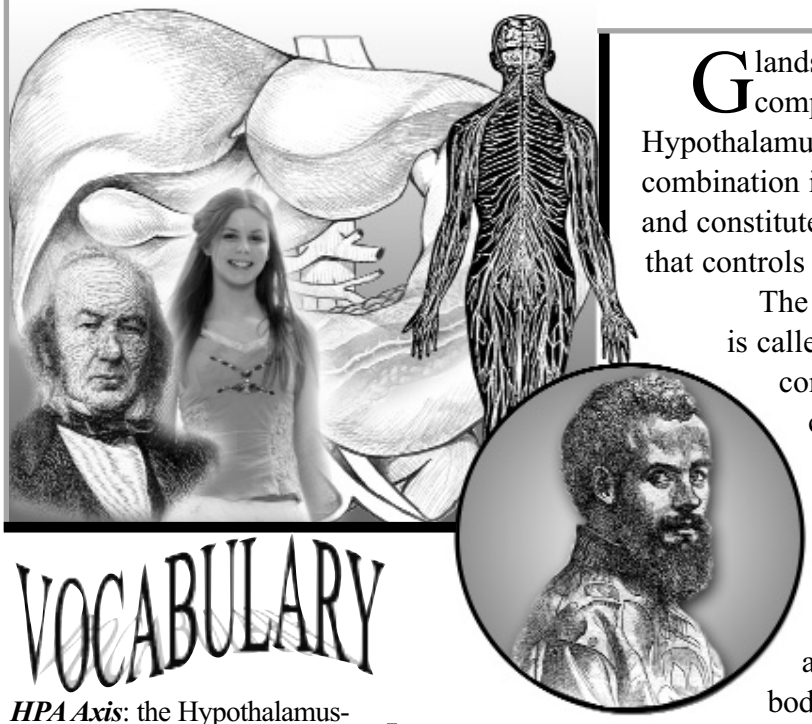
Lesson 4

Chapter 1

THE HUMAN BODY: THE ENDOCRINE SYSTEM— MAJOR ORGANS AND HORMONES

Section 1

Lessons 1-5



Glands perform both simple and complex functions. The Hypothalamus-Pituitary-Adrenal glands combination is also known as the ***HPA Axis***, and constitutes an interrelated system of glands that controls numerous body functions.

The *hypothalamus*, a pea-sized gland, is called "the brain" of the brain. It consists of a tiny cluster of nerve cells located at the center of the base of the brain, and is the control center for most body hormones. The hypothalamus is the principal gland of the ***limbic system*** which connects the mind and its thoughts with the physical body, thereby serving as a link between the nervous system and the endocrine system. All thoughts—good or bad—travel this connective highway and affect bodily functions. This means

VOCABULARY

HPA Axis: the Hypothalamus-Pituitary-Adrenal Glands; an interrelated system of glands

Limbic system: the emotional center of the brain; encompasses hormone-producing glands that constitute a chemical factory

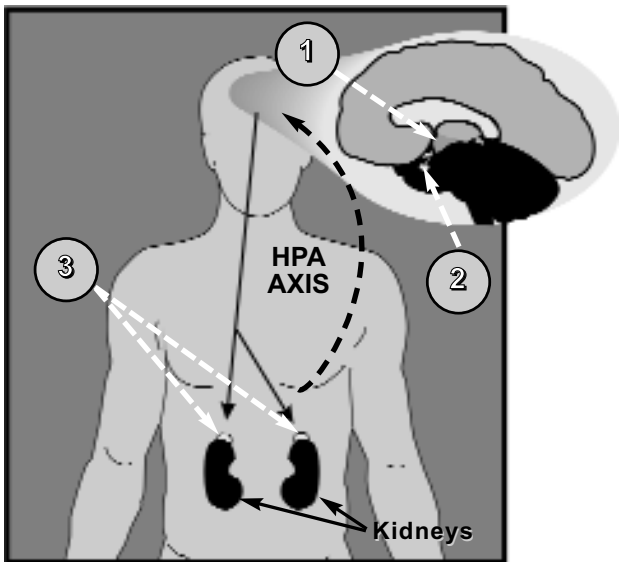
Adrenaline: hormone released by the adrenal gland to control stress; also called *epinephrine*

Noradrenaline: hormone released by the adrenal gland; intensifies effect of adrenaline

Cortisol: a critical hormone produced by the adrenal glands which helps to reduce stress; suppresses inflammation and regulates conversion of carbohydrates into glucose

Location of HPA Axis Gland System

1. **Hypothalamus: secretes CRF hormone in response to stress**
2. **Pituitary gland: CRF binds to pituitary cells which produce ACTH hormone**
3. **Adrenal glands: ACTH stimulates adrenal hormone production of cortisol to reduce harmful effects of stress on the body ststems**



that the hypothalamus responds to your thought life—either positive/beneficial or negative/toxic—by releasing powerful chemicals related to whatever emotions are attached to your thoughts, whether they have positive/beneficial (health enhancing) or negative/toxic (health destroying) implications. Thoughts are represented chemically and electrically in the body, and trigger emotions. Emotions result in attitudes, and attitudes impact bodily functions and behaviour. Thoughts pertaining to love, joy, peace, kindness, gentleness, patience, self-control and forgiveness result in better health and a sense of well-being. However, thoughts of fear, anxiety, anger, hate, resentment, bitterness and such like produce ill health and emotional misery.



The hypothalamus is responsible for regulating many other body functions as well, such as hunger, thirst, sleep and wakefulness. This gland also plays an important role in the regulation of most of the involuntary body mechanisms, including body temperature, sexual drive, the female menstrual cycle, blood pressure and heart rate. Furthermore, the hypothalamus regulates the work of the pituitary gland, one of the most critical glands of the endocrine system.

The *pituitary* is a gland about the size of a pea that protrudes from a tiny stalk at the base of the brain. Although controlled by the hypothalamus, the pituitary is often referred to as the "master gland". The function of the pituitary gland is to act as headquarters for the nervous and the endocrine systems, coordinating their functions. The pituitary gland produces nine major hormones. Some of its hormones stimulate other glands to produce their hormones.

The *adrenal glands* curve over the top of each kidney in the abdomen area. Adrenal glands produce ***adrenaline*** and ***noradrenaline*** which help the body cope with stress. When the body responds to intense emotions such as fright or anger, large amounts of adrenaline are released. This causes a "fight or flight" reaction: instantly, blood pressure rises, eye pupils widen, heart rate increases, and blood is shunted to the most vital organs and to

VOCABULARY

Aldosterone: hormone produced by the adrenal glands; regulates body mineral and water balance

Thyroxin: hormone produced by the thyroid gland; affects nearly all body cells; increases body metabolic rate and rate of cell growth.

Tyrosine: a component of proteins; necessary to production of thyroxine, adrenaline and melanin

Thyroid Releasing Hormone (TRH): hormone produced by the hypothalamus; causes thyroid gland to produce more thyroxin

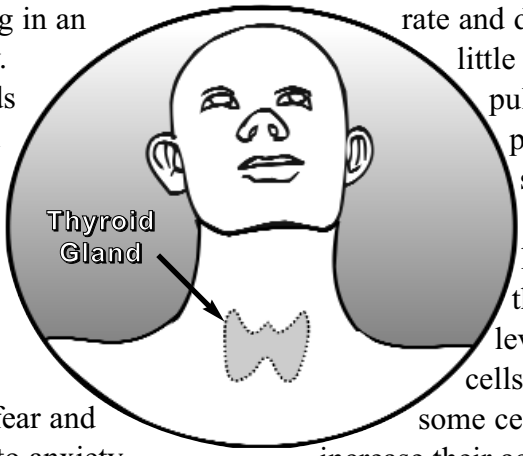
Negative feedback: regulatory system that enables body conditions to remain constant

Tyrosine: a component of proteins; necessary to production of thyroxine, adrenaline and melanin

Gland	Hormone	Effect/Function
Hypothalamus	Corticotrophin Releasing Factor (CRF)	Produced in response to physical or emotional stress, prompts pituitary to produce ACTH
Pituitary	AdrenoCorticoTrophic Hormone (ACTH)	Induces outer wall of adrenal glands (adrenal cortex) to release hormones
	Thyroid-Stimulating Hormone (TSH) or thyrotrophin	Regulates activity of thyroid gland; stimulates thyroid to release thyroxine
	Growth Hormone (GH) or somatropin	Stimulates balanced body growth, avoiding giantism or dwarfism
	AntiDiuretic Hormone (ADH)	Contracts small blood vessels, raises blood pressure, reduces urine excretion, stimulates reabsorption of water
	Follicle-Stimulating Hormone (FSH)	Stimulates growth and maturation of Graafian ovary follicles in females and sperm production in males
	Luteinizing Hormone (LH)	Stimulates ovulation and growth of certain endocrine matter (corpus luteum) in females and testosterone production in males
	Prolactin	Induces mammary glands to produce milk during lactation
	Oxytocin	Initiates after-childbirth uterine contractions and release of milk during lactation
Adrenals	Aldosterone	Regulates salt and water balance
	Cortisol (and other corticosteroids)	Regulates metabolism of proteins, fats and carbohydrates; supresses inflammation
	Adrenaline	Increases rate and strength of heartbeat; overall metabolic rate increase
Thyroid	Thyroxine	Increases metabolic rate; regulates growth and development in children
	Calcitonin	Lowers blood calcium levels; inhibits release of calcium from bone
Parathyroid	ParaThyroid Hormone (PTH) or parathrone	Regulates body's use of calcium and phosphorus
Ovaries	Estrogen	Initiates and maintains female sex characteristics
	Progesterone	Promotes growth and maintenance of uterine lining, formation of placenta in pregnancy
Testes	Testosterone	Responsible for development and maintaining male sex characteristics; sperm development
Thymus	Thymosin	Most pronounced in adolesence; triggers production of T cells for maintenance of immune system; antibody production
Pineal	Melatonin	Helps regulate sleep patterns; appears to regulate onset of puberty
Pancreas	Glucagon	Raises blood glucose levels by converting glycogen to glucose
	Insulin	Lowers blood glucose levels by converting glucose to glycogen

skeletal muscles, resulting in an excessive burst of energy.

The adrenal glands also produce ***cortisol*** and ***aldosterone*** to help the body reduce stress, and are critical for sustaining life. *Cortisol* has been called the "worry hormone" because it is produced in response to fear and vigilance, and gives rise to anxiety. Cortisol also suppresses inflammation and regulates conversion of carbohydrates into glucose, thus providing more strength and endurance for the stress or trauma at hand. However, long-term stress and continued cortisol release can result in health problems affecting many body systems. Prolonged stress can cause or worsen such varied conditions as skin problems, frequent colds and headaches, muscle tenstion, asthma, high blood pressure, heart problems, ulcers, indigestion, bowel problems and so on.



Aldosterone regulates the mineral and water balance in the body. It prevents excessive loss of water through the kidneys and maintains the balance between sodium and potassium in the blood stream which is critical for proper muscle function.

Another major endocrine organ is the *thyroid* gland which produces ***thyroxin***. To make thyroxin, the thyroid gland needs a small amount of iodine and the amino acid ***tyrosine***, which must be obtained from food. Most cells in the body have receptor cites for thyroxin. Consequently, thyroxin affects nearly all the body's cells, increasing the rate at which they use food and oxygen. It also increases the rate of cell growth.

Too much thyroxin in the blood stream results in increased blood pressure, nervousness, increased pulse rate and dangerous weight loss. Too little thyroxin results in a lowered pulse rate, lowered blood pressure, excessive lethargy, sleepiness and weight gain.

The hypothalamus helps to keep the level of thyroxin balanced. When levels of thyroxin drop, most cells slow down their activity, but some cells of the hypothalamus increase their activity. These cells produce another hormone called ***thyroid-releasing hormone*** or TRH. The target cells for TRH are the cells of the thyroid gland; TRH causes the thyroid gland to release more thyroxin.

This type of hormone action is called *feedback regulation*. When the thyroid gland is working too fast, its own hormone—thyroxin—causes the hypothalamus to signal the thyroid gland to slow down. When it is working too slowly, low levels of thyroxin cause the hypothalamus to signal the thyroid gland to speed up hormone production.

The relationship between the thyroid gland and the hypothalamus is an example of ***negative feedback***. In humans, the release of hormones is often regulated through negative feedback. By this means, the secretion of one hormone inhibits further production of another hormone. Negative feedback is what the body uses to fine-tune and control the levels of hormones at all times.

In the next lesson, we will examine another major endocrine gland—the pancreas.

Life Principle



"Take care of your thoughts and your actions will take care of themselves."

—Daniel Orcutt
In *Simple Wisdom* by Kathleen Mahoney



The Human Body

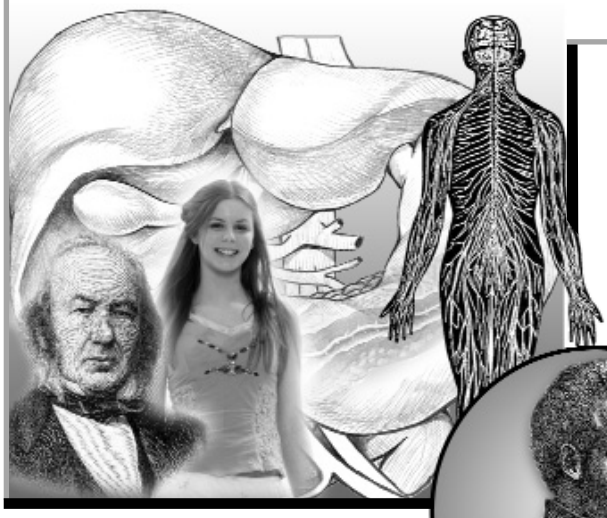
Lesson 5

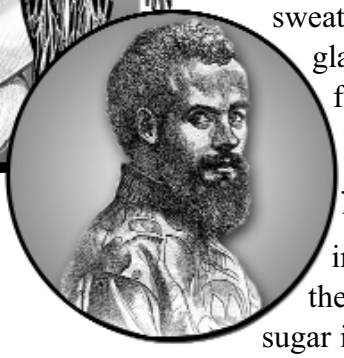
Chapter 1

THE HUMAN BODY: THE ENDOCRINE SYSTEM—THE PANCREAS

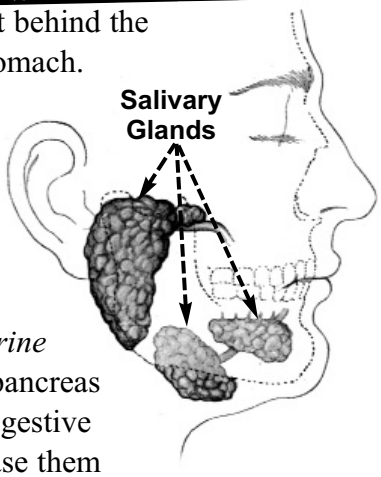
Section 1

Lessons 1-5

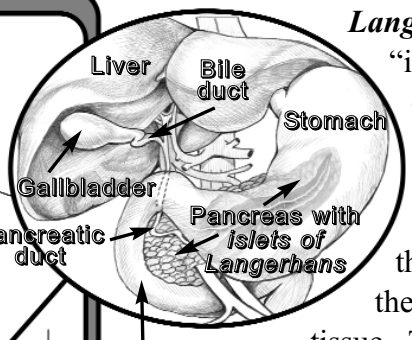


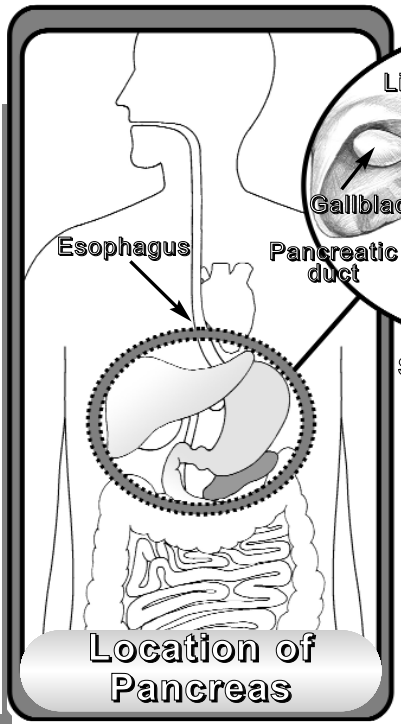


The pancreas lies just behind the lower part of the stomach. It is the second largest gland in the body and is both an *endocrine* and an ***exocrine*** gland. Other exocrine glands include sweat and salivary glands. The *exocrine* function of the pancreas is to produce digestive juices and release them through the pancreatic duct into the intestine. The *endocrine* function of the pancreas is to control the amount of sugar in the blood.



The cells that ultimately control blood sugar levels are called the ***islets of Langerhans***: tiny "islands" of cells named after their discoverer, scattered throughout the pancreatic tissue. Two kinds of cells called ***alpha*** and ***beta*** exist in these clumps. The alpha cells secrete a hormone called ***glucagon*** and the beta cells secrete ***insulin***. Insulin and glucagon work as a check-and-balance system regulating the body's blood sugar level.





VOCABULARY

Exocrine glands: glands that excrete their products into tubes or ducts that do not empty into the bloodstream

Islets of Langerhans: microscopic clumps of cells scattered throughout the pancreatic tissue

Alpha cell: one of two kinds of cells that exist in the islets of Langerhans; produce the hormone *glucagon*

Beta cell: one of two kinds of cells that exist in the islets of Langerhans; produce the hormone *insulin*

Glucagon converts ***glycogen*** to ***glucose***, increasing the concentration of glucose in the blood, while insulin decreases the amount of glucose in the blood.

High blood glucose levels stimulate the release of insulin from the beta cells. Insulin acts on most body cells and increases their ability to transport glucose across the cell membranes. Once inside the cells, glucose is oxidized for energy or converted into glycogen or fat for storage. As blood glucose levels fall, the stimulus for insulin release diminishes. This is another example of automatic negative feedback control.

Diabetic Characteristics & Symptoms

TYPE I	TYPE II
1. Also called *Juvenile-Onset Diabetes*: usually occurs before age 20	1. Also called *Adult-Onset Diabetes*: usually affects people over age 40
2. Constitutes about 10% of diabetics	2. 90% of the time is a consequence of obesity
3. A genetically inherited condition	3. Can normally be treated with diet & exercise rather than insulin
4. Requires daily insulin injection	4. Can exhibit any symptoms of Type I, itemized in points 5-7
5. Promotes extreme thirst and hunger	5. Slow-healing cuts and bruises, blurred vision
6. Causes frequent urination and unusual weight loss	6. Tingling or numbness of extremeties (hands, feet)
7. Produces irritability and great fatigue	7. Frequent infections, including bladder, skin and gum types

VOCABULARY

Glucagon: hormone produced by the pancreatic alpha cells which causes glycogen to be broken down into glucose, thus raising the blood glucose level

Insulin: hormone produced by the pancreatic beta cells which is responsible for lowering blood glucose by promoting the uptake of glucose by most body cells, and by promoting the synthesis and storage of glycogen in the liver; also stimulates protein and fat synthesis

Glycogen: a polysaccharide (starch) formed from carbohydrates; stored in the liver and other tissues until needed by the body to form *glucose*

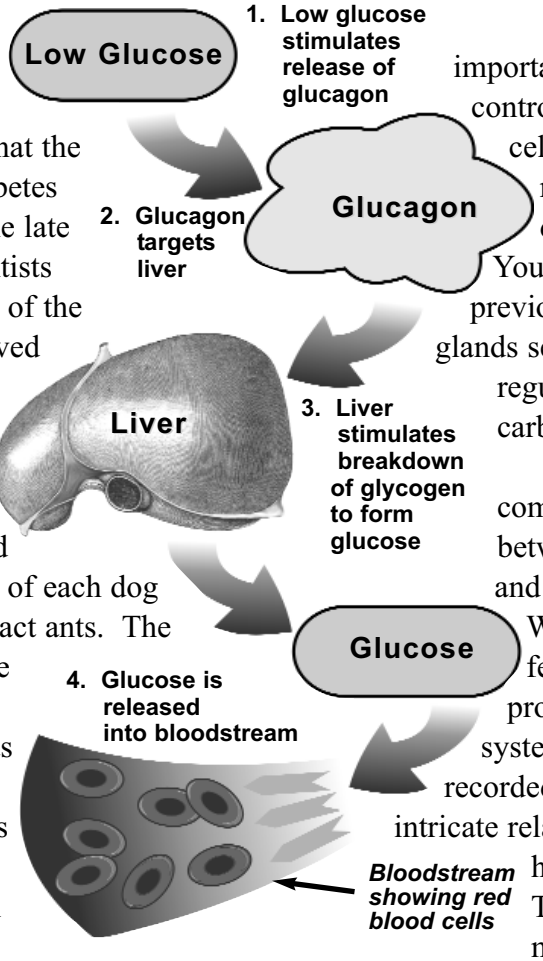
Glucose: the principal sugar in human and animal blood; also called *dextrose* or *grape sugar*

Diabetes mellitus: disorder of the endocrine system in which the pancreas secretes too little insulin, causing an excess of glucose in the bloodstream; the most common disorder of the endocrine system

Insulin decreases blood glucose by accelerating its movement out of the blood, through cell membranes and into cells. Insulin is critical for the use of glucose by the body cells; without it, no glucose can get into muscle cells to be used for energy. Without insulin, blood levels of glucose increase dramatically to levels high above normal. In such instances, glucose begins to spill into the urine. As glucose flushes from the body, dehydration also occurs. The clinical name for this condition is ***diabetes mellitus***. *Diabetes* comes from two Greek words meaning "to pass through". *Mellitus* is Latin for "honey". *Diabetes Mellitus*, then, literally means that something sweet is passing from the body. Since body cells cannot use glucose without sufficient insulin, fats or proteins are released to meet the energy requirements. Loss of body proteins lead to a decreased ability to fight infections; therefore, diabetics must be very careful with their hygiene and in caring for even small cuts and bruises. Two types of diabetes mellitus exist: Type I and Type II. Warning

signs are somewhat overlapped, as the chart on page eighteen indicates.

The first evidence that the pancreas is involved in diabetes mellitus was observed in the late 1800's. Two German scientists who were studying the role of the pancreas in digestion removed the pancreases from a control group of dogs. By chance, they noticed that the urine of each dog without a pancreas attracted ants. Conversely, the urine of each dog with a pancreas did *not* attract ants. The scientists concluded that the urine of a dog without a pancreas contained sugar, as was known to be true of humans with diabetes. This observation led to more research into the connection between the pancreas and diabetes, and ultimately to the discovery of the pancreatic hormone, *insulin*.



Glucagon acts as an antagonist to insulin. Low blood levels of glucose stimulate release of glucagon by the alpha cells. Glucagon's primary target organ is the liver, which stimulates the break down of stored glycogen in order to form glucose and then release it into the blood.

Glucose levels are very important in homeostatic control. The alpha and beta cells of the pancreas help to regulate glucose levels, as do the adrenal glands. You will recall from the previous lesson that the adrenal glands secrete *cortisol*, which regulates the conversion of carbohydrates into glucose.

As you can see, many complex relationships occur between endocrine glands and various body functions. We have discussed only a few of the regulatory processes of the endocrine system. Scientists have recorded many complicated and intricate relationships among hormones and organs. The relationships reflect a marvelous network of mechanical order and systemic codependence.

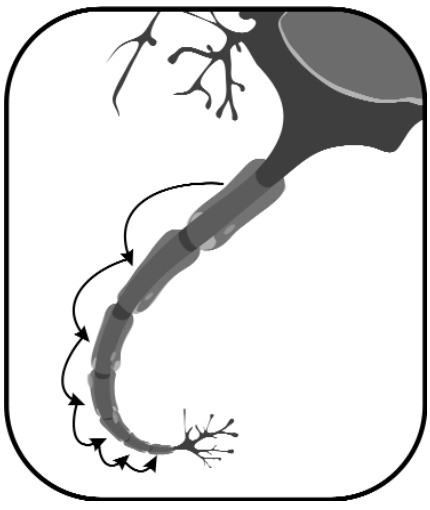
In the next lesson, we will begin a study of the human nervous system.

LIFE PRINCIPLE

"Great discoveries in science often result from chance observations. . ."



—Biological Science: An Inquiry into Life





The Human Body

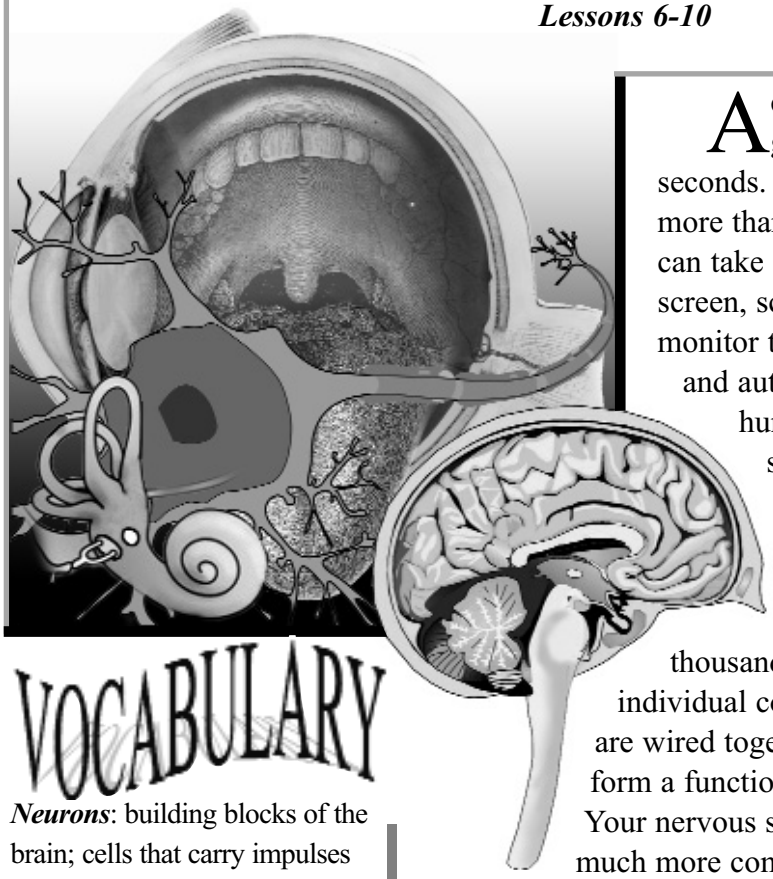
Lesson 6

Chapter 1

THE HUMAN BODY: THE NERVOUS SYSTEM—INTRODUCTION

Section 2

Lessons 6-10



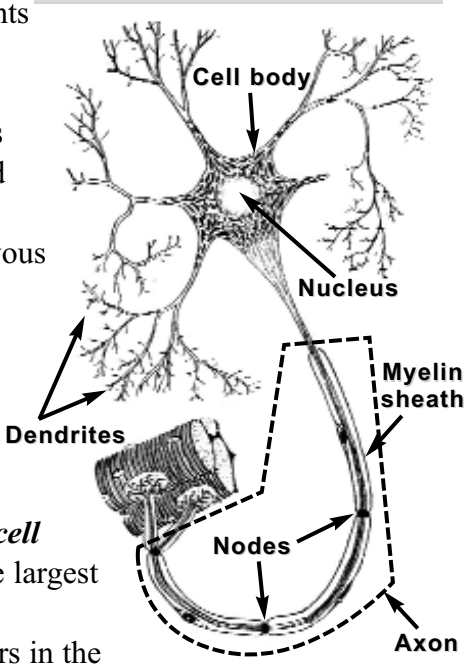
A computer can deliver a page of text, graphics and even a video in a few seconds. The human body can perform much more than these in a fraction of a second. It can take in everything on the computer screen, scan the area around the computer, monitor the sound, light and heat in the room, and automatically regulate the activities of hundreds of internal systems simultaneously.

Inside the computer are the basic components: wires, switches and circuit boards. As you study a computer, you begin to see how thousands of individual components are wired together to form a functional unit. Your nervous system is much more complicated and intricate than a computer.

The basic units of the nervous system are nerve cells called ***neurons***. First named as such in 1891, and sometimes called "the King of cells", these units carry messages in the form of electrical signals known as ***impulses***.

A *neuron* is made up of a ***cell body***, ***dendrites*** and an ***axon***. The largest part of the neuron is its *cell body*. Metabolic activity in the cell occurs in the neuron. In addition, the cell body collects information from the *dendrites*, which are small, spider-like branched extensions that spread out from the cell body. Dendrites carry impulses toward the cell body. They also receive stimuli from their

Neuron



VOCABULARY

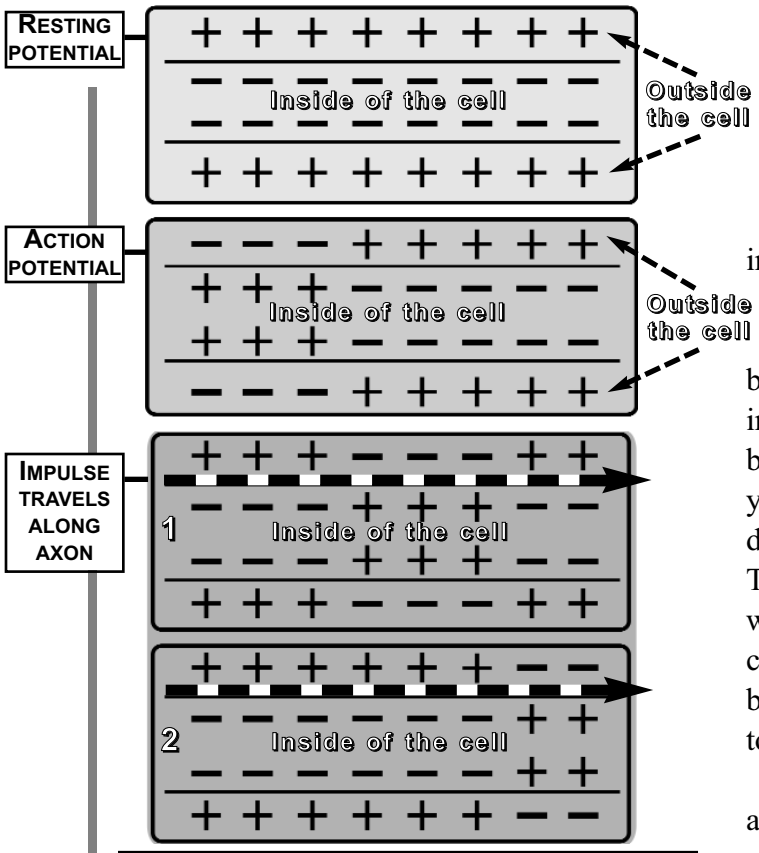
Neurons: building blocks of the brain; cells that carry impulses throughout the nervous system

Impulse: electrical signal or message carried by neurons in the nervous system

Cell body: largest part of the neuron in which metabolic activity takes place

Dendrite: any of many small branched extensions of the cell body of a neuron that store memories and carry impulses toward the cell body

Axon: single, long, branched extension of the cell body of a neuron that carries impulses away from the cell body



Neuron Charges

At rest, the outside of the neuron's membrane is more positively charged than the inside. If a stimulus is applied, causing an impulse, the electrical charges become reversed. The reversal of electrical charges continues as the action potential moves down the axon.

VOCABULARY

Resting potential: product of a net excess of negative changes on the inside of the membrane

Action potential: rapid change in voltage on the inside of the axon from negative to positive and then back to negative

Schwann cells: a chain of supporting cells enclosing the axons of many neurons and forming an insulating layer called the myelin sheath

Myelin sheath: material that forms a protective sheath around an axon; white fatty substance that surrounds many vertebrate nerve cells

Nodes: gaps formed by the Schwann cells on an axon

Synapse: from the Greek word "synapsis", meaning *connection*; place where a neuron can transfer an impulse to another cell

Neurotransmitter: a chemical used by one neuron to signal another cell

immediate surroundings through other neurons' sensory structures in the skin, muscles or internal organs. The long branch or "wire" that carries electrical impulses away from the cell body to the brain is called an *axon* and may reach over a yard in length. A neuron may have many dendrites, but it usually has only one axon. The axon is multi-branched, so it connects with a number of receiving structures. The composite of hundreds of microscopic axons bunched together appears, to the unaided eye, to be only a single white thread.

In the human body, as well as in most animals, neurons are clustered into bundles of fibers called nerves. Some nerves contain only a few neurons, but many others have hundreds and even thousands of neurons. Most brain cells, or neurons, are formed in a preborn child during its nine-month development in the womb at the astounding rate of 250,000 per minute!

THE NERVE IMPULSE

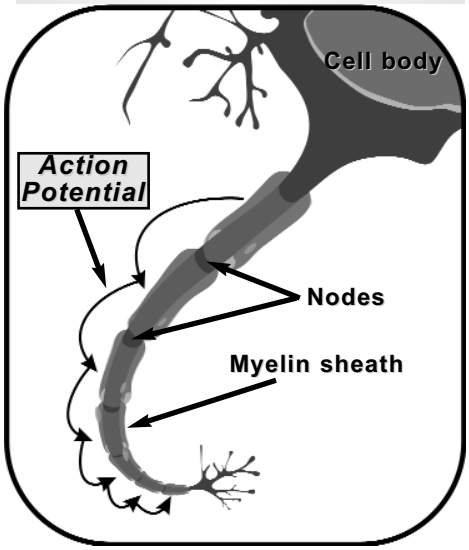
A neuron which carries no impulse is said to be "at rest". A resting neuron has an electrical potential or a charge difference across the cell membrane. The inside of the cell is negatively charged and the outside is positively charged. When the neuron is at rest, the difference in electric charges is called the ***resting potential***.

An impulse begins when a neuron is stimulated by another neuron or by the environment. Once it begins, the impulse travels rapidly down the axon away from the cell body. The impulse is caused by a sudden change in the membrane charge. For a few milliseconds, positive ions rush across the

cell membrane which reverses the charge difference. For that brief moment, the inside of the membrane is more positive than the outside. In less than 10 milliseconds, the potential reverses again and the resting potential is restored.

The rapid change in electrical charge on the inside of the axon is called ***action potential***. A nerve impulse is an action potential traveling down an axon. This entire effect can be compared to a row of dominos. You have probably set up dominos and watched as each domino fell, hitting another, and causing the next in line to fall. That is very similar to what happens in a neuron. Like a domino toppling, the flow of positive charges into one region of the axon causes the membrane just ahead of it to open up and let positive charges flow across the next membrane. This happens repeatedly until the impulse moves along the length of the axon. In a typical axon, the impulse can move as quickly as one meter per second. Once the impulse passes, the resting potential is restored and the neuron is ready for another impulse.

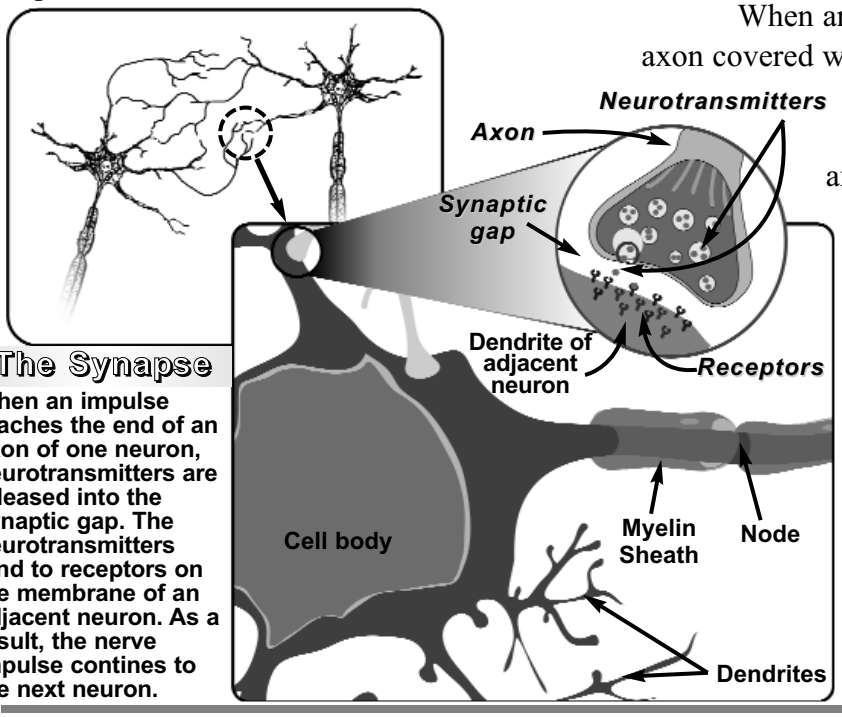
Action Potential



Myelin Sheath

Most electrical wires in your home are insulated with rubber or plastic to prevent short circuits. Our nervous system has an insulating substance that surrounds the axons. In some nerve cells, ***Schwann cells*** grow around the axon to form an insulating layer. This insulating material is known as the ***myelin sheath***. The Schwann cells leave many gaps, called ***nodes***, where the axon membrane is exposed.

When an impulse moves down an axon covered with myelin, the action potential jumps from one node to the next. A large axon with myelin can carry messages at speeds close to 200 yards per second.



The Synapse

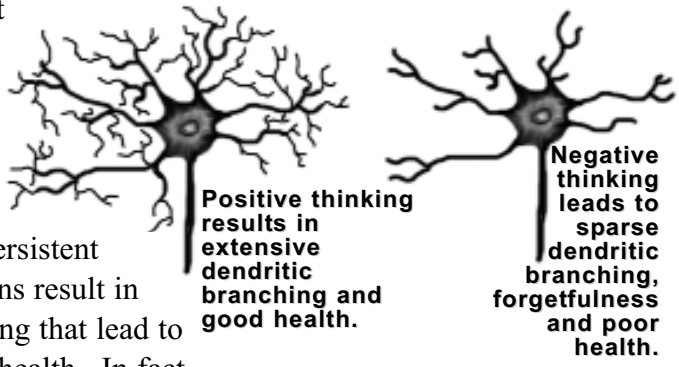
When an impulse reaches the end of an axon of one neuron, neurotransmitters are released into the synaptic gap. The neurotransmitters bind to receptors on the membrane of an adjacent neuron. As a result, the nerve impulse contines to the next neuron.

The Synapse

An impulse that reaches the end of an axon is transferred to another cell by means of ***synapses***. In fact, each neuron is connected to 10,000-50,000 other neurons, directly or indirectly, which results in

possibly 5,000 million, million, million ($5x10^{21}$) linking pathways!

Amazingly, the number of vital links are heavily impacted by one's thought processes. A consistent pattern of positive thinking tends to produce extensive dendrite branching, and beneficial mental and physical health. Persistent negative thought patterns result in sparse dendrite branching that lead to forgetfulness and poor health. In fact, researchers now say that as much as 87% of our illnesses are directly attributable to our negative (toxic) thought patterns and emotions.



The synapse is a small space between the axon of one neuron and the dendrites of the next neuron. The synapse contains tiny sacs filled with ***neurotransmitters***, which are chemicals used by one neuron to signal another cell. When an action potential arrives at the end of an axon, the sacs release the neurotransmitters into the synapse between the two cells. The neurotransmitter molecules attach to receptors on the neighboring cell. This causes electrical stimulation of that cell. If the stimulation is great enough, a new impulse begins. The signal stops once the neurotransmitter supply is depleted. In a fraction of a second after binding to their receptor, the neurotransmitter molecules are released from the cell surface. They may either be broken down by enzymes or recycled by the axon.

In the next lesson, we will continue our study of the human nervous system by looking at its organization.



LIFE PRINCIPLE

"We are fearfully and wonderfully made."

—King David
Second king of Israel, 1000-960 B.C.



The Human Body

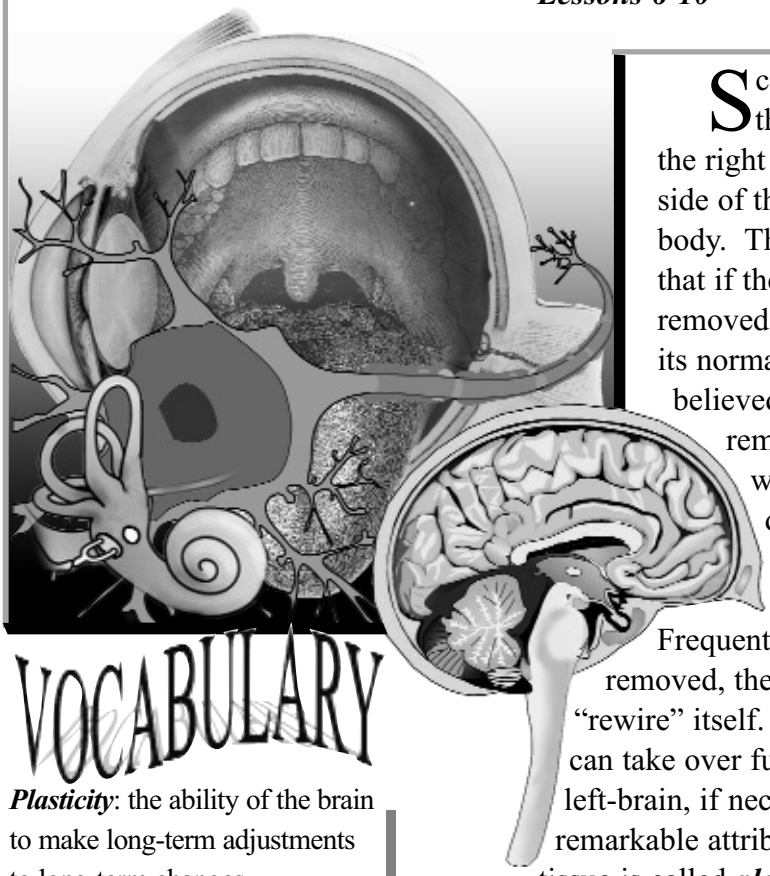
Lesson 7

Chapter 1

THE HUMAN BODY: THE NERVOUS SYSTEM—ORGANIZATION

Section 2

Lessons 6-10



Scientists have known for many years that the left side of the brain controls the right side of the body and that the right side of the brain controls the left side of the body. Therefore, many scientists assumed that if the right side of the brain were removed, the left side of the body would lose its normal function. Likewise, scientists believed that if the left side of the brain were removed, the right side of the body would lose function. In adults, this does occur. However, with adolescents and children, this does not appear to be the norm. Frequently, even when half of the brain is removed, the brain seems to "rewire" itself. The right brain can take over functions of the left-brain, if necessary. This remarkable attribute of nervous tissue is called ***plasticity***.

Another remarkable characteristic of the nervous system is its incredible complexity. About 10^{11} to 10^{12} neurons and 10^{13} to 10^{15} ***glial*** cells exist in the human body. Each neuron has 10,000 synapses. This amounts to 10^{16} connections in the human body. No other natural being in this universe rivals the complexity and order found in the human nervous system. Humans truly are marvelously and wonderfully designed.

The human nervous system is divided into two main parts—the *central nervous system* and the *peripheral nervous system*.

VOCABULARY

Plasticity: the ability of the brain to make long-term adjustments to long-term changes

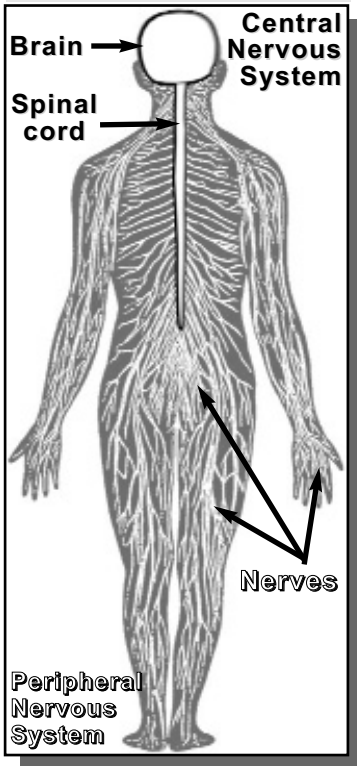
Glial: a non-conducting cell of the nervous system that provides support, insulation and protection for the neurons; support cells

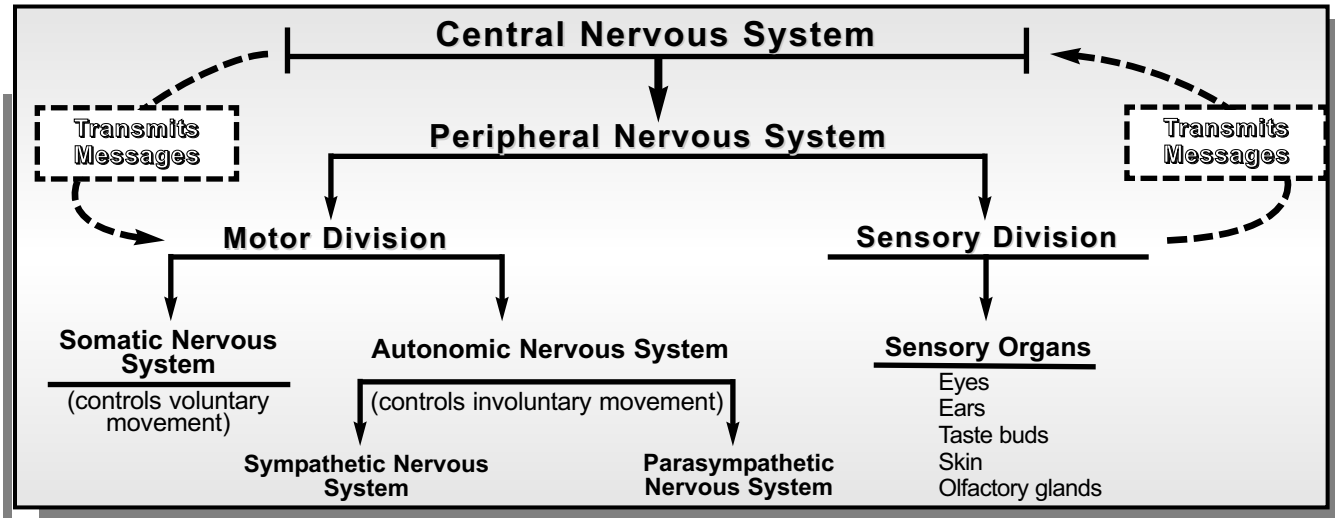
Meninges: three-layers of tough, elastic tissues that cushion the brain and spinal cord

Cerebrospinal fluid: fluid that fills the space between the meninges to cushion the brain and the spinal cord

Somatic nervous system: part of the motor division of the peripheral nervous system that controls voluntary movements

Central & Peripheral Nervous Systems





Central Nervous System

The central nervous system consists of the brain and the spinal cord. The brain and the spinal cord share many structural similarities. The brain is protected by the bones of the skull, and the spinal cord is protected by the vertebrae of the backbone. Both protective shields are cushioned by three layers of rough, elastic tissue called ***meninges***. Between the meninges is a space filled with ***cerebrospinal fluid***, which cushions the brain and the spinal cord. These three elastic layers help to prevent injuries to the central nervous system.

Peripheral Nervous System

The peripheral nervous system includes all the nerves and associated cells that connect the brain and spinal cord to the rest of the body. The peripheral nervous system is responsible for carrying nerve impulses to and from the body's complex structures, and includes innumerable nerves that branch off from the brain and spinal cord.

The total length of nerve fibers in a single person is estimated to be 380,000 kilometers (567,164 miles)—equal to the distance between Earth and the Moon. Equally astounding is the hurricane-force speed—144 kilometers (215 miles) per hour (or 27 miles per second)—with which nerve messages travel through pathways as narrow as one thousandth of a millimeter.

Two divisions exist in the peripheral nervous system—the *sensory division* and the *motor division*. The sensory division carries information from the sense organs to the central nervous system. The motor division transmits messages in the other direction—from the central nervous system to the rest of the body. The motor division is further divided into the ***somatic nervous system*** and the ***autonomic nervous system***.

Somatic Nervous System

The *somatic nervous system* controls voluntary movements. Every time you turn a page of a book or press a computer key, you are using the somatic nervous system to control the movements of your hand. Some somatic nerves are also part of reflexes and act with or without your conscious control.

VOCABULARY

Autonomic nervous system: part of the motor division of the peripheral nervous system that regulates activities not under conscious control

SYMPATHETIC	PARASYMPATHETIC
Increases heartbeat	Decreases heartbeat
Decreases gland activity	Increases gland activity
Decreases digestive process	Increases digestive activity
Decreases reproductive activity	Increases reproductive activity

AUTONOMIC NERVOUS SYSTEM

The ***autonomic nervous system*** regulates activities that are not under your conscious control, including the beating of the heart and the contraction of muscles surrounding the digestive system. This system regulates the activities of various organs throughout the body. The autonomic nervous system consists of two distinct parts—the *sympathetic nervous system* and the *parasympathetic nervous system*. These subsystems are responsible for maintaining balance in activities of body organs by opposite means, as indicated in the chart above.

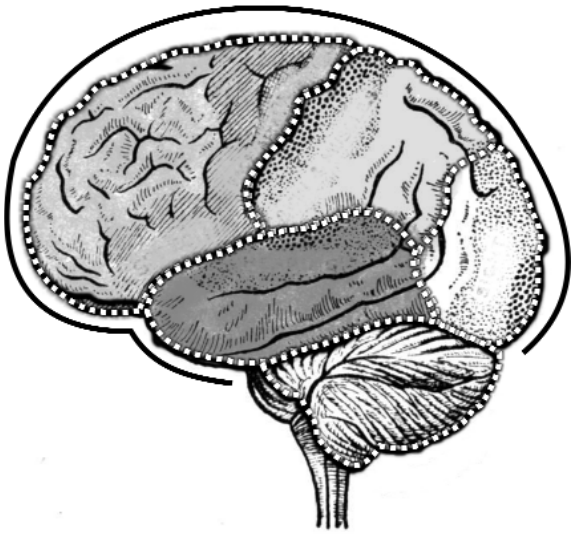
In the next section, we will study the marvelous, mysterious brain.

LIFE PRINCIPLE



"The greatest engineering is the engineering of men."

–Robert Lewis Stevenson (1850-1894)
Scottish author





The Human Body

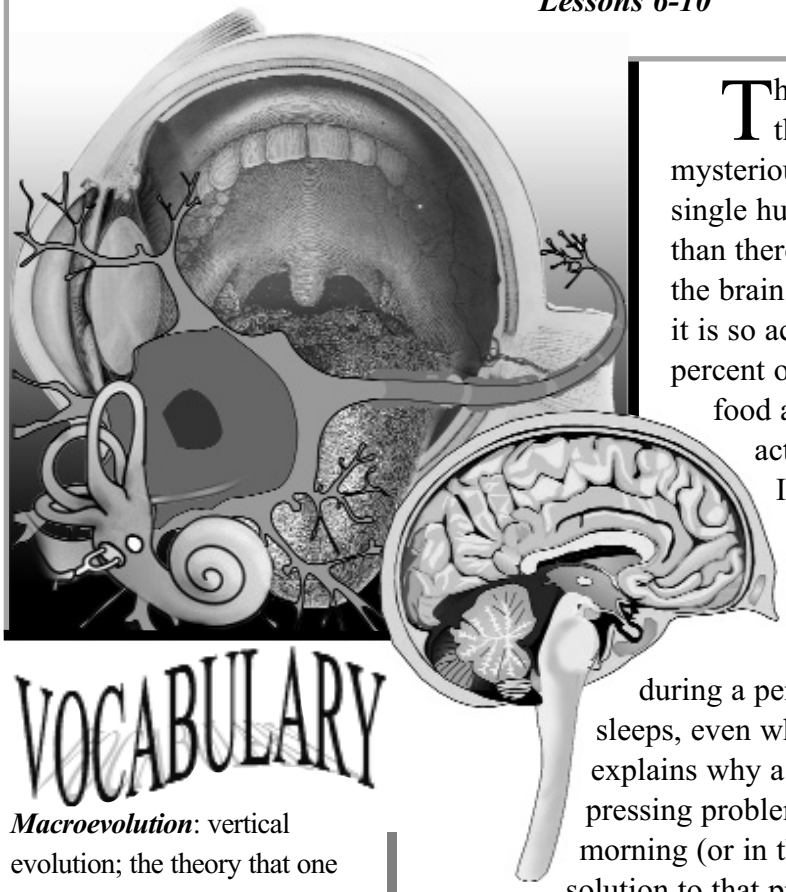
Lesson 8

Chapter 1

Section 2

Lessons 6-10

THE HUMAN BODY: THE NERVOUS SYSTEM—THE BRAIN



The brain is the primary component of the nervous system and is a most mysterious organ. More cells exist in a single human brain (35 billion to 100 billion) than there are people in the world! Although the brain weighs an average of three pounds, it is so active that it may use as much as 25 percent of the body's energy. The supply of food and oxygen needed to support brain activity requires a rich blood supply. If the blood supply is interrupted, even for a few minutes, the brain may suffer serious damage resulting in a vegetative state or in death.

Except for a comatose state, during a person's lifetime the brain never sleeps, even when the rest of the body does. This explains why a person may fall asleep with a pressing problem on his mind and wake up the next morning (or in the middle of the night) with a solution to that problem—the brain was busy thinking during sleep.

The human brain is the most complex system in existence. All the body's cells ultimately report to the brain. The brain is the source of order and wisdom in the body. Popular scientist Isaac Asimov asserted, "In man is a three-pound brain which, as far as we know, is the most complex and orderly arrangement of matter in the universe." Man's phenominal brain and the ability to think separate him from the animal world, and prompt him to contemplate four basic, universal questions pertaining to: *self-worth* (Who am I?), *origins* (Where did I come from?), *life-purpose* (Why am I here?) and *destiny* (Where am I going?).

The complex web of neurons in the brain is home base for all mental processes. All information in your brain is formatted and processed in an electrochemical manner. Each

VOCABULARY

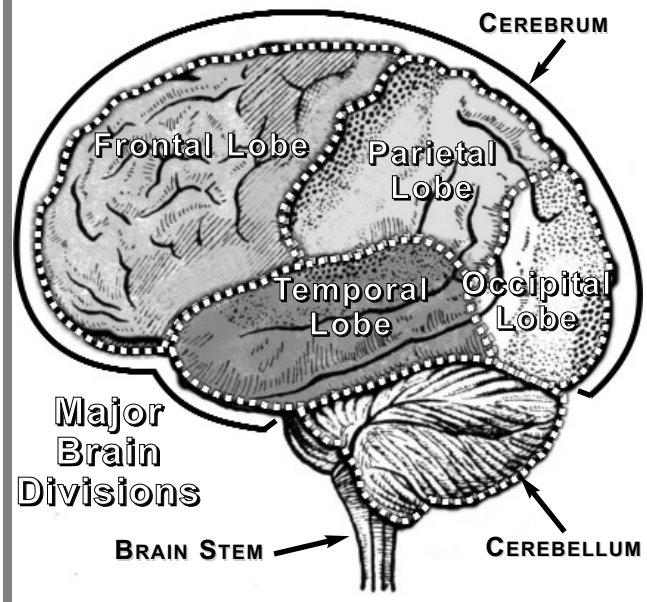
Macroevolution: vertical evolution; the theory that one specie can evolve into another specie over time

Cerebrum: largest and most complex structure of the nervous system; consists of two lobes or hemispheres; controls voluntary activities

Corpus callosum: a thick band of 300 million nerve fibers connecting the right and left cerebral hemispheres of the vertebrate brain

Hippocampus: a part of the limbic system; indisputably vital to memory

mental process consists of neurons transmitting specific electrochemicals across the synapses. As a result, each cell can communicate with every other cell at lightning speed. One billion connections exist in each cubic millimeter of the brain. The brain's total number of connections rivals the number of stars in the universe.



VOCABULARY

Cerebral cortex: deeply creased surface of the cerebrum

Cerebellum: second-largest part of the brain; coordinates movement

Brainstem: structure that connects the brain to the spinal cord; includes the *medulla oblongata* and the *pons*

Medulla oblongata: part of the brainstem that regulates the flow of information between the brain and the rest of the body; controls involuntary functions

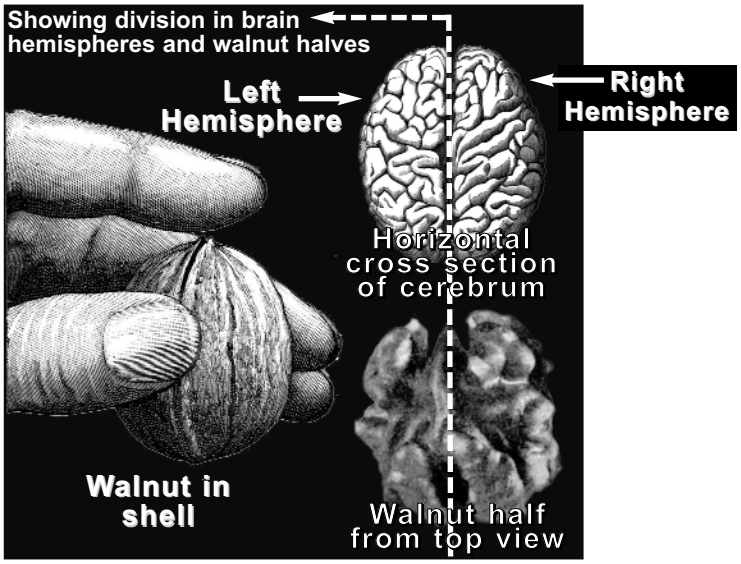
Pons: region of connecting tissue at the base of the brainstem

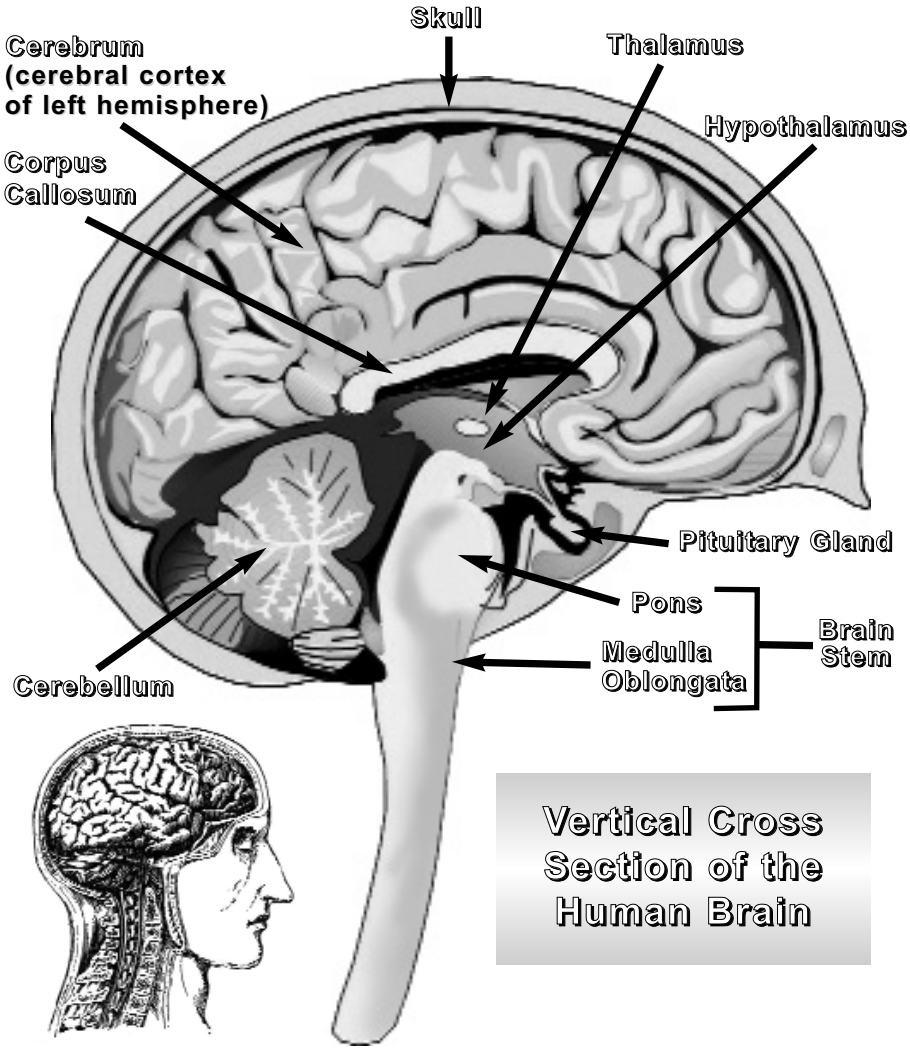
Thalamus: regulates the information that goes to the cerebral cortex

Man-made computer switches interact with not more than two other switches at a time, whereas a brain cell may be wired to 1,000 other cells, each connection following an orderly plan. Indeed, the brain is more than just a super-computer. At one million, million, million computations per second, the human brain (as of the year 1999) was calculated to operate 100 million times faster than the fastest super computer.

The theory of ***macroevolution*** espouses randomness, blind chance, and imperfection over eons until functionality happens. Many scientists, however, question how the brain's order and complexity fit the macroevolutionary model. Because the brain and the nervous system display incredible order, organization, and what appears to be perfect design, many contemporary scientists are concluding that properties of the human central nervous system are not harmonious with the macroevolutionary model.

The brain is divided *vertically* into three parts: the *cerebrum*, the *cerebellum* and the *brainstem*. The ***cerebrum*** is the largest part of the human brain, with an estimated 500,000 to a million kilometers (335,000—670,000 miles) of nerve fibers.





Vertical Cross Section of the Human Brain

It is responsible for functions such as learning, intelligence and judgment. The *cerebrum* is also divided *horizontally* into left and right hemispheres by a deep groove. These halves, or hemispheres, that resemble walnut halves are connected by the ***corpus callosum***, a small "C"-shaped structure about the size of your thumb. The corpus callosum is surrounded by the ***hippocampus*** which holds all incoming information in memory for about 48-72 hours, until the corpus callosum analyzes the information and decides to accept or reject it. We call this "free will", for which scientists think they have identified a genetic code.

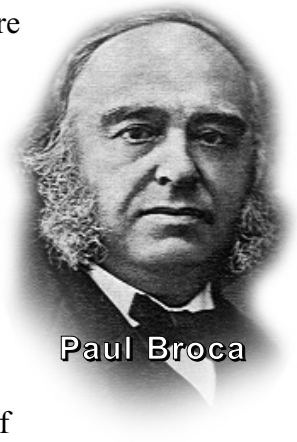
Each hemisphere of the cerebrum controls the functions of the *opposite* side of the body. Therefore, "left-brained" people tend to be *right-handed*, analytical, and proficient in math and science. "Right-brained" persons are naturally *left-handed*, creative and artistic. Persons who were programmed as children to exhibit the opposite of their natural "handedness" are said to have "mixed dominance" and, to some degree, exhibit both sets of traits. Each hemisphere also contains four lobes: the *frontal* lobe, the *parietal* lobe, the *occipital* lobe and the *temporal* lobe.

The surface of the cerebrum, the ***cerebral cortex***, is deeply creased. The creasing enlarges the surface area and increases the number of cells that can be packed into this layer. The total surface area for an adult averages an amazing 2,200 cm., or 72.18 feet! The cerebral cortex processes information from the senses and controls body movement.

The ***cerebellum*** is the second-largest part of the brain and is located just below the cerebrum at the base of the skull. When the cerebral cortex commands a muscle group to move, that message is routed through the cerebellum. The cerebellum coordinates and balances the actions of muscles so the body moves gracefully and efficiently.

The ***brainstem*** connects the brain to the spinal cord. The brainstem includes two regions—the ***medulla oblongata*** and the ***pons***. Some of the body's most important functions, such as the regulation of blood pressure, heart rate, breathing and swallowing, are controlled in this part of the brain. The ***thalamus*** is located just beneath

the cerebrum. The thalamus receives messages from sense organs, including the eyes and the nose, before they are relayed to the cerebral cortex. Just beneath the thalamus is the hypothalamus, a small region that is linked to the pituitary gland.



In the middle of the nineteenth century, French neurologist Paul Broca discovered that a small region in the left frontal lobe of the cerebral cortex controls human speech. This area of the brain is now called *Broca's area*. Broca made his discovery by studying people with brain damage who had lost the ability to speak. He also studied split-brain patients, people whose hemispheres were no longer connected because they had suffered damage to the corpus callosum. Broca's discovery of the speech area of the brain provided some of the first evidence that the left and the right hemispheres of the brain have separate functions, and was one of the first indicators that particular brain functions are localized in specific regions of the brain.

In the next lesson, we will study the senses in the nervous system.

LIFE PRINCIPLE



"Do not go where the path may lead; go instead where there is no path and leave a trail."

—Ralph Waldo Emerson (1803-1882)
U.S. essayist & poet



The Human Body

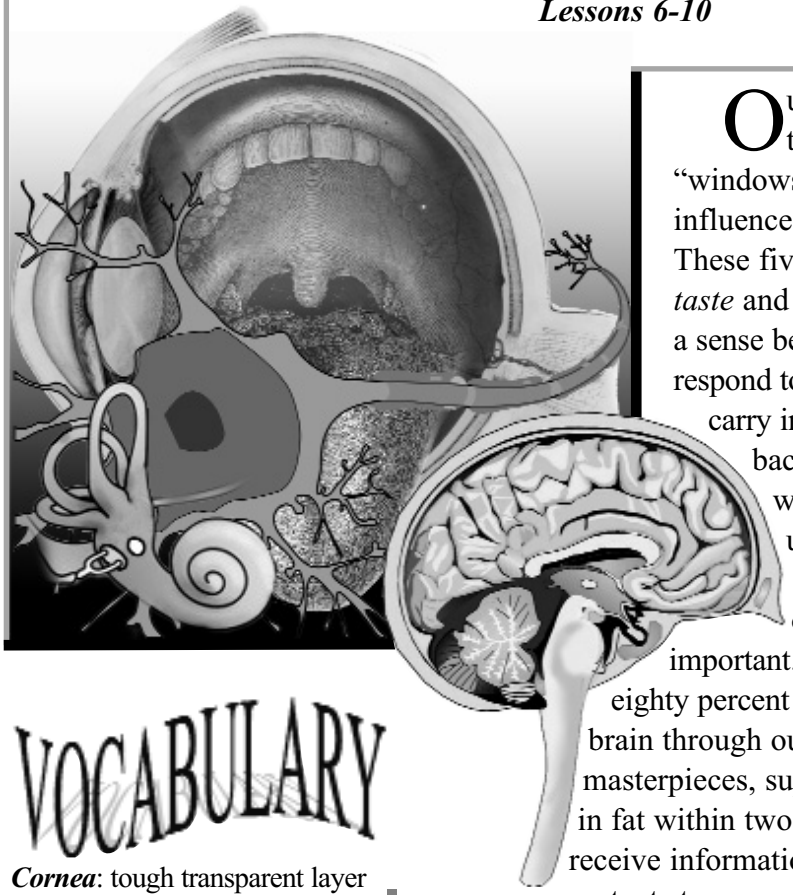
Lesson 9

Chapter 1

THE HUMAN BODY: THE NERVOUS SYSTEM—THE EYES

Section 2

Lessons 6-10



Our five senses, which we too often take for granted, constitute our "windows" to the outside world, and greatly influence our decisions and quality of life. These five senses are *vision*, *hearing*, *smell*, *taste* and *touch*. Each physical recognition of a sense begins with specialized organs that respond to the environment. Sensory neurons carry impulses from the five sense organs back to the central nervous system, where they form the basis for our understanding of the world.

Of all the senses, vision is often considered the most important. According to some estimates, eighty percent of everything we know reaches the brain through our eyes. These physiological masterpieces, supported by tiny muscles, lie nestled in fat within two bony sockets of skin where they receive information from light rays and transmit constant streams of images to the brain by electrical signals. The light rays are either absorbed or reflected. Objects that absorb all of the light rays appear to be black, whereas those that reflect all the light rays appear to be white. Colored objects absorb certain parts of the light spectrum and reflect other parts.

When you look at an object, the light rays reflected from the object enter the eye through the ***cornea***, a tough transparent layer on the surface of the eye. The cornea focuses the light, which then passes through a fluid-filled chamber. At the back of this chamber is a disk of tissue called the ***iris***. Tiny muscles adjust the size of the ***pupil***, to regulate the amount of light that enters the eye. Pigments in the iris give the eye its color, making it appear blue, brown, green or hazel.

Just behind the pupil is the ***lens***, a flexible structure

VOCABULARY

Cornea: tough transparent layer at the surface of the eye through which light enters

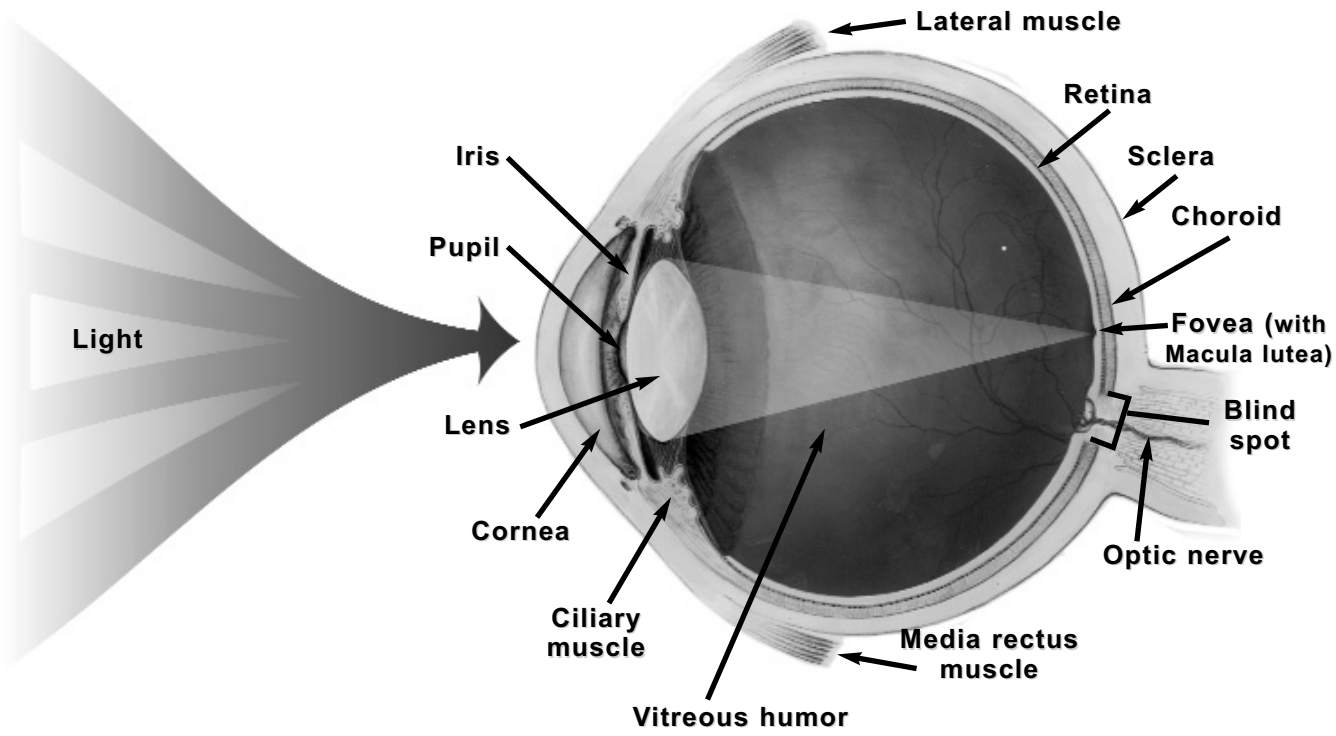
Iris: disk of tissue located at the back of the cornea

Pupil: opening in the iris that regulates the amount of light entering the eye

Lens: flexible structure behind the pupil, filled with a transparent protein; helps adjust eyes to focus to see near or far objects

Vitreous humor: transparent fluid that fills the large chamber behind the lens

Anatomy of the Eye



filled with a transparent protein. Small muscles attached to the lens change its shape to help the eye focus on near or distant objects. Behind the lens is a large chamber filled with a transparent fluid called the ***vitreous humor***.

The lens and the cornea project an image of the scene in front of the eye directly to the *retina*, the layer of cells at the back of the eye. The light-sensitive photoreceptor cells in the retina are called ***rods*** and ***cones***. Rods are extremely sensitive to light, but do not detect color. Cones, however, can detect color in 300 different shades, plus millions of possible color values, but they need more light than do rods to function properly. Rods and cones are wired directly to a series of neurons that are part of the retina. These cells help to analyze the pattern of cells stimulated by light and then relay that information to the brain through the *optic nerve*, a tiny bundle of a million nerve fibers about 2mm (.08 of an inch) in diameter, with each fiber being insulated from the others. Today's advanced ***fiber optics*** technology pales in comparison.

VOCABULARY

Rods: cylinder-shaped, light-sensitive photoreceptor cells in the back of the eye; several hundred are connected to each nerve cell

Cones: light-sensitive photoreceptor cells in the back of the eye; of 3 types—red, green, or blue pigment-sensitive

Fiber Optics: Thin, transparent fibers of glass or plastic (or bundles of such fibers) that transmit light by internal fiber reflections

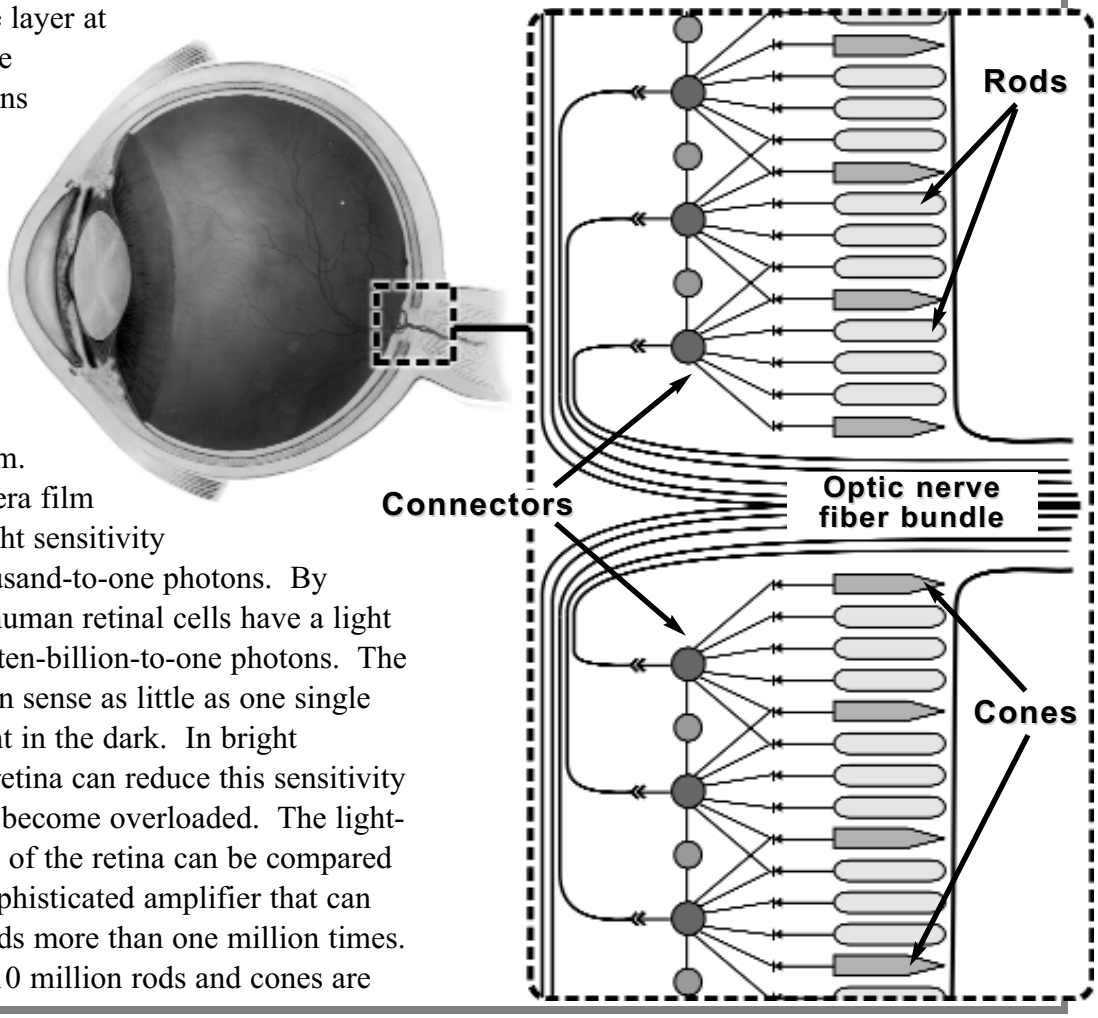
Irreducibly-complex mechanism: a structure so complex that its parts cannot operate independently

A major portion of the human brain is devoted to receiving and analyzing signals from the optic nerve. The point at which the optic nerve leads off from the retina has no rods or cones to receive light and is therefore called the "blind spot". Another retinal feature is the *fovea*, an indentation in the retina. The fovea is surrounded by the *macula lutea*. *Lutea* means "yellow" in Latin. Hence, the fovea is also called the "yellow spot". The fovea is the area of the eye where vision is most accute, due to a very dense concentration of cones.

The eye is built like a camera, but the design is infinitely more sophisticated. The most amazing feature of the human camera-like eye is the *retina*, which can be compared to the film used in an ordinary camera. This light-sensitive layer at the back of the eyeball contains 100 million optic cells, is thinner than a sheet of plastic wrap, and is more sensitive to light than any man-made film. The best camera film can have a light sensitivity ratio of a thousand-to-one photons. By comparison, human retinal cells have a light sensitivity of ten-billion-to-one photons. The human eye can sense as little as one single photon of light in the dark. In bright daylight, the retina can reduce this sensitivity so it does not become overloaded. The light-sensitive cells of the retina can be compared to a highly sophisticated amplifier that can magnify sounds more than one million times.

Over 10 million rods and cones are packed together in the retina with a density of about 200,000 per square millimeter in the central portion. These photoreceptor cells (rods and cones) have a very high rate of metabolism and must completely replace themselves about every seven days. If you were to gaze at a very bright light, such as produced by a welding torch or the Sun, your rods and cones would burn out and blindness would result. (This is why you should never look directly at the Sun, even during a full eclipse.)

Ophthalmologists (eye doctors) estimate that 10 billion calculations occur every second in the retina before an image even gets to the brain. Simultaneously, approximately 10 million other cells are



interacting in complex ways. Scientists estimate that more than one hundred years would be necessary to simulate events that take place in the eye each second. Additionally, if man were able to use current technology to build a single silicon chip capable of simulating the retina, this chip would weigh about 100 pounds, occupy 10,000 cubic inches of space and consume 300 watts of power. Your delicately engineered retina, however, weighs less than one gram, occupies about 0.0003 inches of space and consumes only 0.0001 watts. Indeed, the efficiency of the retina far exceeds the best computer chip that man can design.

Australian scientist Carl Wieland, writing in a scientific publication, stated:

> The simple act of walking into a room and immediately recognizing all the objects in it requires more computing power than a dozen of the world's top super computers put together.

The eye is a vastly superior technology that also can protect itself against dust, dryness and temperature extremes. It can self-repair minor damage, automatically adjust itself for brightness and distance, and process data before sending it to the computer (your brain). The eye has been called "the lamp of the body". Eyes are also known as the "windows of the soul", because our eyes reflect our innermost emotions, such as love, lust, happiness, sadness, confidence, fear, peace, anxiety, anger and many others.

The eye is a good example of an ***"irreducibly-complex" mechanism***. It has many parts that are interdependent, meaning that they cannot function effectively apart from each other. Attempts to explain the evolution of the eye are scientifically untested. Even Charles Darwin seemed to admit that the eye did not fit his evolutionary model. In his book *The Origin of Species*, Darwin wrote:

> To suppose that the eye with all its inimitable contrivances for adjusting the focus to different distances, for admitting different amounts of light, and for the correction of spherical and chromatic aberration, could have been formed by natural selection, seems, I freely confess, absurd in the highest degree.

In the next lesson, we will study the other four senses; hearing, smell, taste and touch.

LIFE PRINCIPLE



"Be careful what you see, for the object of your eye becomes a part of thee."

—Puritan Proverb



The Human Body

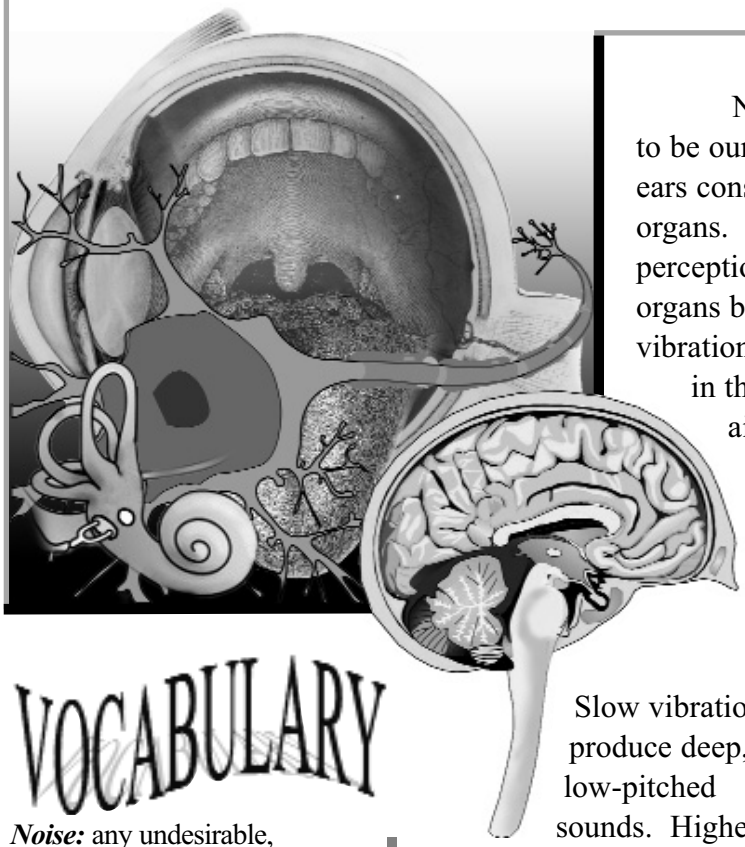
Lesson 10

Chapter 1

THE HUMAN BODY: THE NERVOUS SYSTEM— THE SENSES

Section 2

Lessons 6-10



Hearing and Balance

Next to eyesight, hearing is considered to be our most important sense. Indeed, our ears constitute our highest precision sense organs. Sounds intensify our other sensory perceptions. Sound is produced in our hearing organs by vibrations in the air. Slow vibrations produce deep, low-pitched sounds. Higher pitches result from faster vibrations. Our ears allow us to sense the pitch and determine a sound's loudness, as well as to detect its source. In fact, the ear is deemed the most sensitive of all the human sensory organs. Due to this fact, very loud ***noise*** can actually cause pain. Sound, intensity, or noise level strength, is measured in *decibels* (**dB**).

Decibel Levels of Common Sounds

Sound Source at Close Range	Decibel Levels (approximate)
Threshhold of audibility	0
Normal breathing	10
Leaves rustling	15-18
Soft whispering	20-25
Refrigerator humming	40
Automobile cruising smoothly	50
Normal Conversation	60
Noisy street traffic, Washing machine, Vacuum cleaner	70-80
Waterfall, Food blender, Lawn mower	90
Hair Dryer	95
Train roaring past	98
Power saw, Tractor	100
Jet plane (at about 1,950 feet or 600 meters)	105
Disco music, Loud thunder clap	114

Pain Threshold

Rock concert	125-150
Jackhammer, Pneumatic drill	130
Artillery fire, Air raid siren	135
Jet engine startup	145
Windows break, Ear drum ruptures	160
Rocket launch, 12" cannon	180-225

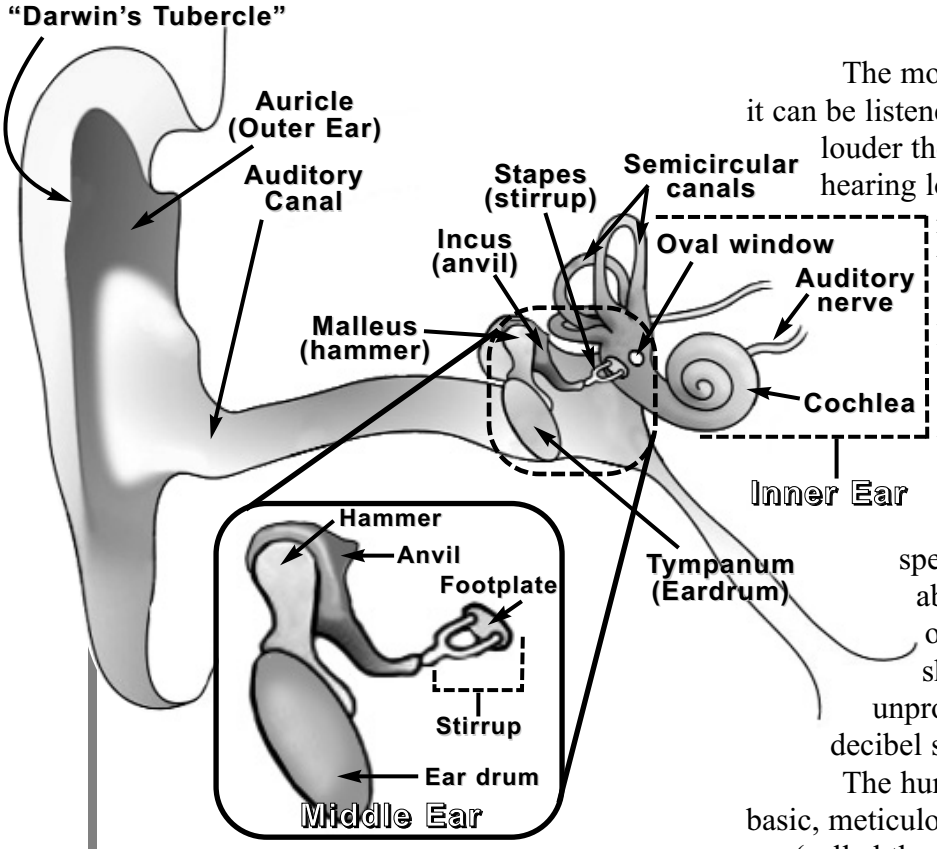
VOCABULARY

Noise: any undesirable, unpleasant sound, especially one that interferes with a person's hearing of something; from the Latin word "nausea"

Denigrate: to defame, belittle or ridicule; to deny the importance or validity of a thing

Auditory canal: region where vibrations enter the ear

Cerumen: a yellow-orange waxy substance secreted by a type of sweat gland in the ear canal; commonly called *ear wax*; from the old Latin word *sera*, meaning "wax"



The more quiet the sound, the longer it can be listened to safely. Conversely, the louder the sound, the greater the risk of hearing loss. Hearing loss occurs with regular, unprotected exposure to noises in excess of 85-110 decibels. Noise-induced hearing loss (NIHL) can be caused either by a one-time exposure to very loud noise or by repeated exposure to various loud sounds over time. Since our ability to speak largely depends on our ability to hear (as we hear ourselves and others speak), we should guard against unprotected exposure to high-decibel sounds.

The human ear is composed of three basic, meticulously designed parts: the outer ear (called the *auricle* or the *pinna*), middle ear and inner ear.

In an article entitled "The Hearing Ear", cell biologist Dr. David Menton explained:

> Long before the radio was invented, the ear was designed to convert pulses of air into electrical signals. To accomplish this marvel, ...each part (of the ear) has a different role in locating and converting signals that our brain can use.
>
> In a series of complex steps, these three parts (outer, inner & middle) are designed to conduct sound through three radically different media—air, bone, and fluid. . . .

The *auricle*, which "traps" sound waves for delivery to the brain to interpret, typically features a slight bulge or "lip" with the curious name of *Darwin's tubercle*. According to German author Werner Gitt in his book, *The Wonder of Man*, "Darwin's tubercle" derived from a book by Charles Darwin. Gitt states:

VOCABULARY

Tympanum: eardrum
Cochlea: complex, fluid-filled portion of the inner ear; smaller in diameter than the end of a ballpoint pen
Organ of Corti: a complex structure of the inner ear; converts mechanical energy produced by the eardrum into electrical energy (signals) en route to the brain; named after Italian anatomist Alfonso Corti who discovered it
Hair cells: tiny cells with microscopic "hairs" (cilia) at the top
Semicircular canals: three fluid-filled organs that help to sense position in space and maintain balance
Therapeutic: healthful, healing
Engender: promote; to cause to exist or develop

Darwin's book, *The Descent of Man and Selection in Relation to Sex* was published in 1871. In it he ***denigrated*** the external human ear, with all its convolutions, as being pointless and useless, a degenerate left-over from some alleged evolutionary history. The little protrusion on the upper outside edge of the auricle has been known since then as "Darwin's tubercle". Generations of researchers after Darwin blindly accepted his verdict on the ear. But in reality, the whole beautiful, convoluted labryrinth that is our auricle is a precise, genetically programmed device that delivers an identical additional signal to the brain after a time lag of one five-thousandths of a second.

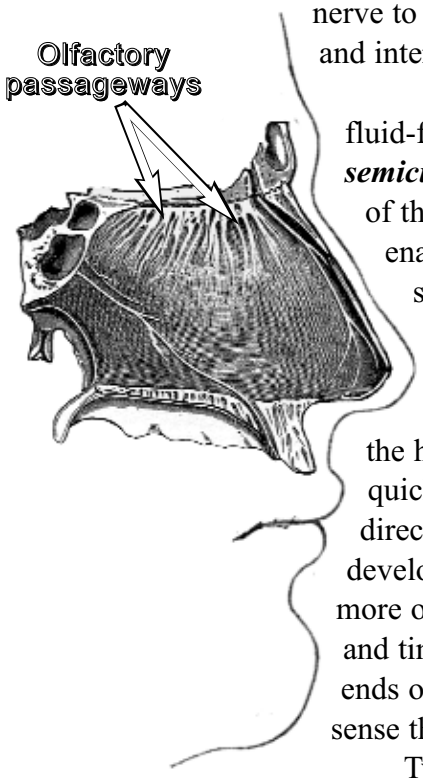
The ***auditory canal*** leading from the auricle to the ear drum is lined with special glands that produce ***cerumen*** which lubricates the canal to prevent irritation. The cerumen, which has anti-bacterial properties, traps many germs and dust particles and is normally conveyed to the front of the ear canal for removal.

Vibrations enter the ear through the auditory canal of the outer ear at 330 meters (or about 914 ft.) per second, causing the ***tympanum*** to vibrate. The vibrations are amplified in the middle ear by the three tiniest bones in the body: the *hammer* (malleus), the *anvil* (incus) and the *stirrup* (stapes). Collectively known as *ossicles*, these are the only human bones that remain the same size throughout life. The ossicles transmit the vibrations to a thin membrane called the *oval window* which covers the opening of the inner ear. The piston-like movement of the stapes' footplate against the oval window then creates pressure waves in the fluid-filled ***cochlea*** of the inner ear.



Vibrations are converted to sound in the high-frequency spirals of the cochlea, specifically in the ***organ of Corti***, which is lined with 15,000 to 30,000 tiny, delicate ***hair cells*** in neatly ordered groups and rows that are pushed back and forth by sound-pressure waves. Different groups of hair cells are responsible for different frequencies. Loud noises damage or break down the fragile hair cells, causing pain, irreversible hearing loss and/or total deafness.

Each microscopic hair tip is equipped with an even smaller "trapdoor", attached to a molecular spring and bracket, which enables the trapdoor to open and close at the mind-staggering rate of 20 to 20,000 times per second! These movements produce electrical nerve impulses that are sent to the brain through the auditory nerve to be processed and interpreted.



The three, fluid-filled ***semicircular canals*** of the cochlea enable the nervous system to sense changes in the position of the head. When the head is moved quickly in any direction, pressure is developed in one or more of the canals, and tiny hairs near the ends of the canals sense these pressures.

Two tiny sacs located below the semicircular canals are embedded in a gelatin-like substance that

contains miniscule grains of calcium carbonate. The downward pressure produced by these tiny grains enables you to sense the pull of gravity. The semicircular canals and the two tiny sacs enable you to sense your body's position and maintain proper body balance.

Smell

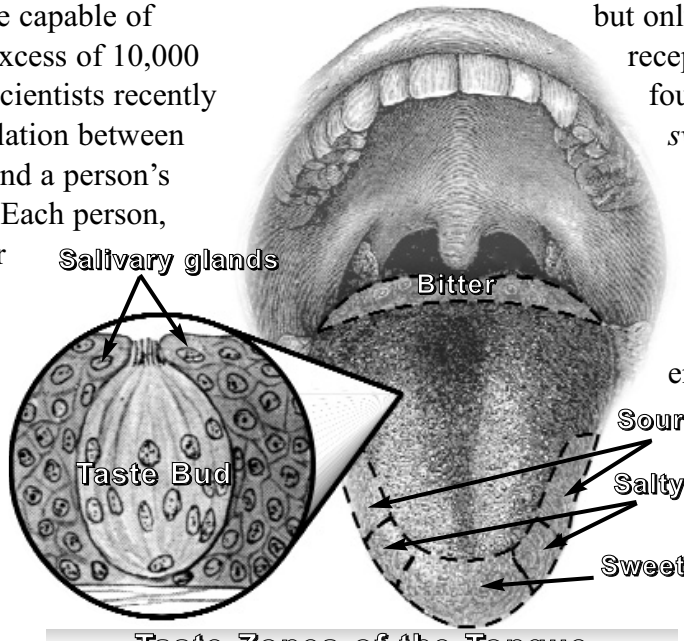
The nose is a unique organ that enables us to deduce numerous details concerning our surroundings. The nose helps us to enjoy food, drink and fragrances, and helps to avoid many dangerous or contaminated substances and situations. Favorable and unfavorable experiences are brought to remembrance through the sense of smell. The sense of smell is actually the ability to detect chemicals. Ten to 25 million special cells in the upper part of the nasal passageway (olfactory region) act as receptors for a variety of chemicals. When stimulated, these cells, called *olfactory neurons*, produce nerve impulses that travel to the central nervous system.

Humans are capable of distinguishing in excess of 10,000 different scents. Scientists recently discovered a correlation between detectable scents and a person's number of genes. Each person, then, has his or her own genetically-programmed olfactory preferences. This explains why something that smells good to you may not impress someone else. Each person also has a unique, personal, genetic scent as exclusive as a snowflake or your fingerprint. This feature enables an infant "unknowingly" to recognize its mother, even if the infant is blind.

Much of what is commonly called the "taste" of food actually depends on your sense of smell. To prove this, recall the last time you had a severe head cold, or eat a few bites of food while holding your nose. You will discover that the food does not have much taste until you open your nose and breathe freely. This is because breathing through your mouth does not transfer favorable scents very well. The good news is that you can avoid being overcome with obnoxious smells by breathing through your mouth—like the next time you chop onions or encounter a skunk.

Taste

Taste and smell are closely connected, although scents are thousands of times easier to detect than flavors. This is because you have thousands of *scent* receptors, but only four types of *taste* receptors. However, these four receptor zones—*sweet*, *salty*, *sour* and *bitter*—still enable you to distinguish between thousands of tastes because of the 5,000 to 10,000 taste buds embedded in your tongue. Your taste zones affect your digestion by sending messages to other glands, even while you are chewing, to dispense the



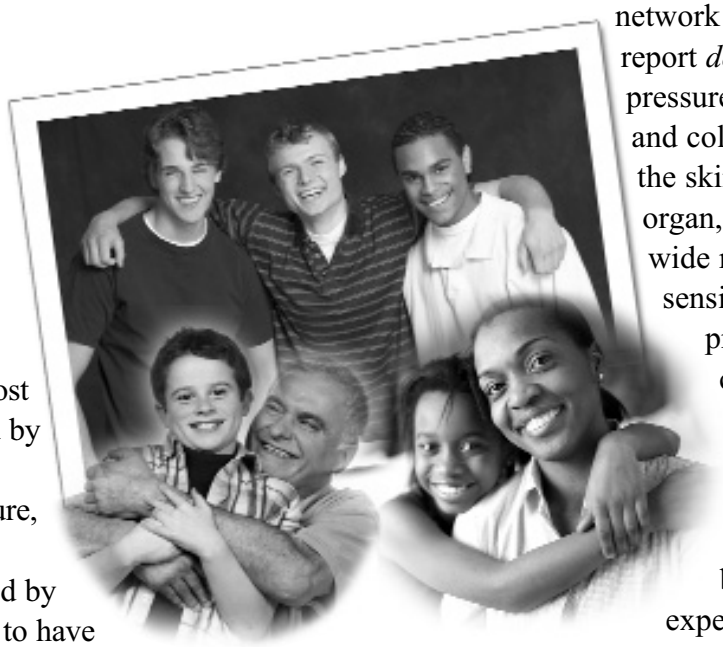
Taste Zones of the Tongue

appropriate secretions needed to metabolize the food about to be swallowed. The *taste zones* also give meaning to many of our verbal expressions, such as, "She is a *sweet* person"; "That was a *bitter* experience"; or "He has such a *sour* attitude."

Taste buds are so named because they resemble tiny flower buds. Taste buds detecting bitter items serve to warn us of toxic substances, as most intensely bitter substances (such as potato sprouts) are poisonous.

TOUCH

The sense of touch is indispensible and is the first sense to develop. This sense helps enable the blind and deaf to orient themselves to their surroundings. While most things may be appraised by our other senses, some things such as temperature, texture, stickiness, and weight must be discerned by touch. Touching is said to have ten times more emotional impact than verbal expressions alone. Appropriate, non-sensual touch and hugs are ***therapeutic*** and ***engender*** bonding.



Our language contains many metaphors that pertain to our sense of touch: our emotions are called "feelings"; we are "deeply touched" by certain words; we have "ticklish" problems or encounter "sticky" situations; a person who offers no resistance to a thing is called a "softy" or a "pushover", and a judge should be "hard" on crime.

The largest sense organ in your body is your skin, which contains different receptors for touch, pressure, heat and cold. Each receptor responds to its particular stimulus and produces nerve impulses that signal the central nervous system. Not all the parts of the body are equally sensitive to touch, because not all parts have the same number of receptors. The greatest concentration of touch receptors is found in your fingers, toes and lips.

The body does not seem to have any special cells dedicated to the sensation of pain, because pain is tied to an elaborate network of sensors that report *degrees* of pressure, touch, heat and cold. Although the skin is a single organ, it displays a wide range of sensitivity to pressure. Less critical areas do not need such sensitivity, and many parts of the body must experience something extraordinary before unusual activities are reported to the brain. Fingers, however, are incredibly sensitive to the slightest feather touch, or differences in touch, yet able to withstand rigorous activity. If you ever shake the hand of a carpenter or an experienced farmer, you will probably feel calluses on their hands. Although calluses are a buildup of tissue, the fingertips are still very sensitive to pressure, but less sensitive to pricks by sharp objects.

Pain is a very important sensation. The main difference between pain and touch is the intensity of the pressure that is exerted.

Pain is usually not thought of as a blessing; however, without sensations of pain, people would unknowingly suffer great physical damage. For example, certain sensations cause us to remove our fingers from hot objects that could inflict severe damage. Persons with Hansen's disease often experience damage due to *lack* of pain sensations. Hansen's disease is commonly known as *leprosy*. People with this disease experience extensive nerve damage which results in a loss of pain sensations. Without pain, these patients' bodies cannot warn the person of certain dangers. Inevitably, people with Hansen's disease damage themselves because they feel no pain; they may unknowingly let hot objects burn their hands or sharp objects cut their fingers.

In the next lesson, we will examine the integumentary system.



LIFE PRINCIPLE

"The quality of our human experience is in large measure determined by our senses."

—Werner Gitt
In *The Wonder of Man*



The Human Body

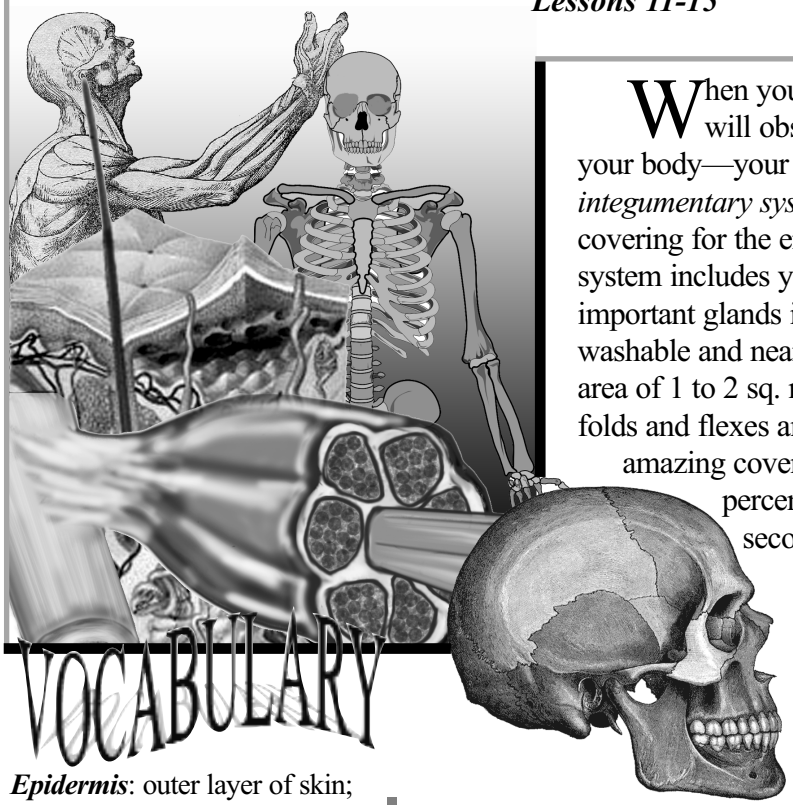
Lesson 11

Chapter 1

THE HUMAN BODY: THE INTEGUMENTARY SYSTEM

Section 3

Lessons 11-15



When you look at yourself in the mirror, you will observe portions of the largest organ of your body—your skin. The skin is part of the *integumentary system* which acts as a protective covering for the entire body. The integumentary system includes your skin, hair, nails, and a number of important glands in the skin. Your skin is elastic, washable and nearly watertight. It covers a surface area of 1 to 2 sq. meters (3.28 to 6.56 sq. feet) as it folds and flexes around joints and bulges. This amazing covering comprises about twelve to fifteen percent of your overall bodyweight and is second only in complexity to your brain.

VOCABULARY

Epidermis: outer layer of skin; from two Greek words meaning *upon* or *above* the skin

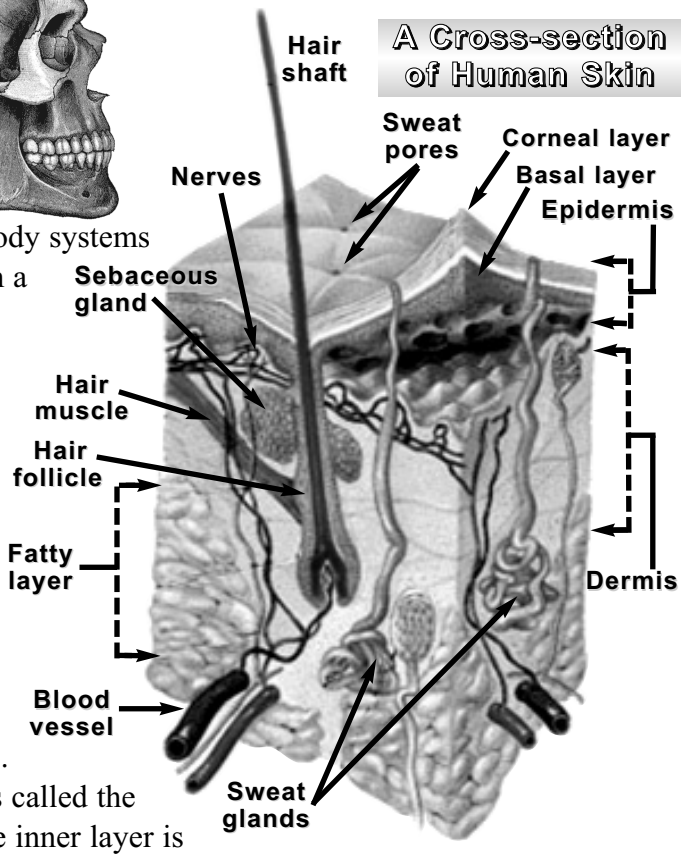
Dermis: inner layer of skin that supports the epidermis; contains nerve endings, blood vessels, smooth muscle and glands

Keratin: a complex protein substance; the chief component of hair, nails, horns and feathers; from the Greek word "keratos" meaning *horn*

Melanocytes: cells in the epidermis that produce pigments found in the epidermis; contain melanin

Melanin: dark-brown pigment that gives skin its color

Several body systems are represented in a cross-section of human skin—notably the integumentary system, the muscular system, the circulatory system and the nervous system. The skin is made up of three layers. The outer layer is called the ***epidermis*** and the inner layer is called the ***dermis***.



Epidermis

The *epidermis* is made up of layers of *epithelial cells*. Deep in the epidermis, these cells grow and divide rapidly, producing new cells that are gradually pushed toward the surface of the skin, where they number about 6,000 per square centimeter. As they move upward, the cells begin making ***keratin***, a tough, flexible protein that is also the major protein found in hair and nails.

As they near the surface, epithelial cells die; however, the keratin remains, forming a tough, waterproof layer on the surface of the skin. Then, as you work, play and bathe, millions of these cells are removed and the skin replaces expired cells with new ones.

Cells that produce pigments are called ***melanocytes*** and are also found in the epidermis. They contain granules of ***melanin***, a dark-brown pigment that gives skin its color. Most people have the same number of melanocytes in their skin, but dark-skinned people produce more melanin than people with light skin.

Dermis

The *dermis* supports the epidermis and contains cells such as nerve endings, glands, blood vessels and smooth muscles. When you feel something by touching it with your fingers, touch receptors in your dermis are picking up the sensation.

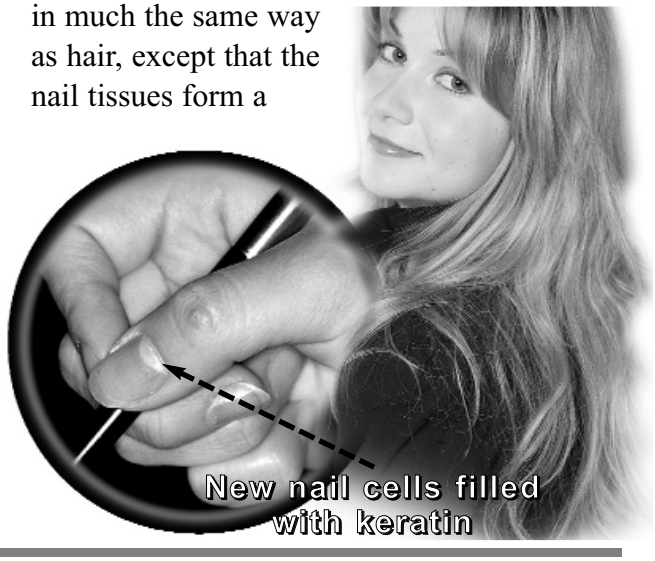
The dermis reacts to the body's needs in a number of ways. For example, on cold days when you need to conserve heat, blood vessels in the dermis narrow, limiting the loss of heat. When the body is hot, the same vessels widen, bringing more blood to the skin. This warms the skin, causing loss of heat.

The dermis also contains two types of glands: 100 *sweat glands* and 15 *sebaceous (oil) glands* per square centimeter of skin. Overall, your body contains about 200 million sweat glands. Your hands and the soles of your feet contain an exceptionally large amount. Sweat glands produce a watery secretion that contains ammonia, salt and other compounds at an average rate of nearly a quart or liter per day that exit the body through the skin. These glands are controlled by the nervous system, which activates them to cool the body when it gets too hot. Sebaceous glands produce an oily secretion that helps keep the epidermis flexible and waterproof.

Nails and Hair

Hair is composed of columns of dead cells filled with ***keratin*** that overlap like roofing shingles. Clusters of such cells make up *hair follicles*, which are anchored in the dermis. Cells multiply in the base of the follicle, causing the hair to grow longer. Hair color is dependent on one's genetic code and results from melanin pigments that are produced in the hair folicle, which, in turn, are subject to influences of diet and stress levels.

Toenails and fingernails are produced in much the same way as hair, except that the nail tissues form a



flattened plate. Nails grow to cover and protect the ends of the fingers and the toes. Have you ever wondered why your fingernails show "half-moons" at the base? The half-moons are where new nail cells are produced and filled with keratin. Older cells are continuously pushed forward, causing our fingernails and toenails to "grow". Actually, both hair and nail cells are dead cells, which is why no pain is felt in cutting them.

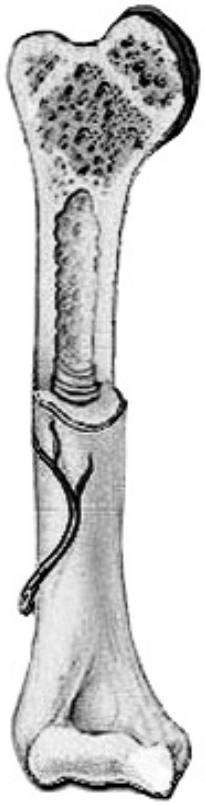
In the next lesson, we will begin a study of the skeletal system.

LIFE PRINCIPLE



"Physical beauty is only skin deep; beauty of character is more than that which meets the eye."

—Ronald E. Johnson, Ph.D.
Educator and author





The Human Body

Lesson 12

Chapter 1

THE HUMAN BODY: THE SKELETAL SYSTEM—PART I

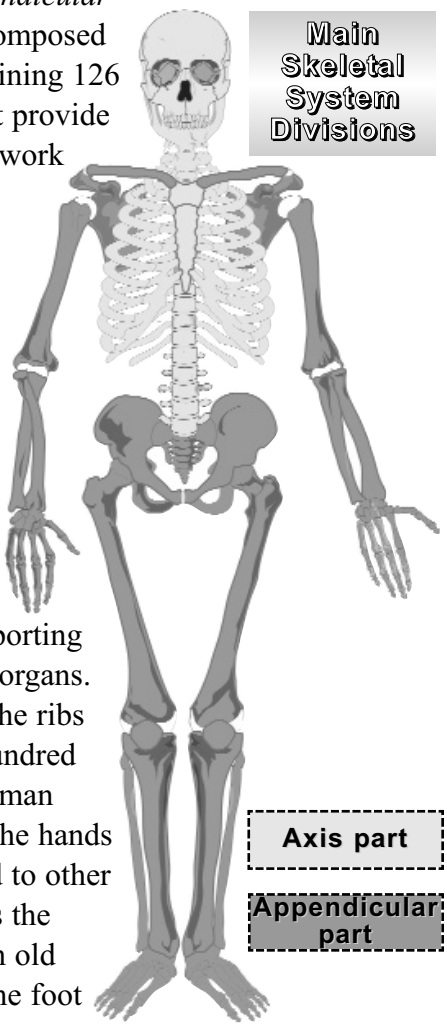
Section 3

Lessons 11-15



The human skeletal system is composed of two main parts: the ***axial skeleton*** and the ***appendicular skeleton***. The *axial* skeleton consists of a total of 80 bones for the skull, ribs, sternum and vertebrae. The skull itself is composed of 29 bones—8 bones form the cranium, 14 constitute facial bones, 6 are middle-ear bones and 1 supports the tongue. The rib cage consists of 12 pairs of curved rib bones attached to the sternum, and the spine is made up of 26 precisely stacked vertebrae.

The *appendicular* skeleton is composed of the remaining 126 bones that provide the framework for the body's appendages: the arms and legs (each of which contain 30 bones), collar bone, shoulder blades and pelvic bones. All together, the human skeleton averages a mere 20 percent of body weight.



The skeleton is the framework of the human body, supporting the body and protecting its internal organs. The skull protects the brain, while the ribs protect the heart and lungs. Two hundred and six bones compose the adult human skeleton, over half of which are in the hands and feet. Most bones are connected to other bones at flexible joints, which gives the human framework much agility. An old Southern spiritual song states that the foot

VOCABULARY

Axial skeleton: main body axis to which other bones attach

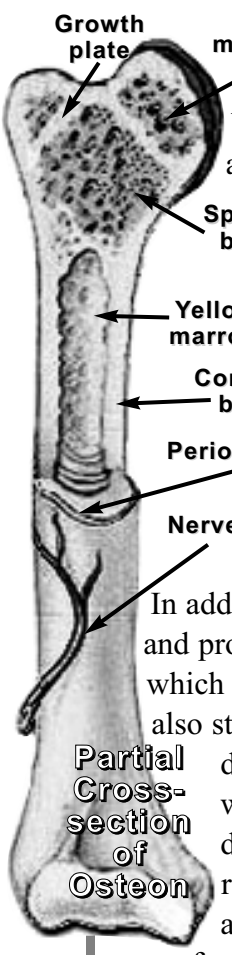
Appendicular skeleton: comprises framework for body's appendages

Hyoid bone: anchors the tongue and is attached to the skull by ligaments

Perisoteum: tough membrane that covers the bones

Compact bone: dense layer of hard bone with spaces for Haversian canals

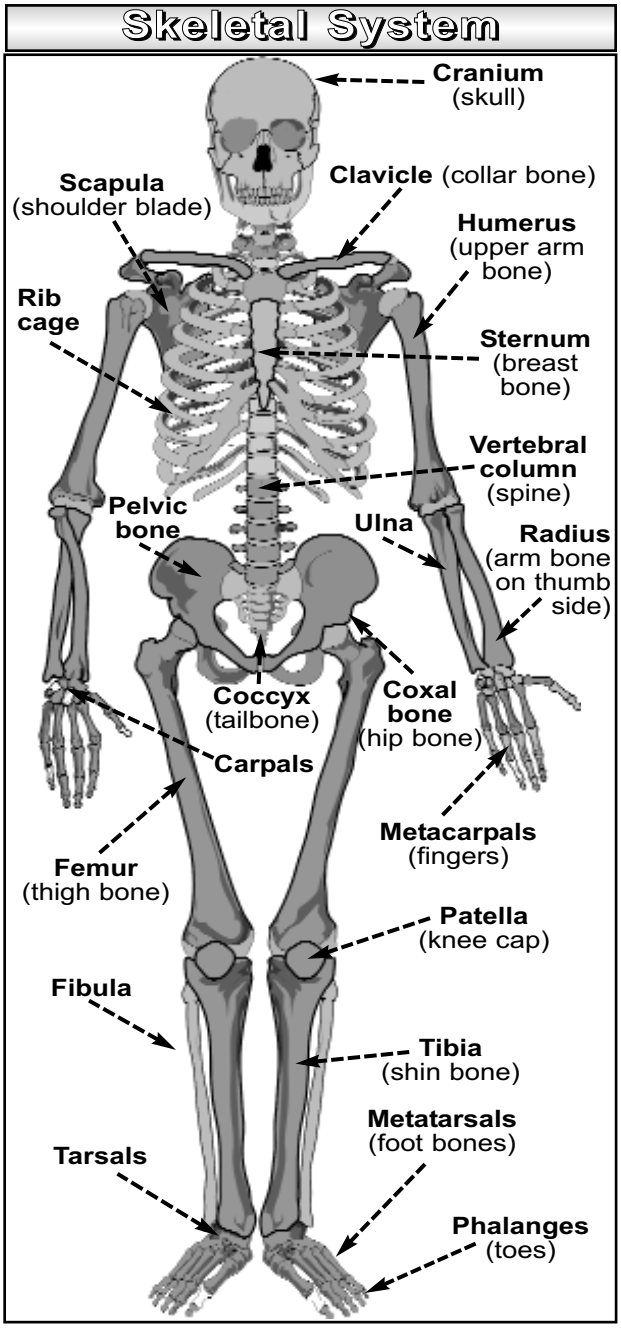
Haversian canals: small channels in compact bone through which nerve and blood vessels run; also called *osteons* from the Greek word for bones



bone is connected to the leg bone and the leg bone is connected to the thighbone. This is true. In fact, every bone is connected to another with one exception. Only the ***hyoid bone*** is not directly connected to another bone. It anchors the tongue and is attached to the skull by ligaments.

Bones serve a number of other purposes in the human anatomy. In addition to providing support, structure and protection, bones also house marrow, which produces blood cells. The bones also store calcium and phosphorus deposits which the body accesses when needed. Additionally, bones detoxify the body system by removing heavy metals, such as lead and arsenic, as well as other toxins from the bloodstream. An ancient Hebrew principle states that bitterness eats away at the bones. The implication is that life's choices and reactions affect one's skeletal system.

Bones come in various shapes and sizes which reflect their varied functions. Long bones, such as the thighbone, act as levers. Short bones, such as those in the wrist, are almost cube-shaped and provide support and flexibility. Flat bones, like ribs, are protective shields. The thighbone, or femur, is the body's longest bone; the ossicles of the middle ear that vibrate to sounds are the smallest human bones.



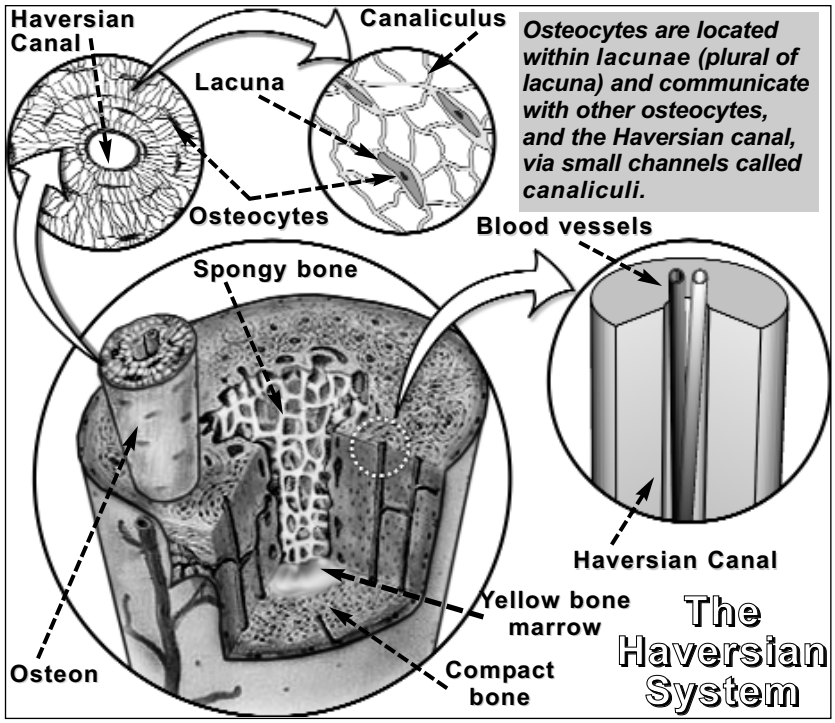
VOCABULARY

Spongy bone: region of resilient, supportive bone tissue within the compact bone with an interlaced pattern that withstands stress

Osteocytes: cells embedded in both compact and spongy bone that help build and maintain bones

Red bone marrow: blood-forming tissue that produces red and white blood cells

Yellow bone marrow: area in bone that contains blood vessels, nerves and fat



Bone Structure

Bones are far from stiff, lifeless sticks. Nerves etch their surfaces and blood vessels flow through them. Bones are continuously alive with metabolic activity. If you have ever broken a bone, you understand how sensitive bones are to contact or stress.

Bones are more complicated than their outward appearance. A cross section reveals cells that resemble tree rings. Bones are surrounded by a tough membrane called the ***perisoteum***. Just inside the periosteum is a dense layer of hard, ***compact bone***. Bone hardness is the most important feature that sets it apart from all other body tissues. Without hardness, bone tissue would be useless for body support. The compact bone layer has a number of openings that allow the nutrient blood vessels to tunnel through to reach the cavity within. A series of ***Haversian canals*** containing nerves and blood vessels run through the compact bone. A region of ***spongy bone*** is usually located just inside the compact bone. Although less dense than compact bone, spongy bone is strong and resilient.

Embedded in both compact and spongy bone are cells called ***osteocytes***. Osteocytes help to build and maintain bones. They deposit the minerals that make up bones and can be reabsorbed when the body needs minerals in other areas.

Inside many larger bones is a region of blood-forming tissue called ***red bone marrow***. Many white, and all red blood cells, are produced in these efficient, red bone marrow factories that manufacture a trillion new cells each day. The red bone marrow also plays an important role in the immune response. ***Yellow bone marrow*** is found inside the main bone cavity and is made up of blood vessels, nerve cells and fat.

Bones begin forming during the first two months of fetal life and continue to grow long after birth. Bone begins as cartilage and gradually becomes bone. Osteocytes near the surface of the bone begin this process, gradually moving inward, depositing minerals that replace the cartilage with bone. The long bones of the arms and legs have growing points at either end called *growth plates*. Cartilage is produced at these plates and then is gradually replaced by bone as the skeleton enlarges.

Bone growth continues into young adulthood, as the genetic code determines the size and height of our skeletal structures. The pituitary gland, working from instructions from the genes, instructs the bones to stop growing at a certain time. The ends of the bones solidify at that point, and bone growth ceases, meaning that a person does not grow taller. Most skeletal growth ceases before

age twenty-one. The end of growth does not mean bones become inert, or inactive, however. Throughout life, new bone is constantly forming while old bone cells are being torn down and reabsorbed.

In the next lesson, we will continue our study of the skeletal system.

LIFE PRINCIPLE



"Either (a respect for truth) is rigid and dependable, like healthy bone, or it is useless."

—Dr. Paul Brand
In *Fearfully & Wonderfully Made*



The Human Body

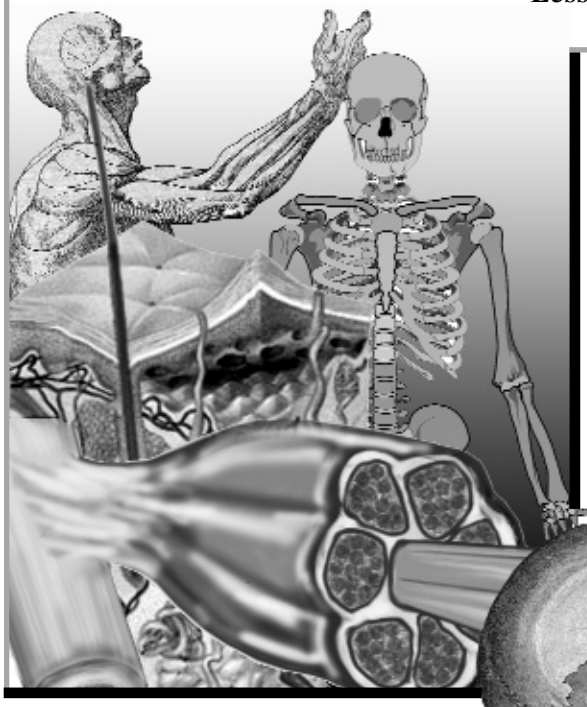
Lesson 13

Chapter 1

THE HUMAN BODY: THE SKELETAL SYSTEM—PART II

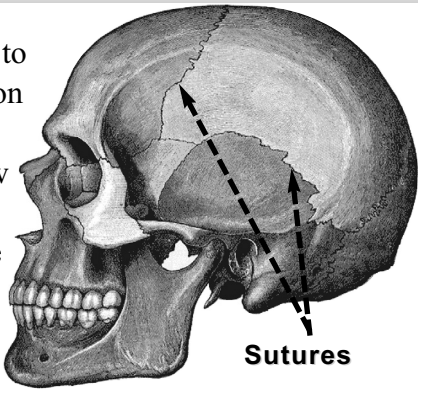
Section 3

Lessons 11-15

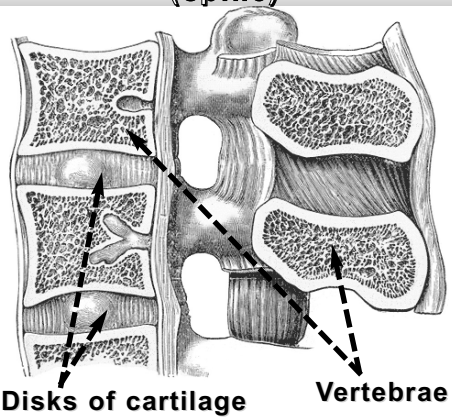


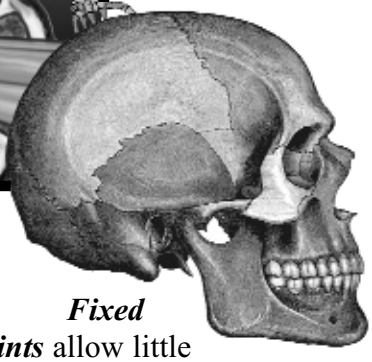
Joints are the places where two bones meet. The ability to move depends not only on the muscles, but also on the joints that must allow bones to move smoothly across each other. Three kinds of joints exist: *fixed*, *slightly moveable* and *freely moveable*.

Fixed joint (skull)



Slightly moveable joint (spine)





Fixed joints allow little or no movement between bones. Some of the most important fixed joints are those of the skull. These joints have not always been so tightly "fixed", however. An infant has a "soft spot" on top of its forehead and other portions of the skull which are not solidified (for purposes of growth) until about age four. Skull bones from middle childhood onward do not move. Their purpose is to protect the brain and sense organs in the head. Skull bones are joined by ***sutures*** which look like cracks in the bone.

Slightly moveable joints allow a small amount of movement. The bones of the spinal column, as well as the ribs, are slightly moveable joints. The bones of the spinal column are separated from each other by pads of fibrous ***cartilage***, called *disks*. Cartilage is extremely flexible and absorbs most of the shocks and strains of everyday activity.

VOCABULARY

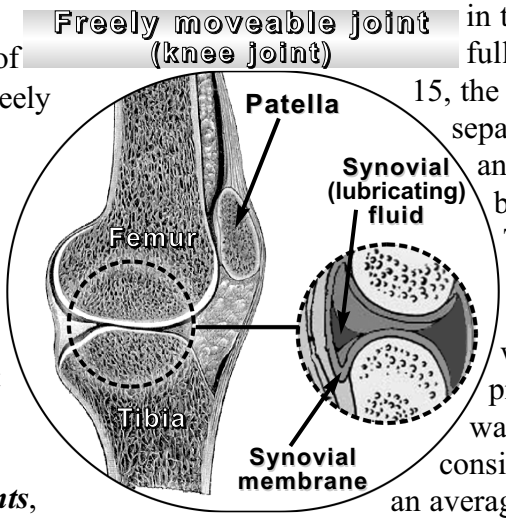
Fixed joint: joining place of two bones where little or no movement exists; also called an immoveable joint

Sutures: lines formed by adjoining cranial bones having only a thin layer of connective tissue in between

Slightly moveable joints: joining place of two bones where a small amount of movement and flexibility exists, such as in the spinal column or ribs

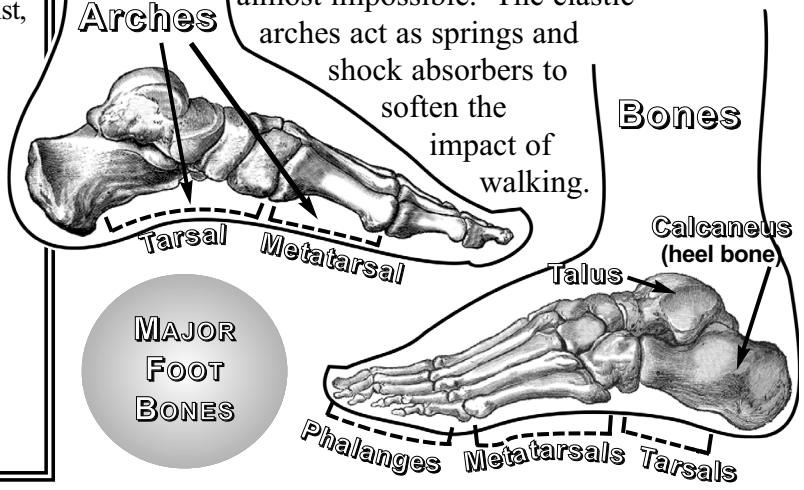
Cartilage: strong, resilient connective tissue

Freely moveable joints allow a wide range of movement. Ball-and-socket joints, located in the shoulders and hips, allow the widest range of movement. Other types of freely moveable joints include the elbow, the toes and the base of the fingers. The bone ends in freely-moveable joints are covered with layers of cartilage, providing a smooth surface at the point of contact. The joint itself is enclosed by a capsule. The capsule may include ***ligaments***, which are tissues that connect the bones of the joint. The capsule may also include ***tendons***, which connect muscles and bones. Inside the capsule is the ***synovial fluid***, a natural lubricant that reduces friction and allows the cartilage-coated bones to readily slip across each other.



THE FOOT

The human foot is a particular marvel in the human skeleton. Not fully formed until nearly age 15, the foot consists of twenty-six separate bones of various sizes and shapes, bound together by a system of ligaments. The foot has two, architecturally-perfect arches that support the weight of the body and provide leverage when walking. This is critical, considering that a person walks an average of 65,000 miles in a normal lifespan, which amounts to about two and a half times around the world! The arches are not rigid; they yield when weight is placed on the foot and spring back as the weight is lifted. These tarsal and metatarsal arches are held in place and supported by a complex network of strong ligaments and tendons that carry the weight of the body, just as steel cables carry the load of a suspension bridge. The ability to walk, to move from place to place, and to balance the tall, upright human body on a comparatively small area is a remarkable feature of the human body. If the foot were flat, rigid and fixed at right angles to the bone of the leg, walking would be almost impossible. The elastic arches act as springs and shock absorbers to soften the impact of walking.



MAJOR FOOT BONES

VOCABULARY

Freely moveable joints: joining place of two bones where a wide range of movements exist, such as in the shoulders, hips, elbows and knees; hinge joints

Ligament: band of tough, elastic tissue that connects the bones of a joint

Tendon: cord of tissue that connects muscles and bones

Synovial fluid: a friction-reducing lubricant found in joints

Orthodontist: a dentist who specializes in straightening irregular teeth by means of braces

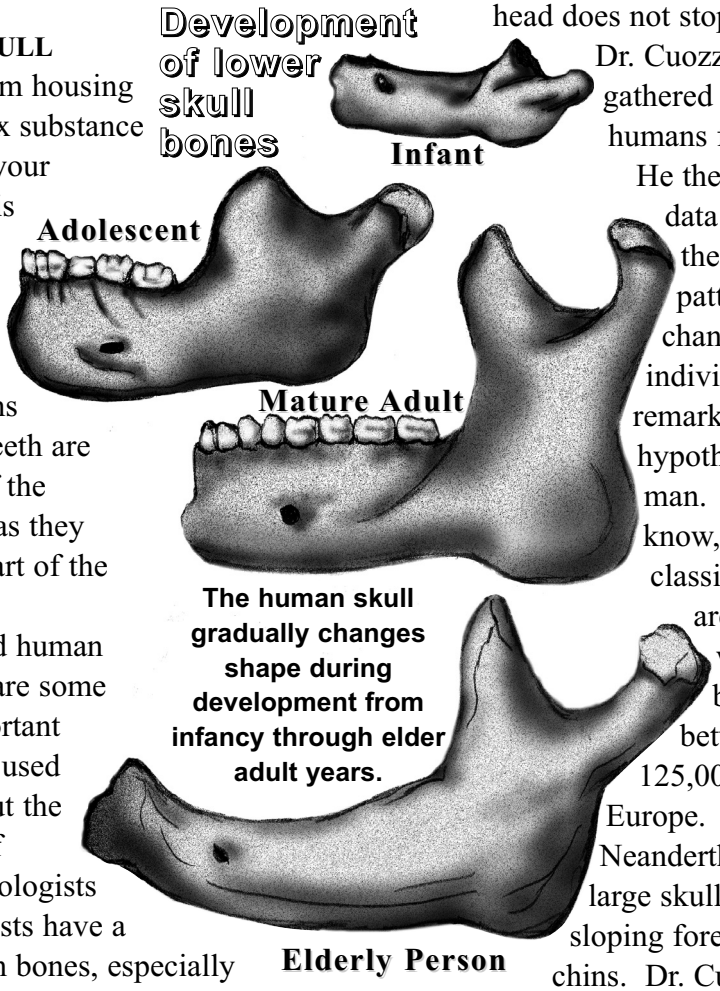
No other creature has feet comparable with the magnificent design of the human foot; its unique features enable great flexibility of movement.

The Skull

Aside from housing the most complex substance in the universe (your brain), the skull is one of the principle groups of bones in the human skeleton. The skull contains 26 bones. The teeth are treated as part of the skeletal system, as they are an integral part of the skull.

Fossilized human skulls and teeth are some of the most important fossil specimens used to speculate about the age and origin of humans. Archaeologists and anthropologists have a special interest in bones, especially skull bones, because they give clues to mankind's history. Let's look at what scientists can tell about the human skull.

A baby's skull is fashioned with cartilage as well as bone. The human skull gradually changes shape during development from fetus to infant to adolescent to adult. This developmental process has been recognized by scientists for several hundred years.



The human skull gradually changes shape during development from infancy through elder adult years.

In his book *Buried Alive*, Dr. Jack Cuozzo, a research ***orthodontist***, presents some fascinating ideas about the human skull. His studies suggest that the human head does not stop growing as it ages. Dr. Cuozzo observed data he gathered from research on humans from birth to age 90. He then extrapolated that data out to 500 years. At the 500-year point, the pattern of projected change would produce an individual that looked remarkably like the hypothetical Neanderthal man. As you probably know, the oldest fossils classified as *Homo sapiens* are the Neanderthals, who some scientists believe lived sometime between 35,000 to 125,000 years ago in Europe. The adult Neanderthals supposedly had large skulls and heavy faces, sloping foreheads and small chins. Dr. Cuozzo's conclusion is that the large-browed Neanderthal man was just an old human whose skeletal features were a natural consequence of aging. Other scientists disagree and propose the theory that human evolution included Neanderthals from Europe and Cro-Magnons from France. Recent DNA studies, however, suggest that the Neanderthals were not human ancestors.

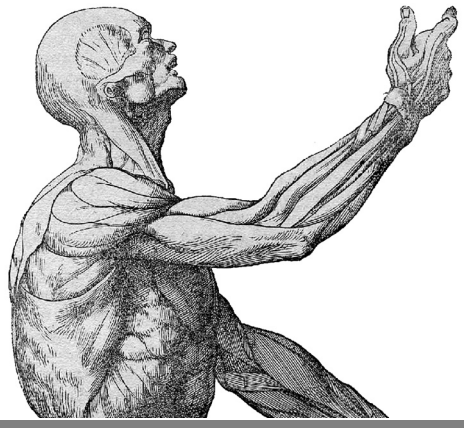
In the next lesson, we will begin a study of the human muscular system.



Life Principle

"Bitterness rots the bones."

—Ancient Hebrew proverb





The Human Body

Lesson 14

Chapter 1

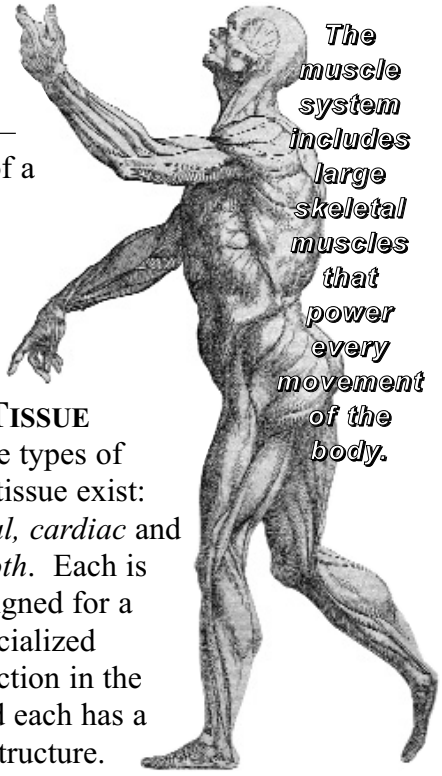
THE HUMAN BODY: THE MUSCULAR SYSTEM—PART I

Section 3

Lessons 11-15



Although the framework of the body consists of bones and joints, ***muscles*** are required to move the body. Motion results from the contraction and relaxation of muscles. The human body contains over 600 major muscles anchored to the skeleton. Inside these muscles are about 6 trillion individual muscle fibers which constitute about 40 percent of the total body weight (twice as much as bones) and are composed of highly specialized cells. The muscular system includes the large muscles, which athletes proudly display as signs of physical strength and development. The largest muscle in the body is the *gluteus maximus*, which forms the buttock. The muscle system also includes thousands of tiny muscles that regulate blood pressure throughout the body, move food through the digestive system and power every movement of the body—from the blink of an eye to the hint of a smile. The smallest muscle is the *stapedius*, which is located near the tiny stapes bone in the middle ear.



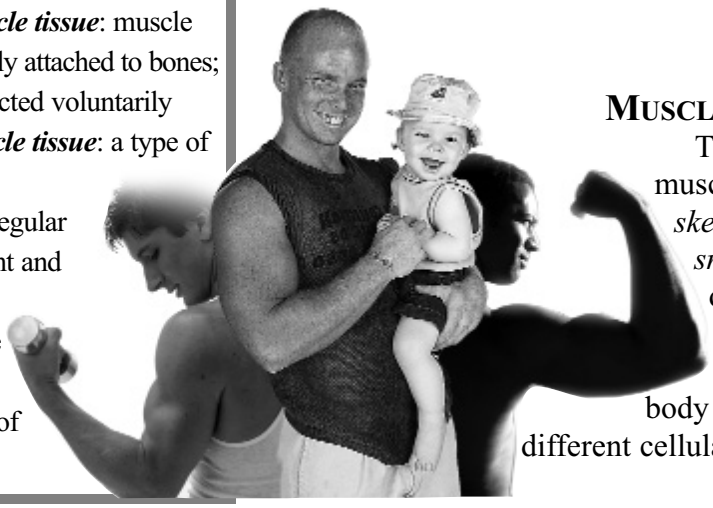
The muscle system includes large skeletal muscles that power every movement of the body.

VOCABULARY

Muscle: body tissue responsible for movement; from a Latin word meaning *mouse*, so called due to the appearance of certain muscles

Skeletal muscle tissue: muscle tissue generally attached to bones; can be contracted voluntarily

Striated muscle tissue: a type of muscle tissue exhibiting a regular pattern of light and dark bands, caused by the regular arrangement of muscle fibers

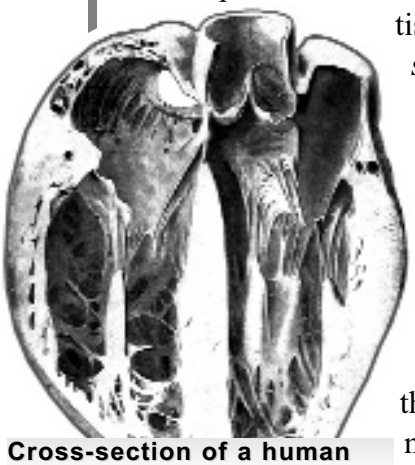


MUSCLE TISSUE

Three types of muscle tissue exist: *skeletal, cardiac* and *smooth*. Each is designed for a specialized function in the body and each has a different cellular structure.

Skeletal Muscular Tissue

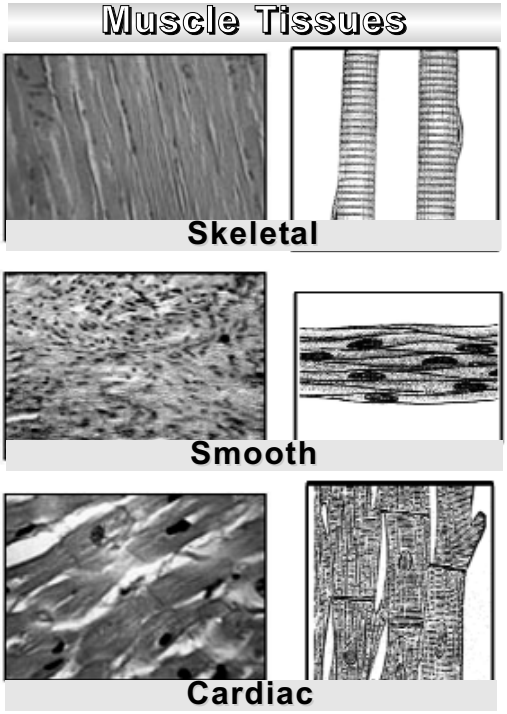
Skeletal muscle tissue is generally attached to the bones of the skeleton by means of *tendons*, and is usually under voluntary control, governed by the somatic nervous system. Skeletal muscle tissue is behind every conscious movement the body makes, whether the action is lifting a bale of hay or tying a shoe. This is because most skeletal muscle tissue is controlled directly by the nervous system. Skeletal muscle cells have many nuclei because they are formed during development by the fusion of many individual cells. Skeletal muscles can be very large—as long as 20 inches in the large muscles of the arms and legs. Under the light microscope, skeletal muscle cells appear to be striped. For this reason, skeletal muscle tissue is often called ***striated muscle tissue***.



Cross-section of a human heart showing various chambers and muscle fibers.

Cardiac Muscle Tissue

Cardiac muscle tissue is found in one place—the heart. Cardiac muscle tissue is striated, but the smaller cardiac muscle cells contain only one nucleus each. Cardiac muscle tissue is red-colored. This muscle is fast acting and powerful, and its actions are involuntary. This means that the heart muscle contracts automatically and rhythmically. Heart muscles are not under the direct control of the central nervous system, but are controlled by the autonomic nervous system. They continually contract and relax throughout life. The average human heart beats 72 times per minute for seventy-five years. This is equivalent to over two billion times in an average lifetime. Blood is pumped through 60,000 miles of blood vessels every day of our lives. During the lifespan of a 75-year old person, the human heart will have pumped 225 million quarts of blood through those 60,000 miles. We will take an in-depth examination of the heart in a future lesson.



Smooth Muscle Tissue

The cells of ***smooth muscle tissue*** are spindle-shaped, have a single nucleus in

VOCABULARY

Cardiac muscle tissue: muscle tissue found in the heart; not under direct control of the central nervous system

Smooth muscle tissue: spindle-shaped, unstriated muscle tissue found in internal organs and blood vessels; not under conscious control of the nervous system

each, and are not striated. Smooth muscle tissue operates the body's automatic processes—those under control of the autonomic nervous system—such as digestion, breathing and heartbeat.

Smooth muscle tissue is found in the walls of blood vessels, the digestive tract and the dermal layer of skin. They react slowly to stimuli from the autonomic nervous system and are responsible for forcing food through the intestines, transporting urine to the kidneys and pumping blood through veins and arteries. These muscles are involuntary and are slow-acting, untiring and steady in action, evidenced by the fact that we are scarcely aware of their operations. Although smooth muscle tissue contracts much more slowly than skeletal muscle tissue, it can maintain its contraction for a much longer period of time.

Without muscles, ligaments and tendons, the skeletal framework would be incapable of movement.

In the next lesson, we will study more about the action and movement of muscles.

Career Bound?

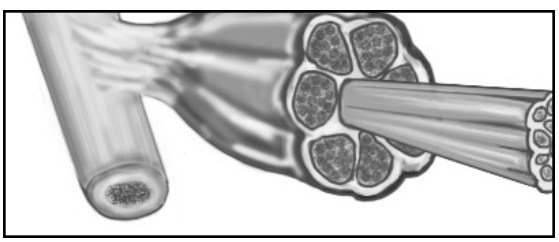
Physical Therapists work to help restore muscle and bone movements, and to relieve pain in injured body parts.



LIFE PRINCIPLE

"The glory of young men is their strength."

—King Solomon
Called "the wisest man who ever lived"





The Human Body

Lesson 15

Chapter 1

THE HUMAN BODY: THE MUSCULAR SYSTEM—PART II

Section 3

Lessons 11-15



To understand how a muscle works, we can look inside the kind of muscle cell that is best understood by scientists—the skeletal muscle cell. Scientists have learned a great deal about skeletal muscle, partly because their regular structure make them easier to study.

MUSCLE STRUCTURE

With the aid of an electron microscope, we can see that the striations in skeletal muscle cells are formed by alternating patterns of thick and thin filaments. These filaments are called ***myofibrils***. The thicker filaments are made of the protein ***myosin***, and the thinner are made of the protein ***actin***. These thick and thin *myofilaments* overlap in a regular pattern, producing the striations that appear under the microscope.

Muscles work by contracting and relaxing. Every muscle movement is a pull. Tiny actin and myosin filaments are the force-producing engines that cause a muscle to contract. These filaments interlock, and are able to slide over each other, shortening the length of the muscle. When the muscle is stretched, the filaments tend to be pulled apart. During shortening (contraction), they shorten by sliding past one another. During contraction, scientists believe that several cross-links are formed between the actin and the myosin filaments. By the process of making and breaking these cross-links, the two filaments move closer to one another and the muscle shortens. The cross-links repeatedly bend, release and reattach farther along the thin filaments. When many actin-myosin cross-bridges go through their cycles in a fraction of a second, the muscle contracts with considerable force. This

VOCABULARY

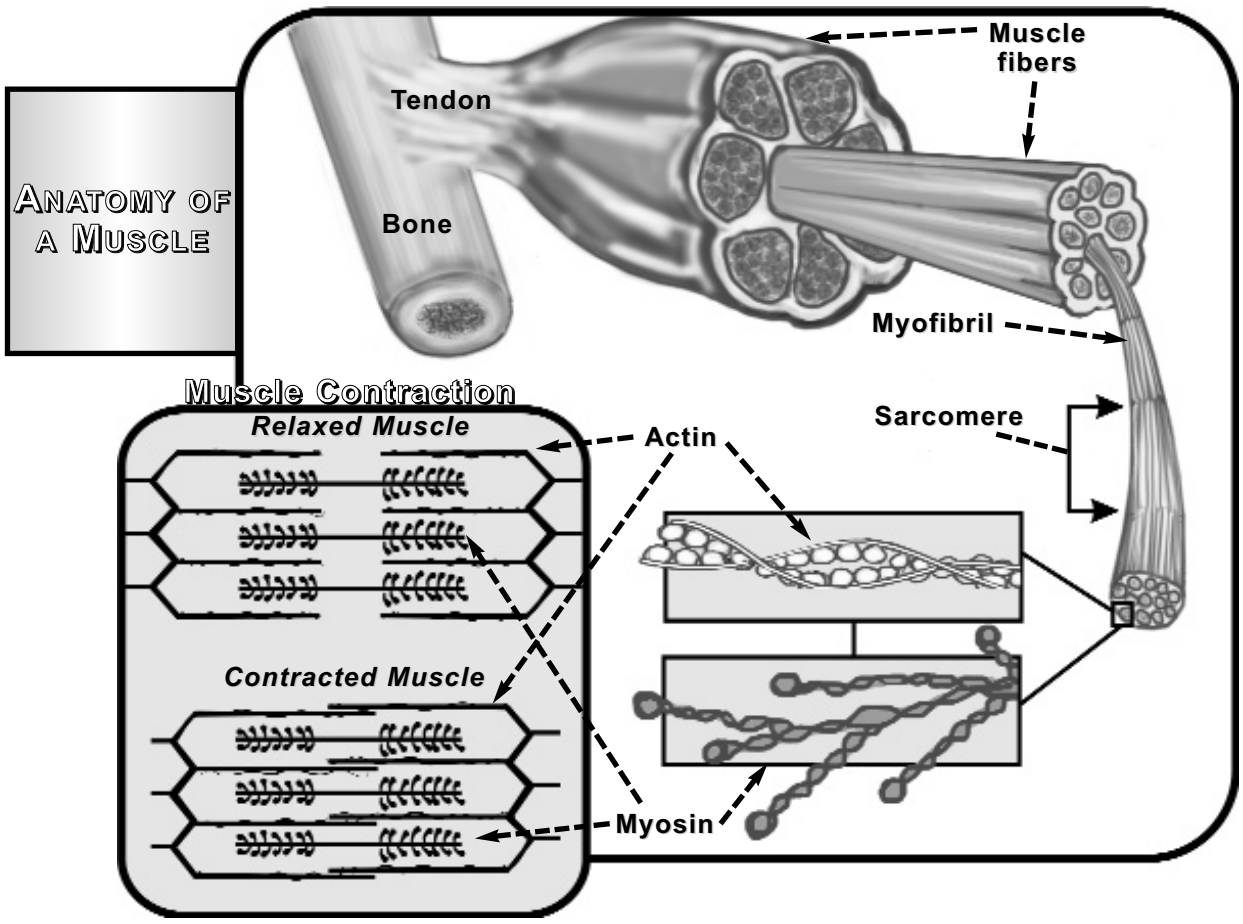
Myofibrils: filaments arranged in longitudinal bundles in muscle cells; composed of thin filaments of actin and thick filaments of myosin

Myosin: protein that makes up the thick filaments of muscle fiber

Actin: protein found in the thin filaments of muscle fiber

Sliding filament theory: concept that thick and thin filaments slide past each other, causing muscles to contract

ATP (Adenosine TriPhosphate): energy storage compound in cells



process is known as the ***sliding filament theory*** of muscle contraction because the thick and thin filaments slide past each other as the muscle shortens.

Mitochondria are quite numerous in skeletal tissues. Mitochondria are the sites of oxidative metabolism, which powers the cell by producing energy in the form of ***ATP (Adenosine TriPhosphate)*** from stored glucose and triglycerides. The energy required for muscle movement is ATP. One molecule of ATP supplies the energy for each cycle. Muscles use a great deal of energy. Active muscles give off enough heat in one hour to boil almost a quart of water!

VOCABULARY

Motor neuron: specialized neuron that carries impulses from the brain or spinal cord to muscles or other organs

Acetylcholine: a neurotransmitter chemical which causes an action potential and, in turn, releases calcium into the cytoplasm of muscle cells

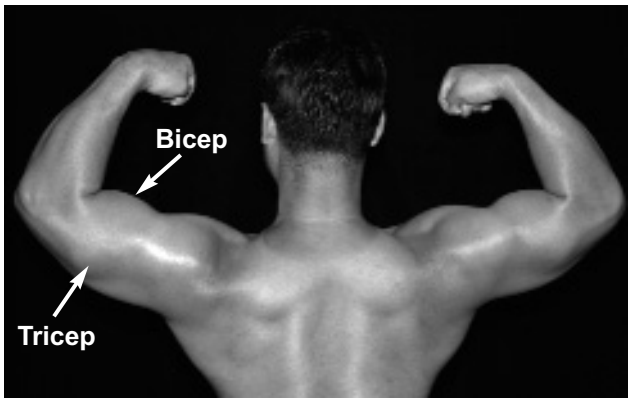
Muscle Contraction

To make well-coordinated movements, muscle contractions must be carefully controlled. In most skeletal muscles, movements are controlled by ***motor neurons***. A single motor neuron may form synapses to one or several muscle cells. An impulse in the motor neuron causes the release of ***acetylcholine***, which is a neurotransmitter that causes a new action potential. This, in turn, causes the release of calcium ions into

the cytoplasm of muscle cells. When calcium ions flow into the cytoplasm, cross-links form, providing energy, and the muscle contracts. The contraction ceases when energy to sustain the contraction is exhausted. Cross-links break down and filiments return to their original positions, relaxing the muscle. Muscle contraction is an all-or-nothing proposition. Muscles do not partially contract.

Muscle Coordination and Movement

Muscles produce force by contracting. Attached to bones by tendons, a muscle can pull two bones together, using the joint between them as a lever. When you lift a heavy object or pull something close to you, muscle contraction produces the movement. An individual muscle can pull by contracting, but it cannot push. If this is true, you may wonder how you can push a door open or how a farmer can push a bale of hay onto a truck.



Most skeletal muscles are arranged in pairs. These pairs oppose each other and produce movements in one of two directions. Your upper arm contains one muscle—the *bicep* which bends the arm. On the other side of the upper arm is another muscle, called the *tricep*, that extends the arm. When you push a door open, the tricep contracts, causing the arm to extend and push against the door.

The synchronization of countless body movements is an amazing phenomenon. The nervous, skeletal and muscular systems must be in total coordination for literally millions of actions each day. Look at the "simple" hand as an example of this awesome process. The hand is capable of 58 distinct movements. These movements allow for dexterity and power for a range of actions, including piano playing, threading a needle or driving a tractor. These actions are all accomplished by muscles in the wrist, forearm and palm. The fingers have no muscles; tendons in the hand must transfer force from arm muscles to the fingers. Consider the movements of the human hand as a concert pianist plays Beethoven's "Fifth Symphony." Of course the pianist is skilled in playing music, but think of the 70 muscles (35 in each hand) which must be coordinated to make the hand movements on the keyboard. The dexterity and coordination of the human thumb and fingers are unique to humans. No other creature demonstrates such sensitive coordination among the fingers, arm, eye and torso.

Certainly, orthopedic surgeons have performed miracles to repair hands that have been injured. However, no surgical procedures exist for improving the movement of a normal, healthy, human hand. Scientists who follow the scientific method of discovery speculate that the uniqueness and complexity of the human hand to perform complicated tasks does not appear to be the result of gradual, random chance.

In the next chapter, we will continue our study of the human body by studying the circulatory system.

LIFE PRINCIPLE



"Reading is to the mind what exercise is to the body."

—Sir Richard Steele (1672-1729)
Irish essayist, dramatist and politician