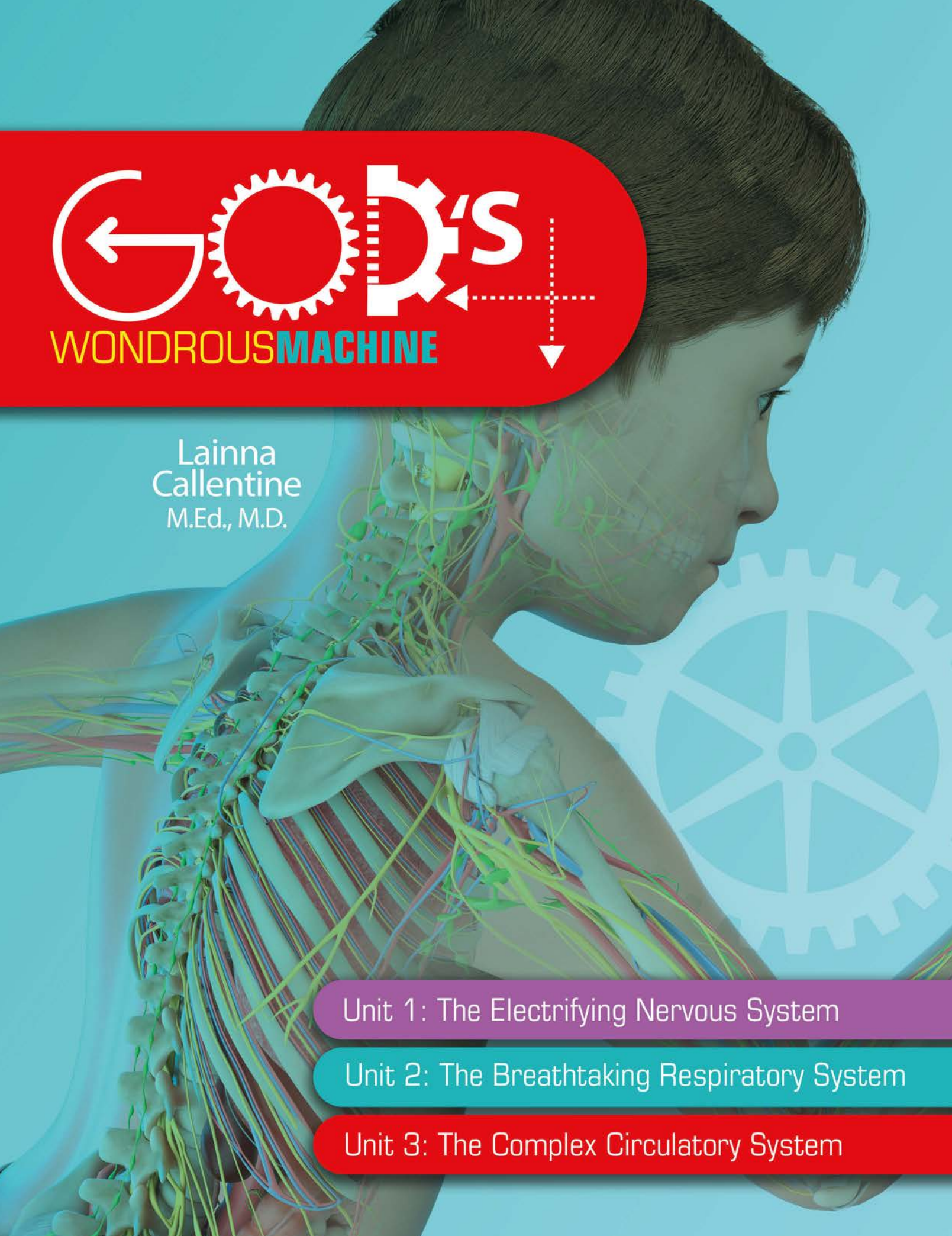

GOD'S WONDROUS MACHINE

Lainna Callentine
M.Ed., M.D.

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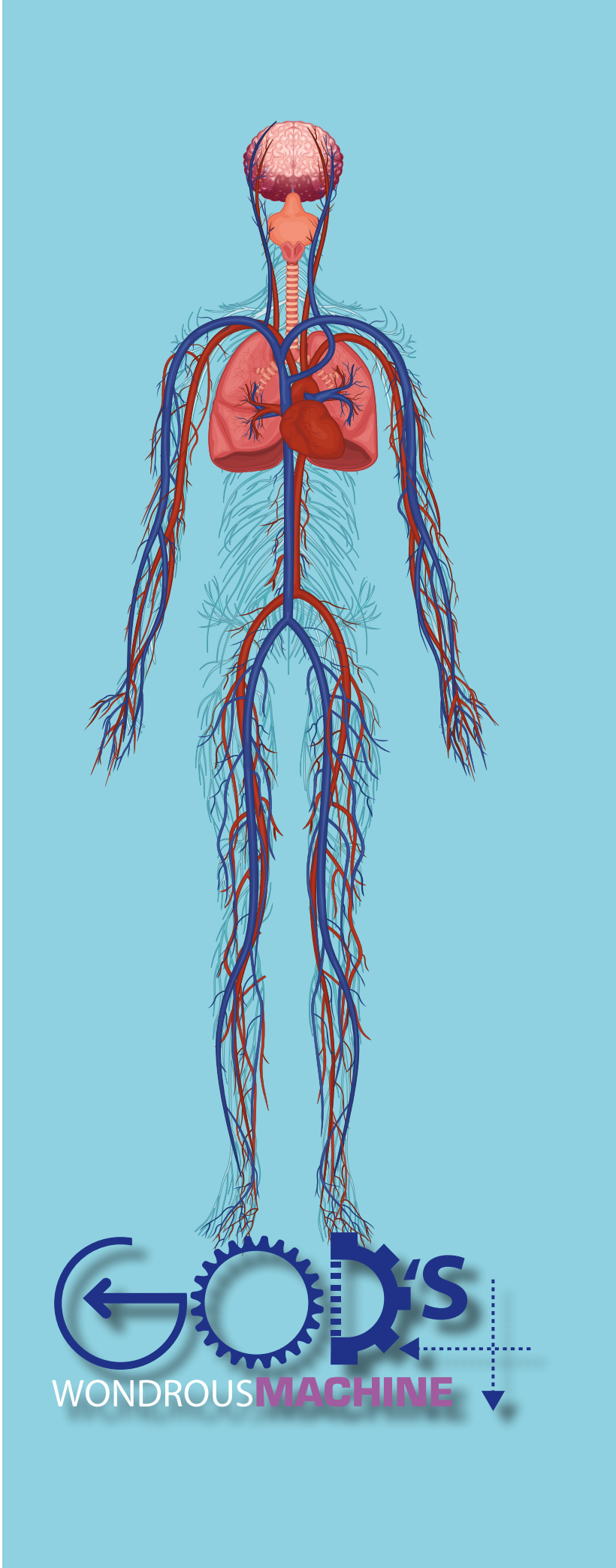

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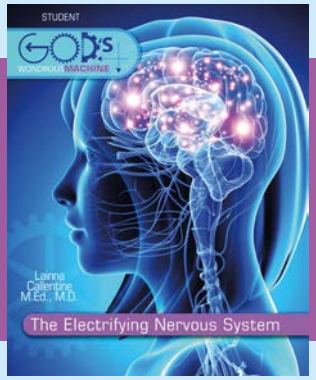
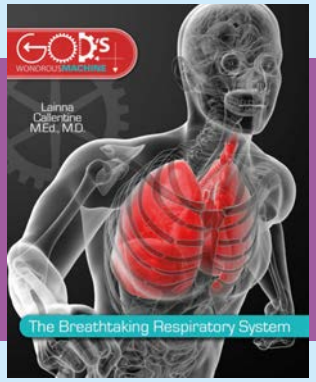
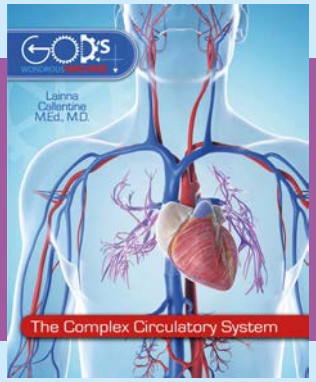
How to Use This Book (All about Us!)

About this *God's Wondrous Machine* series:

Developed by a master's-trained teacher and homeschooling mother who happens to be a pediatrician, this book focuses on the human body's nervous system, respiratory system, and circulatory system. It will create engaging opportunities for children to discover the wonders and workings of the human body.







Three units —
One book!

This book is bursting with vibrantly colorful images, interesting historical and weird facts, anatomy, physiology, and modern innovations. You will engage your senses and have a multitude of choices for hands-on exploration. You will discover aspects of the human body from a doctor's perspective. Each unit focuses on a particular system of the body, discussing how it works and how it doesn't at times. Common questions kids ask are answered to stimulate curiosity, and your senses will be engaged as the world of medicine is demystified.

This book gives many perspectives in science education by connecting to other fields of study (i.e., history, sociology, psychology, and theology), and it encourages the reader to appreciate God's magnificent handiwork: your body.

God's Wondrous Machine recognizes that every learner is not the same. Whether used in a homeschool or classroom setting, the hands-on activities are based on the educational theory of Multiple Intelligence by Howard Gardner (which states there are many types of intelligences and recognizes different learning styles: musical–rhythmic, visual–spatial, verbal–linguistic, logical–mathematical, bodily–kinesthetic, interpersonal, intrapersonal, and naturalistic). It is flexible enough for endless customization for the skills, interests, and abilities of each student.

Dedication
To my dear family, thanks for standing by my side.
D.R., my best friend, thanks for your steadfast love and unending encouragement.
You have been there in sickness and health.
My children: Michael, Jay, and Hannah, where does time go? Thank you for your support and love.

About the Author

Dr. Lainna Callentine has a passion for science. She spent many hours as a child turning over rocks and wading through streams chasing tadpoles. She is from a family of six children. Her parents grew up in the inner city housing projects of Chicago, and her parents felt that education was a powerful tool. They instilled in her and her siblings a great love for learning.

Dr. Callentine wears many hats. She is a coach, teacher, pediatrician, and homeschool mother. She obtained her bachelor's degree in human development and social policy from Northwestern University in the school of education while competing as a full–scholarship athlete. She began her professional career as an elementary school teacher. She obtained her master's degree in education from Widener University. Then she went on to pursue her lifelong dream of becoming a doctor. Dr. Callentine obtained her medical degree from University of Illinois College of Medicine. She worked in one of the busiest emergency rooms in Illinois before answering the call to go home and homeschool her three children.

She founded Sciexperience and travels nationally as a speaker doing inspiring hands-on science workshops for all ages. She continues to utilize her medical training as a missionary doctor in a clinic for the uninsured in the suburbs of Chicago. She is a member of the Christian Medical and Dental Society and The Author's Guild. She enjoys basketball, time with her husband and three kids, and the outdoors.

A Note from the Author

I have always been fascinated by the complexity and intricacy of the human body — how it works and why it doesn't. To be sure, there is more to us than just a physical body. But this wondrous machine that God has fashioned for us is something to marvel. It reveals His very handiwork. There are two fundamental ways God has chosen to reveal Himself to us through His Word and through His creation. We are part of that creation. This book guides and teaches the student to see the evidence of God's design. We truly are "fearfully and wonderfully made."

This book was a culmination of two reinforcing factors in my life: my passion for the life sciences and my desire to see those same sciences presented in a technical but biblically accurate way. Some may feel that the Bible has no bearing on science and only serves to dilute or confuse our understanding of it. This book does not present science apart from the Bible but in light of it. Others may feel that science, especially anatomy and biology, have much more to say about God and the Bible than this book offers. I believe indeed it does. This would require a much broader investigation across multiple disciplines to fully develop.

One issue challenged in Christian books is the controversy between "evolutionary theory" and the Genesis creation account. The immune system, DNA, the complexity of the brain, and virtually every aspect of the human body demonstrates design. This is readily apparent. And this book looks at the parts and systems of the body, how they work, and why they don't, giving credit to God as the author. My hope is that by developing an understanding and appreciation for the miracle that is the human body, one more stumbling block will be removed from trusting in an omnipotent God who created the world as described in Genesis.

To be sure, all science flows from the Creator of the universe, the Designer of its laws, and the One who fashioned our bodies from the dust of the earth and breathed life into them. My hope is that you will see the human body as an amazing example of God's love for us and want to dig deeper into the science that attempts to understand this amazing machine, seeking to know more about the One who designed it. May God bless you as you begin this journey.

In His Service,

Dr. Lainna Callentine

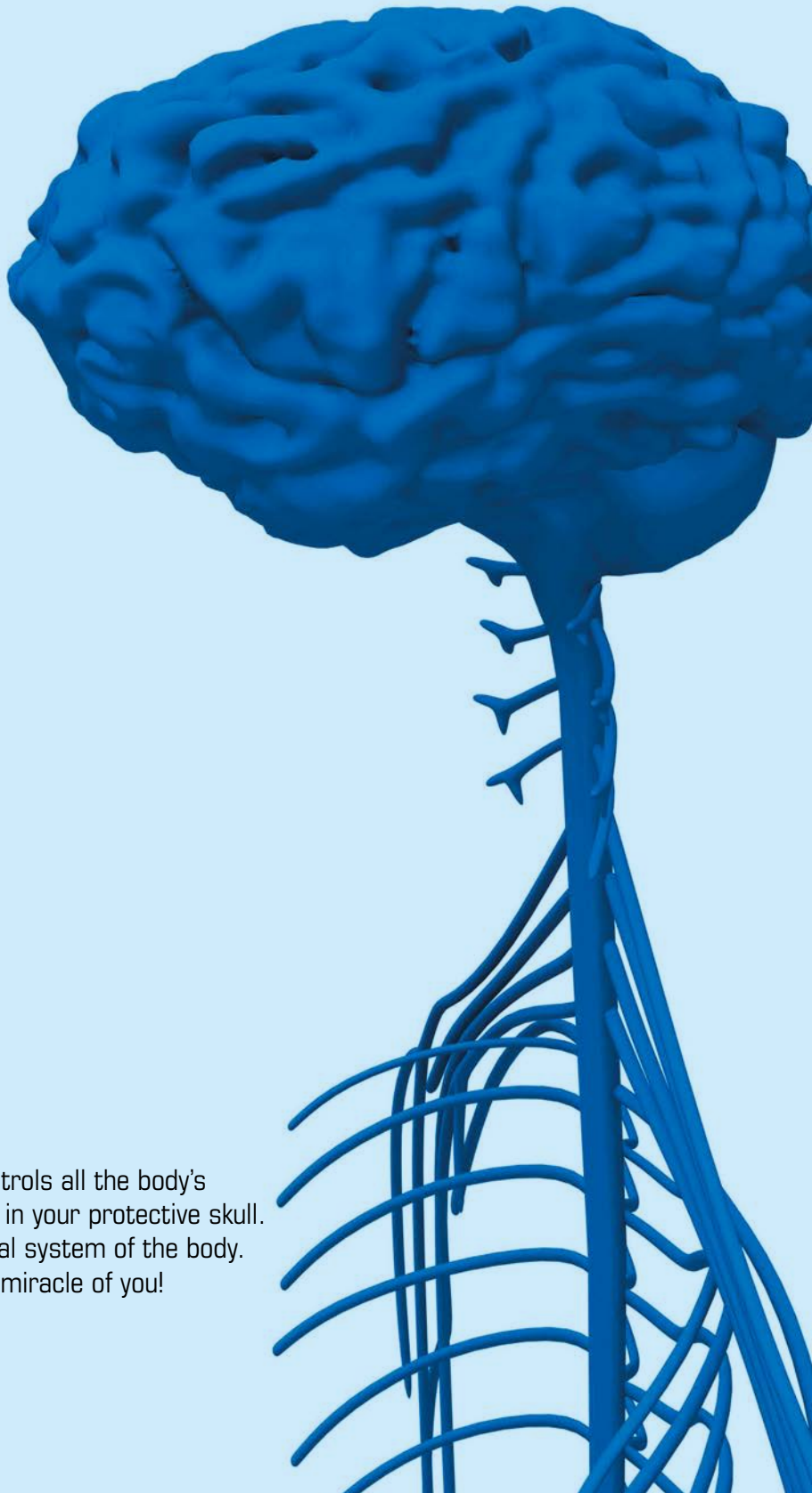
Using the teacher guide

This student book and the available teacher guide were developed to challenge children in all facets of multiple intelligence. The parent/instructor is able to choose and customize hands-on activities that engage a multitude of learning styles and challenge the student to explore life's big issues. The program is specially designed for lower and upper elementary level students, including advanced learners with middle school proficiency!

You can use this book as an interesting:

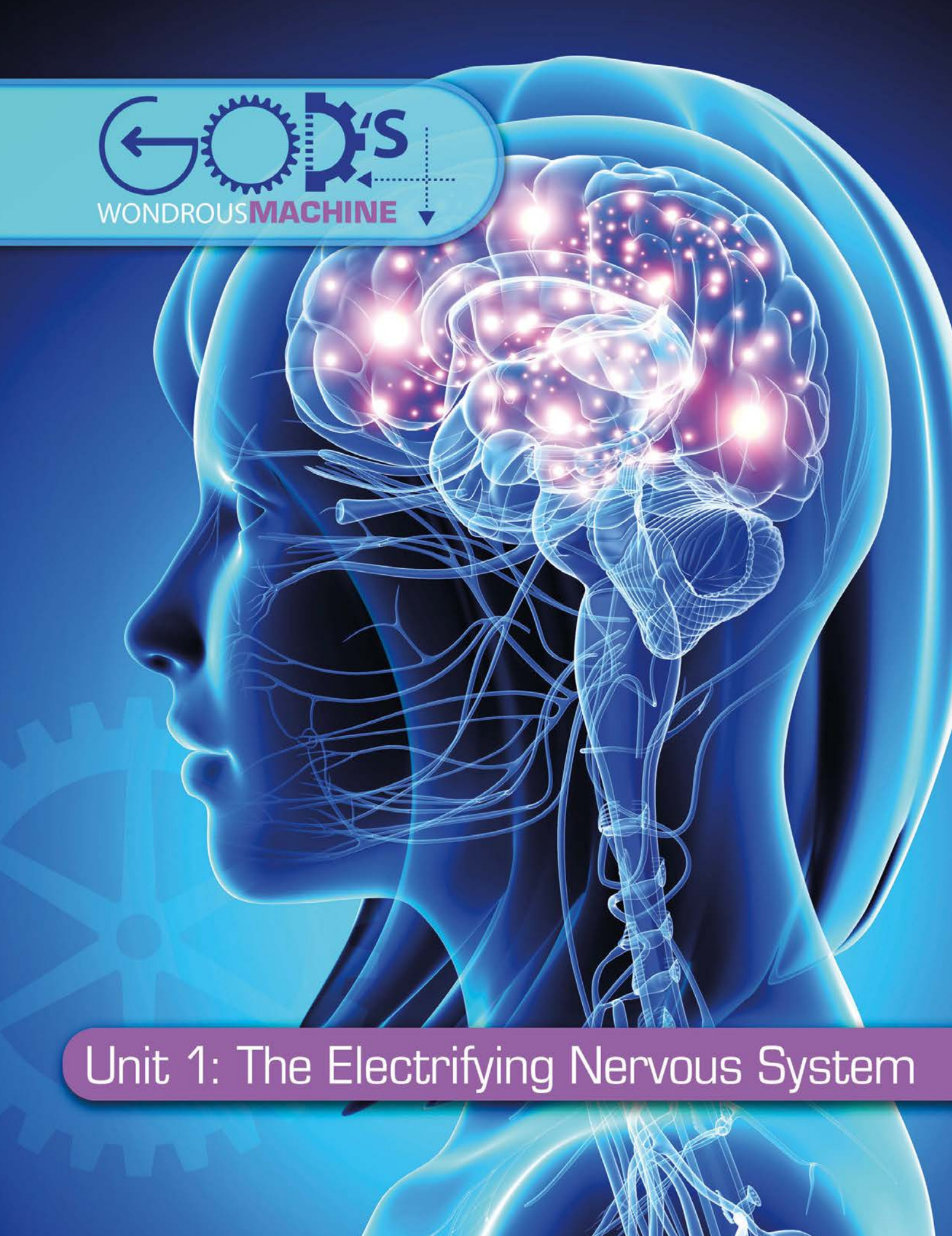
- Unit Study
- Curriculum
- Supplemental Resource

The teacher guide contains perforated sheets for worksheets, and tests, in addition to a flexible educational calendar. This additional material allows for a multiple array of assessment for the instructor (i.e. project based, traditional testing, or portfolio assessment). It is designed to maximize the learning opportunities and retention of information from the book, as kids have fun learning about the mechanics and mysteries of themselves!



From laughing to crying, your brain controls all the body's functions. Your brain lays safely tucked in your protective skull. You will take a trip through the electrical system of the body. Come learn how God has designed the miracle of you!

GOD'S WONDROUS MACHINE



Unit 1: The Electrifying Nervous System

VOCABULARY LEVELS

Choose the word list based on your skill level. Every student should be able to master Level 1 words. Add words from Levels 2 and 3 as needed. More proficient students should be able to learn all three levels.

Level 1 Vocabulary

- Arbor Vitae
- Central Nervous System
- Cerebral Hemispheres
- Cerebellum
- Cerebrum
- Frontal Lobe
- Gray Matter
- Neurons
- Occipital Lobe
- Parietal Lobe
- Temporal Lobe
- White Matter

Level 2 Vocabulary

Review and Know Level 1 Vocabulary

- Autonomic Nervous System
- Blood-Brain Barrier
- Cerebral Spinal Fluid
- Corpus Callosum
- Dermatomes
- Homunculus
- Meninges
- Pituitary Gland

Level 3 Vocabulary

Review and Know Level 1 and 2 Vocabulary

- Astroglia
- Axon
- Broca's and Wernicke's Areas
- Cerebral Palsy
- Dendrites
- Diencephalon
- Ependymal Cells
- Gyrus
- Hypothalamus
- Medulla Oblongata
- Mesencephalon
- Microglia
- Myelin Sheath
- Neuroglia
- Oligodendroglia
- Pons
- Pyrogens
- Shingles
- Synapse
- Thalamus
- Ventricles

God created you with much care, love, and incredible design! The human brain has 1 quadrillion synapses (that is a 1 followed by 15 zeroes or 1,000,000,000,000,000). All those synapses fit into the tiny compartment of your brain. In comparison to man's design, a typical computer has approximately 16,000,000,000 bytes of memory. It would take a million computers to have the equivalent amount of connections to rival the brain!

Level 1 Vocabulary
Level 2 Vocabulary
Level 3 Vocabulary

See it, Say it, Know it!

Word [Pronunciation]	Definition
Arbor Vitae [Arbor ˈvaɪtiː/]	"Tree of life" located in the middle section of the cerebellum; helps to coordinate movement.
Astroglia [ăs-trŏgʹlē-ə]	A type of brain cell that supplies nutrients to the neuron.
Autonomic Nervous System [ôʹtə-nŏmʹĭk]	Self-controlling part of the nervous system that does not require conscious thought to operate.
Axon [ăkʹsŏnʹ]	The part of the neuron through which electrical impulses travel down the body of the nerve cell to other nerve cells; many are wrapped in a white fatty substance called the myelin sheath.
Blood-Brain Barrier	A special barrier that surrounds the brain and acts like the gate keeper from the rest of the body. It is composed of small blood vessels and cells packed close together that act as a filter that blocks unwanted materials from entering the brain.
Broca's Area [Brōʹkəz]	Located on the left hemisphere; the area that houses the motor speech region, which provides the ability to form spoken words.
Central Nervous System	The central nervous system consists of the brain and the spinal cord.
Cerebral Hemispheres [Sĕrʹə-brəl]	The two halves of the brain, right and left.
Cerebral Palsy [Sĕrʹə-brəl pôlʹzē]	A group of disorders that affects the brain and nervous system functions that can affect movement, learning, hearing, vision, and speech. There are different types of cerebral palsy; in one type, an individual may experience spasticity, which means his or her movements are jerky and difficult to coordinate.
Cerebral Spinal Fluid [Sĕrʹə-brəl]	A clear fluid that bathes the brain and spinal cord and transports nutrients, chemical messengers, and waste products.
Cerebellum [sĕrʹə-bĕlʹəm]	The region of the brain located behind the brain stem. The arbor vitae resides here.
Cerebrum [sĕrʹə-brəm]	The main part of the brain composed of the two hemispheres.
Corpus Callosum [kôrʹpəs kə-lōʹsəm]	The arched white matter found in the center of the cerebrum that connects the two hemispheres of the brain.
Dendrites [dĕnʹdrītʹ]	Tentacle-like structures that extend from the cell body of the neuron and reach out to other neurons.

Word [Pronunciation]	Definition
Dermatomes [dûr′mə-tōm′]	Areas or zones of the skin where sensation arises from a particular spinal nerve root.
Diencephalon [dī′ĕn-sĕf′ə-lŏn′, -lən]	A structure in the middle of the brain that connects to the brain-stem; also the location of the thalamus and the hypothalamus.
Ependymal Cells [ĕ-pen′di-măl]	The cells that make up the lining of the ventricles of the brain and of the spinal cord that help in producing spinal fluid.
Fissures [fis·sure]	A groove or deep fold in the cerebral cortex.
Frontal Lobe	The front (anterior) part of the brain involved in reasoning and personality.
Gray Matter	The thin outer rim on the surface of the brain where memory storage, processing, and conscious and subconscious regulation of skeletal movement occur.
Gyrus [Ji´rus]	A rounded convolution (folded or ridged part) on the surface of the brain.
Homunculus [Hō-mŭng′kyə-ləs]	"Very small man," a visual representation of the connection between different body parts and the areas in the brain hemisphere that control them.
Hypothalamus [Hī′pō-thăl′ə-məs]	The part of the brain that regulates body temperature, sleep, and puberty.
Medulla Oblongata [Me·dul·la ŏb′lŏng-gā′tə]	Located in the lower half of the brainstem, connecting to the pons, it regulates the vital functions of breathing, swallowing, and heart rate.
Meninges [Mĕn-in´jēz]	The tough fibrous membranes that cover the brain and spinal cord.
Mesencephalon [Mez″-en-sef´ah-lon]	The midbrain located below the cerebral cortex near the center of the brain. The key in sorting through the visual and auditory data received by the brain.
Microglia [Mi-krog´le-ah]	The "garbage collector" cells of the brain that kill unwanted organ-isms and remove waste products produced by the neurons.
Myelin Sheath [Mī′ĕ-lin shēth]	A substance that coils around and insulates (coats) the nerve cell; made from a lipid (fat).
Neuroglia [Noo-rog-lee-a]	General term for the glia cells of the brain that support nerves. Glia comes from the Greek word meaning "glue."

Level 1 Vocabulary
Level 2 Vocabulary
Level 3 Vocabulary

Word [Pronunciation]	Definition
Neurons [Noŏr′ŏn′]	An electrical conducting cell of the nervous system.
Occipital Lobe [ŏk-sĭp′ĭ-tl]	The back or posterior part of the brain that houses the visual processing center.
Oligodendroglia [ŏl′ĭ-gō-dĕn-drŏg′lē-ə]	The "protector" cells of the nervous system that support, protect, and insulate the axons by helping to form the myelin sheaths.
Parietal Lobe [pa·ri·e·tal]	Located between the frontal and occipital lobes of the brain; serves as the primary sensory cortex. Enables conscious perception of touch, pressure, vibration, pain, taste, and temperature. Memory storage, processing, and conscious and subconscious regulation of skeletal movement also originate in this area.
Pituitary Gland [pi·tu·i·tary]	A pea-sized structure at the base of the skull that secretes hormones. It is the "master gland" of the body by overseeing key functions, such as growth during childhood and the onset of puberty, by controlling male and female hormones.
Pons	Latin for "bridge." Located anterior to (in front of) the cerebellum, it serves as a bridge between the cerebellum and the thalamus, acts as a relay station for sensory information between the structures.
Pyrogens [pī´rə-jən]	A substance released from the brain that tells the hypothalamus to increase the body's temperature, causing a fever.
Shingles	A painful, blistering skin rash caused by the chicken pox virus. Pain, tingling, or burning occurs along a dermatome.
Synapse [sĭn´ăps´]	A small gap between neurons across which electrical information travels from one neuron to the next.
Temporal Lobe [tĕm´pər-əl]	The side (lateral) region of the brain in which the auditory perception, and language comprehension are located.
Thalamus [thăl´ə-məs]	Buried under the cerebral cortex, it serves like a communications center; relays and processes sensory information to various destinations in the brain.
Ventricles [vĕn´trĭ-kəl]	Spaces in the middle part of the brain that produce and are filled with cerebrospinal fluid.
Wernicke's Area [vĕr´nĭ-kēz]	The region of the brain that interprets what one hears and makes sense of spoken communication.
White Matter	Regions of the brain that lie at a deeper depth in brain; the area where neurological nerve tracts are housed.

*Pronunciation Keys from: http://medical-dictionary.thefreedictionary.com

1 Let's Start at the Beginning: Historical Points of Interest

Thinking, crying, breathing, running, skipping, singing, smiling, itching, sneezing, and your beating heart — all of these activities have one thing in common: your brain. Tipping the scales at a mere 3 pounds, it is the integral organ of your body. Your brain operates 24 hours a day, 7 days a week, 365 days a year. It works tirelessly, day in and day out. Serving as the central control center of your body, this marvelous machine is composed of billions of cells that make hundreds of billions of connections without any traffic jams. Through this super highway of connections, we perceive and process impulses that originate inside and outside our bodies.

In this unit, we will explore the mysteries of the brain through investigation of its anatomy (name and location of parts of the body), physiology (how the body functions), histology (microscopic cell structure), and pathology (abnormal health consequences of disease). Let's pick our brains and peer into the ultimate multi-tasker.

A curator for the Smithsonian Institution in 1935 looking at a skull that possibly shows signs of brain surgery from thousands of years ago. Other skulls have been found that also detail new bone growth, indicating that patients survived the initial procedure.

The brain and nervous system are an important control center for your body. It can send signals throughout the body at over 320 feet per second. That is nearly the distance of a football field!

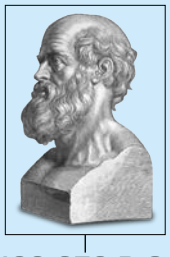
KNOW IT ALL

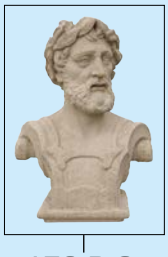
History tells the story of the past. Over time, we have learned a great many things about how the brain works. Our knowledge of the inner workings of the brain continues to grow.

But we have this treasure in jars of clay to show that this all-surpassing power is from God and not from us. We are hard pressed on every side, but not crushed; perplexed, but not in despair; persecuted, but not abandoned; struck down, but not destroyed. We always carry around in our body the death of Jesus, so that the life of Jesus may also be revealed in our body (2 Corinthians 4:7-10; NIV).

Mankind has been on a quest since the beginning of time to understand our external and internal environments. Understanding the brain has been one of those perplexing pursuits. The Bible reminds us that God's power is "all surpassing" and that the life of Jesus is revealed in our bodies. Throughout time, man has continued to gain insight and understanding about the brain and its functions. Yet, even with the achievements of modern neuroscience, the inner workings of the mind are still great mysteries.

Without a doubt, the quality of life for men has improved dramatically through the centuries because of the advances and discoveries that men have made in medicine. The time-line below depicts some of the discoveries made in neuroscience. It provides an idea of how we have acquired knowledge through time.

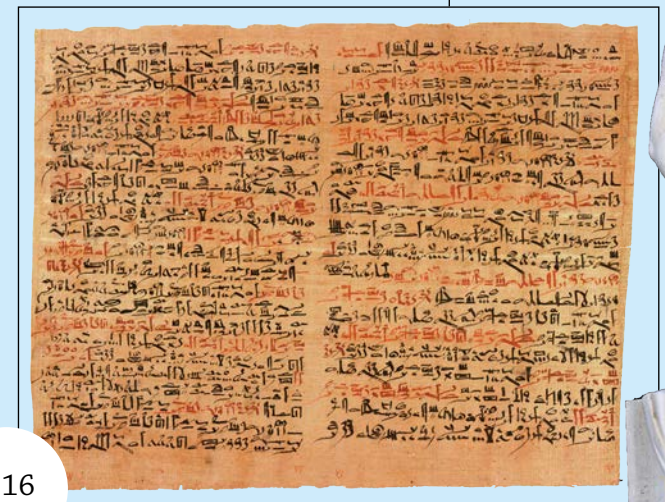




timeline

1700 B.C. — 460-379 B.C. — 335 B.C. — 170 B.C. — Christ's Birth

Edwin Smith — Hippocrates — Aristotle — Galen



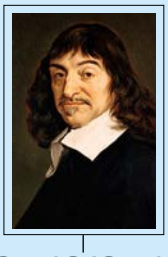
The body is a unit, though it is made up of many parts; and though all its parts are many, they form one body. So it is with Christ....
(1 Corinthians 12:12; NIV)

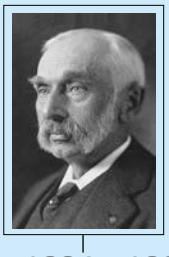
Traveling through the course of time, in 1700 B.C. the Edwin Smith Surgical Papyrus was written. It is the first written record of the nervous system to appear in Egyptian documents that describe cases of brain injury.

Hippocrates (460–379 B.C.) was born 460 years prior to Jesus' birth and was an early doctor known as the "Father of Medicine." Hippocrates felt that it was important that all doctors take an oath, or special promise before they began practicing medicine. He developed the Hippocratic Oath, in which all doctors promise never to use their knowledge to cause harm to anyone under their medical care.

In addition, Hippocrates discussed epilepsy as a problem in the brain. He also believed that the ability to feel sensations and intelligence originated in the brain. This was a very revolutionary idea, because prior to this the consciousness of the mind was believed to reside in the heart.

In 335 B.C., Aristotle wrote about sleep, but believed that mental processes originated in the heart, and that the brain was merely a place to cool hot blood pumped from the heart.





1543 1586 1649 1717 1808 1827 1861 1874 1884 1896 1910 1936 1957

Vesalius, Piccolomini, Descartes, Van Leeuwenhoek, Gall, Morphine, Broca, Wernicke, Godlee, Babinski, Moniz, Penfield

Lead Poisoning

Alice Hamilton (1869-1970), a physician who was the world's leading authority on industrial medicine. In 1910, she discovered the cause of a common illness that produced deadly outcomes in factory workers. The workers would suffer from shakiness, headaches, and loss of muscle control that sometimes lead to paralysis and death. She discovered "plumbism" or lead poisoning. *Plumbum* is the Latin word for lead.

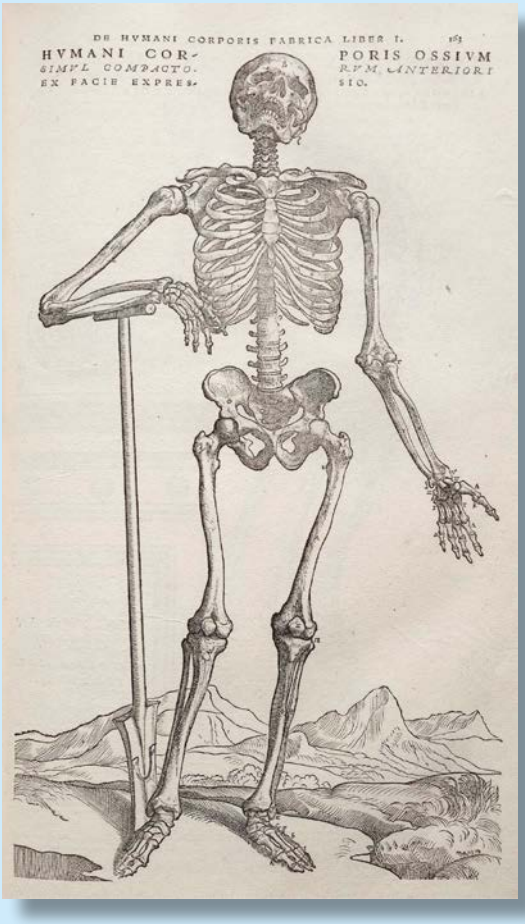


Image from Andreas Vesalius' De humani corporis fabrica (1543), page 163

A Roman physician to the gladiators named Galen dissected the brains of animals in 170 B.C. From his studies, he believed the cerebellum controlled the muscles and the cerebrum, which allows us to sense our environment.

In 1543, Andreas Vesalius published his book, *On the Workings of the Human Body,* which discussed human anatomy, including the brain's structures in detail. Vesalius is credited with being the "father of anatomy." He broke from the traditions of the time by carrying out anatomical dissections. This was a sharp deviation from medical practices because dissection, much less touching of a deceased specimen, was considered unclean and taboo.

Piccolomini was the first to point out the differences between the cerebral cortex and white matter in 1586.

Rene Descartes, in 1649, described the Pineal gland as the control center of the body and mind. The Pineal gland, located in the brain, produces Melatonin, which regulates the sleep cycle (circadian rhythm). A cross-section of a nerve cell was seen in one of the first microscopes by Antonie Van Leeuwenhoek in 1717. Although we know it is now incorrect, Franz Joseph Gall published his work on phrenology. He believed he could distinguish the traits of a person by feeling the bumps on their head.

Paul Broca discovered that different regions of the brain performed specific processes. He discovered "Broca's" Area (named after him) in 1861. This region is located in the frontal lobe of the left hemisphere of the brain and is intimately involved in speech articulation (talking). Near that same time, in 1874, Carl Wernicke published *Der Aphasische Symptomencomplex,* a book on aphasias. Aphasia is the term used to identify a difficulty in forming and understanding language. Wernicke's Area is located close to Broca's Area.

Observe the picture above. Do you see anything missing (a lack of masks, gloves, substances….)? Unlike very advanced and sterile (germ-free) environments for modern surgery, proper sanitary procedures were not practiced.

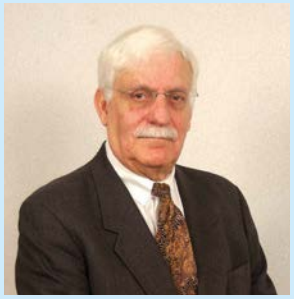
Medical staff sterilizing hands and arms before surgery

Your brain is a very complex and delicate organ. Unlike other parts of the body, disorders of the brain could not be treated or even diagnosed correctly. It wasn't until 1884 when the first successful surgical removal of a brain tumor was performed by Sir Rickman John Godlee. Joseph Babinski was the first to describe the Babinski Reflex. It is a normal reflex in infants but an abnormal reflex in older children and adults. We will learn more on this reflex later.

One of the most grotesque practices in neuroscience was developed in 1936 by Dr. Antonio Egas Moniz, who invented the procedure of frontal lobotomies for the treatment of mental illnesses. This caused changes in the person's personality and sometimes death. Fortunately, this is not practiced today.

Dr. Wilder Penfield developed a visual representation of the brain — called the homunculus — that identifies the sensory regions. We will visit with Dr. Penfield in an upcoming section.

The British Army's first mobile brain surgery unit shown being stocked in 1940. It was staffed with five specialist doctors and two nurses.



And last on our timeline is Dr. Raymond Damadian, who became a pioneer in the field of magnetic resonance imaging (MRI) through his development of several patents and a working machine named Indomitable that could be used for non-invasive detection of cancer in the human body. The first commercial MRI scanner was produced in 1980. This important technology can show disease or any damage in the brain in several ways without using surgery.

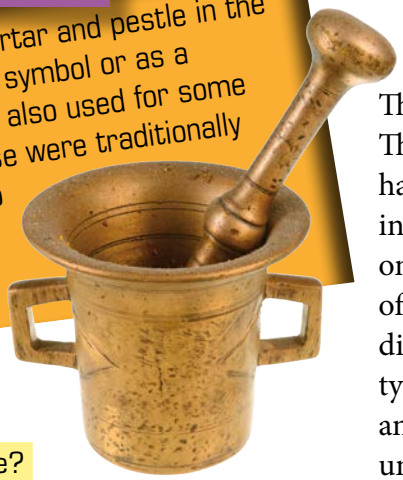
Continuing improvements to MRI technology are helping to discover new details of how our bodies function and ways to discover when there are problems. At left, Dr. Damadian with his pioneering machine, Indomitable.

Word Wise!

ANATOMY refers to the study of the body structure, systems, and organs of living things. The word developed from the Greek words "ana" meaning "up," and "tomia" for cutting.

MODERN MARVELS

You may have seen a mortar and pestle in the drug store – either as a symbol or as a decorative object. While also used for some cooking techniques, these were traditionally used in many cultures to mix up the ingredients in medicine.



Good or Bad Medicine?

When a doctor gives you a prescription for medicine, you go to a pharmacy. Pharmacists are a type of doctor who have special training in drugs and their effects on the body. Before there were pharmacists, there were apothecaries. If you lived in the 15th century, in the times of Christopher Columbus, and became ill, you may have gone to an apothecary. They mixed their own medicines and gave advice on healthcare. Many doctors were able to formulate their own medicines as well. Evidence of prescriptions and instructions for how they were made have even been found on clay tablets as early as ancient Babylon.

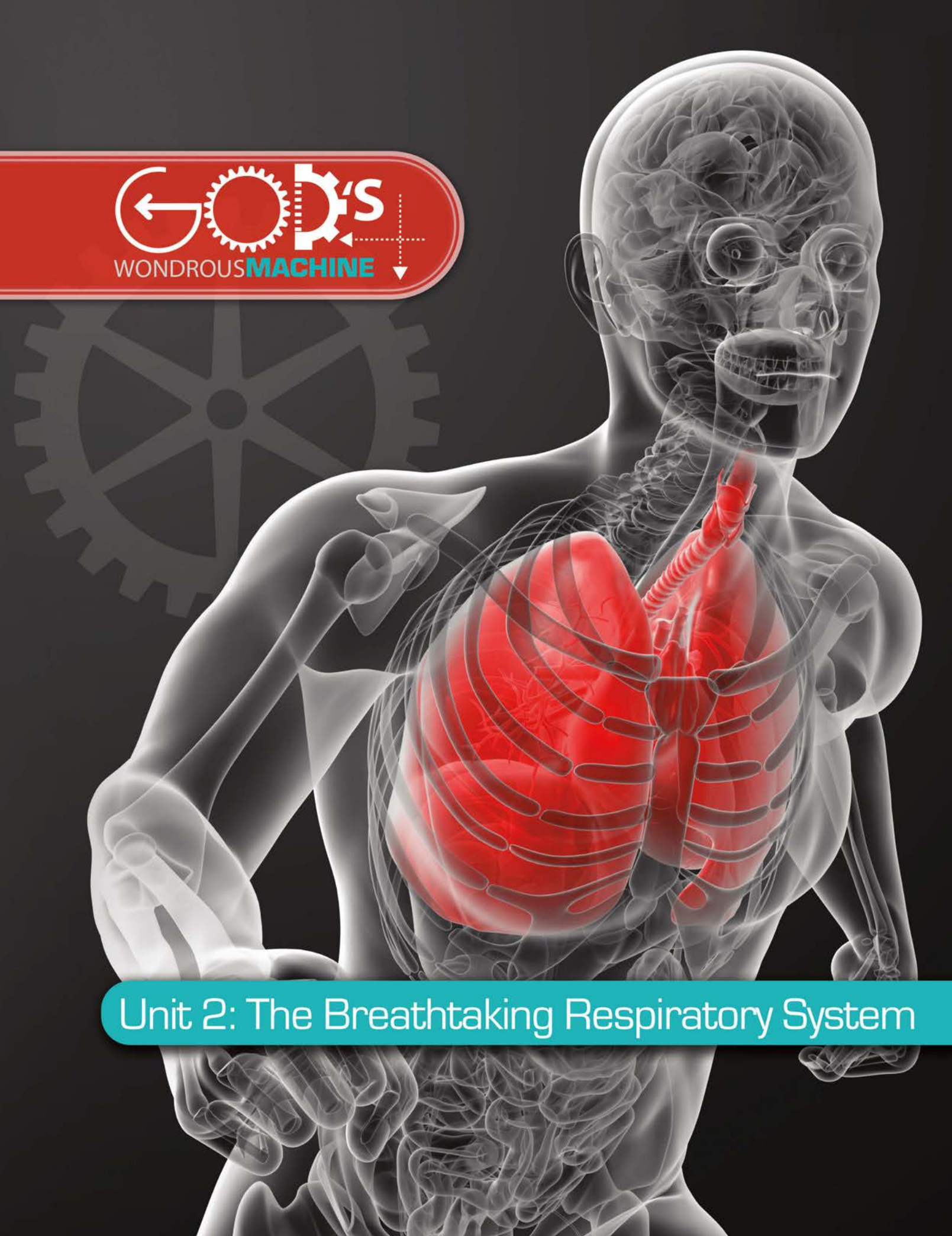
There were no rules in how this had to be done. This meant that while a doctor in one place might have created a specific type of medicine, a doctor in a nearby town might make the same medicine only it would be slightly different in its formula of ingredients. Both might have prescribed a different amount of the medicine for the same type of injury. Now there are strict regulations and professional standards that help to insure uniformity in the formulas and prescriptions for medicine. Drugs for mental health, or psychotropic drugs, are a relatively new invention. Drugs developed for the specific treatment of mental health problems only came into existence after World War II.

Today many medicines are developed by huge corporations who spend billions of dollars in formulating these new drugs. They then have to go through a strict testing and approval process. The Food and Drug Administration is the government agency tasked with approving new medicines in the United States.

BIBLICAL REFERENCES: **The Bible has a multitude of references to the body's organs and systems. However, it does not directly mention the brain.**

Mind	Think	Meditate
Psalm 26:2	Romans 12:3	Psalm 48:9
Matthew 22:37	Philippians 4:8	Psalm 143:5
Luke 10:27	Proverbs 23:7	Psalm 119:15, 23, 27, 48, 78, 97, 99, 148
1 Peter 4:7	2 Peter 3:1	
Psalm 7:9	1 Corinthians 14:20	Colossians 3:2

GOD'S WONDROUS MACHINE



Unit 2: The Breathtaking Respiratory System

VOCABULARY LEVELS

Choose the word list based on your skill level. Every student should be able to master Level 1 words. Add words from Levels 2 and 3 as needed. More proficient students should be able to learn all three levels.

Level 1 Vocabulary

- Allergy
- Inhale
- Stethoscope
- Alveoli
- Larynx
- Upper Respiratory Tract
- Asthma
- Lower Respiratory Tract
- Virus
- Bacteria
- Mucus
- Vocal Cords
- Bronchi
- Nares
- Carbon Dioxide
- Pharynx
- Cilia
- Exhale

Level 2 Vocabulary

Review and Know Level 1 Vocabulary

- Allergens
- Influenza
- Trachea
- Anosmia
- Iron Lung
- Ventilation
- Antiseptic
- Laryngitis
- Bronchioles
- Pandemic
- Cystic Fibrosis
- Physiologist
- Diffusion
- Pleura Sac
- Epidemic
- Polio
- Epiglottis
- Sinuses

Level 3 Vocabulary

Review and Know Level 1 and 2 Vocabulary

- Apneustic Center
- Chemoreceptors
- Cribriform Plate
- Epithelium
- Gestation
- Goblet Cells
- Nasal Turbinate
- Organogenesis
- Pneumotaxic Center
- Surfactant
- Tracheostomy

The surface area of the lungs is roughly the same size as a tennis court. God's amazing design of the lungs means that you use this large surface area for the diffusion of oxygen and carbon dioxide for breathing!

See It, Say It, Know It!

Level 1 Vocabulary
Level 2 Vocabulary
Level 3 Vocabulary

Word [Pronunciation]	Definition
Allergens al·ler·gen (al´er-jen)	A foreign substance, such as mites in house dust or animal dander, that, when inhaled, causes the airways to narrow and produces symptoms of asthma
Allergy al·ler·gy (al´er-je)	An abnormally high, acquired sensitivity to certain substances, such as drugs, pollens, or microorganisms, that may include such symptoms as sneezing, itching, and skin rashes
Alveolus al-ve´o-lus Alveoli alve´oli (plural form)	Small air sacs or cavities in the lung that give the tissue a honeycomb appearance and expand its surface area for the exchange of oxygen and carbon dioxide
Anosmia an·os·mi·a	Loss of the sense of smell
Antiseptic an·ti·sep·tic	Capable of preventing infection by inhibiting the growth of bacteria
Apneustic Center app·new·stik sen·ter	The neurons in the brain stem controlling normal respiration
Asthma asth·ma	A common inflammatory disease of the lungs characterized by episodic airway obstruction caused by extensive narrowing of the bronchi and bronchioles. Common symptoms of asthma include wheezing, coughing, and shortness of breath.
Bacteria bac·te·ri·a	Organisms not able to be seen except under a microscope, found in rotting matter, in air, in soil, and in living bodies, some being the germs of disease
Bronchi bronc-i	The two branches of the trachea that extend into the lungs
Bronchioles bron·chi·ole	Any of the small, thin-walled tubes that branch from a bronchus and end in the alveolar sacs of the lung
Carbon Dioxide car·bon di·ox·ide	A colorless, odorless, incombustible gas, CO_2, formed during respiration, combustion, and organic decomposition and used in food refrigeration, carbonated beverages, inert atmospheres, fire extinguishers, and aerosols
Chemoreceptors che·mo·re·cep·tor	A sensory nerve stimulated by chemical means
Cilia cil·i·a	Short, hairlike, rhythmically beating organelles on the surface of certain cells that provide mobility, as in protozoans, or move fluids and particles along ducts in multicellular forms

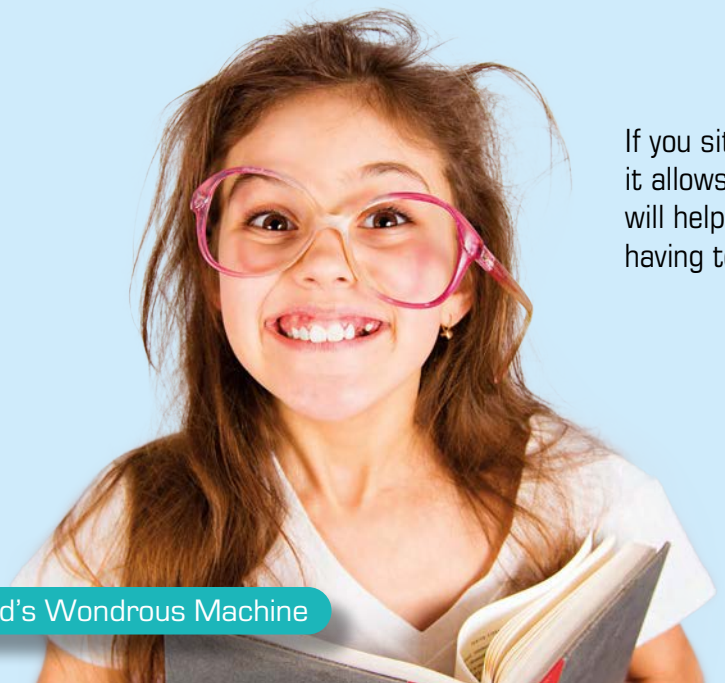
Word [Pronunciation]	Definition
Cribriform Plate crib-i-form plate	Located in the ethmoid bone of the skull in the nasal cavity where the nerve endings of the sense of smell are found
Cystic Fibrosis cys′tic fibro′sis	An inherited disorder of the exocrine glands, usually developing during early childhood and affecting mainly the pancreas, respiratory system, and sweat glands. It is marked by the production of abnormally thick mucus by the affected glands, usually resulting in chronic respiratory infections and impaired pancreatic function.
Diffusion dif·fu·sion	The movement of atoms or molecules from an area of higher concentration to an area of lower concentration. Atoms and small molecules can move across a cell membrane by diffusion.
Epidemic ep·i·dem·ic	An outbreak of a disease or illness that spreads rapidly among individuals in an area or population at the same time
Epiglottis ep·i·glot·tis	The thin elastic cartilaginous structure located at the root of the tongue that folds over the glottis to prevent food and liquid from entering the trachea during the act of swallowing
Epithelium ep·i·the·li·um	Any tissue layer covering body surfaces or lining the internal surfaces of body cavities, tubes, and hollow organs
Exhale ex·hale	To breathe out
Gestation ges·ta·tion	The period during which unborn young are “carried” inside the womb
Goblet Cells Gob-let cells	Cells in the respiratory tract that produce mucus
Influenza in·flu·en·za	A highly contagious and often epidemic viral disease characterized by fever, tiredness, muscular aches and pains, and inflammation of the respiratory passages
Inhale in·hale	To breathe in; inspire
Iron Lung i′ron lung	An airtight metal cylinder enclosing the entire body up to the neck and providing artificial respiration when the respiratory muscles are paralyzed, as by poliomyelitis
Laryngitis lar·yn·gi·tis	Inflammation of the larynx, often with accompanying sore throat, hoarseness or loss of voice, and dry cough

Level 1 Vocabulary
Level 2 Vocabulary
Level 3 Vocabulary

Word [Pronunciation]	Definition
Larynx lar·ynx	The upper part of the trachea in most vertebrate animals, containing the vocal cords. The walls of the larynx are made of cartilage. Sound is produced by air passing through the larynx on the way to the lungs, causing the walls of the larynx to vibrate. The pitch of the sound that is produced can be altered by the pull of muscles, which changes the tension of the vocal cords. Also called voice box.
Lower Respiratory Tract lo·wer res·pir·a·tory tract	Consisting of all the structures in the respiratory tract lying below the larynx. The lower respiratory tract is composed of the trachea and lungs. The lungs include the bronchi, respiratory bronchioles, alveolar ducts, alveolar sacs, and alveoli.
Mucus mu·cus	The slimy, viscous substance secreted as a protective lubricant by mucous membranes. Mucus is composed chiefly of large glycoproteins called mucins and inorganic salts suspended in water.
Nares nar·is	An external opening in the nasal cavity of a vertebrate; a nostril
Nasal Turbinate Na-sal tur·bi·nate	Any of the scrolled spongy bones of the nasal passages in man and other vertebrates
Organogenesis or·gan·o·gen·e·sis	The development of bodily organs
Pandemic Pan·dem·ic	An epidemic that spreads over a very wide area, such as an entire country or continent
Pharynx phar·ynx	The passage that leads from the cavities of the nose and mouth to the larynx (voice box) and esophagus. Air passes through the pharynx on the way to the lungs, and food enters the esophagus from the pharynx.
Physiologist phys·i·ol·o·gist	Biologist specializing in physiology (the biological study of the functions of living organisms and their parts)
Pleura Sac pleu·ra sac	A membrane that encloses each lung and lines the chest cavity
Pneumotaxic Center pneu·mo·tax·ic sen·ter	A nerve center in the upper pons of the brain stem that rhythmically inhibits inspiration
Polio po·li·o	Poliomyelitis, an acute viral disease marked by inflammation of nerve cells of the brain stem and spinal cord that can affect the ability to walk and breathe

Word [Pronunciation]	Definition
Sinuses si·nus·es	A cavity or hollow space in a bone of the skull, especially one that connects with the nose
Stethoscope steth·o·scope	An instrument for listening to the sounds made within the body, typically consisting of a hollow disc that transmits the sound through hollow tubes to earpieces
Surfactant sur·fac·tant	Surfactant reduces the surface tension of fluid in the lungs and helps make the small air sacs in the lungs (alveoli) more stable.
Trachea tra·che·a	A thin-walled, cartilaginous tube descending from the larynx to the bronchi and carrying air to the lungs; also called windpipe
Tracheostomy tra·che·os·to·my	Surgical construction of an opening in the trachea, usually by making an incision in the front of the neck, for the insertion of a catheter or tube to facilitate breathing
Upper Respiratory Tract up·per res·puh·rah·tow·ree tract	Composed of the parts of the upper respiratory system: the nose, sinuses, pharynx, and larynx
Ventilation ven·ti·la·tion	The exchange of air between the lungs and the environment, including inhalation and exhalation
Virus vi·rus	Any of various extremely small, often disease-causing agents consisting of a particle (the virion), containing a segment of RNA or DNA within a protein coat known as a capsid. Viruses are not technically considered living organisms because they cannot carry out biological processes.
Vocal Cords vo′·cal cords	The two folded pairs of membranes in the larynx (voice box) that vibrate when air that is exhaled passes through them, producing sound

*Most pronunciation keys from: http://medical-dictionary.thefreedictionary.com



If you sit up straight while reading a book out loud, it allows you to use more of your lung capacity. This will help keep you from getting short of breath or having to gasp for air in the middle of a sentence!

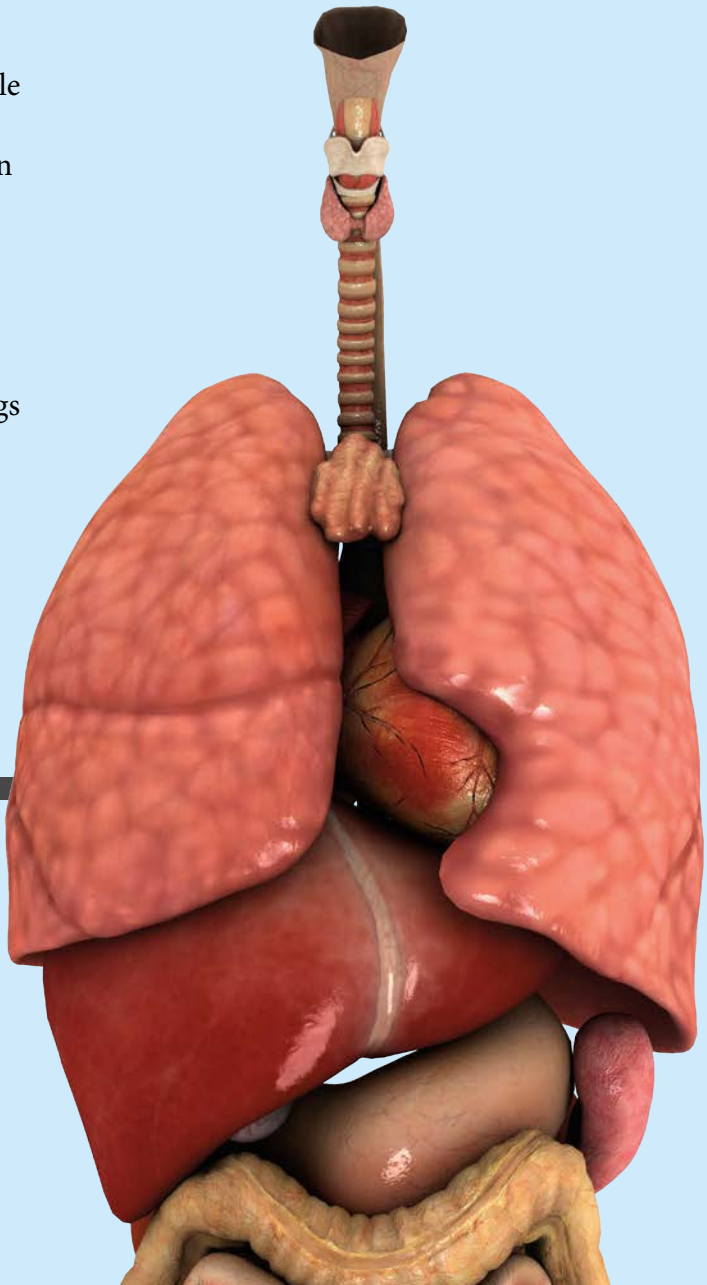
When you laugh, the muscles in your chest and your diaphragm contract, pushing air out of the lungs in a quick rush that makes your larynx vibrate to make the sound of laughter – ha ha! It has been observed that the average young child laughs nearly 300 times in a day. Adults, on average, laugh 15 to 100 times a day.

Laughter is good medicine! It helps to reduce pain and blood sugar levels. Proverbs 17:22 says, "A cheerful heart is good medicine, but a crushed spirit dries up the bones."

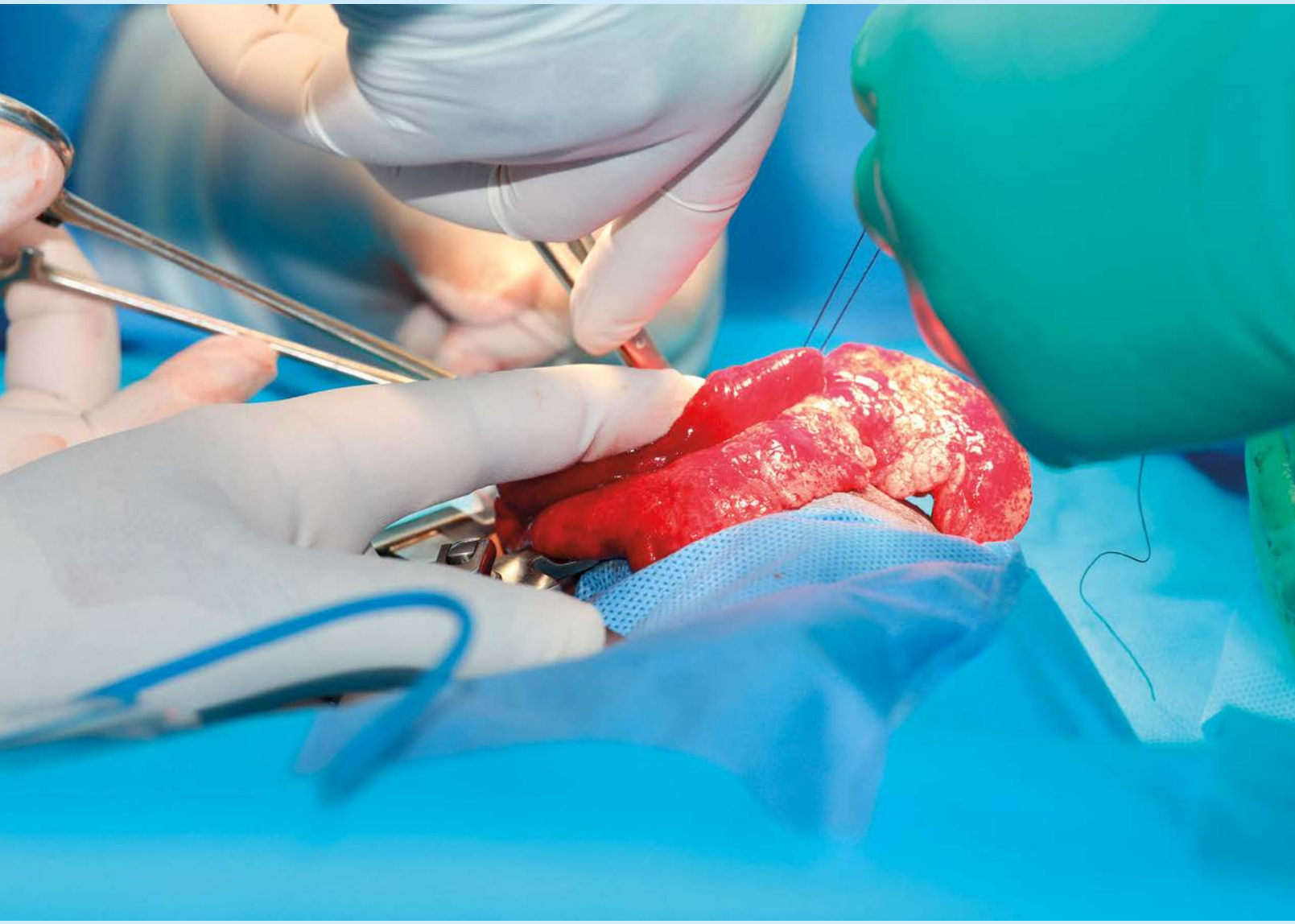
1 Introduction: Why Do We Breathe?

With a loud-piercing wail, each of us entered this world as a crying baby taking in our first breath of air. That breath ushers in a new independent life outside the mother's womb. Created from the dust on the ground and with the breath God breathed into his lungs, Adam took his first breath. This life-giving force originates from none other than God: the giver of life and breath. The respiratory system is yet another demonstration of God's provision, our human frailty, and our complete dependence on Him.

Why do we breathe? We breathe because we eat. Okay, that sounds a bit ridiculous. But it makes sense when we look at our bodies as an incredible engine. For an engine to carry out all of its processes, it needs energy. Oxygen is needed to burn and utilize the fuel we eat. The billions of cells in our bodies grab the oxygen we breathe from the red blood cells that travel by and utilize it to perform all of its complicated actions. The cells throw out the garbage from their day's work in the form of a gas called carbon dioxide. The lungs inhale oxygen and exhale carbon dioxide.



The capillaries in the lungs would extend 1,600 kilometers, almost 995 miles, if placed end to end. That is just slightly shorter than the distance between New York City and Tampa, Florida or almost equal to the distance between Chicago and Denver.



Sit back and breathe in. Come, as we embark on a captivating voyage through the wind tunnels of the body, and be prepared to be amazed. At the first stop on our journey, we will peer into the Bible and see what God's Word says about this life force. We will then take a look back in the pages of time and learn about discoveries that have helped shape our understanding of the respiratory system today. We will learn about the anatomy and physiology of this inverted tree-like structure called the lungs.

Discover remarkable things about your soft, spongy lungs. Did you know it is the only organ in your body that can actually float on water? The surface area of the alveoli (the small air sacs of the lungs) alone could cover the surface of an entire tennis court! Breeze in and witness this incredible expanse of God's Wondrous Machine. It will take your breath away!

2 Respiratory History Timeline: A Walk Back in Time

But isn't history just about a bunch of dead people? Why should it matter to me? How important is medical history for a particular system of the body? The dates and events are meaningless to our lives, right? Wrong. As you dive into "God's Wondrous Machine," you will see how these events have shaped what we understand to be true today. We encounter real problems in life. It is through those problems that we acquire new knowledge and original ways to solve those problems. History connects the past with the present and the future. When we study history, we can observe how things change over time and understand the situations and life circumstances that generate the necessity of innovation and invention. As you read, observe the frailty of our being and how God has given us each unique minds to help impact the world in which we live. You will see that the knowledge base that you now bring to the table far exceeds the knowledge of people from yesterday. We are confronted with new problems. The hope is that you will play a part in creating real solutions to the problems we encounter today to impact the advances of tomorrow.

Let's set sail through the pages of time and see how the various discoveries have provided a platform for future breakthroughs.

500 B.C.

Anaximenes, of ancient Greece, believed that all things were made of air. He called it *pneuma* which means "breath" in Greek. The Greeks believed everything was alive and breathing.

470 B.C.

Empedocles, the Greek philosopher, taught that all things were made of four elements — earth, air, fire, and water.

350 B.C.

Aristotle thought the heart was on fire. Breathing in cooled the fire and kept it from burning up the whole body.

1660

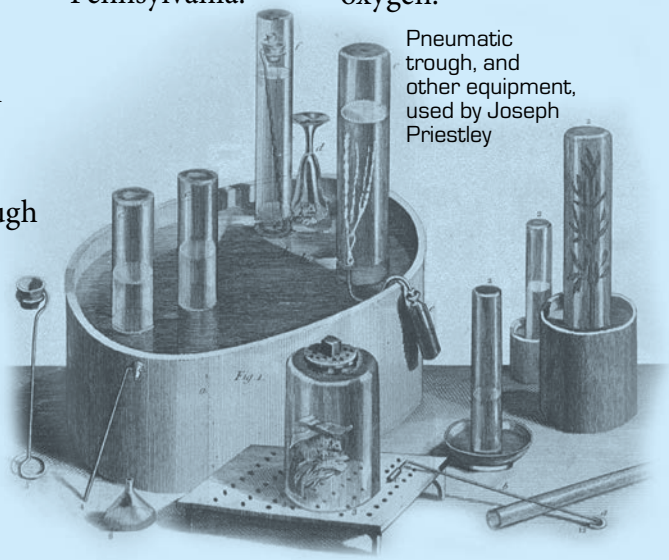
Marcello Malpighi, born in Crevalcore, Italy, March 10, 1628, showed that the lungs consist of many small air pockets and a complex system of blood vessels by observing capillaries through a microscope. He described the circulation of blood.

1765

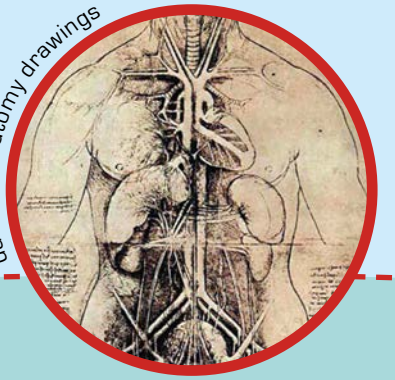
John Morgan founded the first medical school in America at the College of Pennsylvania.

1772-1774

Joseph Priestley discovered nitrous oxide and is credited with the discovery of oxygen.



Pneumatic trough, and other equipment, used by Joseph Priestley



da Vinci anatomy drawings

280-271 B.C.

Greek physician Erasistratus came very close to recognizing the circulation of the blood, especially by noting the relationship of the lungs to the circulating system.

A.D. 170

Galen taught that the secret of life was a spirit or *pneuma* that came from the air.

1500

Leonardo da Vinci, Italian painter and inventor, suggested that air was not made from one element but a combination of two gases.

1643

Evangelista Torricelli proved that air had weight and took up space.

1660

Robert Hooke, an Englishman, found that parts of the body act like pumps. Our ribs help pump air in and out of the lungs.

Re-enactment of the first operation under anesthesia

1779

Thomas Beddoes and Humphry Davy recognized nitrous oxide's anesthetizing effects, but did not think to use it to take away pain.

1779

Lavoisier proposed the name "oxygen" for the part of air that is breathed and responsible for combustion. He discovered that air was composed mainly of two components — oxygen and nitrogen.

1819

Treatise on Diagnosis by Listening to Sounds by physician Theophile René Laennec was written in which he demonstrated the use of a tube for investigating the lungs and heart sounds.

1845

Anesthetic inhaler invented. *Anesthetic* comes from the Greek word meaning "loss of feeling." Prior to the invention of anesthesia, patients were strapped down and held by strong individuals as the surgeon speedily worked.

1845

William Morton, an American doctor, used ether to extract a tooth from a patient. A sealed glass jar with an air valve containing several ether-soaked sponges was used, with a long rubber tube as a mouthpiece.

Early flexible stethoscopes

Jules Bordet

1847

Chloroform came into use. It was found that it was particularly useful in childbirth by James Young Simpson. This met a great deal of criticism — it was believed that it was always a woman's fate to suffer pain during childbirth. Queen Victoria popularized its use when she used it during the birth of her seventh child, Leopold.

Queen Victoria, with the Princess Royal

1855

George Phillip Cammann, an American doctor, took Laennec's idea and developed the stethoscope we know today.

1882

Robert Koch discovers the bacterium that causes tuberculosis, the first definite association of a germ with a specific human disease.

1904

The National Association for the Study and Prevention of Tuberculosis was founded. This organization later became the American Lung Association.

1906

Jules Bordet discovered *Bordetella pertussis*, the bacterium that causes whooping cough.

Dr. Dorothy Andersen

1938

Dr. Dorothy Andersen, a pathologist at Columbia-Presbyterian Babies and Children's Hospital in New York, was the first to document and observe the problems of cystic fibrosis, a genetic disease.

1953

Dr. Paul di Sant'Agnese developed an effective technique of diagnosing cystic fibrosis called the Sweat Test.

Franklin D. Roosevelt

Thousands send dimes to aid the Infantile Paralysis Foundation

1927

Phillip Drinker developed the "iron lung," a mechanical metal device that encased a patient to help him breathe.

1938

Corneille Heymans of Belgium won the Nobel Prize for physiology or medicine for his discoveries in respiratory regulation.

1938

The National Foundation for Infantile Paralysis was established by Franklin D. Roosevelt. This organization's name was later changed to the March of Dimes.

Dr. Jonas Salk

1955

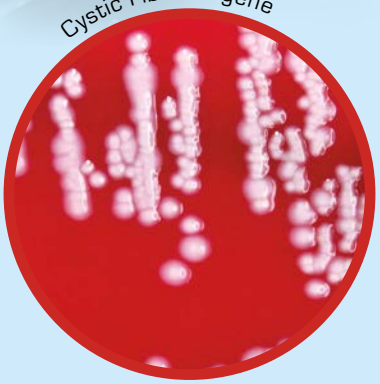
Dr. Jonas Salk, an American medical researcher, developed an injectable polio vaccine based upon a live weakened polio virus.

1957

Dr. Albert Sabin, a Polish American microbiologist, developed an oral (taken by mouth) vaccine that used a live weakened version of the polio virus.

1989

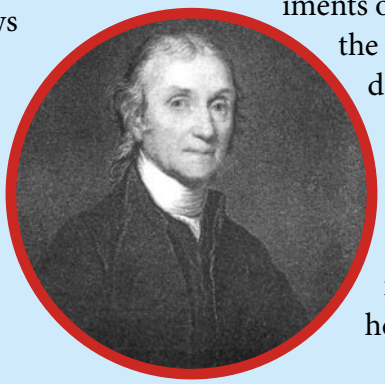
The gene responsible for cystic fibrosis was identified, giving hopes of a cure one day by gene therapy.



Cystic Fibrosis gene

Joseph Priestley: The Dissenter Discovers Oxygen

Joseph Priestley (1733–1804) was born on March 13, 1733, in Fieldhead, England. Joseph's father died shortly after his birth. Joseph's mother was a devout religious woman who taught Joseph about God. As Joseph grew, he had a ravenous appetite for the Bible and learning. Faith and religion were central parts of daily life in England. England's official church was the Anglican Church, or the Church of England. It was a powerful organization and controlled many aspects of daily life. As Joseph matured in his faith, his views changed from the views held by the Anglican Church. Joseph became a dissenter. Dissenters were a diverse group that included Baptists, Lutherans, Methodists, Presbyterians, and Quakers that disagreed with the Church of England and broke away. Dissenters had limited rights in England. They could not attend the large universities, like Oxford and Cambridge. Nonetheless, Joseph pursued his passion for learning and God. He became an instructor at a local academy, a scientist, and was ordained as a Dissenting minister.



Priestley published six volumes of *Experiments and Observations on Different Kinds of Air* between 1772 and 1790. He detailed his experiments on gases or "airs." He is credited for the discovery of several gases: nitrogen dioxide, ammonia, nitrous oxide (laughing gas), nitrogen, and oxygen. The success that Priestley experienced as a scientist is credited to his keen mind and his ability to design ingenious contraptions to study gases he discovered.

The Breath of Life

Breathing is essential to life. Without the air that rushes into your lungs you would cease to exist. The Bible makes many references to breathing. Our Heavenly Father is the giver of life and through His breath He calls all creatures into existence. In Genesis 2:7 it says, "Then the LORD God formed a man from the dust of the ground and breathed into his nostrils the breath of life, and the man became a living being."

There is no evidence here of man being formed from an evolutionary process, but rather being formed from the actual loving hands of God. Job, through all his adversity, knew where his life force came from. In Job 33:4 he states, "The Spirit of God has made me; the breath of the Almighty gives me life." Remember, as Psalm 150:6 states, "Let everything that has breath praise the LORD. Praise the LORD."

Biblical References:			
2 Samuel 22:16	Job 4:9	John 20:22	Acts 17:25
Isaiah 11:4	Ezekiel 37:5–10	Isaiah 30:28	

The Haldanes and Their Bad Gas

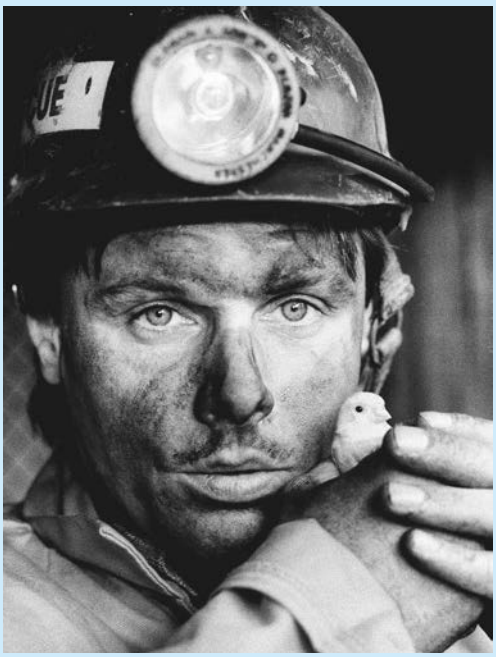
Today, scientific research is heavily managed and monitored. In the 1970s, the Food and Drug Administration (FDA) developed laws to protect human subjects taking part in clinical trials. Clinical trials are research studies that determine how well new medical approaches work in people.

Prior to this time, there was no standard on how things were tested on people. Many doctors and scientists would do unsafe practices on themselves or others in order to observe and learn new medical advances. There are two such scientists, father and son, who used themselves as human guinea pigs. (Guinea pigs have been commonly used in laboratory studies.) John and Jack Haldane utilized their bodies for scientific exploration. They made many contributions to our understanding of the respiratory system and the nature of gases.

John Haldane was a Scottish physiologist born in the late 1800s. A physiologist is a type of scientist that strives to understand how body systems work. Mr. Haldane demonstrated an insatiable thirst for knowledge. He would conduct experiments on himself. He would check the quality of air by locking himself in closed chambers and inhaling potentially deadly gases. He would then record the effects it had on his body and mind. John's son, Jack, was quick to get into the act. Jack began his own experimentation at three years of age when he gladly allowed his father to take a small amount of his blood for study. At the ripe old age of four years, Jack started breathing "bad air" in the underground railway and mines, and at 13 years he dove into the ocean in a leaky diving suit. Jack was a child scientist by his father's side.

On many occasions, the Haldanes felt the ill effects of their experiments. They suffered from headaches, vomiting, passing out, and on some occasions even turned blue. John was able to show that most of these ill effects were not due to a lack of oxygen but a build-up of carbon dioxide in their bloodstream.

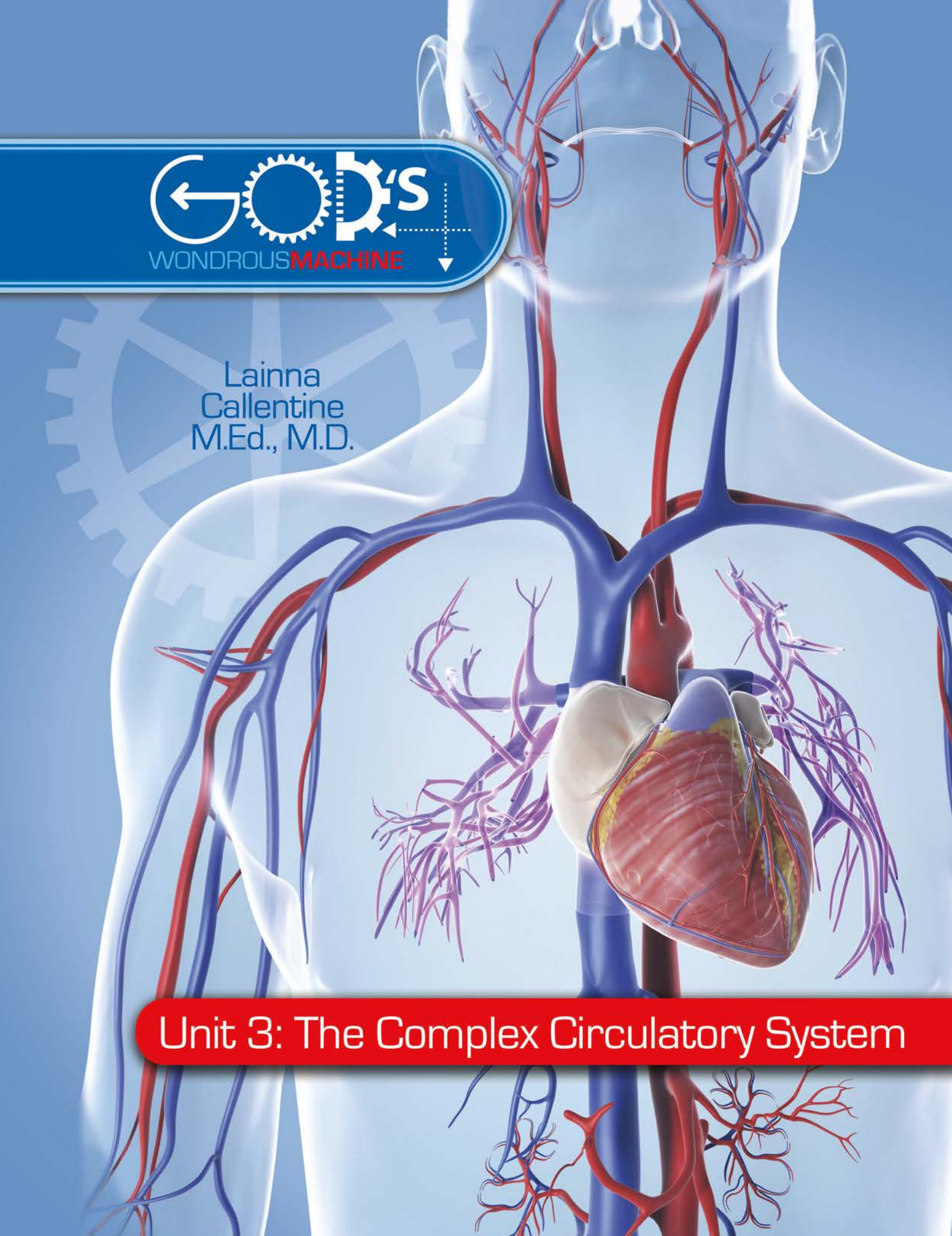
They did many crazy things. It is not surprising that the family motto of the Haldane family was just one word — "suffer." They inhaled many mixtures of gases and studied the effects on their bodies. They were one of the first to identify that breathing was controlled by the blood-brain barrier that transported gases to a sensitive area of the brain. They were the experts on the hazards of breathing bad air. Their discoveries revolutionized and protected the jobs of miners, soldiers, deep sea divers, and submarine dwellers. They unlocked the mysteries of respiration and the gases that affect us.



John Haldane came up with the idea of using canaries as an early warning system. The miners carried a caged canary into the coal mine and if dangerous gases like carbon monoxide were present they would kill the canary before the miners felt the ill effects.

GOD'S WONDROUS MACHINE

Lainna
Callentine
M.Ed., M.D.



Unit 3: The Complex Circulatory System

VOCABULARY LEVELS

Choose the word list based on your skill level. Every student should be able to master Level 1 words. Add words from Levels 2 and 3 as needed. More proficient students should be able to learn all three levels.

Level 1 Vocabulary

- Anemia
- Aorta
- Arteries
- Arterioles
- Atrium
- Bone marrow
- Closed circulatory system
- Fetus
- Hemoglobin
- Open circulatory system
- Prothrombin
- Red Blood Cells
- Stethoscope
- Valves
- Veins
- White blood cells

Level 2 Vocabulary

Review and Know Level 1 Vocabulary

- Antibodies
- Antigens
- Buffy coat
- Capillary
- Coronary
- Epicardium
- Erythrocytes
- Hematophagic
- Hemophilia
- Hemostasis
- Malaria
- Myocardium
- Pericardial sac
- Platelets
- Sickle cell anemia
- Stem cell
- Syncope
- Systole
- Tachycardia
- Universal donor
- Universal receiver
- Ventricles

Level 3 Vocabulary

Review and Know Level 1 and 2 Vocabulary

- Auscultate
- Bradycardia
- Centrifuge
- Chordae tendineae
- Diastole
- Electrocardiogram
- Endocardium
- Hematopoiesis
- Myocardial infarction
- Prothrombin
- Sinoatrial node
- Tricuspid valve
- Venules

See It, Say It, Know It!

Level 1 Vocabulary
Level 2 Vocabulary
Level 3 Vocabulary

Word [Pronunciation]	Definition
Anemia [ah-ne´me-ah]	A problem with the blood in which oxygen delivered to the organs and tissues is decreased. It can be a symptom of many different diseases.
Antibodies [an-ti-bod-eez]	Blood proteins that are made to attack a specific invader, like bacteria or viruses. They set off a cascade of events to assist the body in a stronger defense.
Antigens [an´tĭ-jenz]	A foreign substance, like bacteria or virus, that triggers an immune response and causes antibodies to spring into action.
Aorta [a-or´tah]	The largest artery in the body that originates from the left ventricle and sends oxygenated blood to the body.
Arteries [ahr´ter-ez]	Vessels that carry oxygenated blood from the heart to the body.
Arterioles [ahr-te´re-ōlz]	Small vessels that carry oxygenated blood that connects to capillaries.
Atrium [a´tre-um]	The upper chambers of the heart in which blood enters the heart. There are two atrium, the right and left atriums.
Auscultate [ô´skəl-tāt´]	To listen; to listen to the sounds of the body.
Bradycardia [brady-car-dia]	A slow heartbeat that is typically less than 60 beats a minute for an adult.
Bone marrow [bohn mar´o]	The soft, spongy material in the middle of bones.
Buffy coat [bufé kōt]	When blood is centrifuged, spun in a test tube in a machine, the blood separates into three parts. This middle part is composed of white blood cells and platelets
Capillary [kap´ĭ-lar″e]	Smallest arterial blood vessel; connects the arterioles with the venules.
Centrifuge [cen´trĭ-fūj]	To spin around; a machine used to spin test tubes of blood at high speeds in order to cause the parts of blood to separate.
Closed circulatory system	A blood system composed of vessels of different sizes that encloses the blood at all times. The blood is pumped by the heart and does not fill body cavities.
Chordae tendineae [kor´dah ten di nee a]	Fibrous strings that connect to the edges of the heart valves. They keep the valves from inverting or flipping backwards. Also known as the "heart strings."

Word [Pronunciation]	Definition
Coronary [kôr´ə-nĕr´ē,]	The blood vessels that line the outside of the heart.
Diastole [dī-ăs´tə-lē]	The phase in the heartbeat when the heart muscle relaxes and allows the heart chambers to fill with blood.
Electrocardiogram [ĭ-lĕk´trō-kär´dē-ə-grăm´]	A machine that graphically records the heart's electrical activity.
Endocardium [ĕn´dō-kär´dē-əm]	The inner muscle layer of the heart; the muscle that lines the inside of the heart.
Epicardium [ĕp´ĭ-kär´dē-əm]	The outer muscle layer of the heart that lies under the pericardial sac.
Erythrocytes [ē•rith•rō•sits]	A red blood cell that contains hemoglobin and transports oxygen.
Fetus [fē´təs]	An unborn baby.
Hematophagic [hĕ̆mă-tō-fā̆jē-ă]	The act of an animal or insect like a mosquito drinking blood.
Hematopoiesis [he″mah-to-poi-e´sis]	The formation of blood cells. In the fetus, it takes place at sites including the liver, spleen, and thymus. From birth throughout the rest of life, it is mainly in the bone marrow.
Hemoglobin [he´mo-glo″bin]	A protein housed in red blood cells that contain iron. Hemoglobin facilitates in carrying oxygen.
Hemophilia [*hee-m*uh-*fil-ee*-uh]	Any of several X-linked genetic disorders transmitted from the mother's genes, is a disease that occurs mainly in males. Excessive bleeding occurs due to the absence or abnormality of a clotting factor in the blood.
Hemostasis [he″mo-sta´sis]	Stopping the escape of blood by natural means (either clot formation or vessel spasm).
Malaria [muh-lair-ee-uh]	A disease transmitted by mosquitos in which a parasite infects the red blood cells; can be deadly.
Myocardial infarction [mi″o-kahr´de-al in-fark´ shun]	A heart attack.
Myocardium [mi″o-kar´de-um]	The middle and thickest layer of the heart wall muscle.
Open circulatory system	System in which the blood is pumped by the heart and fills the body cavities. The blood does not stay within the vessels.

Level 1 Vocabulary
Level 2 Vocabulary
Level 3 Vocabulary

Word [Pronunciation]	Definition
Pericardial sac [per″ĭ-kahr´de-al sak]	Fibrous double-layered sac that surrounds the heart. It is filled with a lubricant that allows the heart to move without friction.
Platelets [plat'lits]	Small cells in the blood that are important in hemostasis, forming blood clots.
Prothrombin [pro-throm´bin]	A clotting factor, made in the liver, that is in the blood. It is activated to thrombin for clot formation.
Red blood cells	Cells in the blood that contain hemoglobin, an iron that carries oxygen.
Sickle cell anemia [ah-ne´me-ah]	A blood disease that is inherited in which the red blood cells become misshaped to a sickle-like appearance. Causes long-term problems.
Sinoatrial node [sahy-noh-ey-tree-uh]	A mass of muscle tissue on the top of the right atrium that is the electrical pacemaker of the heart.
Stem cell	A cell that has the ability to differentiate to other specialized cells.
Stethoscope [steth´o-skōp]	A medical device used to listen and magnify the sounds heard in the body.
Syncope [sing´kah-pe]	To lose consciousness; pass out.
Systole [sis´to-le]	The phase in the heart cycle of beating in which the heart chambers contract to expel blood out of the heart.
Tachycardia [tak″e-kahr´de-ah]	A fast heartbeat that typically is over 100 beats a minute in an adult.
Tricuspid valve	The heart valve between the right atrium and right ventricle.
Universal donor	A person who has type O blood.
Universal receiver	A person who has type AB blood.
Valves [valv]	The "door" between the chambers of the heart that prevents blood from flowing backwards.
Veins [vān]	Blood vessels in the body that carry deoxygenated blood. They transport blood to the heart.
Ventricles [ven´trĭ-k'l]	The lower chambers of the heart.
Venules [ven´ūl]	Small blood vessels that carry deoxygenated blood toward the heart. They connect the capillaries to the veins.
White blood cells	Blood cells that are part of the immune system that fight invaders that attack the body.

*Pronunciation Keys from http://medical-dictionary.thefreedictionary.com

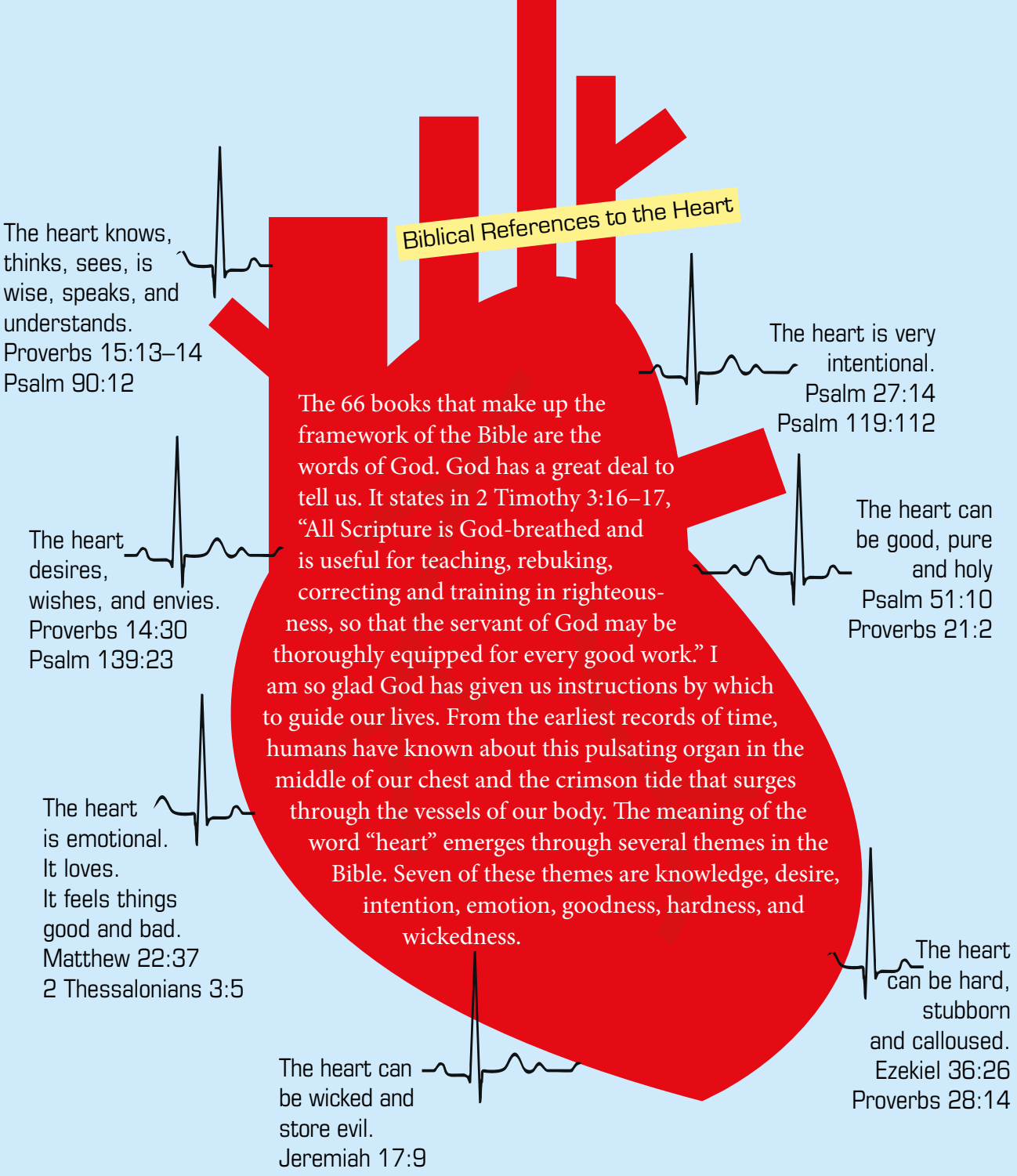
Introduction

Lightning flashed. The cloud hurled its pellets downward. A blood-curdling scream resonated through the cold, dank, and dreary marble halls . . . a suspenseful way to begin a book on *The Complex Circulatory System,* right? Just the mention of the word or seeing blood causes some people to feel woozy and go wobbly in the knees. Some people will even pass out at the very sight of blood. Take heart. There will be no need to be faint of heart.

Our heart beats passionately. It never stops. It never rests. It works around the clock, day and night. It starts to beat after you were conceived in your mother's womb at 3 to 4 weeks (a full-term pregnancy is 40 weeks), and continues until the day God calls you heavenward. Aside from our Heavenly Father, Lord, God, and Jesus, no two words are more heavily mentioned in the Bible than "blood" and "heart." The word blood is mentioned in the Bible over 400 times. Heart is mentioned over a staggering 900 times. We will take a look at some of the powerful images illustrated and represented by these words.

The Complex Circulatory System will catapult you into a whole new dimension. First, we will take an historical excursion through the pages of time and see how our knowledge of the circulatory system has expanded. We will learn all about blood, where it comes from, and how clots develop. Next, we will wade through the life-giving fluid that courses through the highways of your body. We will explore bloodsucking critters and enter the atrium of the heart and peer into the heart's many rooms. My prayer is that as we journey through the tributaries of your body, you will gain a deeper understanding of the magnificent artistry God has fashioned in you.

Trust in the Lord with all your heart, and do not lean on your own understanding. In all your ways acknowledge him, and he will make straight your paths (Proverbs 3:5–6).

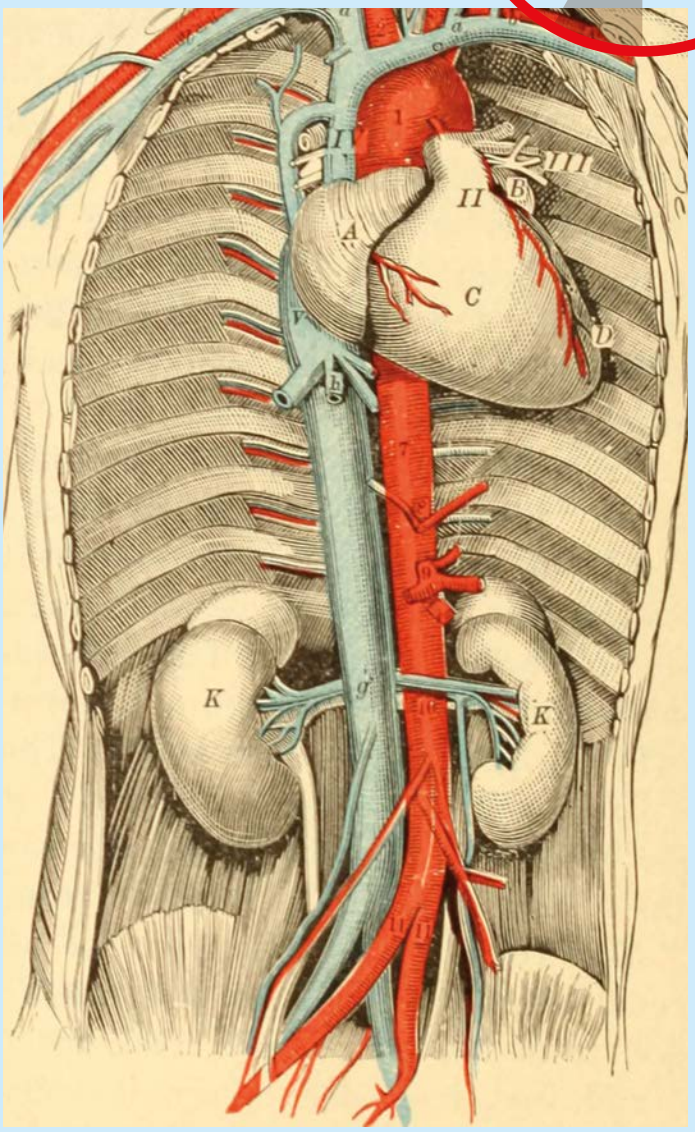


It has taken us many generations to acquire the understanding of the heart in the context of our biological processes. Our Lord amazes me. Before man made these "great" discoveries, God's creation and order already existed. We have just begun to understand some of the complexities of His handiwork, to put words and descriptions to this order. We continue to gain increasing understanding of this order. Never will our understanding and intellect put us on equal footing with our Lord. May our hearts become tender to the soothing words and guidance of our Heavenly Father.

1 Historical Timeline of Circulatory System

Any time when we peek back at the timelines of history, it is important to remember that it is an account of the past. People's accounts can differ depending on that particular person's perspective. The context in which an historical event occurs is important to take in consideration. Context is the circumstances or situation in which something happens. These discoveries did not happen inside an airless and weightless vacuum. Our progress in science builds on our prior knowledge. Each intellectual discovery provides a foothold to reach up to further our understanding. Scientific reasoning can be very delicate and at times silenced depending on a person's or culture's worldview. We will take a look at this as we tour the historical timeline of the circulatory system.

We begin in the year 384 B.C. with Aristotle who was born in Macedonia. He was a Greek philosopher and scientist. He believed the heart was the center of a person. The heart was where the soul dwelled and was where blood was manufactured in the body. In 340 B.C., Praxagoras was the first to differentiate between arteries and veins. He believed that the arteries had their origin in the heart and carried "pneuma." Pneuma has its origins in Greek. It means to "breathe" and is related to the "spirit" and the "soul" in the religious context. Arteries were full of "spiritual" air. Erasistratus, a Greek anatomist (one who studies the body) and royal physician, described the heart as being a pump. He also in 250s B.C. saw the heart as a source of both arteries and veins. This was the wisdom of the times. This set the stage for one of the most influential physicians of the middle ages. Claudius Galenus, was born in Pergamum, Asia Minor (Western Turkey), during the peak of the Roman Empire in the approximate year of A.D.



129. He was better known as Galen. Galen left an indelible mark on the anatomical world. So deep was his impact that his view of the circulatory system was believed for 15 centuries!

Word Wise!

TOURNIQUET is any device that uses pressure to stop the flow of blood, usually through the arteries of an arm or leg, as after a serious injury.

If you lived in these times you would believe the following about the body:

> The body's function was to refine the food you ate. Natural spirits had their beginnings in the food and drink you consumed. Vital spirits were derived from the air. Veins carried natural spirits. Arteries carried vital spirits.
>
> Food was transformed in the liver. Veins originated at the liver. These veins contained the four humors or liquids of the body: yellow and black bile, blood, and phlegm. The blood of the veins went to the heart, and air and blood mixed in the left side of the heart. The heart was like a burning cauldron that produced heat and provided body warmth. (The brain cooled the body.) The humors naturally flowed around the body and went only where they were needed. The blood was consumed.

Why was this view so important? This theory guided the ideas about the origin of disease. Illness and disease were seen as functions of an imbalance of humors or a shift in its flow in the body. Treatment was aimed at restoration of this natural balance. Bloodletting was the practice of bleeding someone to restore this "healthy" balance. (We will talk a bit more about this later.) Tourniquets, which stop blood flow in an artery or vein, were also applied to parts of the body in attempts to redirect the flow of blood to other areas of the body. Today, we only use tourniquets in emergency situations to stop the bleeding from a wound.

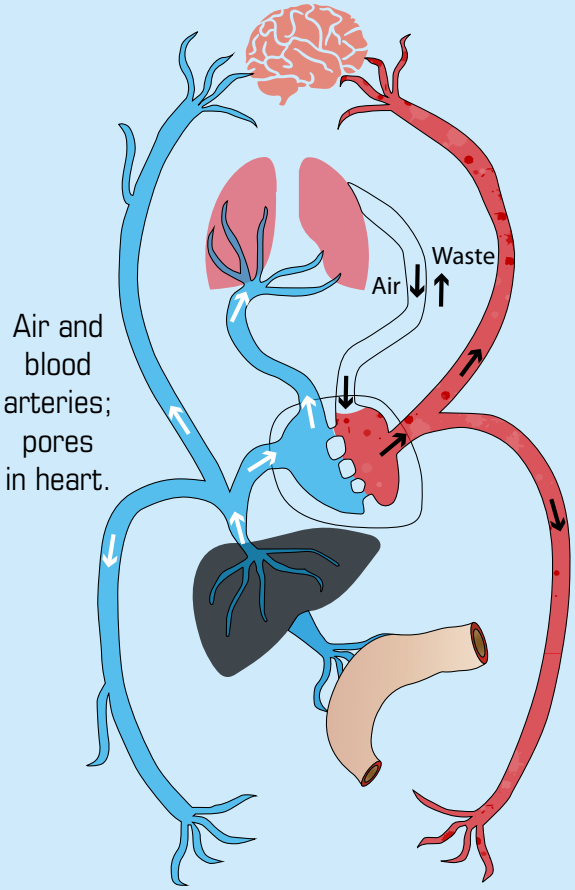
Galen began his study of medicine at the age of 16. At the age of 28, he was appointed to the post of surgeon to the gladiators. He received a great deal of on-the-job training patching up wounded gladiators. In the year A.D. 162, he became the leading authority on medical knowledge and was appointed to the position of physician to the emperor. Galen left the world a legacy of these essential views:

	Galen's View	Modern View
1.	Veins contained blood. These veins were open ended, and the blood bathed the organs.	Veins do in fact carry blood. They are not open ended or bathe the organs. They carry deoxygenated blood.
2.	A small amount of the blood provided nourishment to the lungs.	All the blood in the body is transported to the lungs to obtain oxygen.
3.	The heart pulsated.	The heart does beat and therefore it could be considered to "pulsate."
4.	Breathing cooled the heated body and yielded the vital spirits.	Breathing is not the essential way that the body cools itself. "Vital" spirits are not taken up by the lungs.
5.	Arteries contained air and blood.	Arteries do contain blood. Oxygen is dissolved in the blood and is transported on hemoglobin in the red blood cells.
6.	Arteries were located deep in the body and pulsated. The blood in the arteries was hotter, thinner, and more "spirituous." Veins were located close to the surface.	Arteries can lay deep and superficially in the body. They do pulsate with each beat of the heart.
7.	The whole body breathes in and out.	The lungs do the breathing.

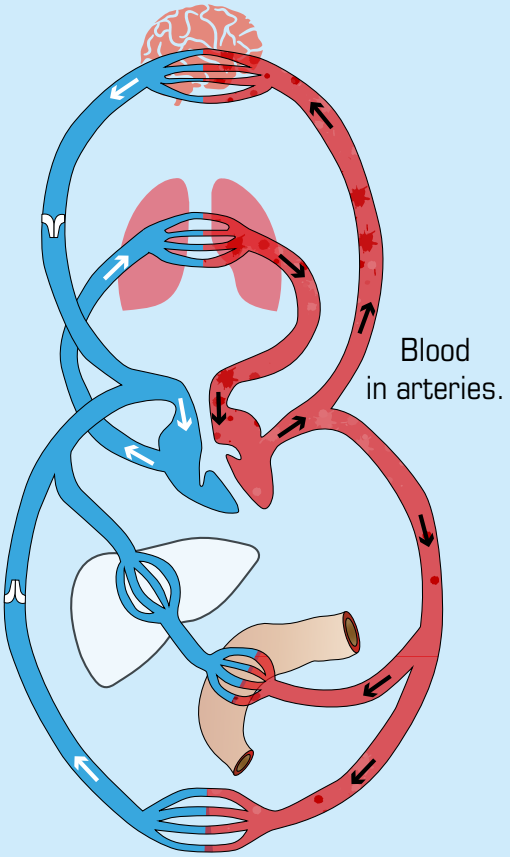
This accepted view of the body did not advance for nearly 15 centuries. History and science discovery was guided by the worldview of the times. Over the course of these 15 centuries, the Roman Catholic Church dominated the attitudes and direction of the world of medicine. In essence, anyone who disagreed with the established church was labeled a heretic and was severally punished. A heretic is someone who dissents or disagrees from the established views or what is thought as the revealed truth. Illness was seen strictly as punishment from God. Today we have a process called the scientific method in which one asks questions, develops a hypothesis, and tests this hypothesis through experimentation. During this time, there was no tradition in the way scientific knowledge was acquired. People feared testing commonly held beliefs proposed by Galen. They also feared the church. It wasn't until the Reformation, among other events, when Martin Luther on October 31, 1517, nailed his *95 Theses* on the door of the All Saints' Church in Wittenberg. He challenged the church. The two over-arching points of his theses were that the Bible was the center of religious authority and that we reach salvation by our faith and not just by our deeds.

Fast forward hundreds of years to modern times, and we still have a battle of worldviews. Faith and belief in the Bible do not suppress scientific ideas and advancement. In fact, they are supported more and more with each new discovery, which furthers us to magnify the great designer in our Heavenly Father.

Galen's open-ended vascular system



Harvey's closed circulatory system



This symbol for the barber's pole began during the Dark Ages; the red represented the bloody bandages wrapped around a pole. Early versions had a brass wash basin on the top and bottom. The top basin was a representation of where the leeches were kept. The bottom one was the symbol for the basin used to collect the blood. The staff was the item that a patient would grasp to encourage the flow of blood after a bloodletting procedure.

2000 B.C.

to A.D.1500

Mayan kings and queens who ruled in Central America would open their own veins so that their blood could be used in ceremonies.

460-370 B.C.

Ancient Greek doctor Hippocrates (460–370 B.C.), was considered the father of medicine. He is credited with the idea of the four humors.

335 B.C.

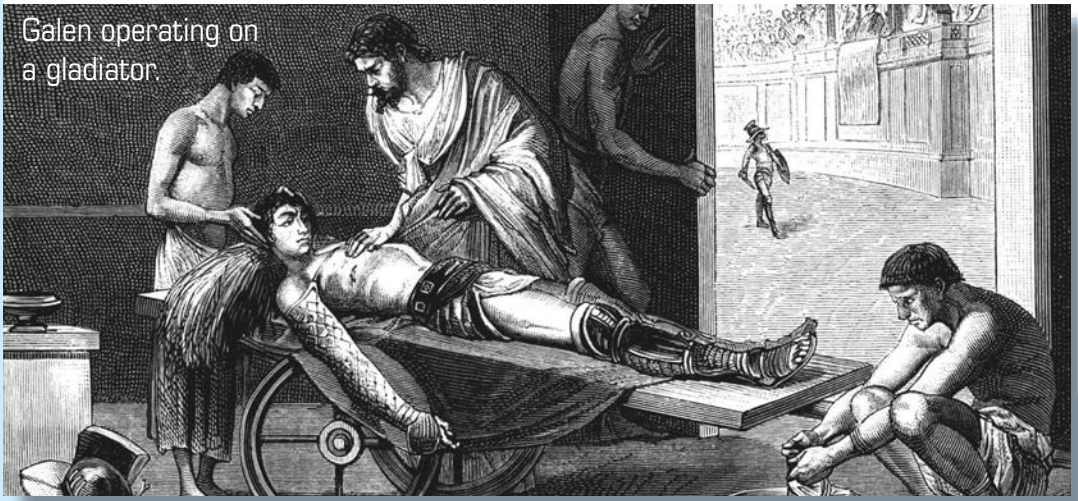
Herophilus (335–280 B.C.), a Greek doctor, was considered to be the father of anatomy.

129-200

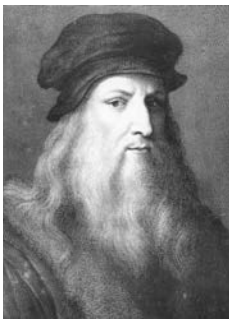
Claudius Galen of Pergamon (129–200) operated on gladiators. He greatly influenced the understanding of medicine and anatomy in the middle ages based on Hippocrates theory of the four humors.

410-1095

In medieval times, barbers were also surgeons. Doctors of the time considered surgery messy and beneath them. Barbers were good with a sharp blade, not only could they cut hair, but they would practice procedures from bloodletting to amputation of limbs. The barber pole was originally red and white striped.



Galen operating on a gladiator.



1500

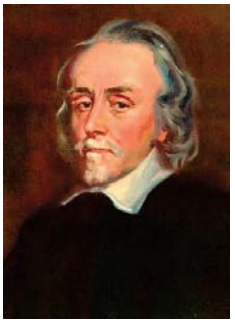
Leonardo Da Vinci (1452–1519) noted tiny "hairs" in tissues. He was interested in the link between form and action of the body. He made the first accurate drawing of the body as well as the heart and its valves.

1553

Michael Servetus (1511?–1553) was a theologian and physician who was burned at the stake. He was considered a heretic for his description of the circulation of the blood through the lungs.

1543

Andreas Vesalius (1514–1564) wrote one of the first books on the human anatomy entitled *De Humani Corporis Fabrica (On the Fabric of the Human Body).*



1578

William Harvey (1578–1657), an English physician, was the first to describe blood circulation in the body. He stated that blood flowed in a closed circuit — it was conserved, which means that the blood was not consumed by the organs. His discovery caused him much concern because it went against centuries of medical thought. He said, "Not only do I fear danger to myself from malice of a few, but I dread lest I have all men as enemies."

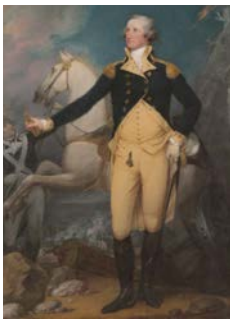
1666

Richard Lower (1631–1691), a physician, followed the works of William Harvey. He pioneered the idea of blood transfusions. He experimented on transfusing dogs. He even transfused a lamb's blood into a human — but such practices were very dangerous so laws in both England and France were created to stop it!

Lower transfusing blood into a man's arm from a lamb.

1670

Marcello Malpighi of Bologna (1628–1691), a biologist and physician, utilized a primitive microscope and discovered a network of tiny vessels called capillaries in the lung of a frog. This discovery linked the arteries and veins.



1799

George Washington (1732–1799) died due to bloodletting. After a day of riding his horse out in the cold, he returned to find his throat sore. Soreness and the swelling in his throat advanced. He became short of breath, and a team of doctors were called. They utilized the most "effective" treatment of the times, bloodletting. It is said nearly 40 percent of his blood volume was removed, and he died. Before dying, George Washington thanked the doctors for their excellent care.

1818

James Blundell (1791–1878) became the first in the United States to perform a successful blood transfusion. The transfusion was performed on a woman who had just delivered a baby. She immediately suffered from severe bleeding. He took 4 ounces from the woman's husband and transfused it into her. Today we know it's not that simple. People have one of four different types of blood, and it can be deadly if you receive the wrong kind during a transfusion.

1823

The first medical journal, *The Lancet,* was published. *The Lancet* still exists today. It is one of the leading medical journals. Thomas Wakley (1792–1862) first published it on October 5, 1823. As the journal was going to press he stated, "A lancet can be an arched window to let in the light or it can be a sharp surgical instrument to cut out the dross and I intend to use it in both senses." A lancet was the indispensable tool utilized in bloodletting. It was used to cut the skin and blood vessels.

1832

The laws were changed, and medical professionals could legally use donated bodies for study and dissection.

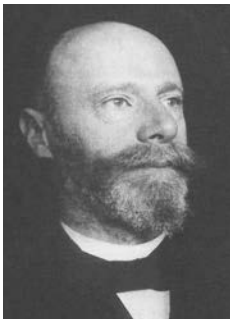
The picture above is Rembrandt van Rijn's *The Anatomy Lesson of Dr. Nicolaes Tulp,* completed in 1632. Dissection was not limited to the eager learning eyes of apprentice doctors of the day; dissections were also held for public "amusement." You could even buy tickets for these events.

1893

Daniel Hale Williams (1856–1931) was an African American general surgeon who performed the first successful open heart surgery and founded the first non-segregated hospital in the United States. He operated on James Cornish at Provident Hospital in Chicago. Mr. Cornish had been stabbed in the heart. Today's common practice of blood transfusion and the use of blood products was not safely utilized at that time. Even without this life-saving practice, he was able to suture (sew) the covering around Cornish's heart, saving his life.

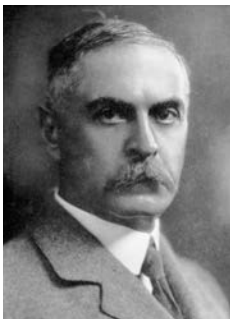
1896

Ernest Henry Starling (1866–1927), an English physiologist (a person who studies the body's processes), was the first to explain the maintenance of a fluid balance in the body. It is called Starling's Law. The law states that the stroke volume (the amount of blood pumped into the left ventricle per a heartbeat) of the heart will increase with additional blood filling into the ventricle. The more the heart wall stretches due to increased blood flow, the more force the heart muscle will use to contract.



1903

Willem Einthoven (1860–1927) was a Dutch doctor and physiologist who invented the first electrocardiogram (EKG or ECG). It was already understood and accepted in medicine that the heart generated electrical activity. However, prior to Einthoven's invention, the only way to record this activity was placing electrodes directly on the heart muscle. This was impractical. He won the Nobel Prize in Physiology or Medicine in 1924.



1900's

Karl Landsteiner (1868–1943) an Austrian-born biologist and physician was the first to identify the major blood groups: A, B, AB, and O. He discovered that agglutinins were found on blood red blood cells that caused an immune reaction in which blood clumps when two different types of blood are mixed.

1919

Jules Bordet (1870–1961), physician, was awarded the Nobel Prize in Physiology or Medicine for his discovery of factors in blood that destroy bacteria and how the blood breaks apart (called hemolysis) due to foreign blood cells in the body.

1920s

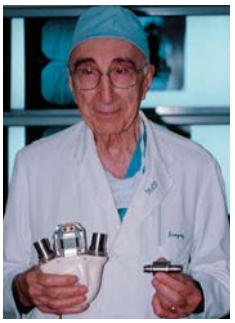
Werner Forssmann (1904–1979), a physician born in Berlin, used himself as a test subject to prove the medical procedure for cardiac catherization was possible. He inserted a catheter, a type of tube, threading it into a vein at the fold of his arm and pushed the tube deeper and deeper until the top was inside the right side of his heart. With the tube still in, he went to the hospital radiology department and took x-rays to confirm his findings. He was awarded the Noble Prize in Physiology or Medicine in 1956.

1930s

Charles Richard Drew (1904–1950), was an African American physician and surgeon who is credited for blood banks. He studied how blood transfusions were given, and invented better techniques for storing blood. During World War II, he utilized this new knowledge to help provide life-saving blood storage to help wounded soldiers in the field.

1944

Helen Brooke Taussig (1898–1986), physician, is credited with being the founder of pediatric cardiology. She assisted in the development of the Blalock-Taussig Shunt. This is a surgical procedure that helps children born with heart defects, "blue baby syndrome," that cause them to be blue. She was awarded the Medal of Freedom from President Lyndon Johnson. In 1965, she became the first woman president of the American Heart Association.



1952

Michael DeBakey (1908–2008) invented a new kind of graft for repairing torn arteries. In 1932, he invented a part for the first heart-lung machines. These machines are utilized for heart surgery. He was the first person to identify the smoking of cigarettes as a connection to lung cancer. In the 1950s, the DeBakey Dacron Graft was used in repairing damaged blood vessels.

1967

Christiaan N. Barnard (1922–2001), a South African cardiac surgeon, was a pioneer who performed the first successful human heart transplant. Although his patient lived only 21 days after, it was still considered a great success.

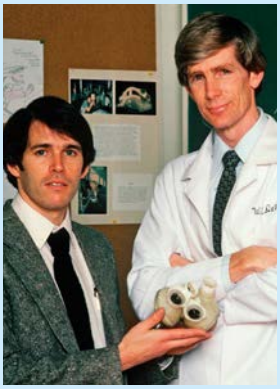
1982

Barney Clark at 61 years of age survived a Jarvik-7 artificial heart for 112 days. Dr. William DeVries (1943–) performed the surgery. Clark knew that his chances for long-term survival were not likely, but he agreed to the heart to help further medicine.

1991

Dr. Drew Gaffney (1946–), physician, flew on NASA's space shuttle as a "payload specialist." A payload specialist is someone who rides as an expert in a particular field. While on board, he studied how the heart and the circulatory system adapted to flight in space. This was the first mission to explore the human body in space. A catheter, a long tube, was inserted into his elbow prior to lift off and threaded to his heart. This allowed close measurement of his heart functions.

A number of artificial hearts were proposed and experimented with since the first one by Vladimir Demikhov in 1937, who transplanted it into a dog. There were limited successes in tests with animals, but this helped to advance understanding of the challenges. Here you can see the major blood vessels on the Jarvik-7, an aluminum and plastic artificial heart used during the first successful human implant in 1982 at the University of Utah Medical Centre in Salt Lake City. The Jarvik-7 heart relied on external power for compressed air and electricity. The patient had a six-foot lifeline to the support equipment.



Dr. Robert Jarvik, developer of the Jarvik-7 artificial heart, and Dr. William DeVries who, with Dr. Tom Kessler (not pictured), performed the first successful permanent artificial heart surgery.

The first total artificial heart implanted in a human body was developed by Domingo Liotta and placed by surgeon Dr. Denton Cooley in 1969 at St. Luke's Episcopal Hospital in Houston. (Dr. Liotta joined the staff at the hospital in Texas in 1961 as the director of the Artificial Heart Program. He was hired by Dr. Michael DeBakey.) The patient lived for sixty-four hours with the artificial heart pumping oxygenated blood through his body until a human heart could be available for transplant. The patient died soon after receiving a real heart, and there was criticism about the use of the Liotta-Cooley plastic heart. However, it did show how artificial hearts could be used until real hearts were donated.

Word Wise!

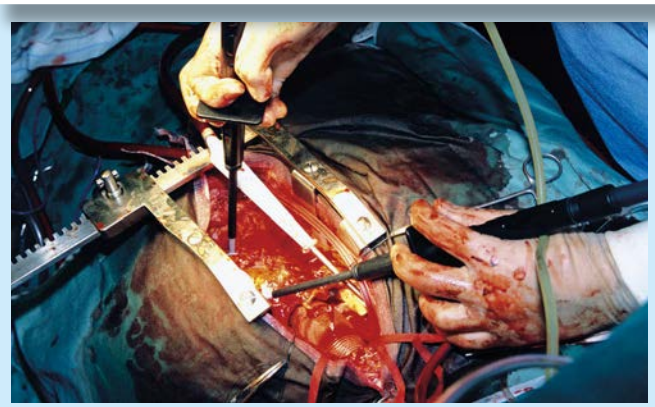
The HIPPOCRATIC OATH, named after Hippocrates, is an oath that doctors are required to swear upon upholding professional standards in practicing medicine and the care of the patients.

Our knowledge of medicine continues to march on.

Today, we are looking at new ways to diagnose heart disease much earlier. An item with great promise is the Computed Tomography Angiography or CTA. It helps to find small blocks in the arteries that surround the heart. A dye is injected in a vessel in a patient's arm. A special x-ray machine called a CT scanner takes images of the heart and the dye flowing through the blood vessels. It can show where blockage exists in the vessels.

A new artificial blood is being tested in the United Kingdom. If successful, it could provide an answer to blood shortages. Perhaps it can be used in patients who refuse blood transfusion on the grounds of religious objection.

Maybe God has a plan for you to make contributions to the field of cardiology. He has given you unlimited potential. Walk boldly. Keep your eyes on Him. Look for ways to magnify His wonder.



Racial segregation existed in the United States and even existed in the donation of blood. Charles Richard Drew resigned from his position with the American Red Cross over this issue. The American Red Cross did not change its position on this policy of segregation until 1950.