ANATOMY 360°

The Ultimate Visual Guide to the Human Body

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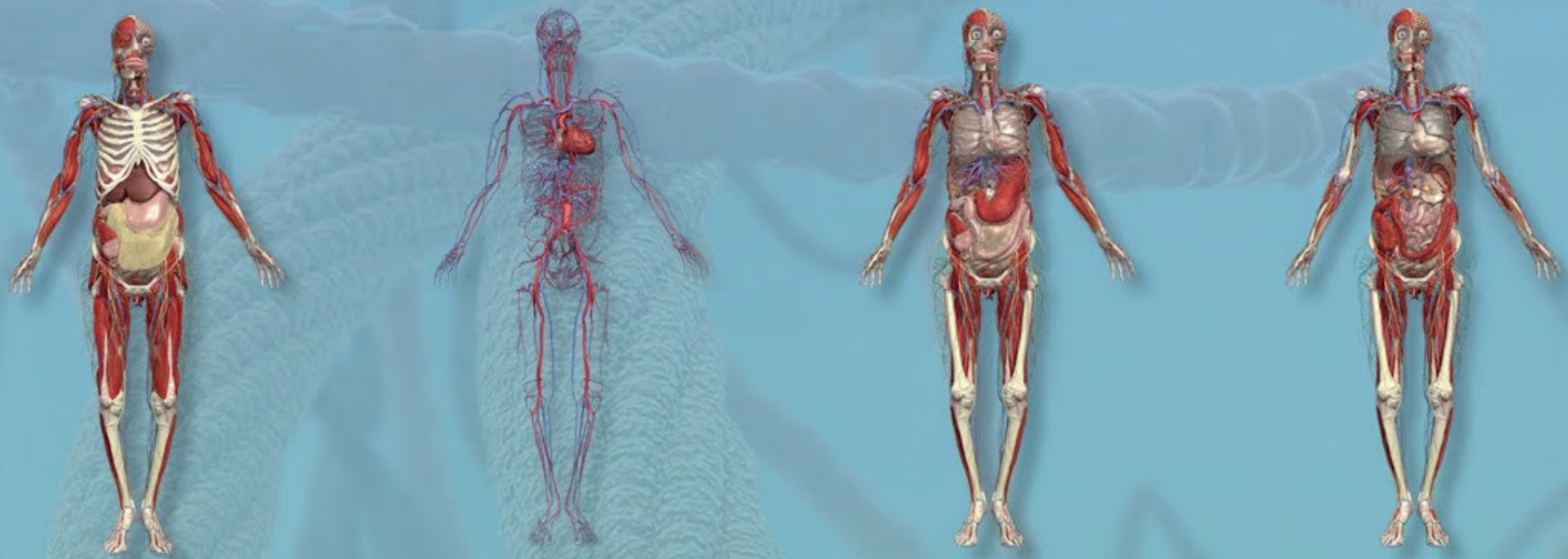
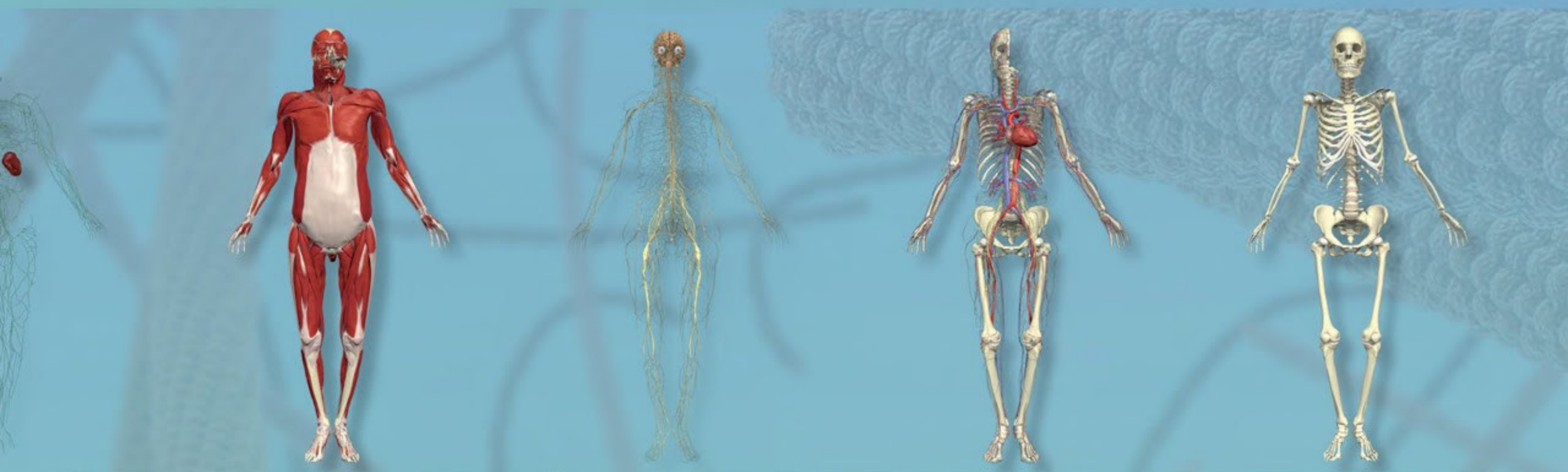
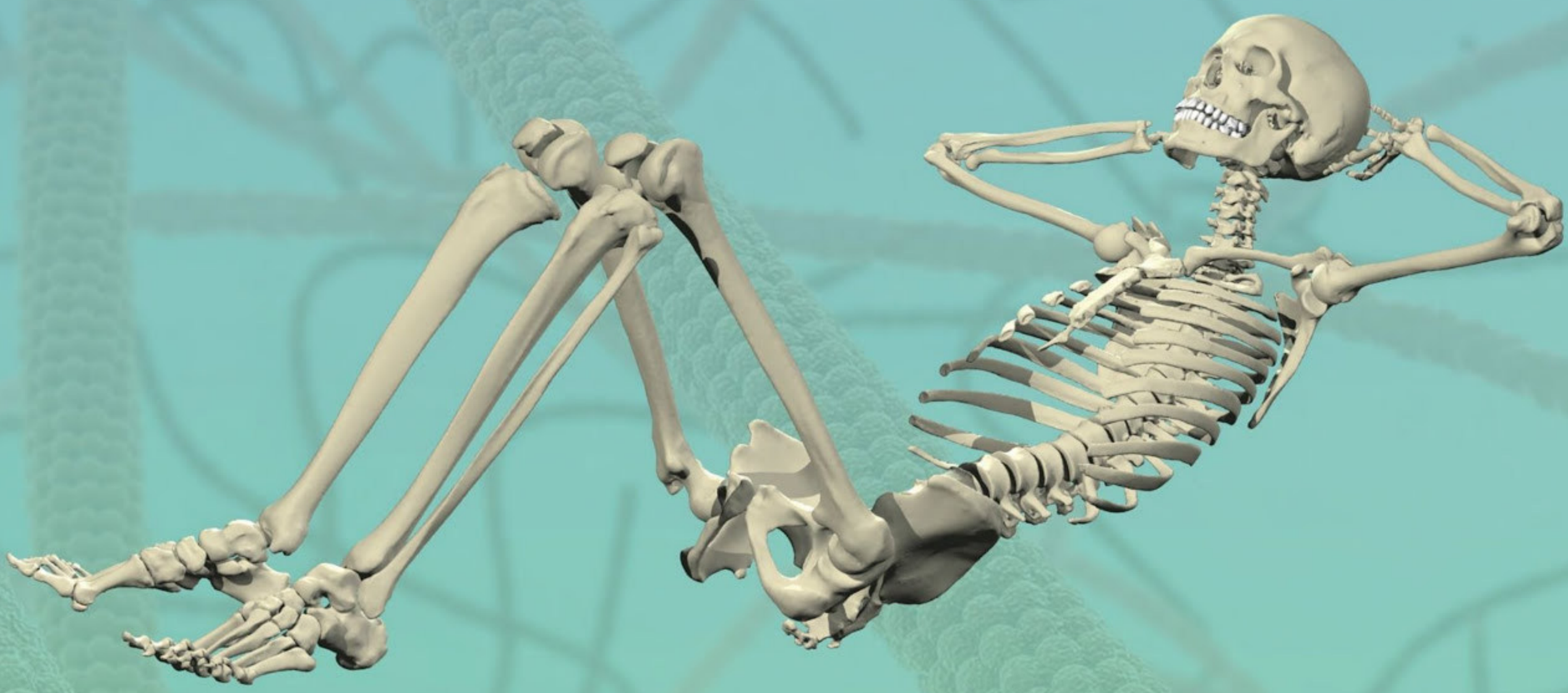






About the Images

The amazing images found within this book were taken from the interactive products of Primal Pictures. They were generated from a comprehensive 3-D model that took twenty years to complete and are made up of more than 7,000 individual anatomical structures. Any combination of structures can be seen from any angle, allowing the vast array of images you can see in this book to be created.

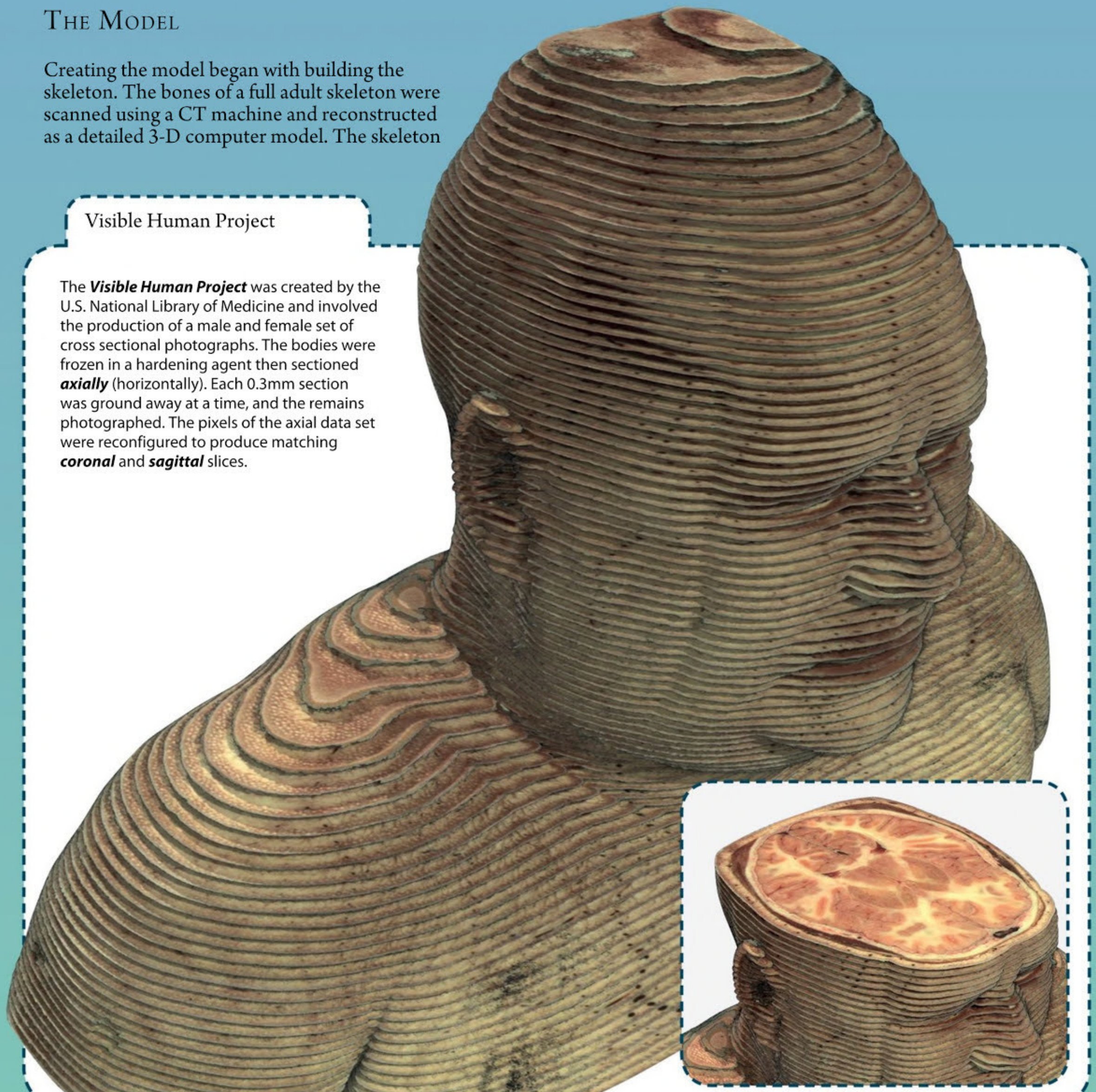
The Model

Creating the model began with building the skeleton. The bones of a full adult skeleton were scanned using a CT machine and reconstructed as a detailed 3-D computer model. The skeleton could then act as a framework for the soft tissues of the body that were modeled.

Structures such as the muscles, vessels, nerves, and organs were constructed in a process using data from Primal MRI data and the Visible Human Project.

Visible Human Project

The ***Visible Human Project*** was created by the U.S. National Library of Medicine and involved the production of a male and female set of cross sectional photographs. The bodies were frozen in a hardening agent then sectioned ***axially*** (horizontally). Each 0.3mm section was ground away at a time, and the remains photographed. The pixels of the axial data set were reconfigured to produce matching ***coronal*** and ***sagittal*** slices.

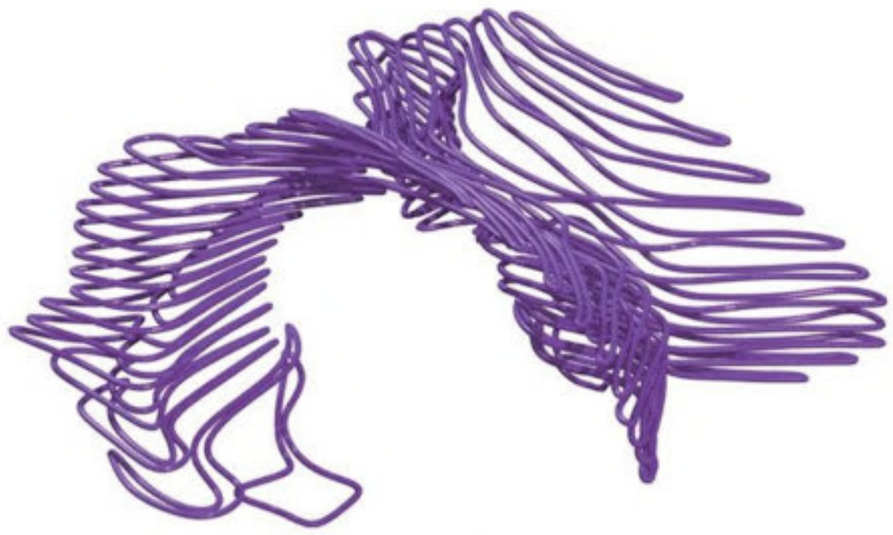


Segmentation

Our anatomy team viewed the cross-sectional images and used an in-house program to digitally outline every individual anatomical structure at each level, and often in all three planes. This process is known as ***segmentation*** and took the team over four years to complete. Once each component was labeled throughout the entire data set, the labels were transferred into the 3-D computer graphics package, ***Houdini***.

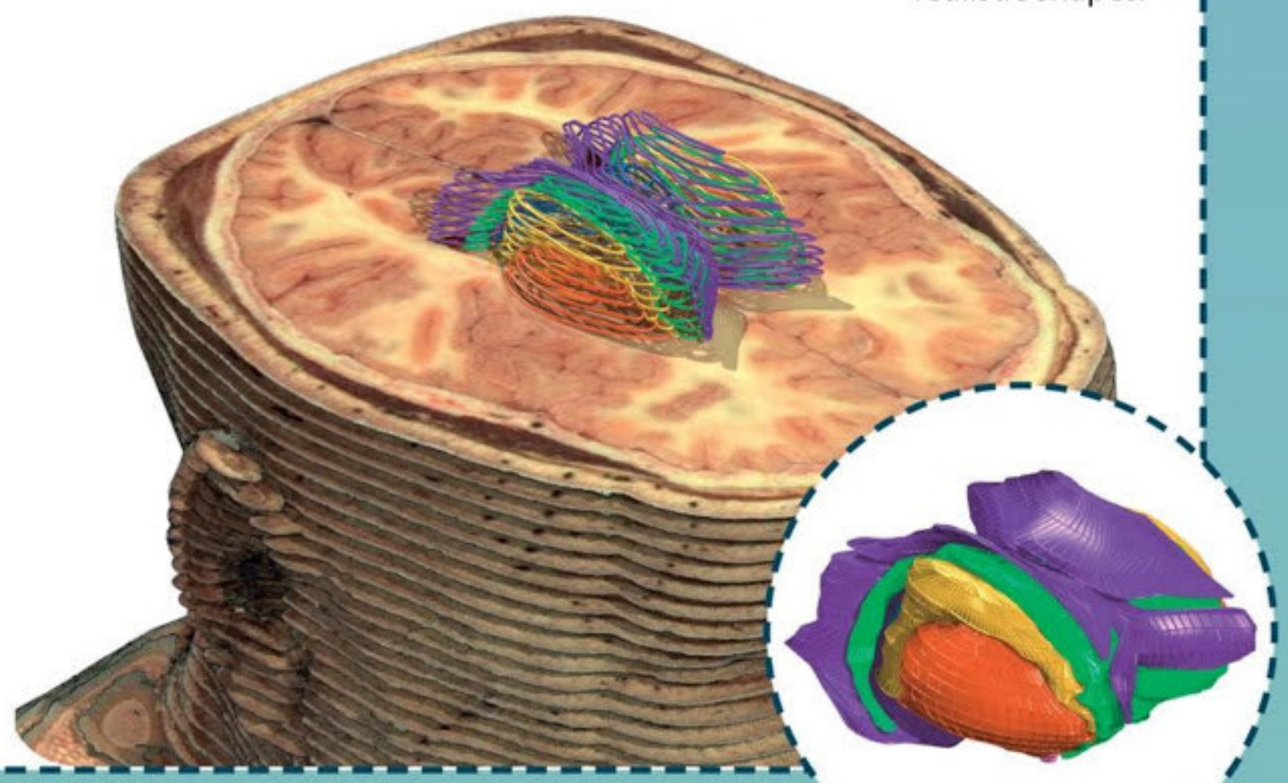
This image shows a label around the ***caudate nucleus*** of the brain on an axial slice.

Splines

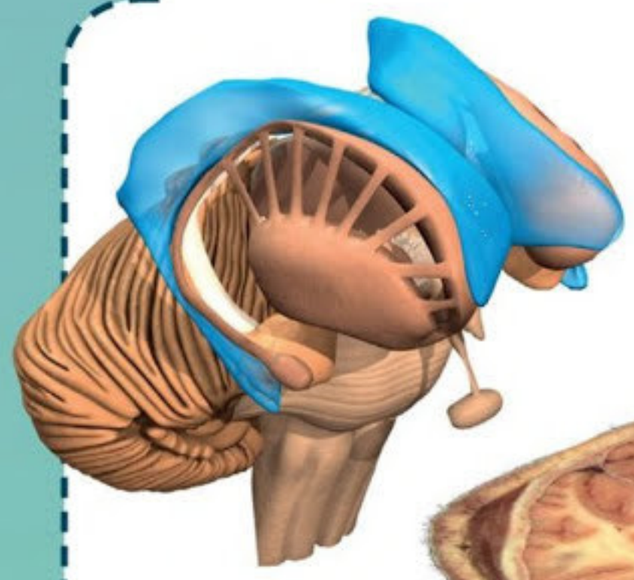


In Houdini, the graphics team used the labels to create a 3-D shape of each anatomical component. Here are the rings for the lateral ventricles of the brain seen in axial, sagittal, and coronal directions, and combined together.

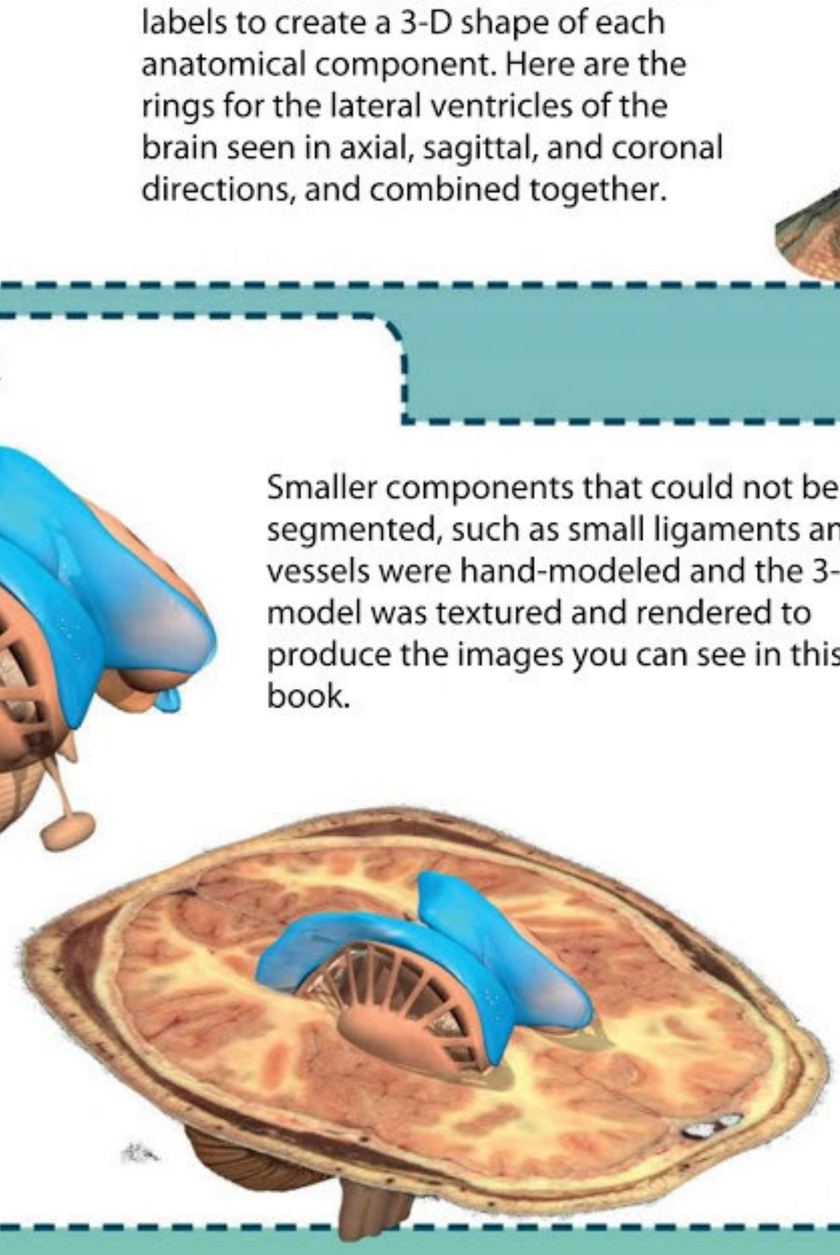
The sets of rings taken were then skinned and manually manipulated to provide smooth realistic shapes.

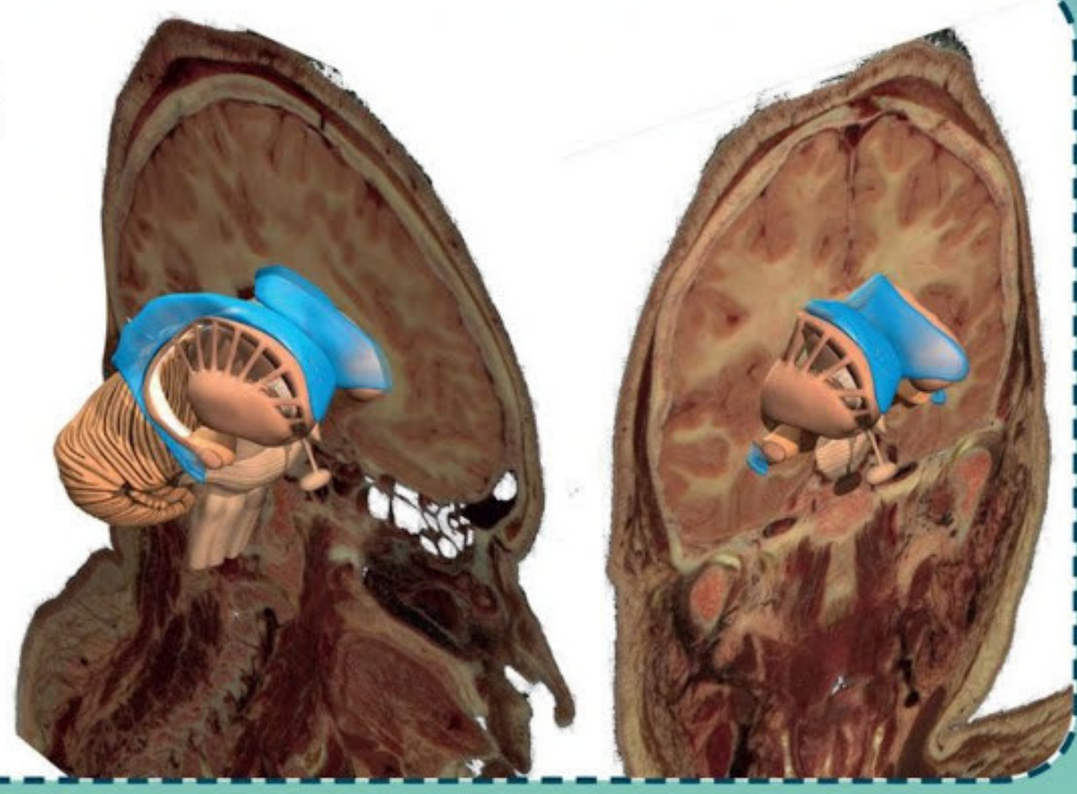


Final model

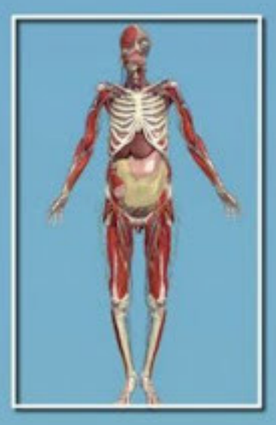


Smaller components that could not be segmented, such as small ligaments and vessels were hand-modeled and the 3-D model was textured and rendered to produce the images you can see in this book.





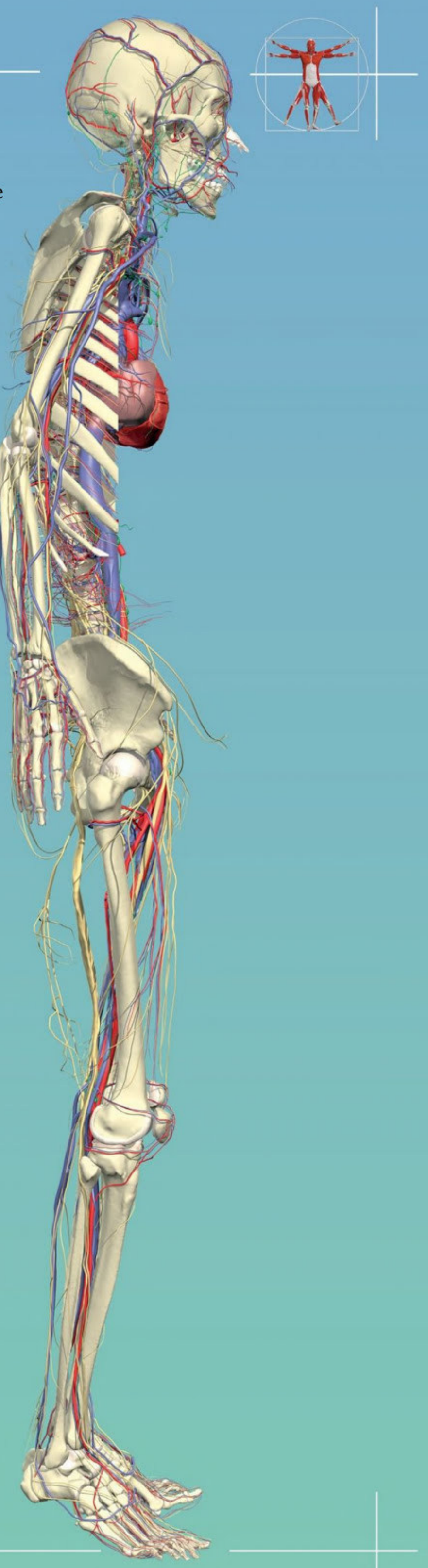
Whole Body Overview



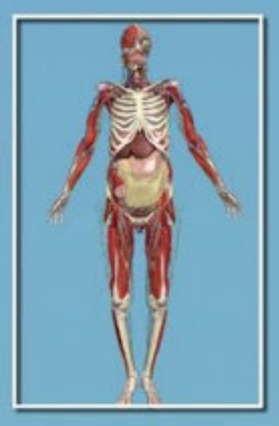
The human body is truly amazing. At this very moment numerous chemical reactions are taking place within the trillions of specialized cells that make up our tissues, organs, and systems. Working together, they allow us to move, to grow, to breathe, to eat, to react to our environment, and even to interact with one another. Thanks to our incredible bodies, we are living organisms that not only survive, but thrive, here on planet Earth. As we take this journey through the human body we will see the remarkable way in which the body is adapted and organized to allow this to happen.

Human anatomy is the branch of science that studies the structure of the human body. In the past, this has involved dissecting human bodies to separate and reveal the different parts. However, new technology such as magnetic resonance imaging (MRI) now allows us to view the structure of the entire human body without making a single cut.

Human anatomy is closely linked with another branch of science called physiology. This is the study of the way in which the body works. It is helpful to keep in mind that the structure of a body part is related to the task that it performs—form (anatomy) is related to function (physiology).



Generalized Cell



A cell is the smallest individual building block of a living organism. There are many different types of cell, depending upon the substances they produce and the functions they perform. Examples include skin, muscle, and nerve cells. Each cell contains organelles which are specialized regions within a cell that work together to keep the cell alive, and to help it carry out its function.

Did you know?

It is estimated that there are approximately 100,000 billion cells in the average adult human (that's 10 followed by thirteen zeros!)

Cytoplasm
is the part of the cell lying between the plasma membrane and the nucleus. The fluid in the cytoplasm in which the organelles are suspended is known as the cytosol.

Nucleus

Endoplasmic reticulum

Golgi complex

Centrioles

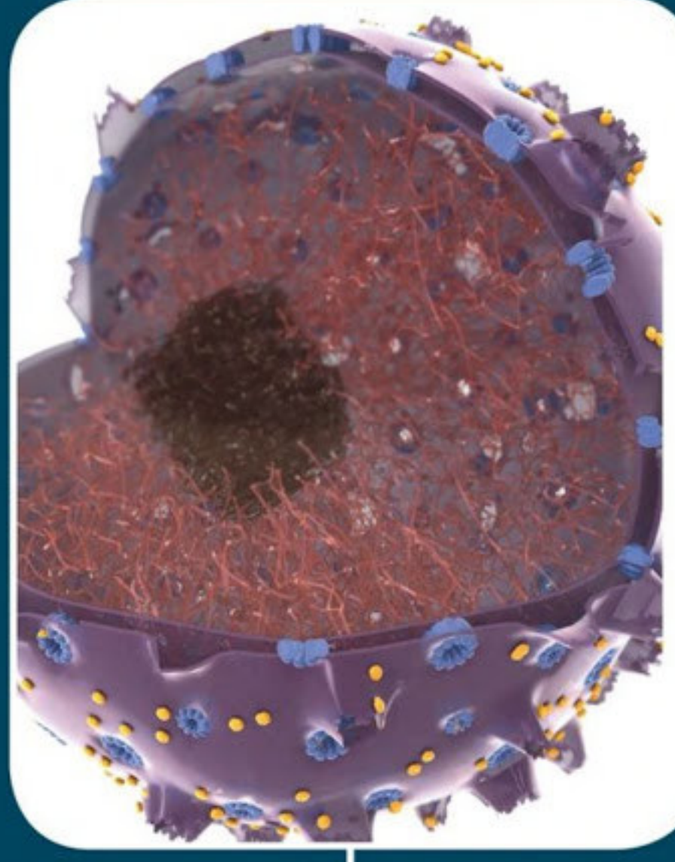
Lysosomes
are organelles that contain substances that can break down waste material and debris within the cell.

Mitochondria

Cytoskeletons
are organelles that contain substances that can break down waste material and debris within the cell.

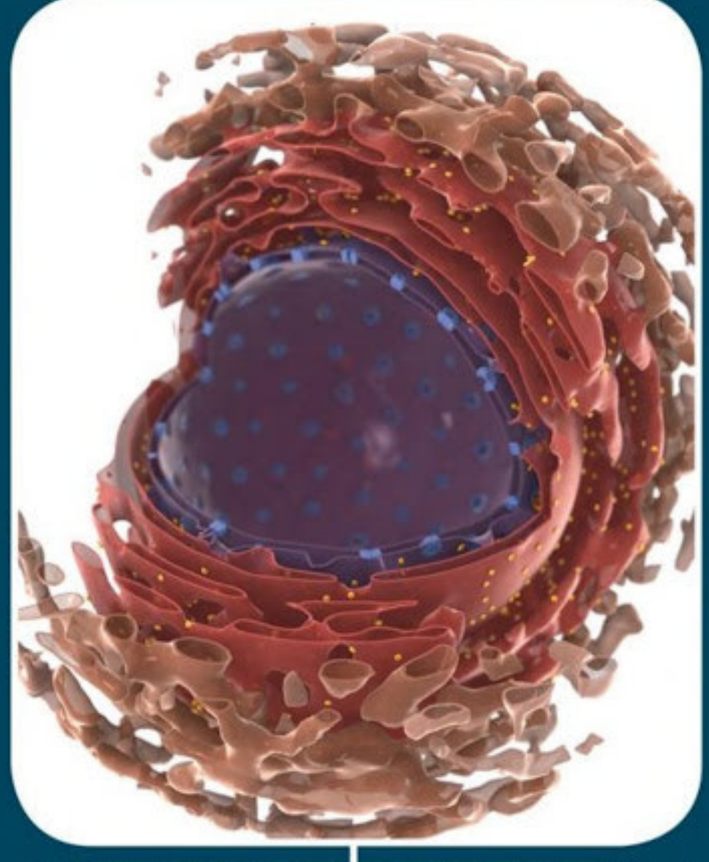
Plasma membrane
is a barrier that separates the inside of the cell from the environment.

Organelles



Nucleus
is the control center of each cell. The nucleus contains most of the cell's genetic information.

Golgi complex
can be thought of as an "intracellular post office." Products made by the cell are labeled and packaged for delivery to other areas, or for export out of the cell.



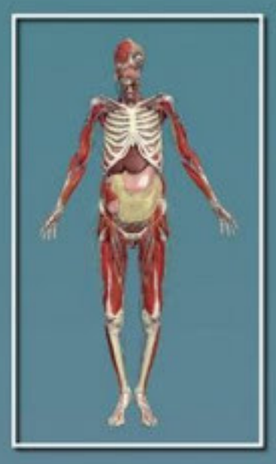
Endoplasmic reticulum
is involved in producing and processing proteins. In some cells it also has a role in the processing of fats and sugars.

Mitochondria
are the "power stations" of the cell. They provide energy using the oxygen and nutrients delivered to the cell.

Cytoskeleton
provides structural support for the cell as well as helping move things from one part of the cell to another.

Centrioles
are specialized structures involved in cell division.

Cell Division



Most cells in the human body are able to divide. There are two methods of cell division, mitosis and meiosis. These processes are divided into different phases.

Body (somatic) cells divide by mitosis. This produces two genetically identical copies of the parent cell, which can replace worn out cells, and allow growth to occur.

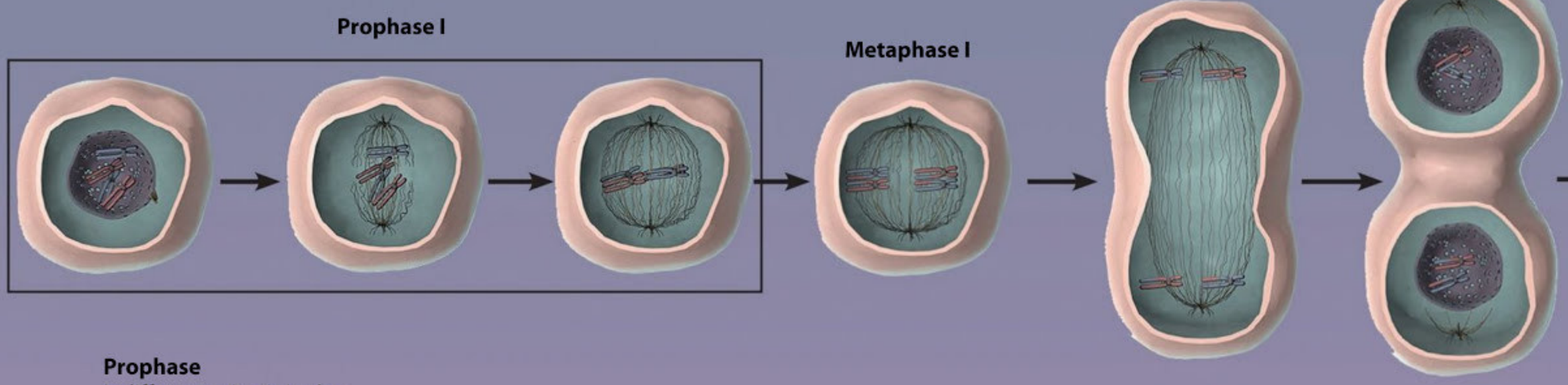
Reproductive (germ) cells divide by meiosis. This produces four genetically unique cells called gametes (either sperm or egg cells), which have half (1n) the genetic material of the parent cell. Gametes allow reproduction and the creation of a new human being.

Mitosis

is the type of cell division that takes place in body (somatic) cells.

Meiosis

is the type of cell division that takes place in reproductive (germ) cells. It is a two-step process. The key difference to mitosis is that the resulting cells have only half the normal content of genetic material.



Prophase
It differs to mitosis in that there is exchange of genetic material between the paired chromosomes. This means that the gametes are genetically different from each other.

Cytokinesis
is the process by which the cell splits in two, each containing an identical set of genetic material.

Interphase
is where the cell prepares for mitosis.

Telophase
is where a nuclear membrane forms around the two sets of chromosome.

Phrophase II

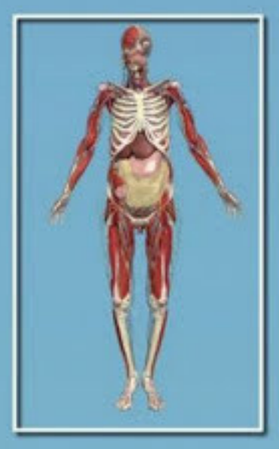
Metaphase II

Anaphase II

Telophase II

Resulting Cells (in each)

Plasma Membrane



The plasma membrane is a flexible barrier that separates and protects the cell contents from the outside environment. It is selectively permeable, which means that only certain substances can pass through it. This allows the plasma membrane to control what enters and leaves the cell, and to precisely regulate the environment within the cell. The plasma membrane is formed by two layers of phospholipids, within which cholesterol and various specialized proteins are embedded. These proteins are the cell's main way of interacting with the external environment, and they include channels, signals, receptors, carriers, and enzymes.

Glycolipids
are a type of fat (lipid) with a chain of sugars attached. They allow cells to be recognized by other cells.

Cell adhesion molecules
allow cells to bind to one another and to the surrounding connective tissue.

Enzymes
speed up certain chemical reactions either inside or outside the cell.

Cholesterol molecules
help stabilize the plasma membrane.

Phospholipid bilayer
provides a flexible semi-permeable barrier in which various proteins and glycolipids are embedded.

Plasma Membrane

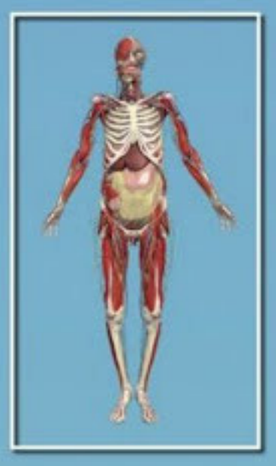
Cell identification molecules allow cells to signal and communicate with each other.

Receptor proteins detect when specific molecules bind to them, often leading to a change in cell behavior.

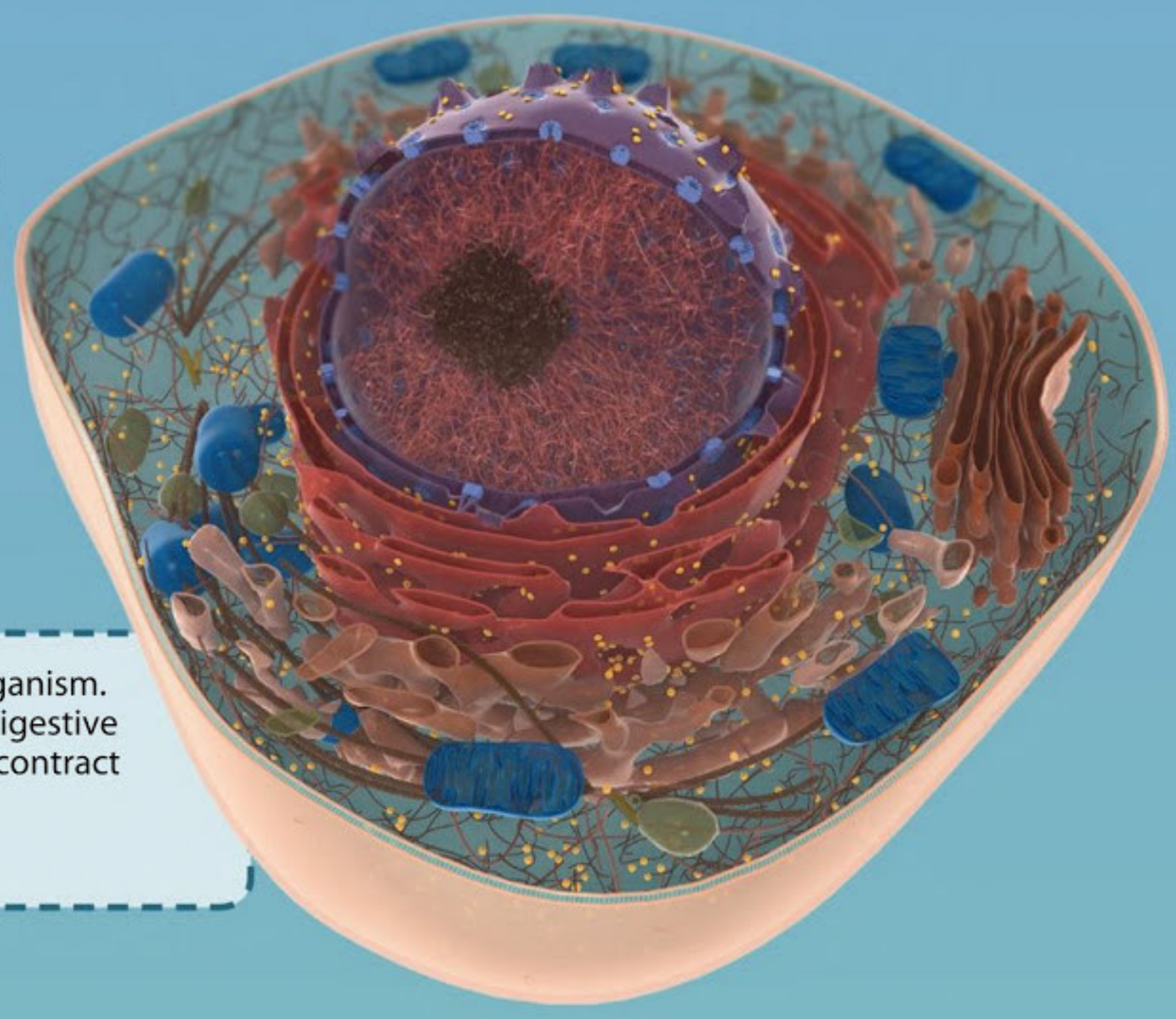
Carrier proteins can undergo shape changes which allow them to move large molecules from outside the cell to inside the cell.

Channel proteins allow the passage of certain chemical substances, depending upon their size and electrical charge.

Organization of Tissues



The human body contains trillions of individual cells. To maximize efficiency and function, this vast number of cells are organized and grouped according to the function that they perform. This leads to a hierarchy of cells, tissues, organs, systems, and organisms, where each level increases in both structural and functional complexity.

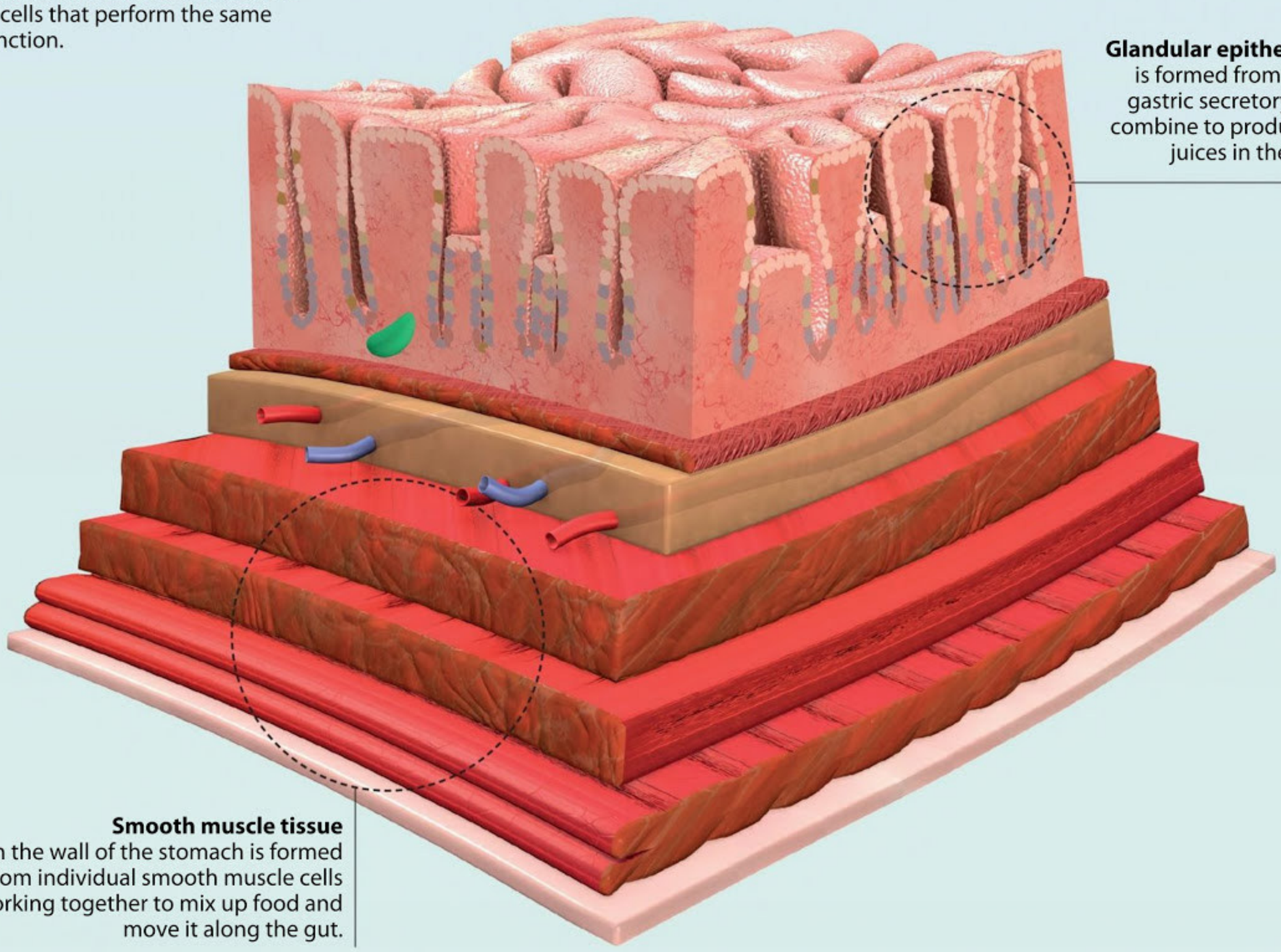


Cells

A cell is the basic building block of life within an organism. Most cells have a specific function; some produce digestive secretions like the cells lining the gut, while others contract like muscle cells for example.

Tissue

Tissue is formed from collections of cells that perform the same function.

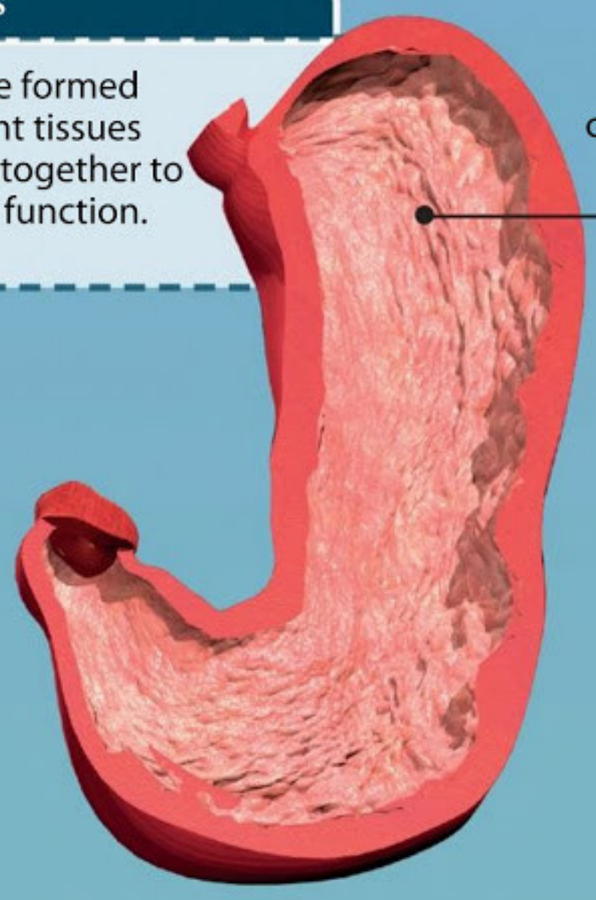


Glandular epithelial tissue is formed from individual gastric secretory cells that combine to produce gastric juices in the stomach.

Smooth muscle tissue in the wall of the stomach is formed from individual smooth muscle cells working together to mix up food and move it along the gut.

Organs

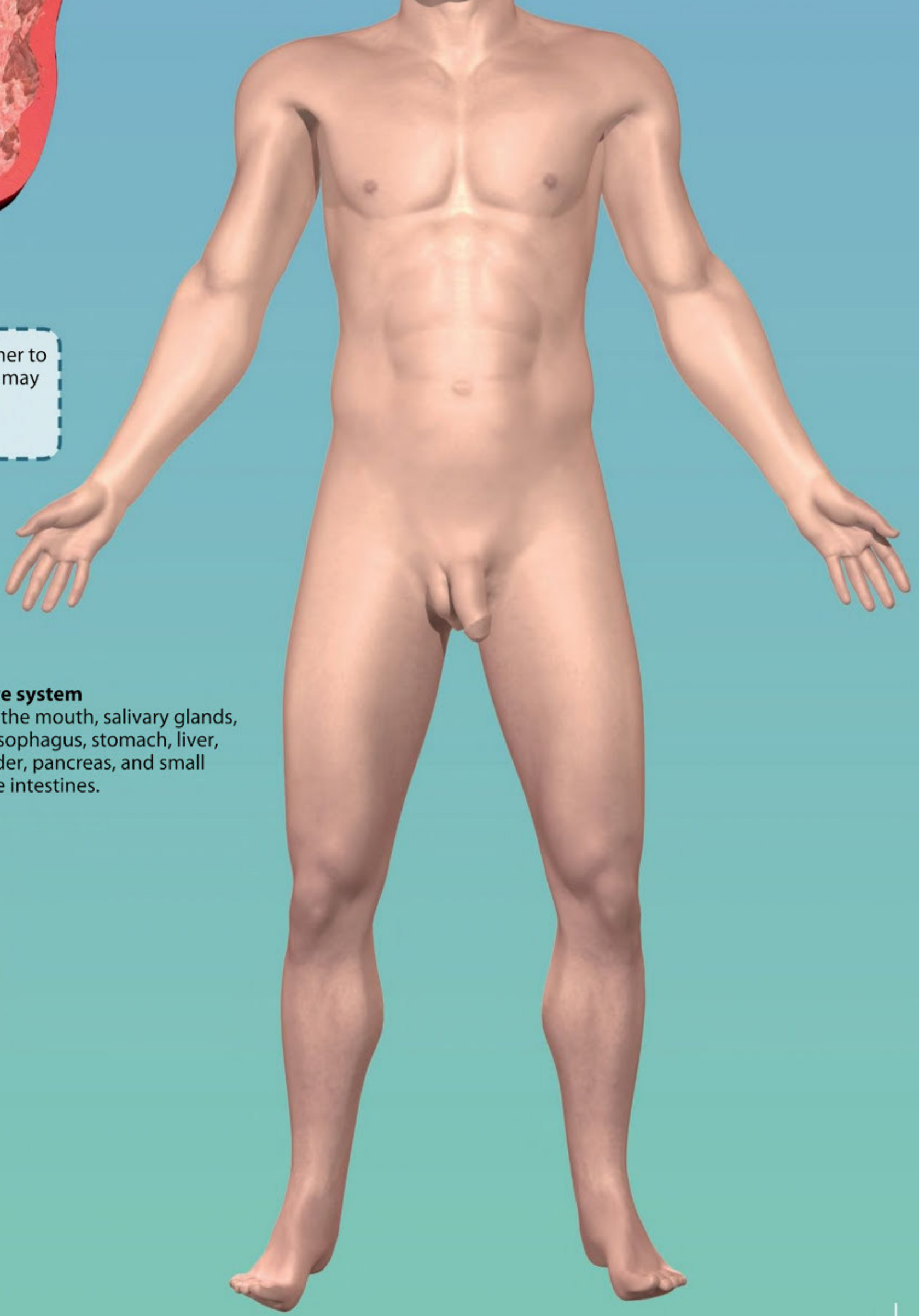
Organs are formed by different tissues that work together to perform a function.



The stomach
is an organ that is formed from glandular epithelial tissue, connective tissue, nervous tissue and smooth muscle tissue.

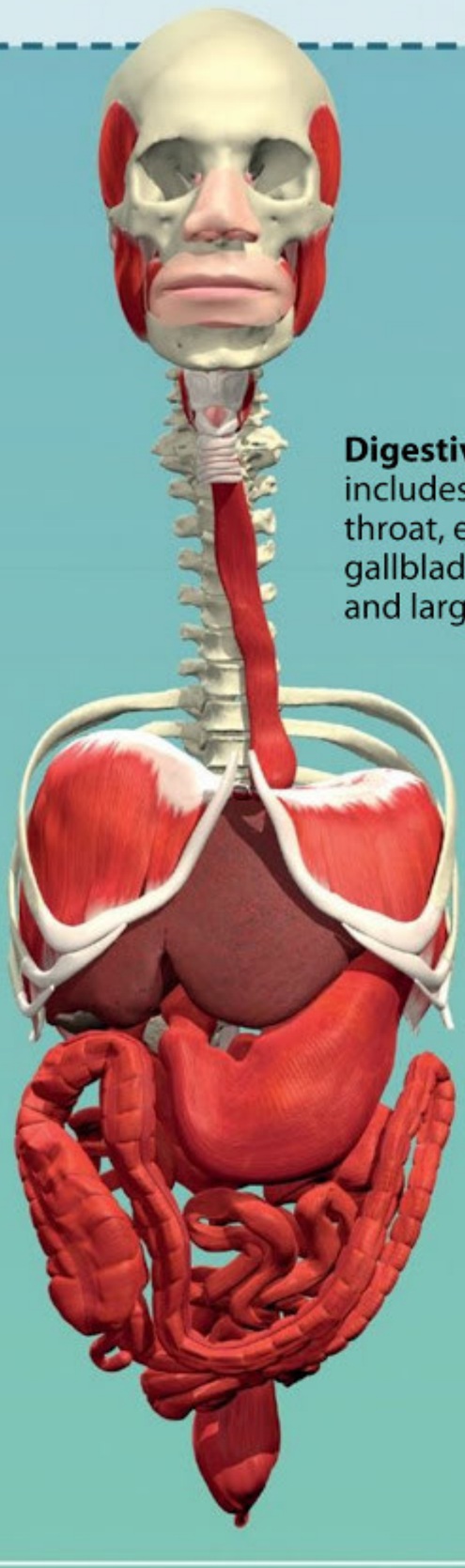
Organisms

An organism is made up of many different systems all working together.



Systems

Systems are any organs working together to produce the same effect. Some organs may belong to more than one system.



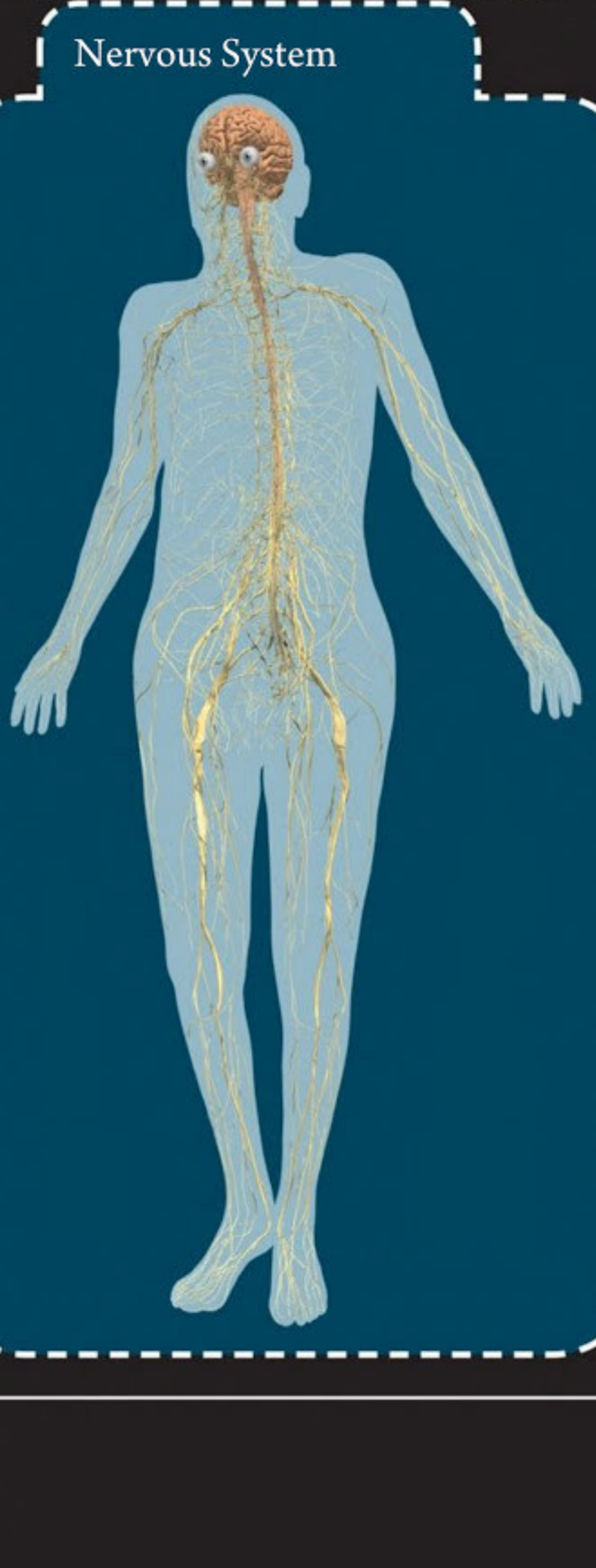
Digestive system
includes the mouth, salivary glands, throat, esophagus, stomach, liver, gallbladder, pancreas, and small and large intestines.

Skeletal System

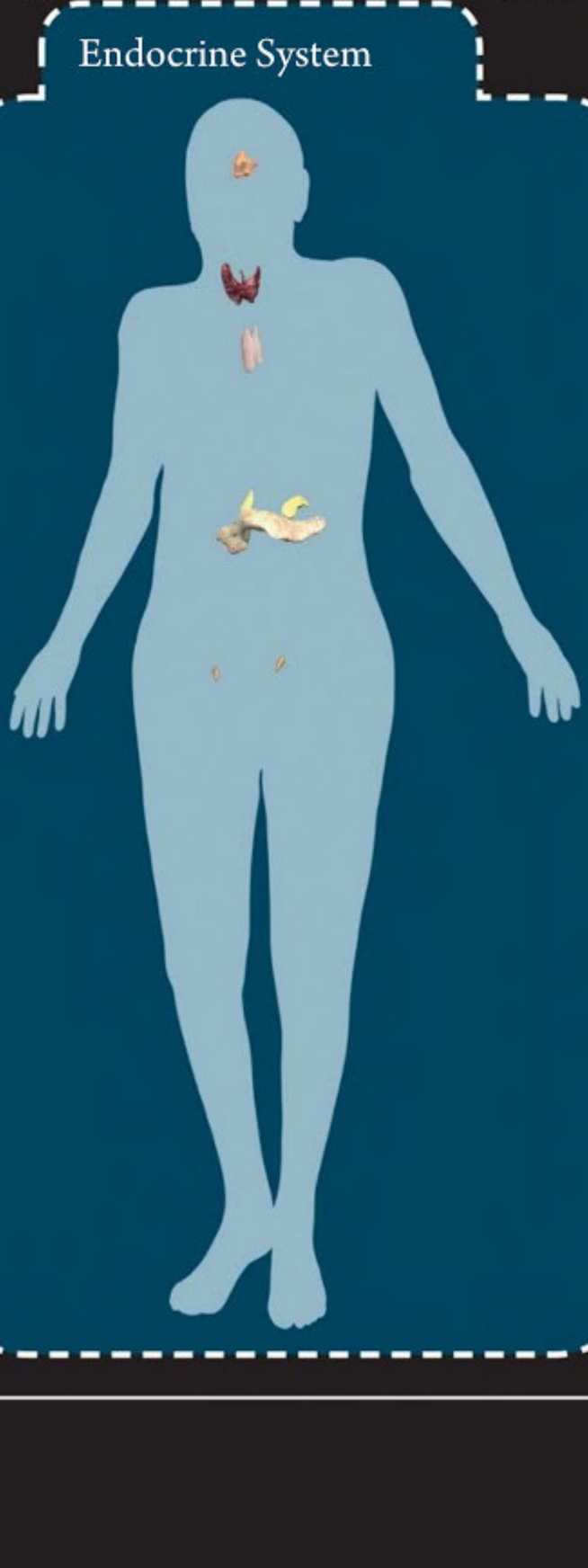
Muscular System

Cardiovascular System

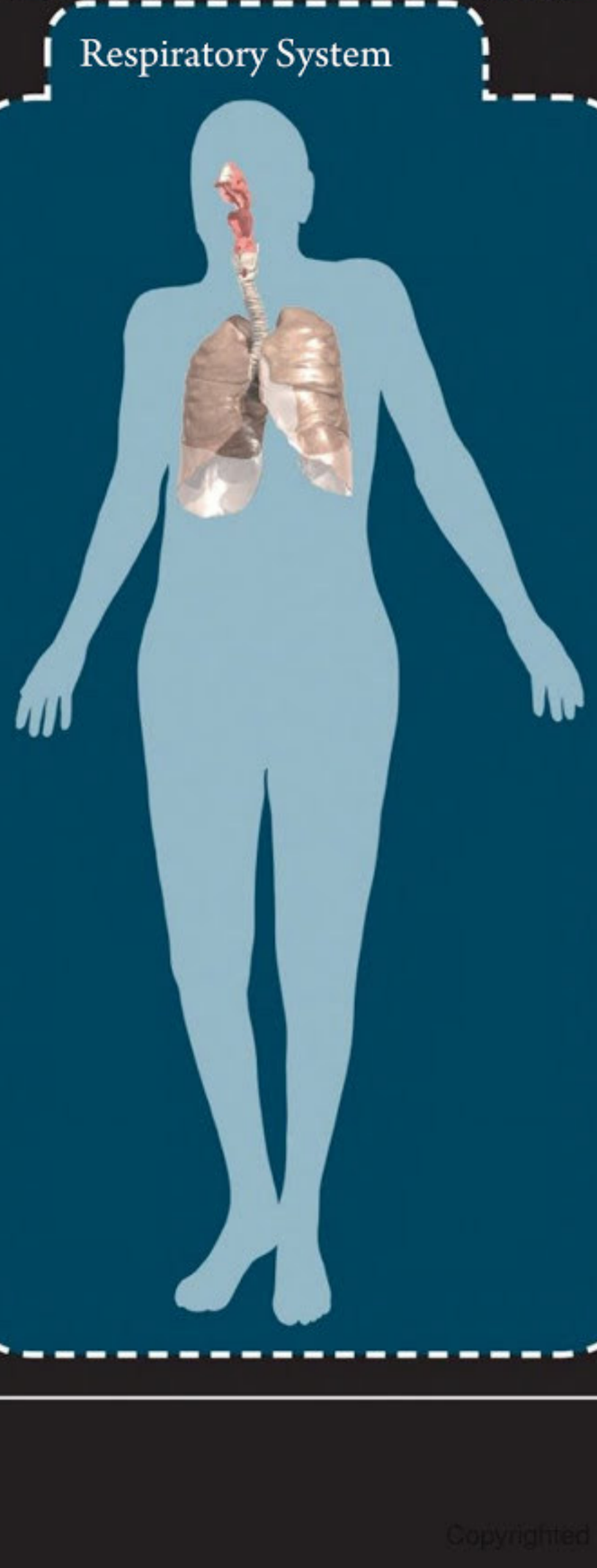
Nervous System

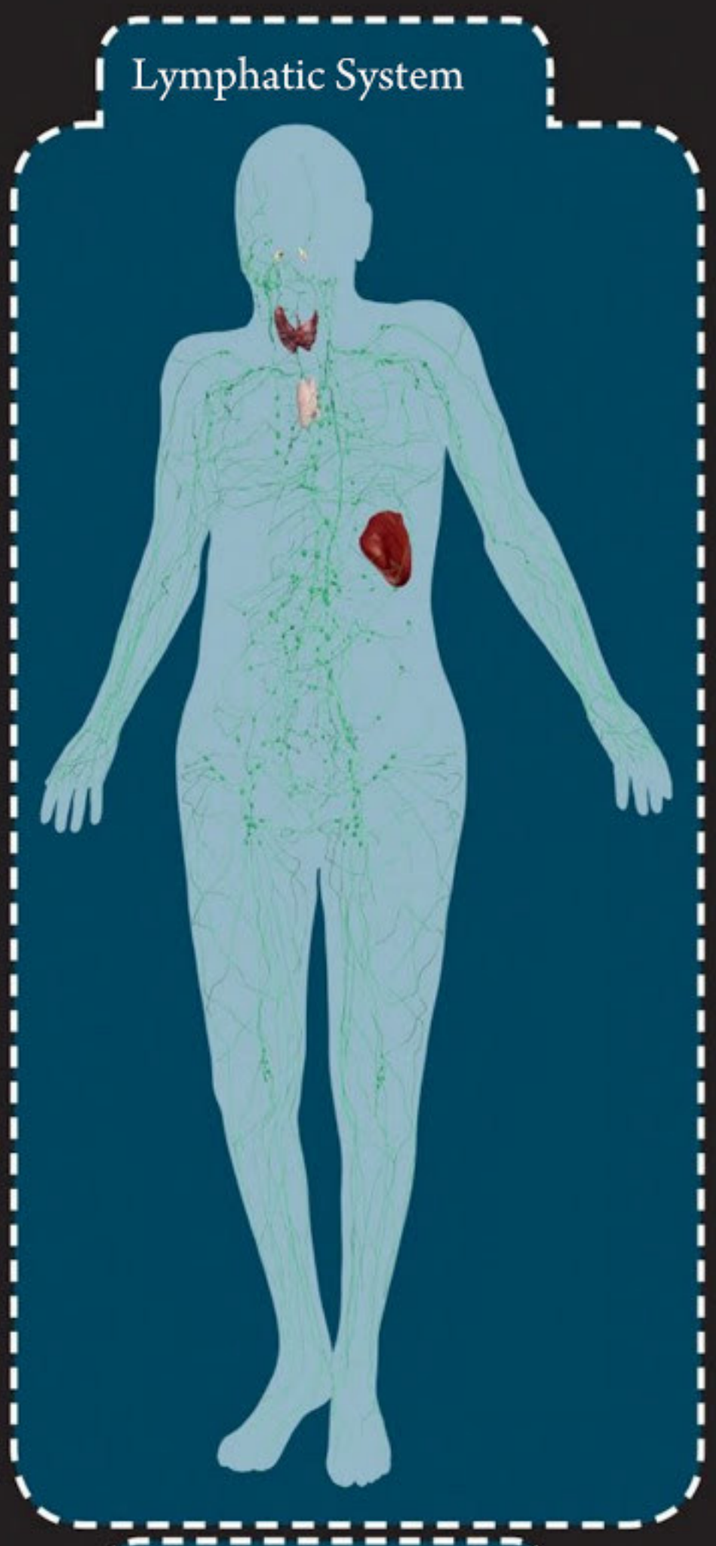


Endocrine System



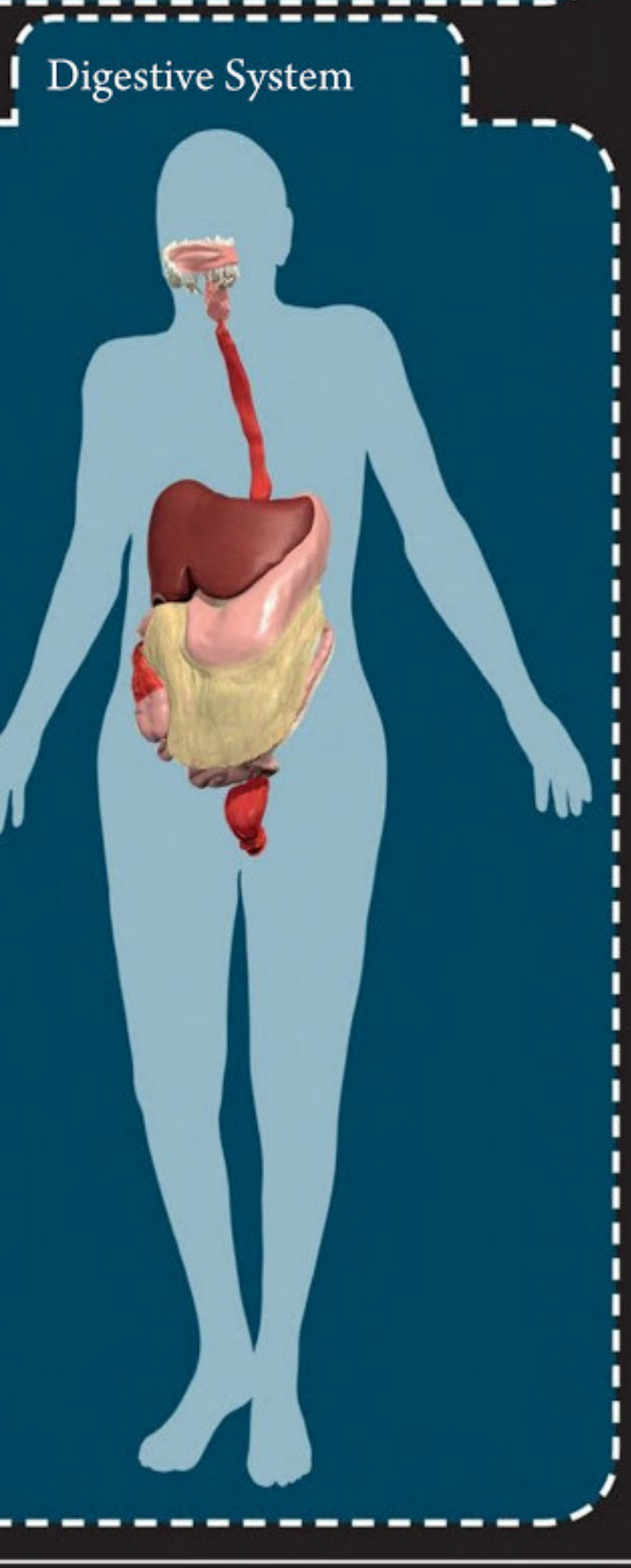
Respiratory System

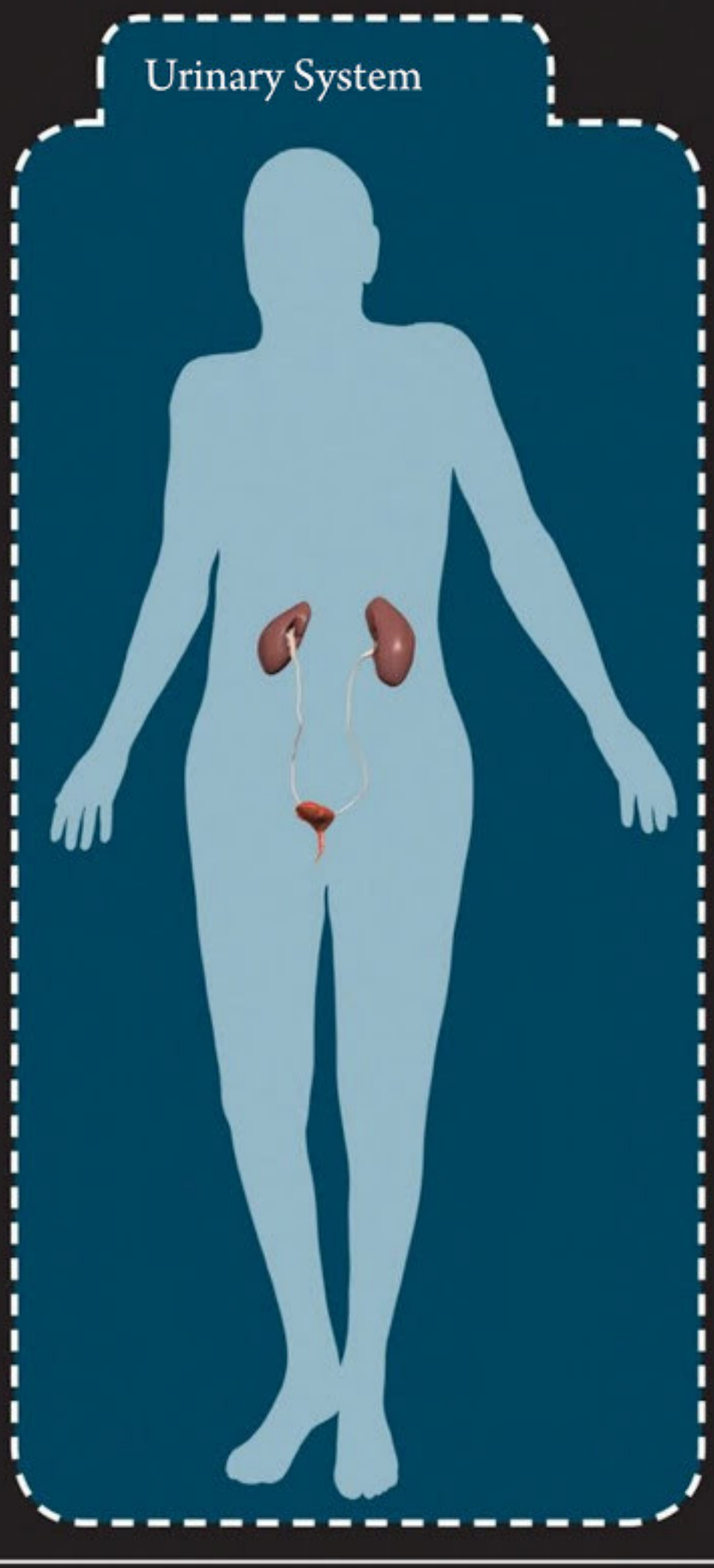


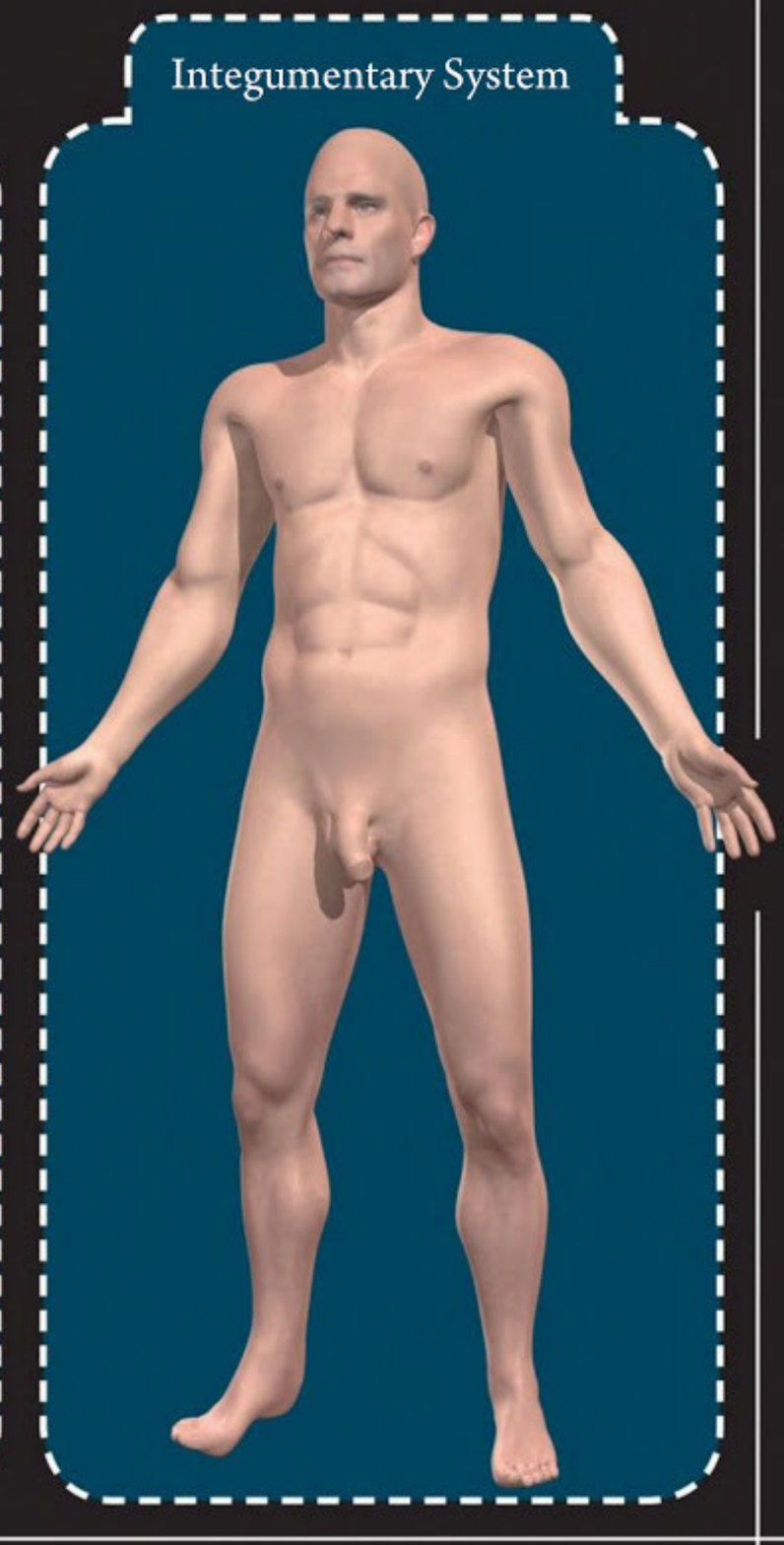


The human body is arranged so that all the specialized processes necessary for it to survive and reproduce are carried out by different systems.

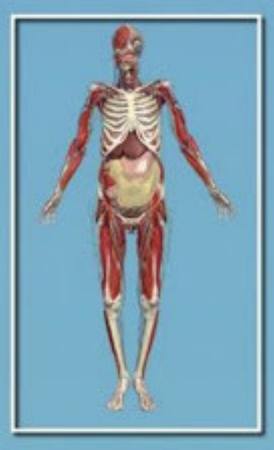
Each system is made up of a number of different organs, working together to achieve a common goal. In a similar way, all of the systems have to cooperate and work together for the human body to function properly.



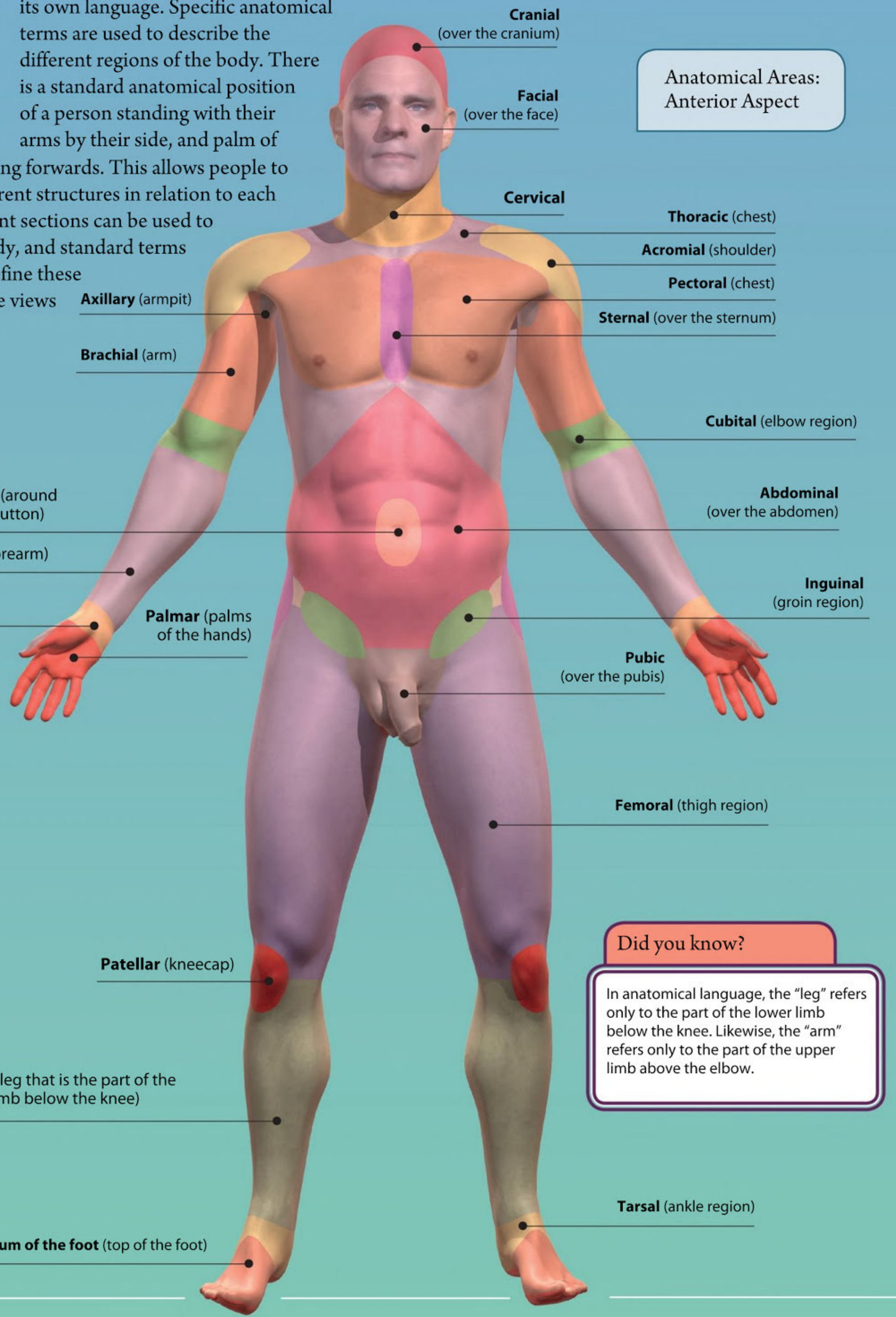




Anatomical Language



To avoid confusion, anatomy has developed its own language. Specific anatomical terms are used to describe the different regions of the body. There is a standard anatomical position of a person standing with their arms by their side, and palm of the hands facing forwards. This allows people to describe different structures in relation to each other. Different sections can be used to divide the body, and standard terms are used to define these planes and the views they produce.

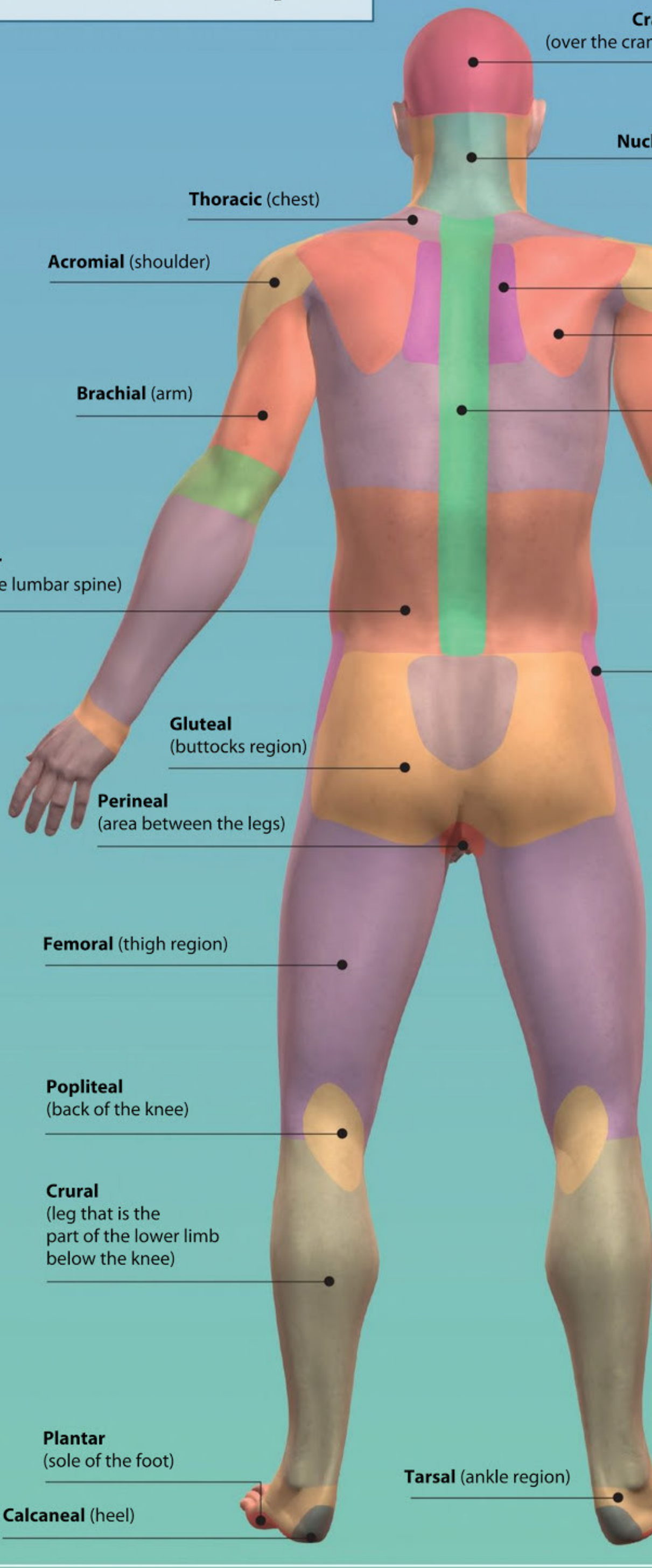


Anatomical Areas: Anterior Aspect

Did you know?

In anatomical language, the "leg" refers only to the part of the lower limb below the knee. Likewise, the "arm" refers only to the part of the upper limb above the elbow.

Anatomical Areas: Posterior Aspect



Cranial
(over the cranium)

Nuchal (back of the neck)

Thoracic (chest)

Acromial (shoulder)

Interscapular
(region between the shoulder blades)

Scapular (shoulder blades)

Vertebral
(over the vertebral column)

Brachial (arm)

Cubital (elbow region)

Lumbar
(over the lumbar spine)

Coxal (hip bone)

Carpal (wrist)

Dorsum
(backs of the hands)

Gluteal
(buttocks region)

Perineal
(area between the legs)

Femoral (thigh region)

Popliteal
(back of the knee)

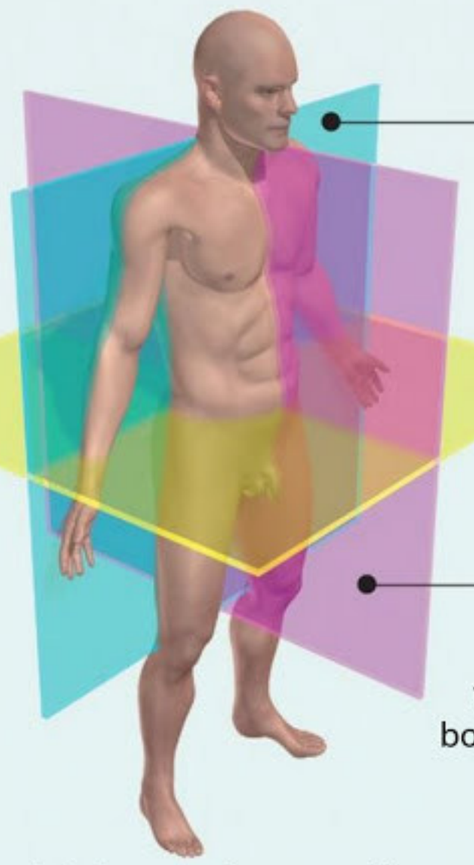
Crural
(leg that is the part of the lower limb below the knee)

Plantar
(sole of the foot)

Calcaneal (heel)

Tarsal (ankle region)

Anatomical Planes

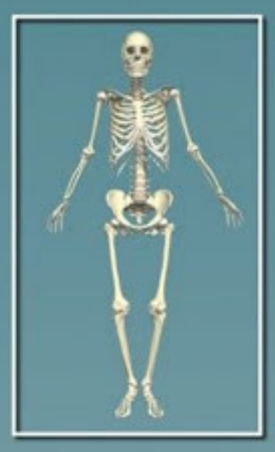


Coronal plane
is a vertical line that divides the body into a front and back section

Sagittal plane
is a vertical line that divides the body into left and right sections

Axial plane is a horizontal line that divides the body into upper and lower sections

Tissues of the Skeletal System



The bones of the skeletal system are living organs that provide protection, support, and movement. They are the body's main store of calcium, and the site of blood cell production. The structure of a typical long bone illustrates the adaptations that make it both strong enough to bear our weight and protect us, yet light enough for us to move it.

Anatomy of a Long Bone

Epiphyseal line
is the site of the growth plate in mature long bones.

Trabecular bone or spongy bone
consists of struts of bone. It is found in the epiphyses and lining the inner parts of a long bone.

Epiphysis
is the end of a long bone.

Metaphysis
is the area between the diaphysis and epiphysis.

Diaphysis
is the shaft of a long bone.

Medullary cavity,
or marrow cavity, is the area where blood cells are produced.

Cortical bone
is the dense outer layer of bone.

Osteons
are repeating layers of bone tissue and bone cells formed around a central canal that contains blood vessels and nerves.

Cortical bone,
or compact bone, is made up of numerous osteons. This makes it very strong and dense.

Periosteum
is a layer of fibrous tissue that lines, protects, and nourishes most of the outer bone surface. It allows ligaments and tendons to attach to a bone.

Trabecular or spongy bone
consists of columns and struts of bone. It provides strength while minimizing weight.

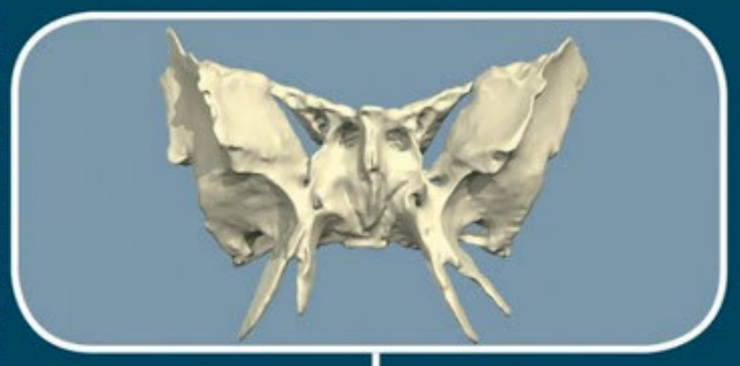
Spongy Bone

Classification of Bone

Long bones,
for example thigh bones, are longer than they are wide.

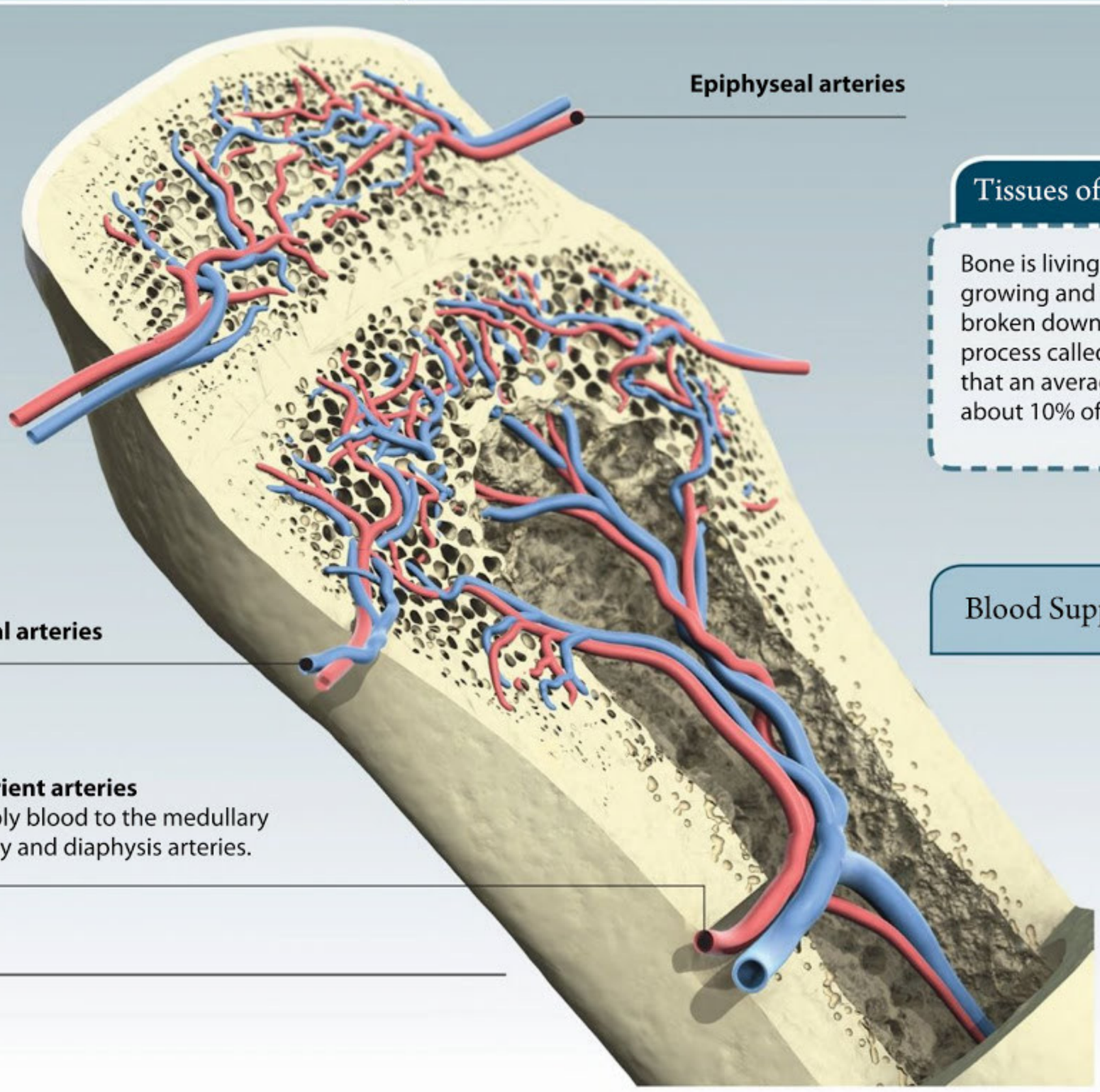
Sesamoid bones,
for example patella (kneecap), are formed inside tendons.

Flat bones,
for example frontal bone of the skull, form thin plates of bone.



Irregular bones,
for example sphenoid bone of the skull, form shapes that do not fit into any of the other groups.

Short bones,
for example wrist bones, tend to be equal in both length and width.

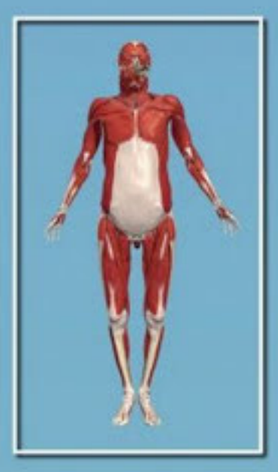


Tissues of Skeletal System

Bone is living tissue that is constantly growing and repairing itself. Old bone is broken down and new bone is formed in a process called remodeling. It is estimated that an average adult skeleton remodels about 10% of its bone each year.

Blood Supply to Bone

Tissues of the Muscular System



The main role of the muscular system is to produce movement. It does this through specialized muscle cells that are able to contract and alter their length. There are three main types of muscle tissue: skeletal, smooth, and cardiac. Skeletal muscle is attached to the skeletal system via tendons. It is under voluntary control. Smooth and cardiac muscle are termed involuntary muscles, as their contractions can occur without conscious control. Smooth muscle is mainly located within the walls of the internal organs. Cardiac muscle is found in the heart.

Smooth muscle

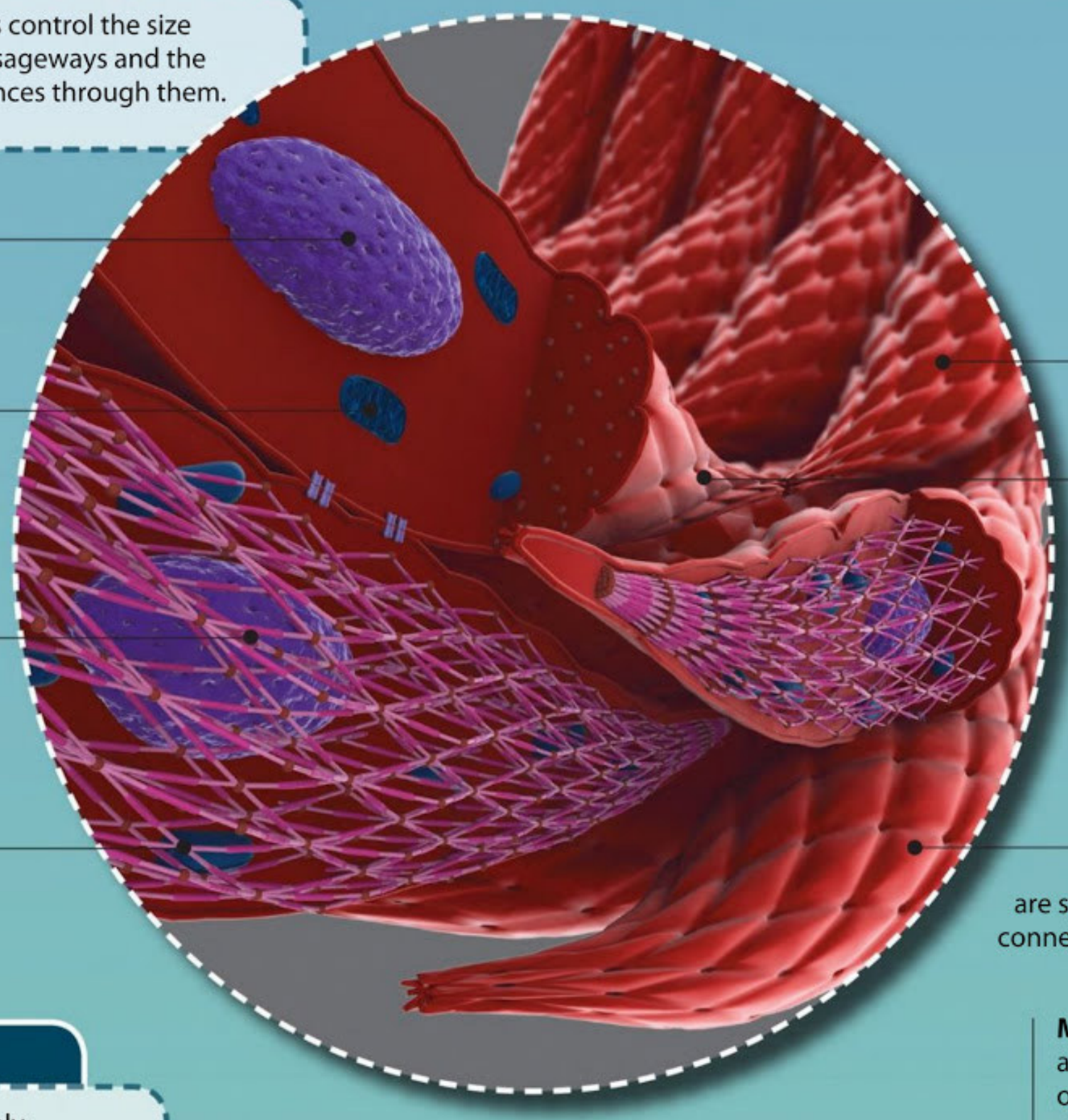
Smooth muscle helps control the size of internal organ passageways and the movement of substances through them.

Nucleus

Mitochondria produce energy for muscle contraction.

Contractile filaments produce shortening of each smooth muscle cell.

Dense bodies are points of attachment for parts of the contractile filaments.



Smooth muscle cells are spindle shaped and form close connections with surrounding cells.

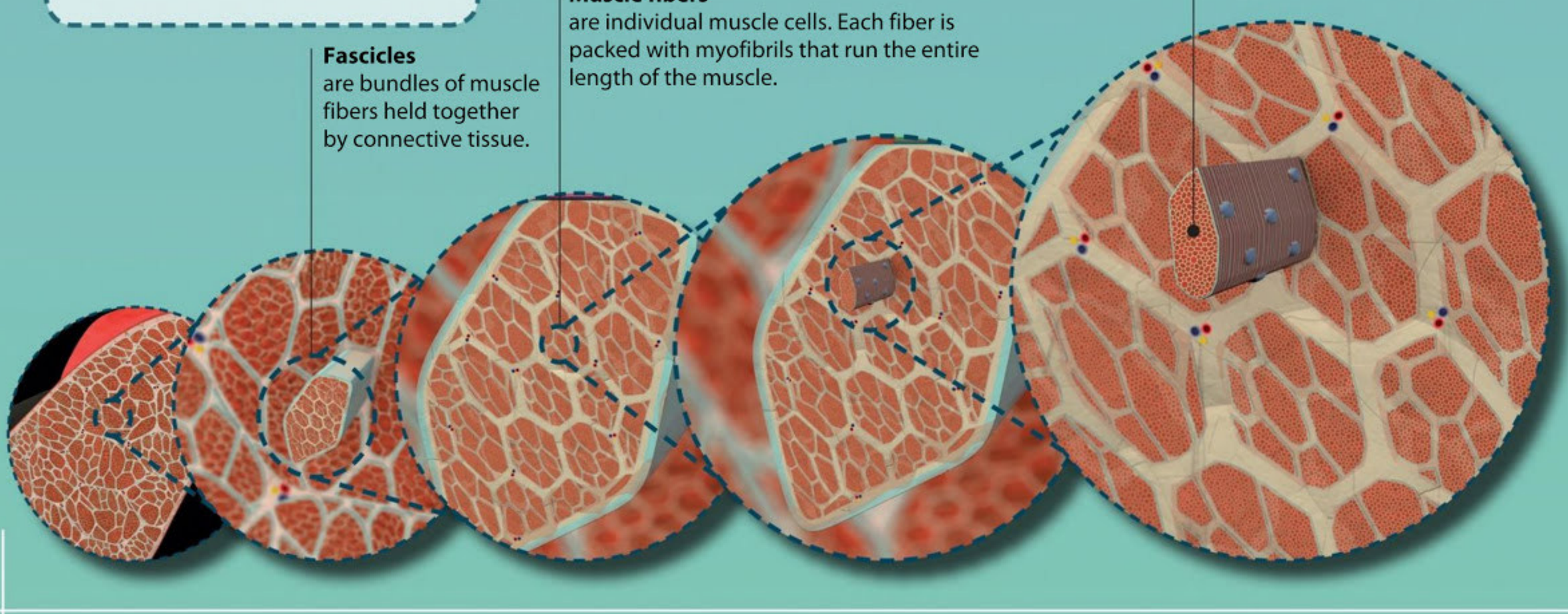
Skeletal muscle

Skeletal muscle has a highly organized structure.

Fascicles are bundles of muscle fibers held together by connective tissue.

Muscle fibers are individual muscle cells. Each fiber is packed with myofibrils that run the entire length of the muscle.

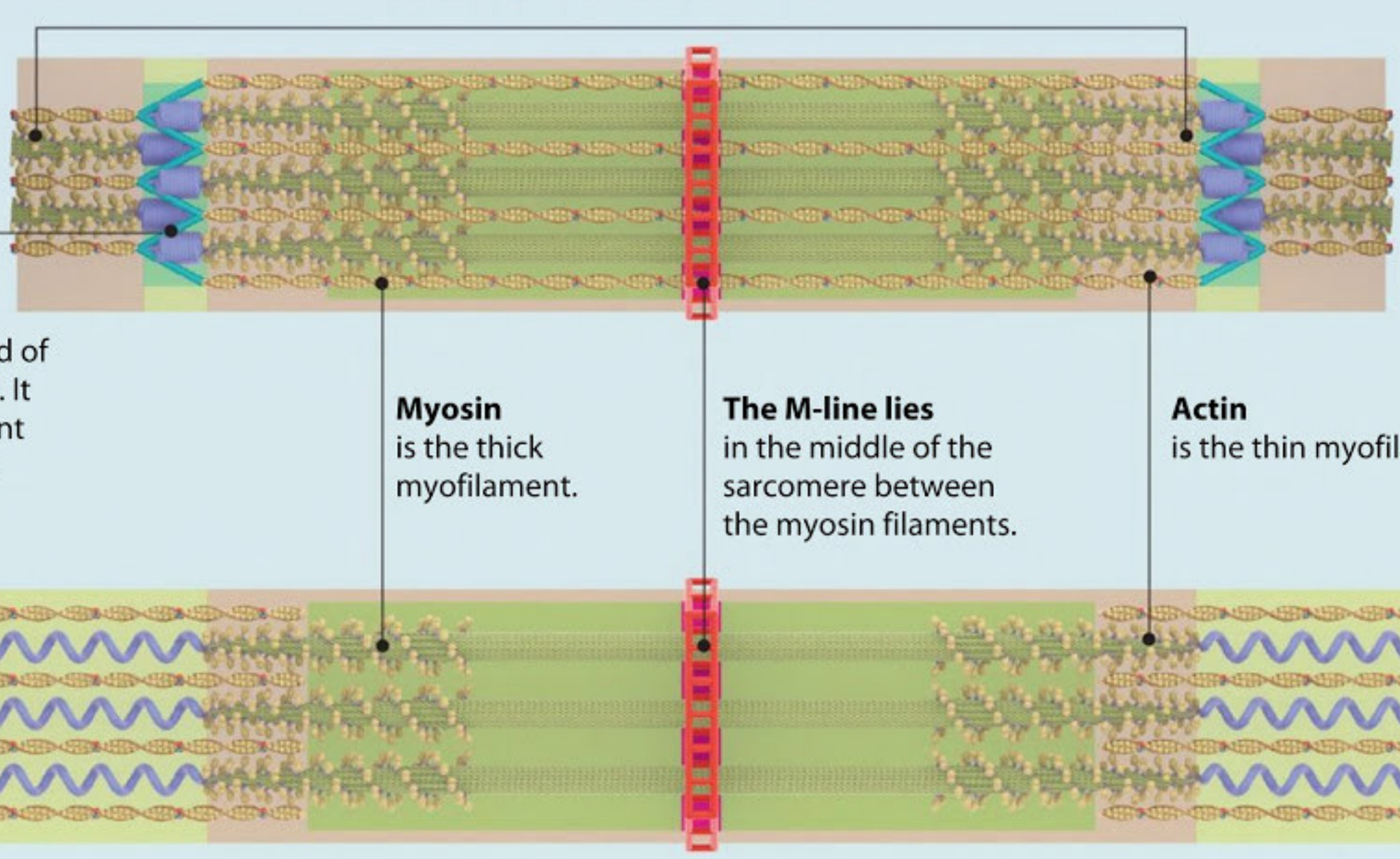
Myofibrils are organized collections of specialized proteins called myofilaments, that use energy to cause muscle contraction.



Sarcomere

Sarcomeres are regular repeating divisions of the myofibrils. The myofilaments within each sarcomere use energy to slide past each other, causing shortening of the entire muscle (contraction).

Sarcomere (contracted muscle)



The Z-line
lies at each end of the sarcomere. It provides a point of attachment for the actin filaments.

Myosin
is the thick myofilament.

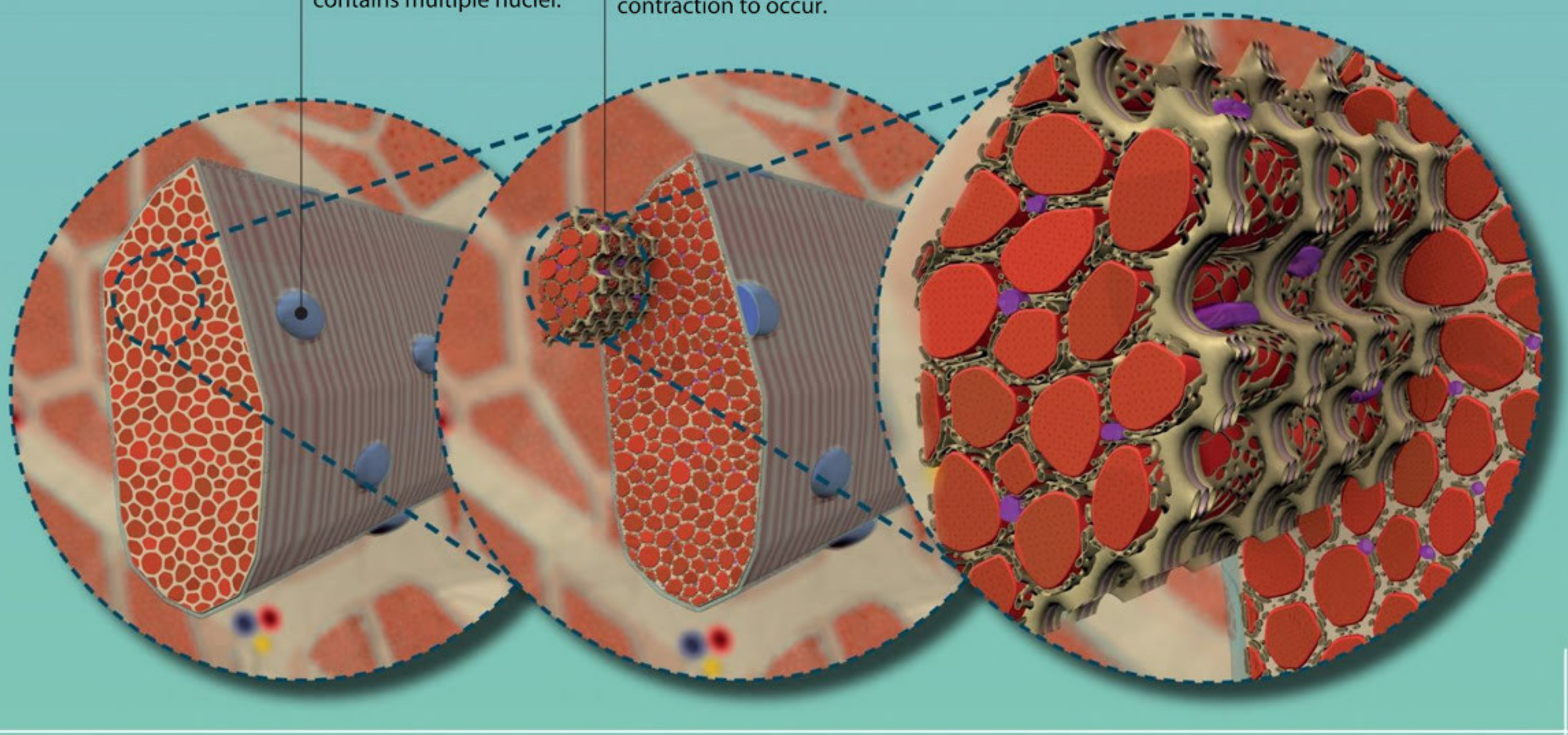
The M-line lies
in the middle of the sarcomere between the myosin filaments.

Actin
is the thin myofilament.

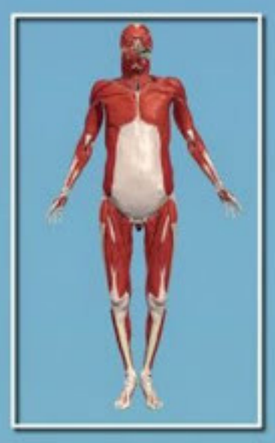
Sarcomere (relaxed muscle)

Nuclei
Each skeletal muscle fiber contains multiple nuclei.

Sarcoplasmic reticulum
and its extensions surround the myofibrils and deliver calcium to them. This is necessary for contraction to occur.



Gross Anatomy of the Muscular System



There are over 600 muscles in the human body. Working together they allow us to run and jump, to skip and dance, to eat and speak. Skeletal muscles come in various shapes and sizes, and can be grouped according to the way in which their fibers are organized. Muscles are connected to bones by tough fibrous tissue called tendons.

Latissimus dorsi
pulls the arm toward the body.

Gluteus maximus
forms the buttocks. It is the largest muscle in the body.

Gastrocnemius
is one of the calf muscles at the back of the leg.

Calcaneal tendon,
or Achilles tendon, is the tough fibrous tissue that connects the calf muscles to the heel bone (calcaneum).

Biceps femoris
is one of the hamstring muscles that bend the knee.

Temporalis
closes the jaw.

Orbicularis oculi
closes the eye.

Deltoid
raises the arm.

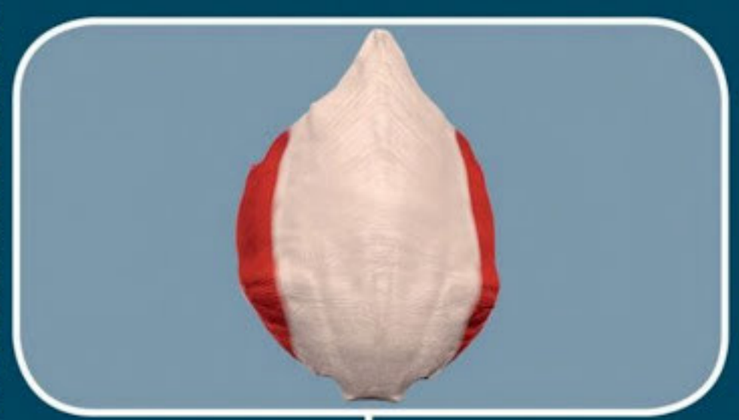
Biceps brachii
bends the elbow.

Pectoralis major
pulls the arm
towards the body.

External oblique
is one of the abdominal wall
muscles that move the trunk.

Classification of Muscles

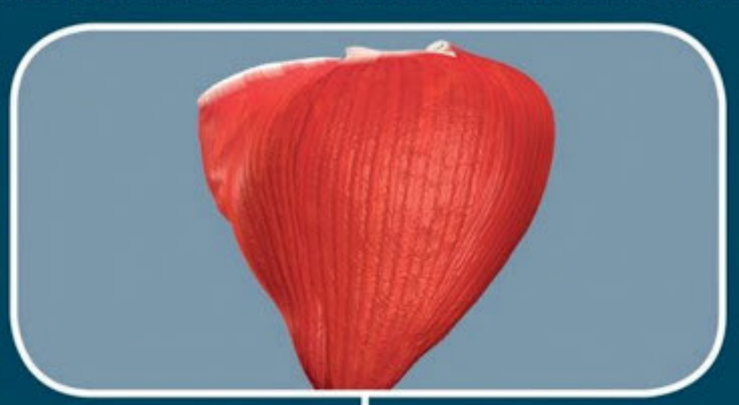
Fusiform muscles
have thick muscle bellies that taper to form one or more tendons, for example biceps brachii.



Parallel muscles
have muscle fibers that run straight from one end of the muscle to the other, for example external oblique.

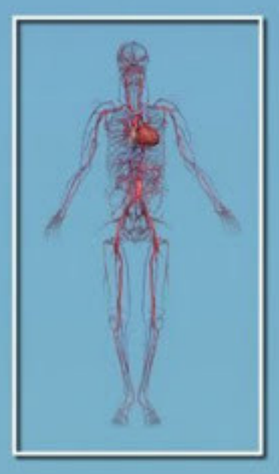
Triangular muscles
have fibers that come from many directions before meeting on a single tendon, for example temporalis.

Circular muscles
are found around an opening, and are able to close it when they contract, for example orbicularis oculi.



Pennate muscles
have a central tendon to which fibers attach at various angles, similar to a birds feather, for example deltoid.

Tissues of the Cardiovascular System



The cardiovascular system is made up of the heart and blood vessels. Together, they provide a constant supply of oxygen and nutrient-rich blood to all the tissues of the body, while removing any waste products. The heart is a muscular organ made up of specialized cardiac muscle tissue. It pumps blood around the body's blood vessels, of which there are three main types: arteries, capillaries, and veins.

Cardiac Muscle

Sarcolemma
is the muscle cell plasma membrane.

Sarcoplasmic reticulum
supplies the myofibrils with the calcium they need to contract.

Sarcomere.
Like skeletal muscle, cardiac myofibrils are divided into regular repeating units called sarcomeres.

Intercalated disks
connect neighboring cardiac muscle cells, allowing them to contract in a coordinated way.

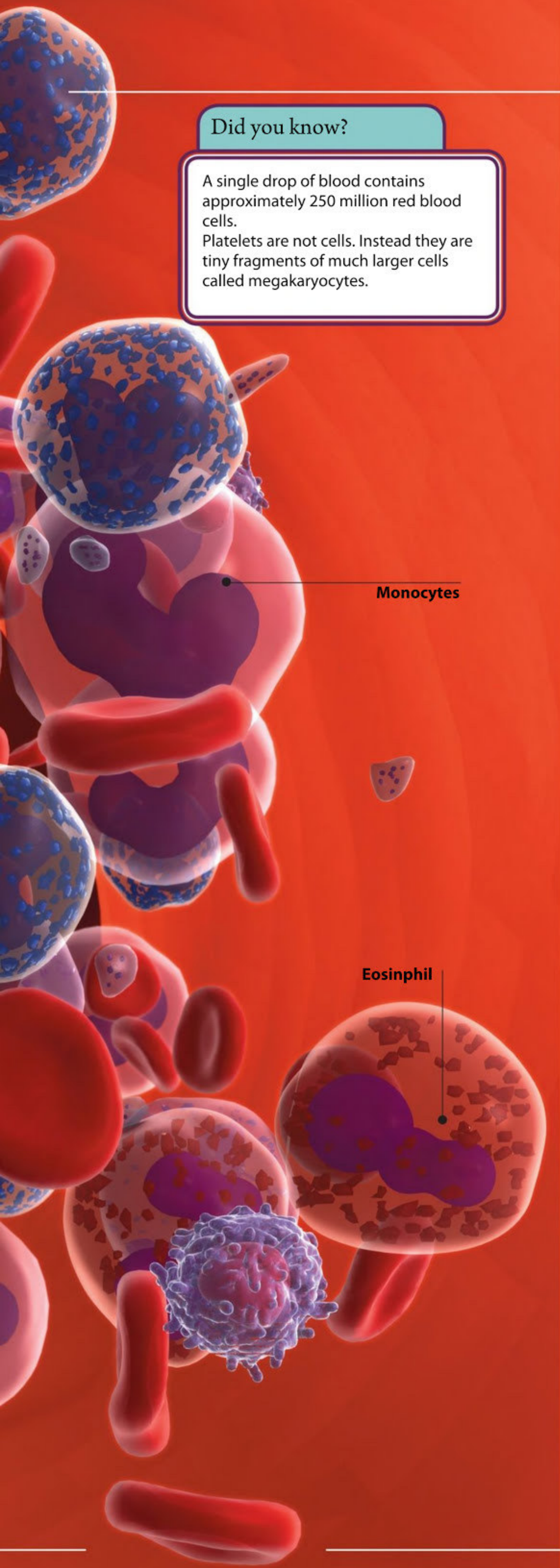
Mitochondria
provide energy to the cardiac muscle cells.

Myofibrils
are organized bundles of specialized thick and thin proteins called myofilaments.

Nucleus

Did you know?

A single drop of blood contains approximately 250 million red blood cells.
Platelets are not cells. Instead they are tiny fragments of much larger cells called megakaryocytes.



Formed Elements of Blood

Erythrocytes (red blood cells)
transport oxygen from the lungs to the tissues. The red color is due to the presence of a specialized oxygen-carrying protein called hemoglobin.

Platelets
are small fragments of cells that help our blood to clot.

Lymphocytes
are white blood cells that can fight a wide range of infectious organisms. There are three types of lymphocyte: B-cells, T-cells, and natural killer (NK) cells.

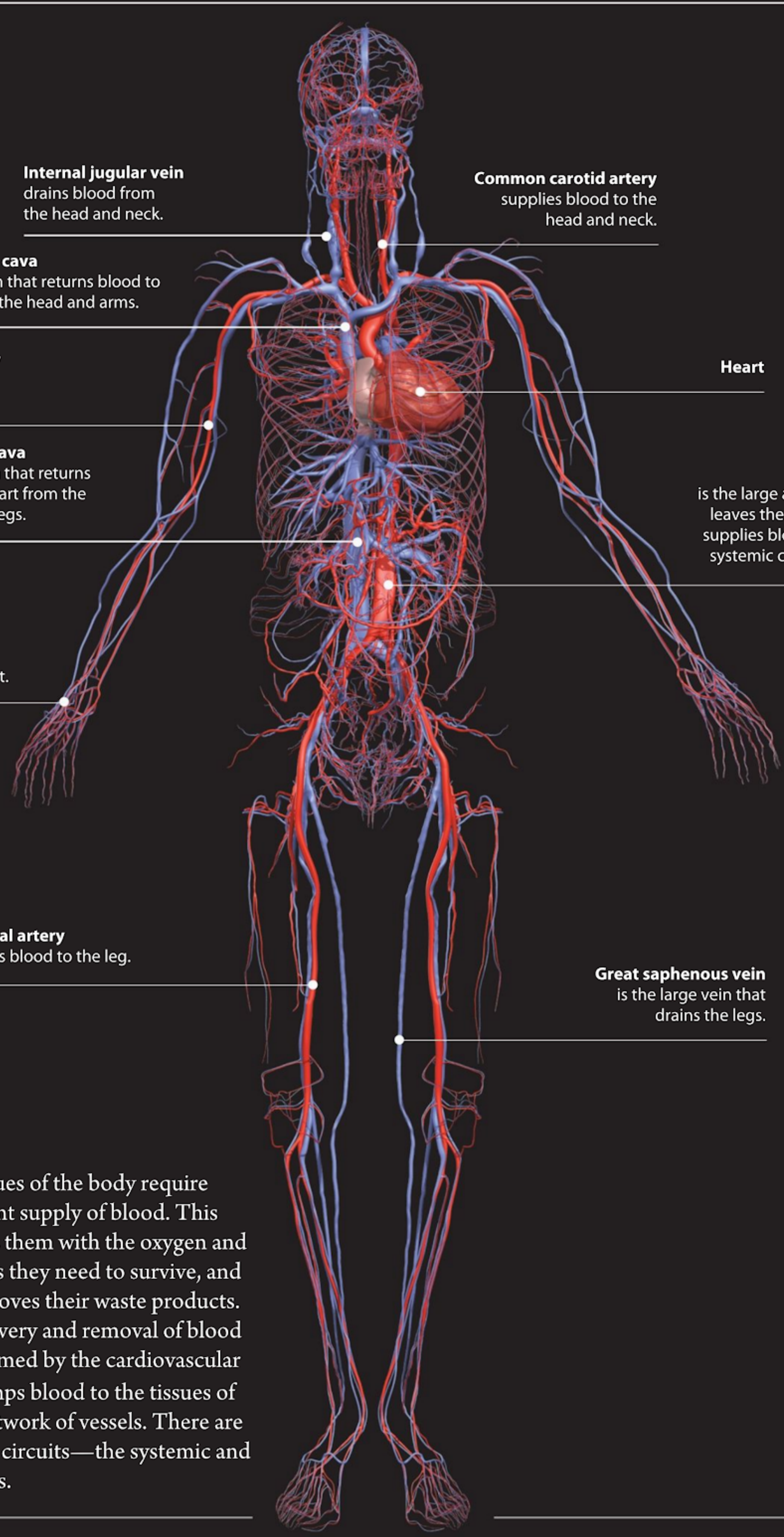
Monocytes
are white blood cells that can move into the tissues, where they are called macrophages. They remove cell debris and infectious organisms by engulfing them—a process known as phagocytosis.

Neutrophils
are the most common white blood cell. They have irregularly shaped nuclei. Their granules contain substances used to kill infectious organisms.

Eosinophil
is a type of white blood cell particularly involved in fighting parasite infections.

Basophils
are the least abundant white blood cells. Their granules contain substances that cause inflammation when released.

Gross Anatomy of the Cardiovascular System



Internal jugular vein
drains blood from the head and neck.

Common carotid artery
supplies blood to the head and neck.

Superior vena cava
is the large vein that returns blood to the heart from the head and arms.

Brachial artery
provides blood to the arm.

Heart

Inferior vena cava
is the main vein that returns blood to the heart from the abdomen and legs.

Aorta
is the large artery that leaves the heart and supplies blood to the systemic circulation.

Radial artery
delivers blood to the hand. Its pulsations can be felt at the wrist.

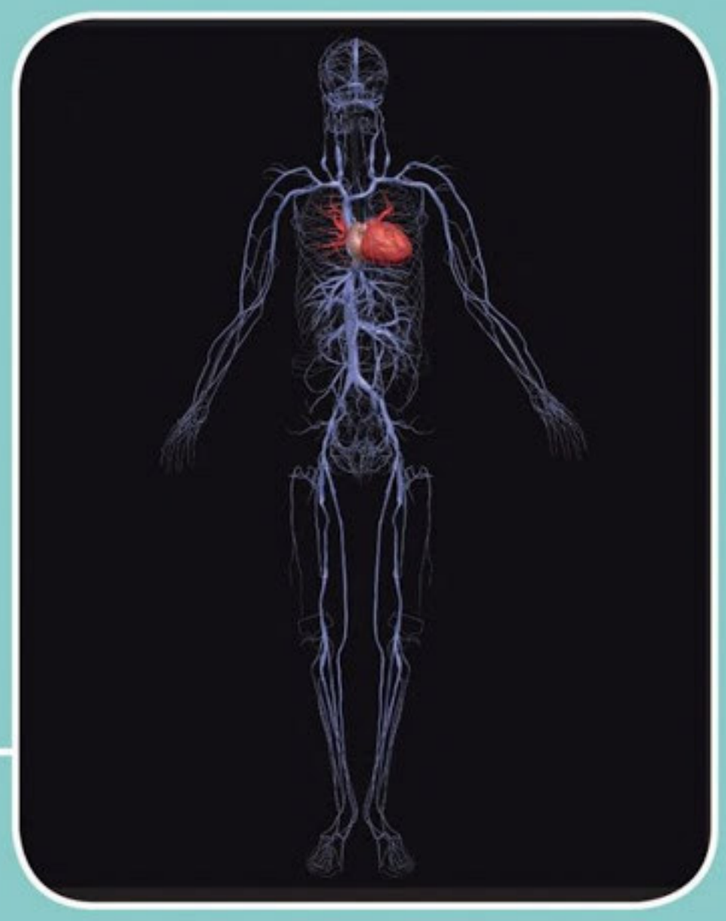
Femoral artery
delivers blood to the leg.

Great saphenous vein
is the large vein that drains the legs.

The tissues of the body require a constant supply of blood. This provides them with the oxygen and nutrients they need to survive, and also removes their waste products. The delivery and removal of blood is performed by the cardiovascular system. The heart pumps blood to the tissues of the body through a network of vessels. There are two main blood vessel circuits—the systemic and pulmonary circulations.

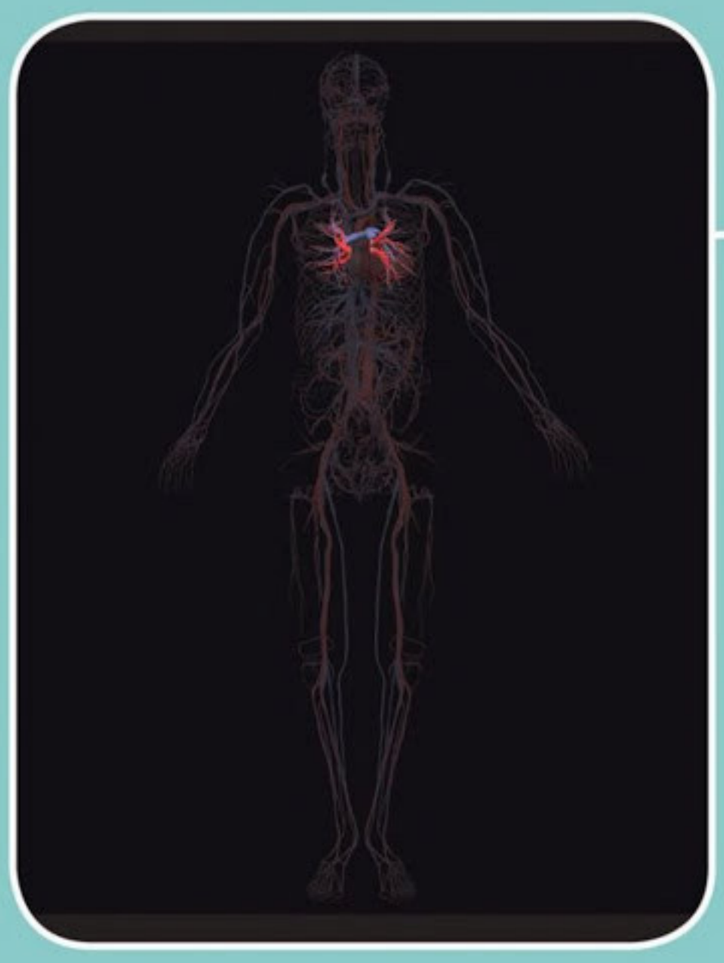
Circulatory Systems

Arteries
carry blood away from the heart.

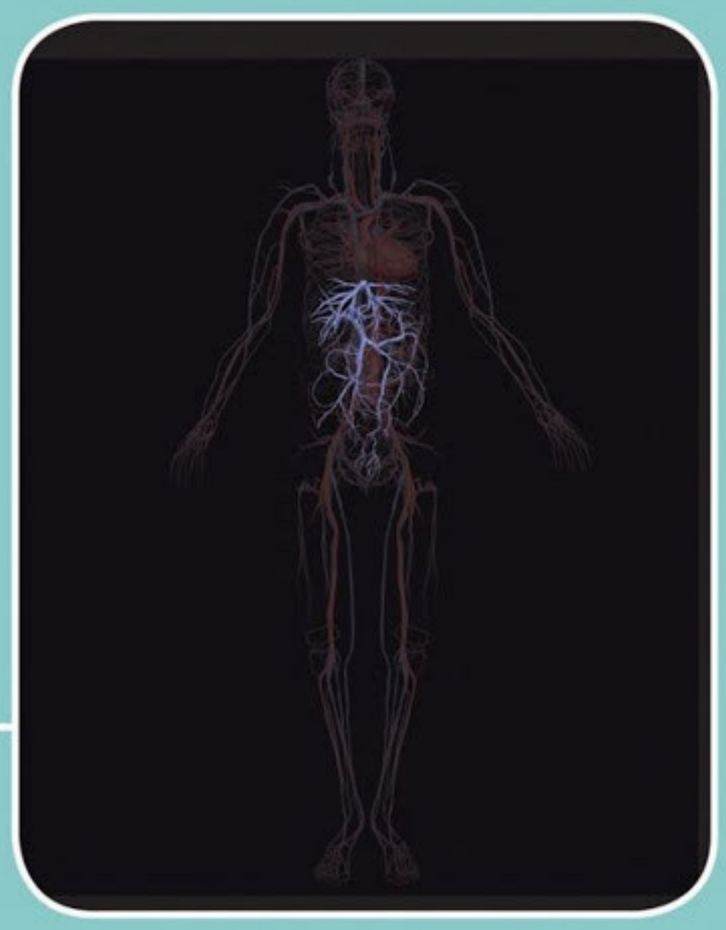


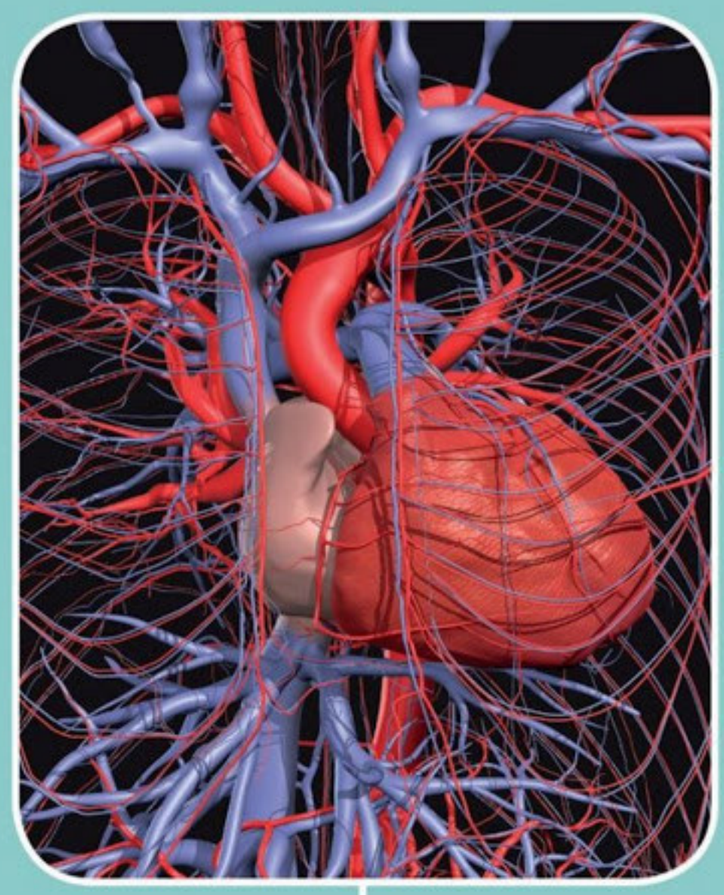
Veins
carry blood back to the heart.

Systemic Circulation
carries blood from the heart to the tissues of the body, before returning it to the heart. In the tissues, oxygen is removed from the blood and carbon dioxide added.



Pulmonary Circulation
carries blood from the heart to the lungs, before returning it to the heart. In the lungs, oxygen is added to the blood and carbon dioxide removed.



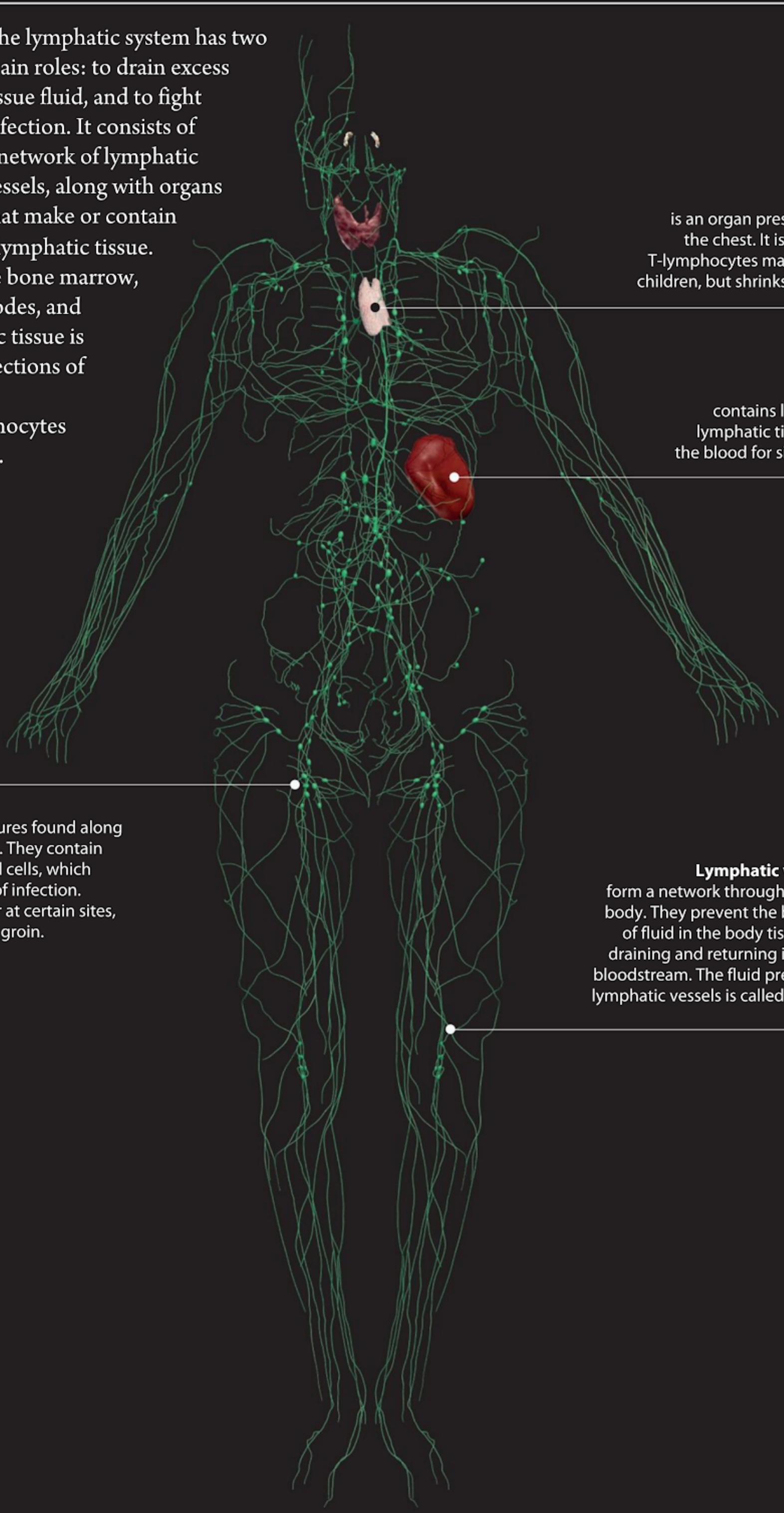


Portal Circulation
vessels carry nutrient rich blood from the gut for processing in the liver.

Heart
is a muscular organ which pumps blood around the network of blood vessels.

Lymphatic System

The lymphatic system has two main roles: to drain excess tissue fluid, and to fight infection. It consists of a network of lymphatic vessels, along with organs that make or contain large amounts of lymphatic tissue. These include the bone marrow, thymus, lymph nodes, and spleen. Lymphatic tissue is formed from collections of white blood cells, particularly lymphocytes and macrophages.



Thymus
is an organ present at the top of the chest. It is the place where T-lymphocytes mature. It is large in children, but shrinks as we get older.

Spleen
contains large amounts of lymphatic tissue. It monitors the blood for signs of infection.

Lymph nodes
are small bean-shaped structures found along the lymphatic vessel network. They contain large numbers of white blood cells, which monitor the lymph for signs of infection. Lymph nodes group together at certain sites, such as the neck, armpit, and groin.

Lymphatic vessels
form a network throughout the body. They prevent the buildup of fluid in the body tissues by draining and returning it to the bloodstream. The fluid present in lymphatic vessels is called lymph.

Valve
prevents backflow of lymph.

Cortex
is the outer part of the lymph node.
It is packed with white blood cells.

Follicles
are collections of B-lymphocytes.

Medulla
is the inner part of the
lymph node and contains
T-lymphocytes, macrophages,
and antibody producing cells
called plasma cells.

Outgoing lymphatic vessel
transports lymph away from
the lymph node.

Blood vessels
enter and leave the lymph node at
an indented area called the hilum.

Incoming lymphatic vessels
deliver lymph to the lymph node.

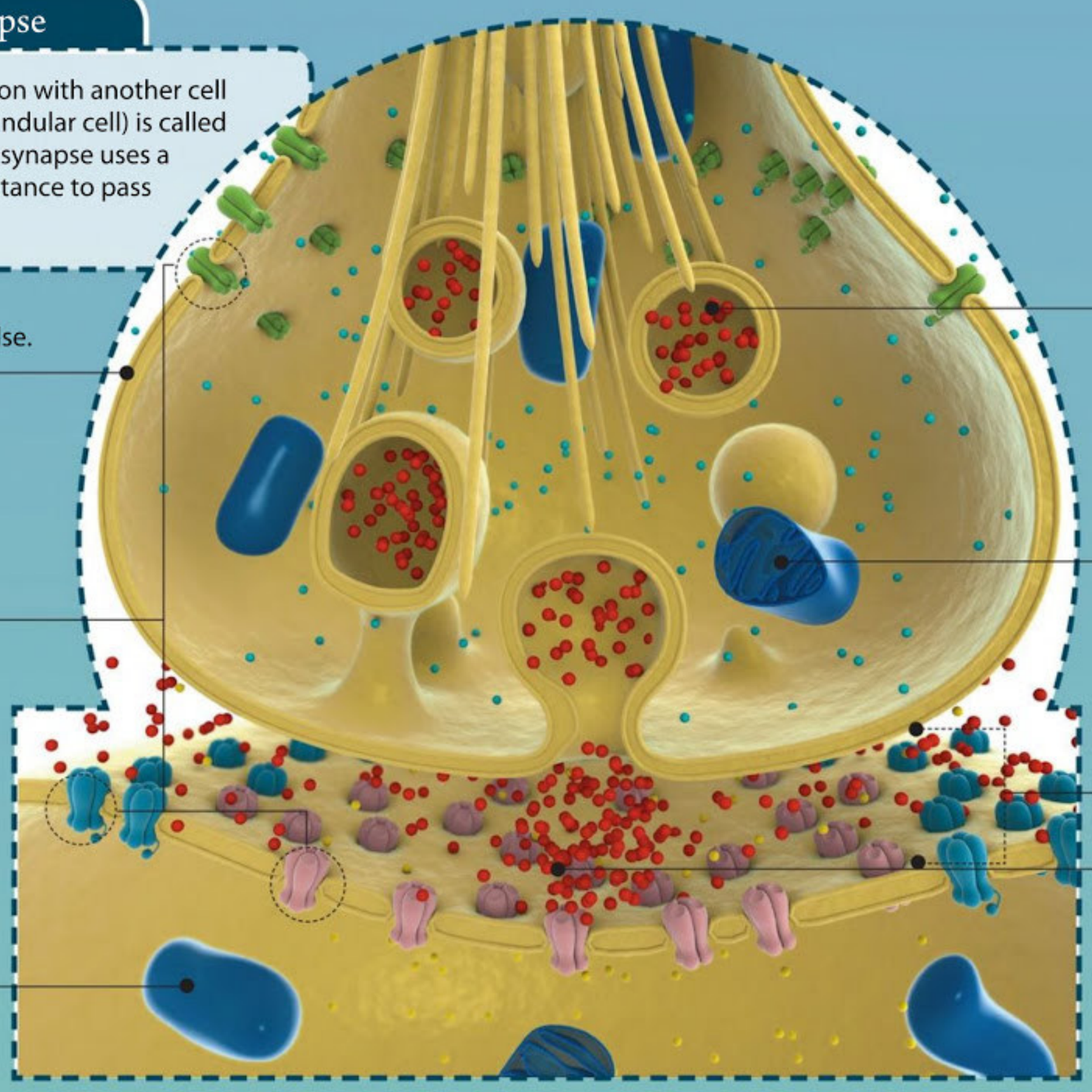
Lymph Node

Tissues of the Nervous System

The nervous system consists of the brain, spinal cord, and nerves. It allows us to see, hear, smell, taste, touch, move, feel, remember, and much more. To do all this requires the rapid, coordinated transmission of multiple signals, between different parts of the body. This is possible through the billions of specialized nerve cells (neurons) that conduct electrical signals, known as nerve impulses.

Chemical Synapse

The junction of a neuron with another cell (neuron, muscle or glandular cell) is called a synapse. A chemical synapse uses a neurotransmitter substance to pass the nerve impulse on.



Presynaptic neuron
delivers the nerve impulse.

Ion channels
open in response to either nerve impulses or the presence of a neurotransmitter.

Postsynaptic cell
receives the nerve impulse.

Synaptic vesicles
store the neurotransmitter before it is released.

Mitochondria

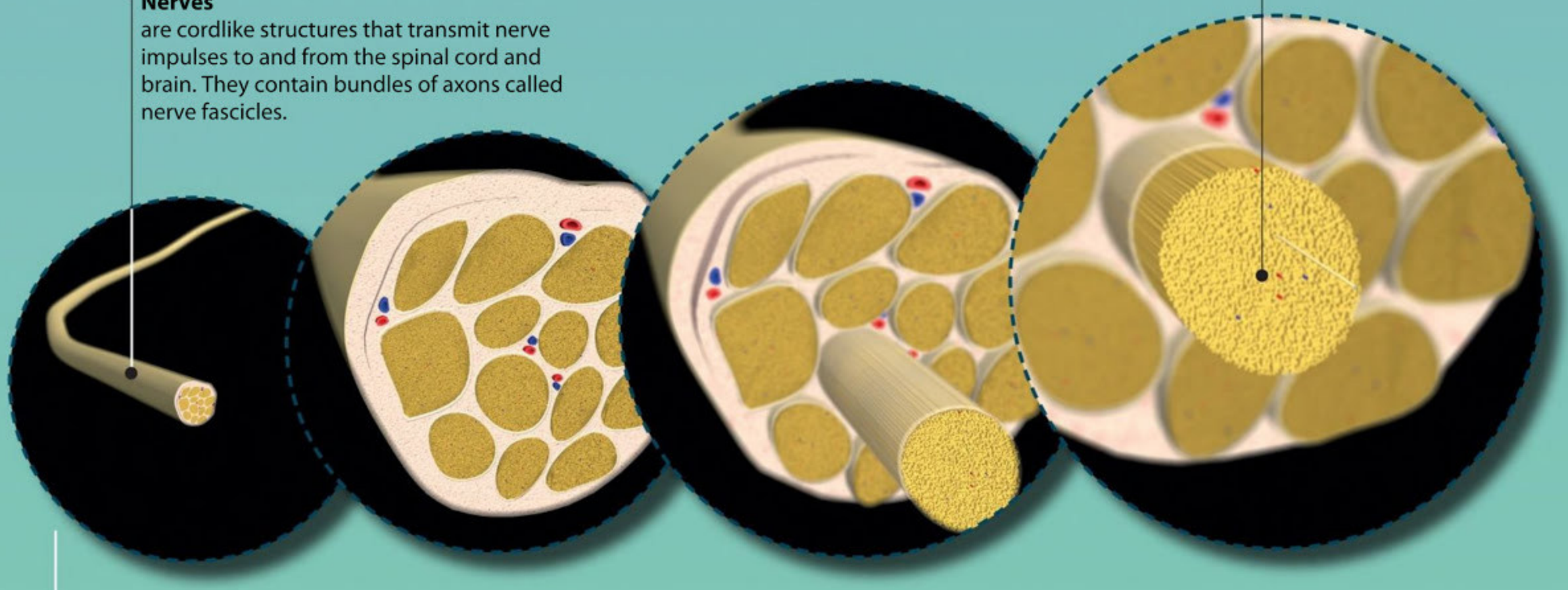
Synaptic cleft
is the gap between the two cells.

Neurotransmitters
are chemicals released from the end of a presynaptic neuron when a nerve impulse arrives. It crosses the synaptic cleft and binds to ion channels, which trigger a nerve impulse in the postsynaptic cell.

Microanatomy of a Neuron

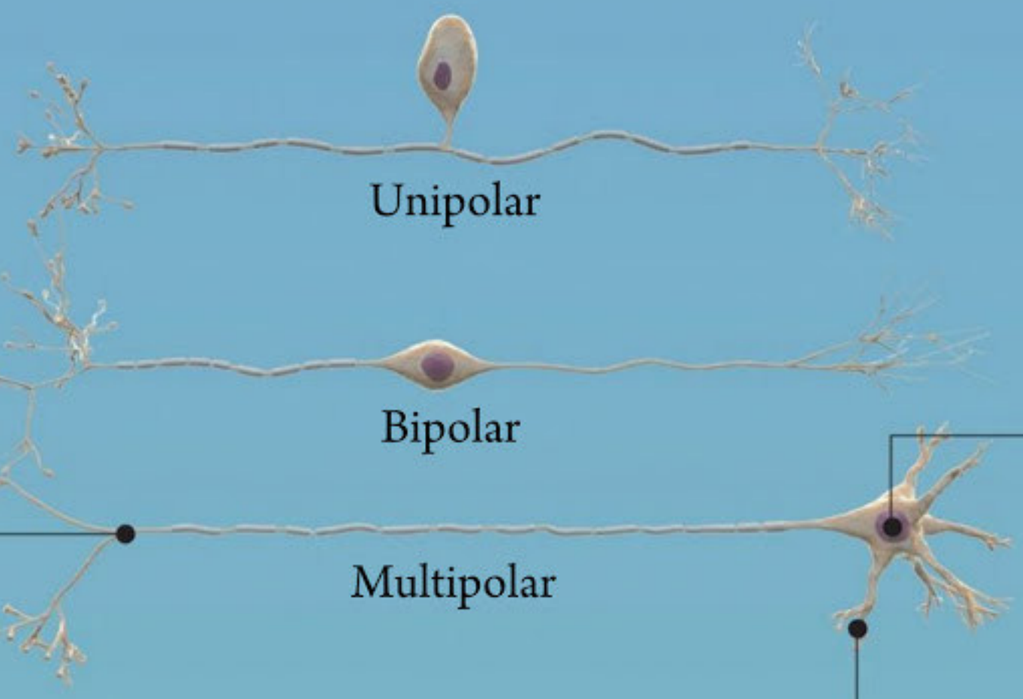
Nerves
are cordlike structures that transmit nerve impulses to and from the spinal cord and brain. They contain bundles of axons called nerve fascicles.

Nerve fascicles
contain bundles of nerve fibers.



Neurons

Neurons are classified according to the number of fibers entering and leaving their cell body.



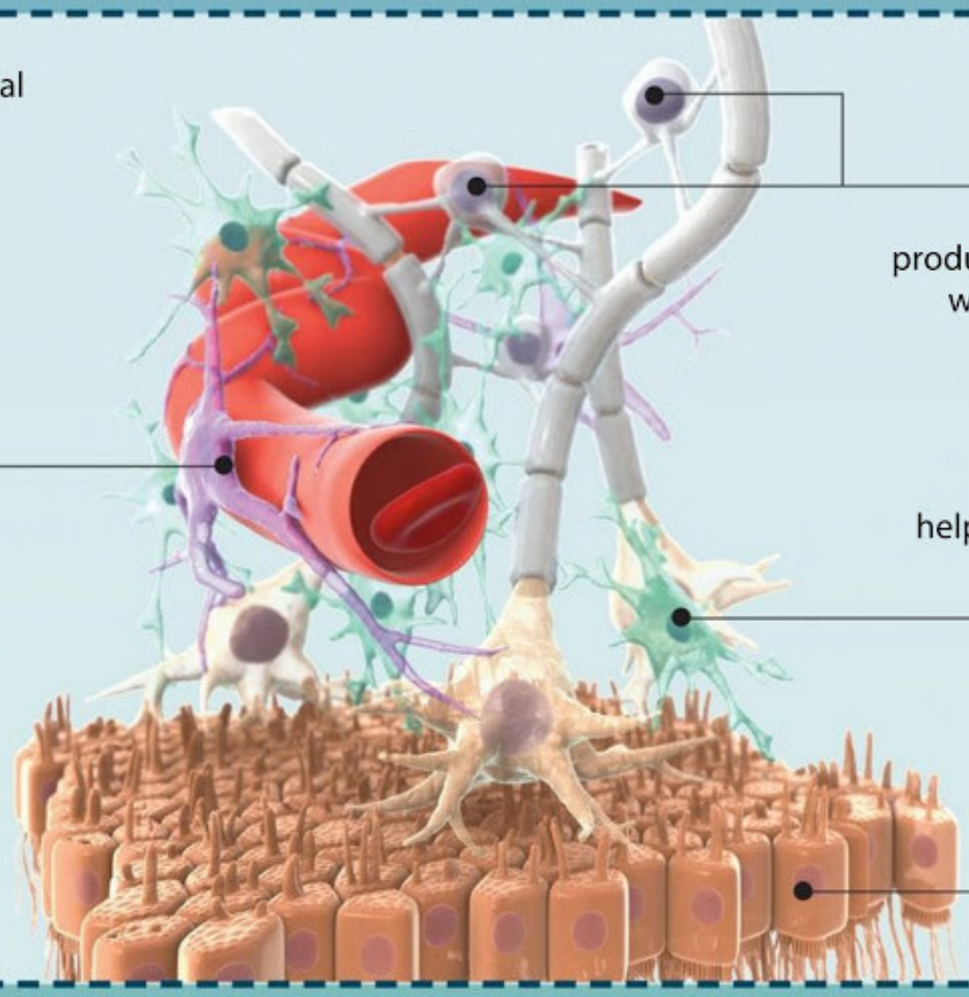
Axons
are thin fibers, which carry nerve impulses to other neurons or cells.

Cell body
contains the neuron's nucleus.

Dendrites
are relatively short, thin fibers that receive impulses from other neurons.

Neuroglia

Neuroglia are cells that provide structural and nutritional support to the neurons.



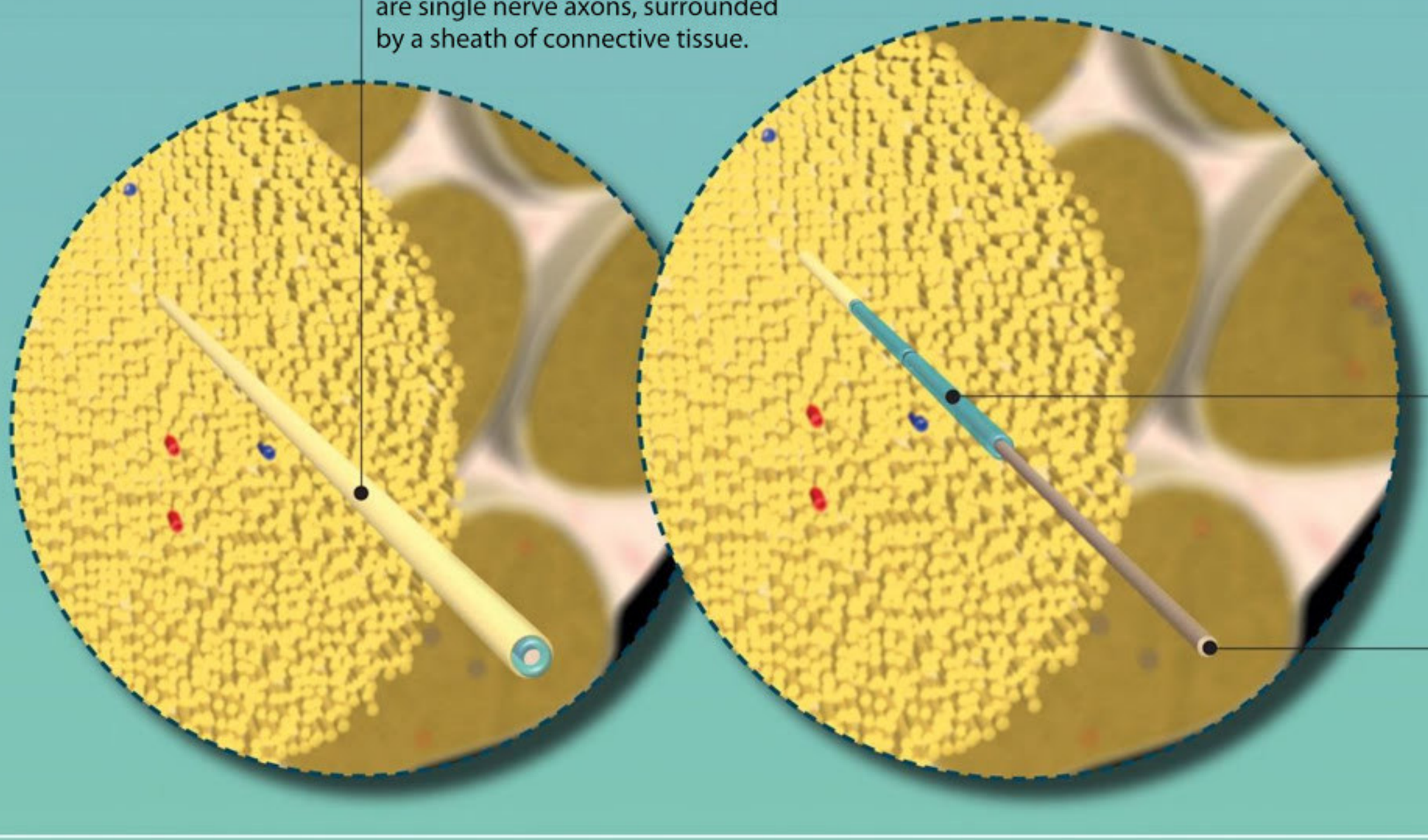
Oligodendrocytes
produce myelin sheaths for neurons within the brain and spinal cord.

Astrocytes
provide support and nutrition to neurons within the brain and spinal cord.

Microglia
help fight infection within the brain and spinal cord.

Ependymal cells
produce and monitor the fluid that circulates around the brain and spinal cord.

Nerve fibers
are single nerve axons, surrounded by a sheath of connective tissue.



Myelin sheath
insulates the axons of some neurons, allowing them to conduct impulses faster.

Axon