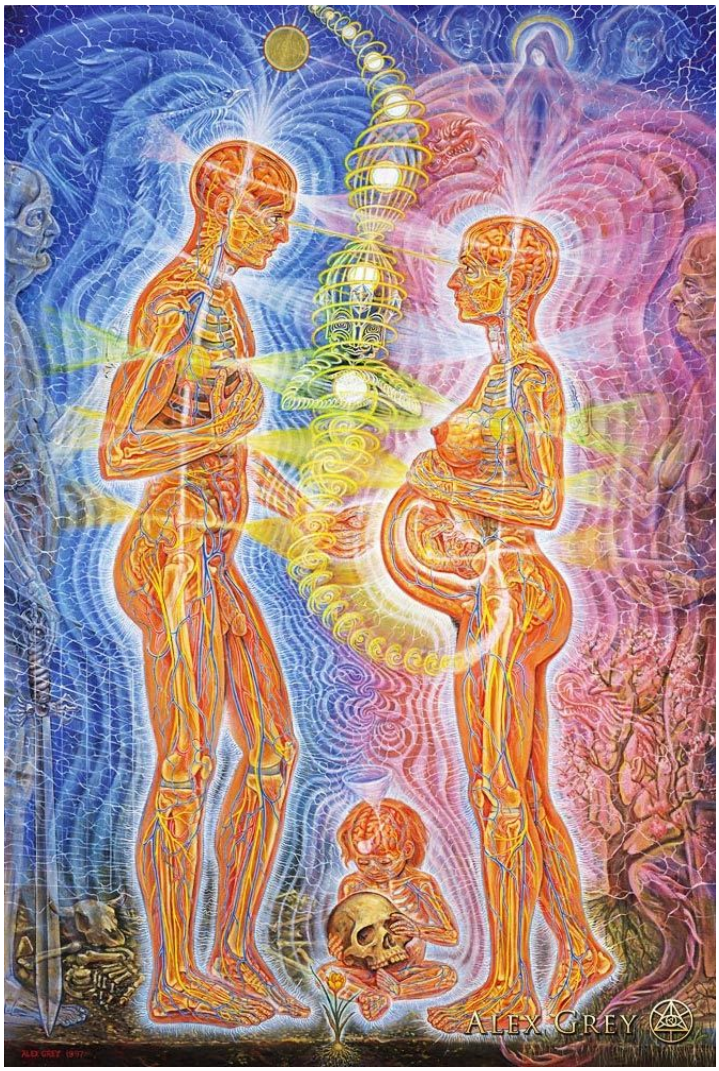


Physiology for Yogis

Additional course content for 200-hr programs

By Zach Beach, www.zachbeach.com

"*As someone who has been an MD for over twenty years, I can tell you that yoga is quite simply the most powerful system of overall health and well-being I have ever seen. Even if you are currently among what might be called the temporarily healthy, as preventive medicine, yoga is as close to one-stop shopping as you can find. This single comprehensive system can reduce stress, increase flexibility, improve balance, promote strength, heighten cardiovascular conditioning, lower blood pressure, reduce overweight, strengthen bones, prevent injuries, lift mood, improve immune function, increase the oxygen supply to the tissues, heighten sexual functioning and fulfillment, foster psychological equanimity, and promote spiritual well-being… and that's only a partial list.*" - Timothy McCall, Yoga as Medicine

Recommended Reading

- Alan Fogel, *The Psychophysiology of Self-Awareness*
- Amanda Blake, *Your Body is Your Brain*
- Ann Swanson, *Science of Yoga*
- Blandine Calais-Germain, *The Anatomy of Breathing*
- Charles Eisenstein*, The Yoga of Eating*
- Daniel Siegel, *Mindsight*
- Darian Leader and David Corfield, *Why Do People Get Ill?*
- Deane and Anne Ornish, *Undo It!*
- Emeran Mayer MD, *The Mind-Gut Connection*
- Kenneth Saladin, *Anatomy & Physiology*
- Linda Hartley, *Wisdom of the Body Moving*
- Max Strom, *A Life Worth Breathing*
- Stephen Porges, *The Pocket Guide to Polyvagal Theory*
- Swami Rama, Rudolph Ballentine, Alan Hymes, *Science of Breath*

Outline

Introduction

Yoga Is Internal Exercise. The Rest Is All Circus. – K Pattabhi Jois

Yoga is many things: a philosophy, a practice, a spirituality, **a holistic system of health**. It is also a journey deep into the nature of the body, how it works, and **how to live optimally**.

Through yoga we learn to see our body as a temple, and treat it as such. Through the practice of yoga we also discover that **our body is quite the miracle**. Right now, as you read these words, **trillions of cells** (are 37 trillion, in fact) are working diligently and countless functions are operating optimally to keep you alive. **The heart is pumping to** transport oxygen to your muscles, acid is being secreted in your **stomach** to break down your food, your **kidneys and liver** are filtering out toxins to be expelled from the body as waste, **billions of neurons** are firing to allow these words to enter your consciousness. It is simply incredible how many processes need to go right for the human body merely exist.

How does yoga affect and improve the functioning in our bodies? For that let us turn to the work of **Vishnudevananda Saraswati** (1927-1993). A disciple of Sivananda Saraswati and founder of the *International Sivananda Yoga Vedanta Centres and Ashrams*, he established the Sivananda Yoga Teachers' Training Course, one of the first yoga teacher training programs in the West.

In that YTT course, Vishnudevananda emphasized what he called **The Five Points of Yoga:**

These five points are closely related to our own understanding of the body in modern anatomy and physiology.
The physiology lessons in this handout will look at the four systems of the body most closely related to Vishnudevananda's points. They are

- The **respiratory system** (proper breathing)
- The **cardiovascular system** (proper exercise)
- The **nervous system** (proper thinking)
- The **digestive system** (proper diet)

And of course proper relaxation affects all these systems as well.

If **anatomy** is how the body is *built* (our body's overall structure), **physiology** is how it all *works together* (our body's functions and relationships). Learning about how these systems work will both inform your yoga practice and better your ability to apply scientific principles to asana, pranayama, and meditation practices, as well as maintaining a proper yoga diet.

Since yoga is still a new development in the West, **there is much research to be done** on the beneficial effects of yoga on the body. Much of our knowledge related to yoga physiology comes from exercise science as a whole, while many claims but the yoga community are scientifically unfounded.

Use these lessons as **foundational knowledge on the inner functioning of the body**, while keeping an open mind for **all the unknown, mysterious, and magical ways** yoga transforms our body, mind, and heart for fully optimized holistic healthy living.

Namaste.

-Zach

"People sometimes hear the word mindfulness and think religion. But the reality is that focusing our attention in this way is a biological process that promotes health—a form of brain hygiene—not a religion. Various religions may encourage this health-promoting practice, but learning the skill of mindful awareness is simply a way of cultivating what we have defined as the integration of consciousness." - Dan Siegel, Mindsight

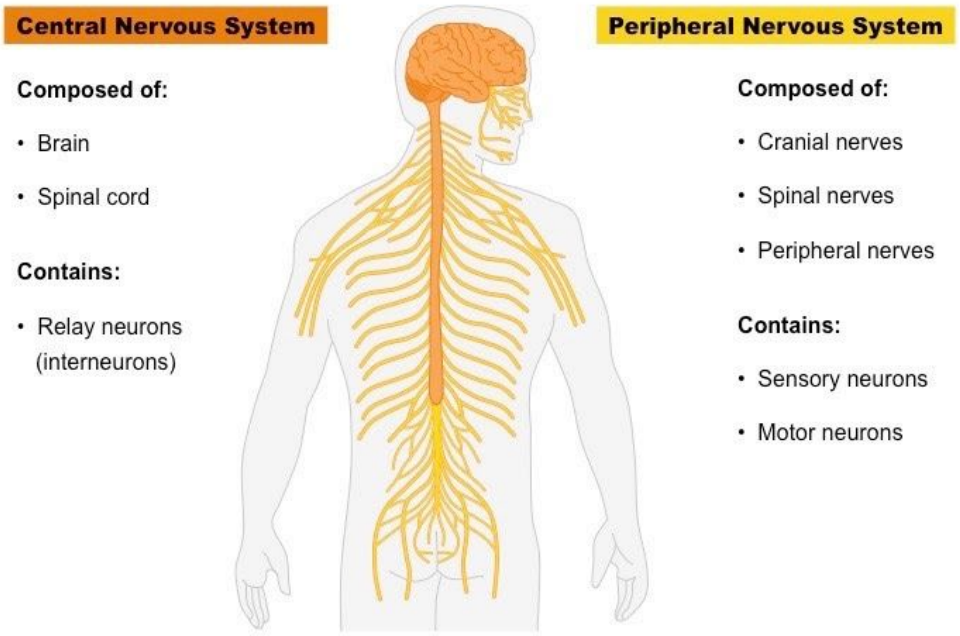
The Nervous System

To begin our understanding of our physiology, we can turn to the system in control of it all: The Nervous System.

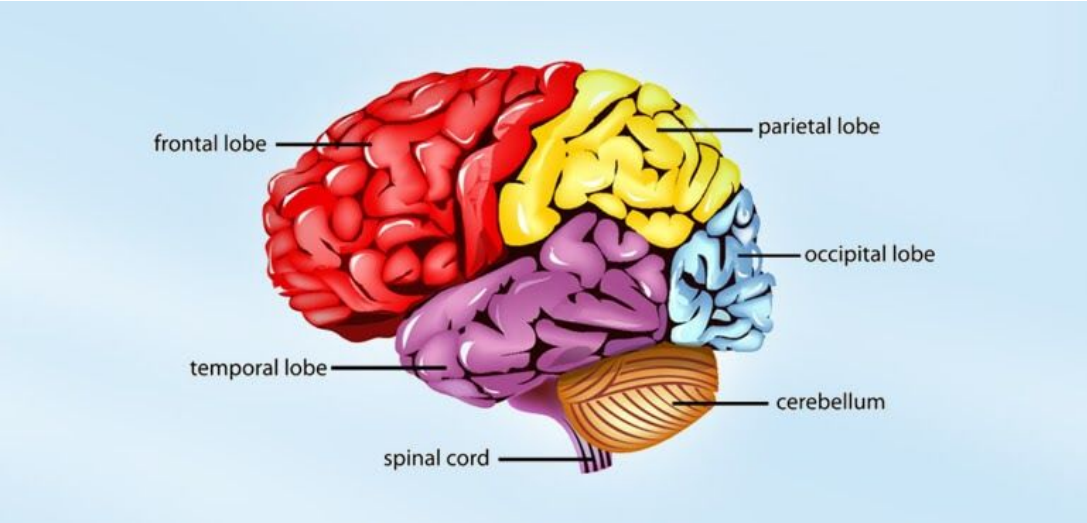
The Basics

The nervous system is a complex collection of nerves and specialized cells known as neurons that transmit signals between different parts of the body. The nervous system is essentially the body's electrical wiring.

Structurally, the nervous system has two components: the **central nervous system** and the **peripheral nervous system**. The central nervous system is made up of the **brain** and **spinal cord**. The peripheral nervous system consists of **sensory neurons**, **ganglia** (clusters of neurons) and **nerves** that connect to one another and to the central nervous system.



Our brain, the upper part of the central nervous system, is the most complex and incredible piece of matter in the entire universe. Our brain has over 100 billion neurons. Each neuron can be connected to up to 10,000 other neurons, passing signals to each other along as many as 1,000 trillion synaptic connections. It said that there are as many possible configurations our brain can take as there are atoms in the entire universe!



Each side of our brain contains four lobes. The **frontal lobe** is important for cognitive functions and control of voluntary movement or activity. The **parietal lobe** processes information about temperature, taste, touch and movement, while the **occipital lobe** is primarily responsible for vision. The **temporal lobe** processes memories, integrating them with sensations of taste, sound, sight and touch.

Mindfulness and Neuroplasticity

Today we know that **the brain has great plasticity** and can change, adapt, and transform over the course of our lifetimes. This means that each of us has the ability to change the very circuitry of our brain by following the golden rule of neuroplasticity: **neurons that fire together wire together.**

Every thought we have increases the propensity of having that thought again. This is why we come to our meditation cushion and our yoga mat every day; to **begin the cultivation of positive mental states**. The brain is molded by **experience, repetition, and intention**.

Neuroscientists have found that our **focused attention is critical** to neuroplasticity. In other words, what we pay attention to matters. Along with focused attention, other factors that enhance neuroplasticity include aerobic **exercise, novelty, and emotional arousal**.

Of particular interest to meditators and yogis the a part of the brain just behind the forehead: **the prefrontal cortex** (PFC). The PFC links together the otherwise separate regions of the brain that think, feel and connect to the body. Research has shown that mindfulness exercises this part of the brain.

There are **eight major functions of middle prefrontal cortex** (mPFC):

1. Regulating the body
2. Attuning to others
3. Balancing emotions
4. Being flexible in our responses
5. Soothing fear
6. Creating empathy
7. Insight
8. Moral awareness and intuition

Looking at these functions, we can see just how important our mPFC is, and why **meditation has the potential to transform our society and way of life**.

Yogic and other meditative traditions have taught us that after compassion meditation, feelings of empathy arise more readily, effortlessly, and often accompanied by a desire to act for the benefit of others.

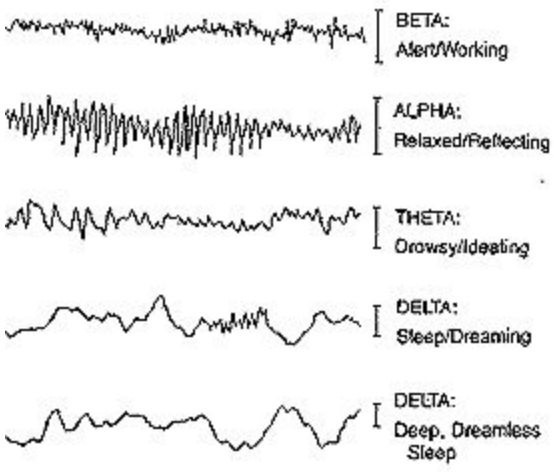
Modern scientific research has confirmed what practitioners have found experientially: by integrating parts of the middle prefrontal cortex by focusing attention on the present moment, **our practice paves the way for attuned communication, emotional balance, empathy, and insight**.

Brain waves

At the root of all our thoughts, emotions and behaviors is the communication between neurons within our brains. **Brainwaves are produced by synchronised electrical pulses** from masses of neurons communicating with each other. There are four main types of brain waves: **beta, alpha, theta, and delta**. Two more types, **gamma and infra-low waves**, are only just recently discovered more is being learned about them every day.

INFRA-LOW (<.5HZ)

Infra-Low brain waves (also known as Slow Cortical Potentials), are thought to be **the basic cortical rhythms that underlie our higher brain functions**. Very little is known about infra-low brain waves. Their slow nature make them difficult to detect and accurately measure, so few studies have been done. They appear to take a major role in brain timing and network function.



DELTA WAVES (.5 TO 3 HZ)

Delta brain waves are slow, loud brain waves (low frequency and deeply penetrating, like a drum beat). They are generated in **deepest meditation and dreamless sleep**. They never go down to zero because that would mean that you were brain dead. But, deep dreamless sleep would take

you down to the lowest frequency. Typically, 2 to 3 cycles a second.

THETA WAVES (3 TO 8 HZ)
The theta frequency range is normally between 5 and 8 cycles a second, although sometimes as low as three. A person who has taken time off from a task and begins to **daydream** is often in a theta brainwave state. A person who is driving on a freeway, and discovers that they can't recall the last five miles, is often in a theta state--induced by the process of freeway driving. **Theta is our gateway to learning, memory, and intuition**. In theta, our senses are withdrawn from the external world and focused on signals originating from within. It is that twilight state which we normally only experience fleetingly as we wake or drift off to sleep. In theta we are in a dream; vivid imagery, intuition and information beyond our normal conscious awareness.

ALPHA WAVES (8 TO 12 HZ)
Alpha brain waves are dominant during quietly flowing thoughts, and in some meditative states. Alpha is **the resting state for the brain**. A person who has completed a task and sits down to rest is often in an alpha state. A person who takes time out to reflect or meditate is usually in an alpha state. A person who takes a break from a conference and walks in the garden is often in an alpha state. **Alpha waves aid overall mental coordination, calmness, alertness, mind/body integration and learning**.

Yoga is believed to increase our alpha waves.

BETA WAVES (12 TO 38 HZ)
Beta brain waves dominate our **normal waking state of consciousness** when attention is directed towards cognitive tasks and the outside world. Beta is a ‘fast’ activity, present when we are alert, attentive, engaged in problem solving, judgment, decision making, or focused mental activity.

Beta brain waves are further divided into three bands; Lo-Beta (Beta1, 12-15Hz) can be thought of as a 'fast idle', or musing. Beta (Beta2, 15-22Hz) is high engagement or actively figuring something out. Hi-Beta (Beta3, 22-38Hz) is highly complex thought, integrating new experiences, high anxiety, or excitement. Continual high frequency processing is not a very efficient way to run the brain, as it takes a tremendous amount of energy.

GAMMA WAVES (38 TO 42 HZ)
Gamma brainwaves are the fastest of brain waves (high frequency, like a flute), and relate to simultaneous processing of information from different brain areas. Gamma brainwaves pass information rapidly and quietly. The most subtle of the brainwave frequencies, the mind has to be quiet to access gamma.

Gamma was dismissed as 'spare brain noise' until researchers discovered it was **highly active when in states of universal love, altruism, and the “higher virtues.”** It is speculated that gamma rhythms

modulate perception and consciousness, and that a greater presence of gamma relates to expanded consciousness and spiritual emergence.

BRAIN WAVES SUMMARY

When we go to bed and read for a few minutes before attempting sleep, we are likely to be in low beta. When we put the book down, turn off the lights and close our eyes, our brainwaves will descend from beta, to alpha, to theta and finally, when we fall asleep, to delta.

When an individual awakes from a deep sleep in preparation for getting up, their brainwave frequencies will increase through the different specific stages of brainwave activity. That is, they will increase from delta to theta and then to alpha and finally, when the alarm goes off, into beta.

Yoga's Effect on the brain

Researchers are only beginning to discover the myriad of effects that yoga has on our brains. Some things they have already discovered include:

- **Increased GABA** - Gamma-aminobutyric acid counteracts anxiety and stress symptoms, leading to more relaxation
- **Increased serotonin** - Serotonin helps to regulate your mood.
- **Increased BDNF** - Brain-derived neurotropic factor is a protein responsible for neuron healthy and neuroplasticity.
- **Regulated Dopamine** - Dopamine acts as your body's reward system and dysfunction is associated with addiction. Research suggests that meditation results in improved self-regulation.
- **Reduced Cortisol** - Cortisol is a stress hormone.
- **Reduced Norepinephrine** - Another stress hormone (also known as adrenaline)

Yoga and the unification of consciousness

Yoga, coming from the word *to yoke*, meaning *to bring together.* Through yoga we integrate mind, body, heart, soul, and spirit. The practice of meditation, the last three steps in Patanjali's 8-limbed system, also integrates our brain.

According to neuroscientists, **a more integrated brain is at the heart of our well-being**. Integration is seen as the essential mechanism of health as it promotes a flexible and adaptive way of being that is filled with vitality and creativity. The ultimate outcome of integration is harmony. The absence of integration leads to chaos and rigidity.

Integration of the left and right hemispheres allows us to put feelings into words, consider feelings in conscious awareness, and integrate the positive and negative affective biases of the left and right hemispheres

What is known as **top-town** (cortical to subcortical) **integrations** includes the ability of the cortex to process, inhibit, and organize the reflexes, impulses and emotions generated by the brainstem and limbic

system. This is crucial to knowing our emotions without getting so caught up in them, which can help us make good decisions in life. **Moral reasoning**, for example, requires the integrative capacity of the middle prefrontal region of the brain both to **sense the emotional meaning of present challenges and to override immediate impulses** in order to create moral actions and respond to those challenges.

Meditation, as mentioned before, produces more gamma waves, which is indicative of massive, far-flung assemblies of neurons firing with a high degree of temporal precision. By firing in sync, neurons cause these far-flung networks to work together, with the result that **cognitive and emotional processes become more integrated and coherent**.

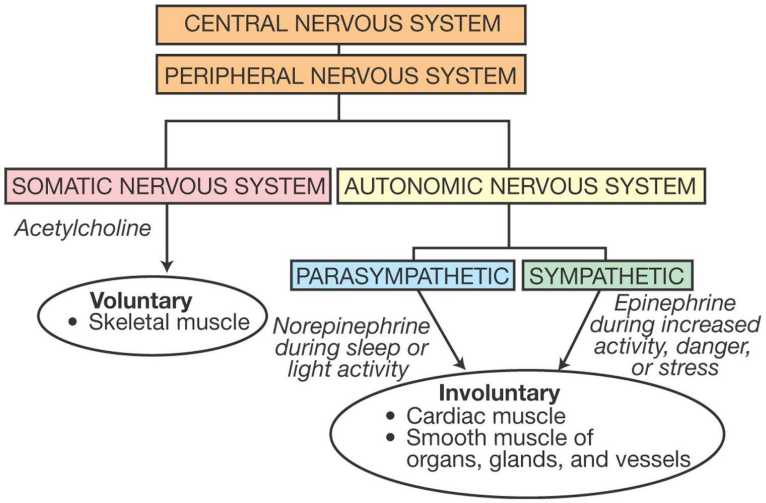
The Peripheral Nervous System

The peripheral nervous system (PNS) is the portion of the nervous system that is outside the brain and spinal cord. The nerves in the PNS connect **the central nervous system (CNS)** to sensory organs, such as the eye and ear, and to other organs of the body, muscles, blood vessels, and glands.

Functionally, the nervous system has two main subdivisions: the **somatic**, or voluntary, component; and the **autonomic**, or involuntary, component. The autonomic nervous system regulates certain body processes, such as blood pressure and the rate of breathing, that work without conscious effort. The somatic system consists of nerves that connect the brain and spinal cord with muscles and sensory receptors in the skin.

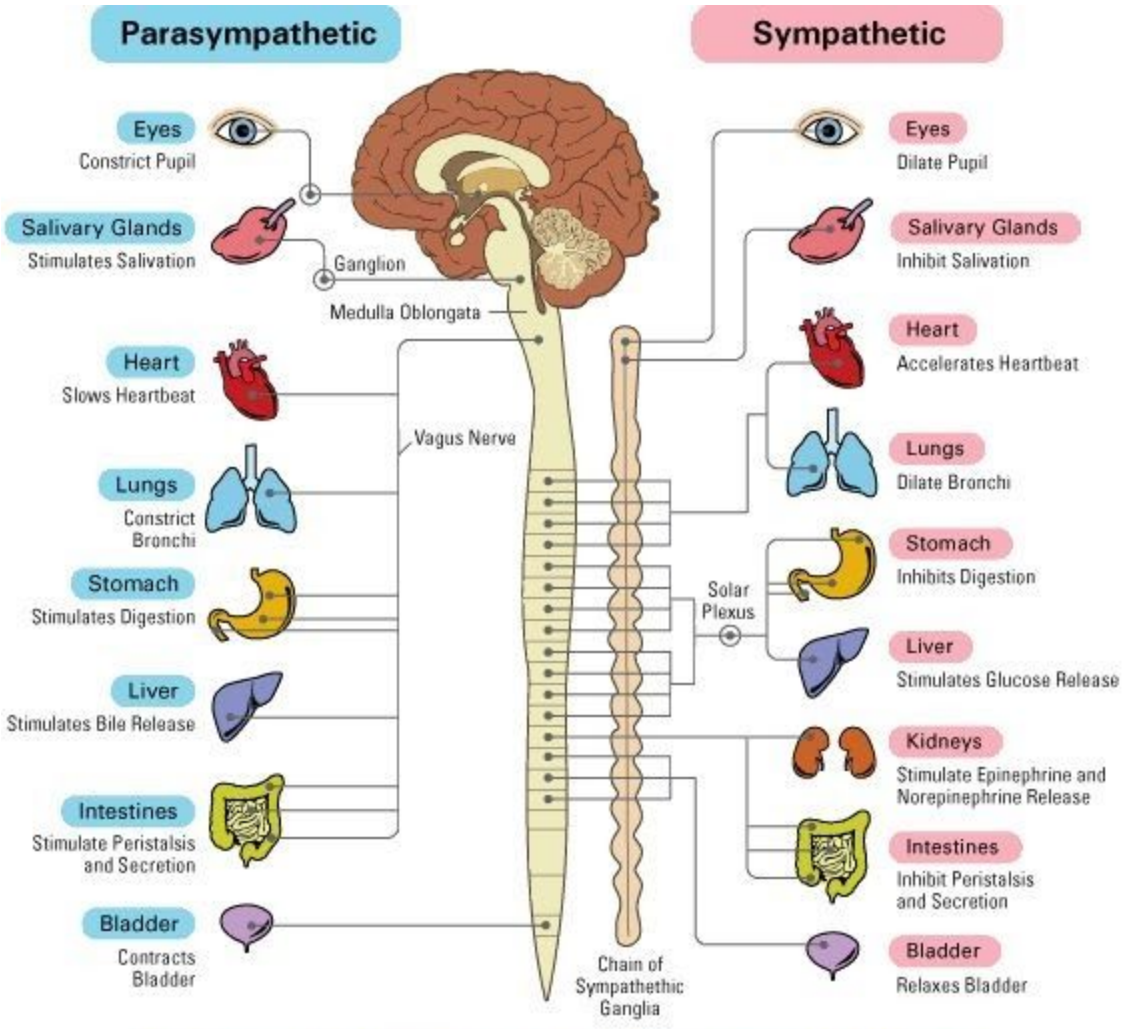
The autonomic nervous system is further divided into **parasympathetic** (rest and digest, or feed and breed) and **sympathetic** (flight, fright, freeze) systems. These systems work hand in hand to maintain homeostasis in the body.

It might help to think of these systems as like the accelerator and brake pedal of a car. As you drive, you need both of them to maintain a steady speed. Below we see the PNS and SNS coordinate functions in the body: We can see this full breakdown below:



While you may have been taught in school that we have 5 senses (touch, taste, hearing, smelling, seeing) in reality the central nervous system receives all sorts of sensory input from the body. **Chemoreceptors** detect the presence of chemicals. **Thermoreceptors** detect changes in temperature. **Mechanoreceptors** detect mechanical forces. We can also sense the need to urinate and defecate, as well as feelings of wetness. All of these inputs come through via the peripheral nervous system.

The peripheral nerves include the 12 cranial nerves, the spinal nerves and roots, and the autonomic nerves. The autonomic nerves are concerned with automatic functions of the body, specifically with the regulation of the heart muscle, the tiny muscles that line the walls of blood vessels, and glands.



Yoga's effect on the Nervous System

Yoga, as a practice not just for the body, but for the mind and heart too, is intimately connected with the nervous system.

First and foremost, **yoga enhances our PNS**. By keeping an even breath during stressful positions, and ensuring a long and luxurious savasana, our PNS becomes predominant and helps us live a more stress-free and happy life. This is why we **come out of savasana very slowly;** any sudden movements or bright lights will stimulate the SNS.

Studies also show that noisy workplaces--even when workers believe they aren't bothered by the sounds--can activate the body's stress response system. Thus sensory overload is likely to be exacerbating already sky-high stress levels in the modern world. By coming to a calm and gentle yoga class, yoga practitioners are able to better drop in and relax their mind and bodies.

Two other important sensory connections yogis should know about are **proprioception** and **interoception**. Proprioception is the awareness of our body in space. Proprioception helps our balance and lowers our risk of falling and hurting ourselves, along with being safe overall.

Interoception is our ability to notice physiological changes in our bodies. Kids who struggle with the interoceptive sense may have trouble knowing when they feel hungry, full, hot, cold or thirsty. **Interoception is an important part of our intuition, and trusting our bodies innate wisdom to respond to situations.**

Interoception works because neural networks throughout the interior of the body, including those surrounding the hollow organs, such as the intestines and the heart, send complex sensory input to the brain. This data forms the foundation for visceral maps that helps us have a “gut feeling” or a “heartfelt” sense. Such input from the body forms a vital source of intuition and powerfully influences our reasoning and the way we create meaning in our lives.

"Your heart is like a great river after a long spell of rain, spilling over its banks. All signposts that once stood on the ground are gone, inundated and carried away by that rush of water. And still the rain beats down on the surface of the river. Every time you see a flood like that on the news you tell yourself: That's it. That's my heart." - Haruki Murakami

The Cardiovascular System

Now that we have examined just how closely the mind and heart interact, let us consider the role of the entire cardiovascular system.

The Basics

"**Cardio**" literally means of the heart, and "**vascular**" means the circulation of fluids. The cardiovascular system then consists of the **heart, blood vessels, and the approximately 5 liters of blood that the blood vessels transport**.

The cardiovascular system has three major functions: transportation of materials, protection from pathogens, and regulation of the body's homeostasis.

- **Transportation**: The cardiovascular system transports blood to almost all of the body's tissues. The **blood delivers essential nutrients and oxygen and removes wastes and carbon dioxide** to be processed or removed from the body. Hormones are transported throughout the body via the blood's liquid plasma.

- **Protection**: The cardiovascular system **protects the body through its white blood cells.** White blood cells clean up cellular debris and fight pathogens that have entered the body. Platelets and red blood cells form scabs to seal wounds and prevent pathogens from entering the body and liquids from leaking out. Blood also carries antibodies that provide specific immunity to pathogens that the body has previously been exposed to or has been vaccinated against.

- **Regulation**: The cardiovascular system is instrumental in the body's ability to maintain **homeostatic control of several internal conditions.** Blood vessels help maintain a stable body temperature by controlling the blood flow to the surface of the skin. Blood vessels near the skin's surface open during times of overheating to allow hot blood to dump its heat into the body's surroundings. In the case of hypothermia, these blood vessels constrict to keep blood flowing only to vital organs in the body's core. Blood also helps balance the body's pH due to the presence of bicarbonate ions, which act as a buffer solution. Finally, the albumins in blood plasma help to balance the osmotic concentration of the body's cells by maintaining an isotonic environment.

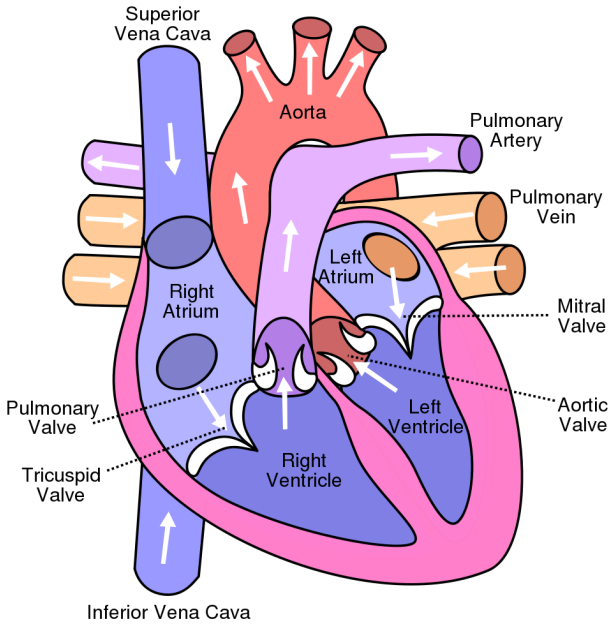
Many serious conditions and diseases can cause our cardiovascular system to stop working properly. Quite often, when we do not do enough about them proactively, resulting in emergencies. This is why **we must exercise for a healthy heart.**

Responsible for transporting oxygen, nutrients, hormones, and cellular waste products throughout the body, the cardiovascular system is powered by **the body's hardest-working organ — the heart**, which is only about the size of a closed fist. Even at rest, the average heart easily pumps over 5 liters of blood throughout the body every minute.

The Heart and Its Circulatory Loops

The Heart

The heart is our muscular pumping organ located medial to the lungs along the body's midline in the thoracic region. The bottom tip of the heart, known as its apex, is turned to the left, so that about 2/3 of the heart is located on the body's left side with the other 1/3 on right. The top of the heart, known as the heart's base, connects to the great blood vessels of the body: the **aorta, vena cava, pulmonary trunk,** and **pulmonary veins**.



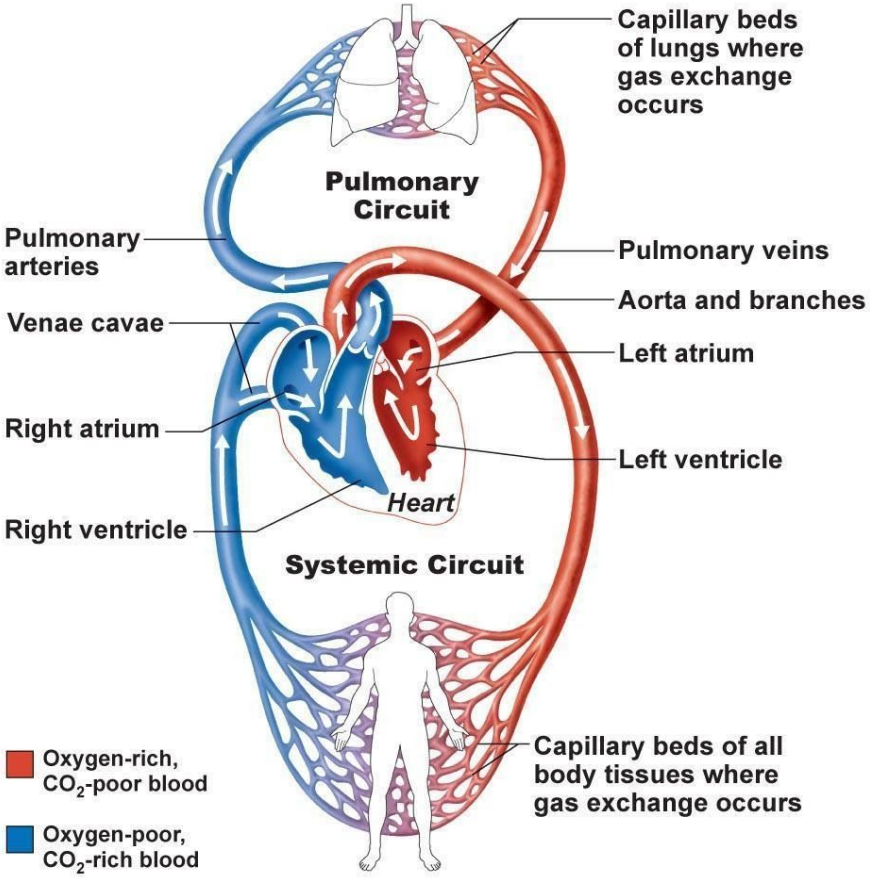
The heart is **a four-chambered "double pump,"** where each side (left and right) operates as a separate pump. The left and right sides of the heart are separated by a muscular wall of tissue known as the septum of the heart. The right side of the heart receives deoxygenated blood from the systemic veins and pumps it to the lungs for oxygenation. The left side of the heart receives oxygenated blood from the lungs and pumps it through the systemic arteries to the tissues of the body. Each heartbeat results in the simultaneous pumping of both sides of the heart, making the heart a very efficient pump.

Circulatory Loops

There are 2 primary circulatory loops in the human body: the pulmonary circulation loop and the systemic circulation loop.

- **Pulmonary circulation** transports deoxygenated blood from the right side of the heart to the lungs, where the blood picks up oxygen and returns to the left side of the heart. The pumping chambers of the heart that support the pulmonary circulation loop are the right atrium and right ventricle.

- **Systemic circulation** carries highly oxygenated blood from the left side of the heart to all of the tissues of the body (with the exception of the heart and lungs). Systemic circulation removes wastes from body tissues and returns deoxygenated blood to the right side of the heart. The left atrium and left ventricle of the heart are the pumping chambers for the systemic circulation loop.



There are a few secondary circulatory loops as well:

- **Coronary Circulation:** The heart has its own set of blood vessels that provide the myocardium with the oxygen and nutrients necessary to pump blood throughout the body. The left and right coronary arteries branch off from the aorta and provide blood to the left and right sides of the heart. The coronary sinus is a vein on the posterior side of the heart that returns deoxygenated blood from the myocardium to the vena cava.

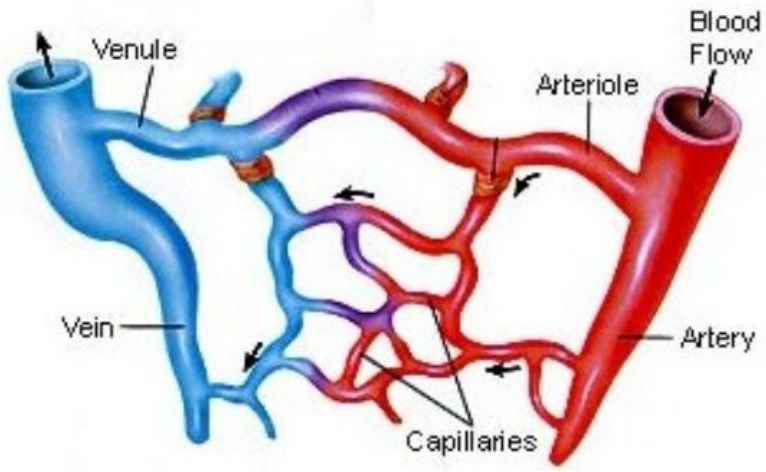
- **Hepatic Portal Circulation:** The veins of the stomach and intestines perform a unique function: instead of carrying blood directly back to the heart, they carry blood to the liver through the hepatic portal vein. Blood leaving the digestive organs is rich in nutrients and other chemicals absorbed from food. **The liver removes toxins, stores sugars, and processes the products of digestion** before they reach the other body tissues. Blood from the liver then returns to the heart through the inferior vena cava.

Blood Vessels

Blood vessels are the body's highways that allow blood to flow quickly and efficiently from the heart to every region of the body and back again. The size of blood vessels corresponds with the amount of blood that passes through the vessel.

There are three major types of blood vessels: **arteries, capillaries and veins**. Blood vessels are often named after either the region of the body through which they carry blood or for nearby structures. For example, the **brachiocephalic artery** carries blood into the brachial (arm) and cephalic (head) regions. One of its branches, the **subclavian artery**, runs under the clavicle; hence the name subclavian. The subclavian artery runs into the axillary region where it becomes known as the axillary artery.

heart ➔ artery ➔ arteriole ➔ capillary ➔ venule ➔ vein ➔ heart



Arteries are blood vessels that carry blood away from the heart. Blood carried by arteries is usually highly oxygenated, having just left the lungs on its way to the body's tissues. The pulmonary trunk and arteries of the pulmonary circulation loop provide an exception to this rule — these arteries carry deoxygenated blood from the heart to the lungs to be oxygenated.

Arterioles are narrower arteries that branch off from the ends of arteries and carry blood to capillaries. They face much lower blood pressures than arteries due to their greater number, decreased blood volume, and distance from the direct pressure of the heart. Thus arteriole walls are much thinner than those of arteries. Arterioles, like arteries, are able to use smooth muscle to control their aperture and regulate blood flow and blood pressure.

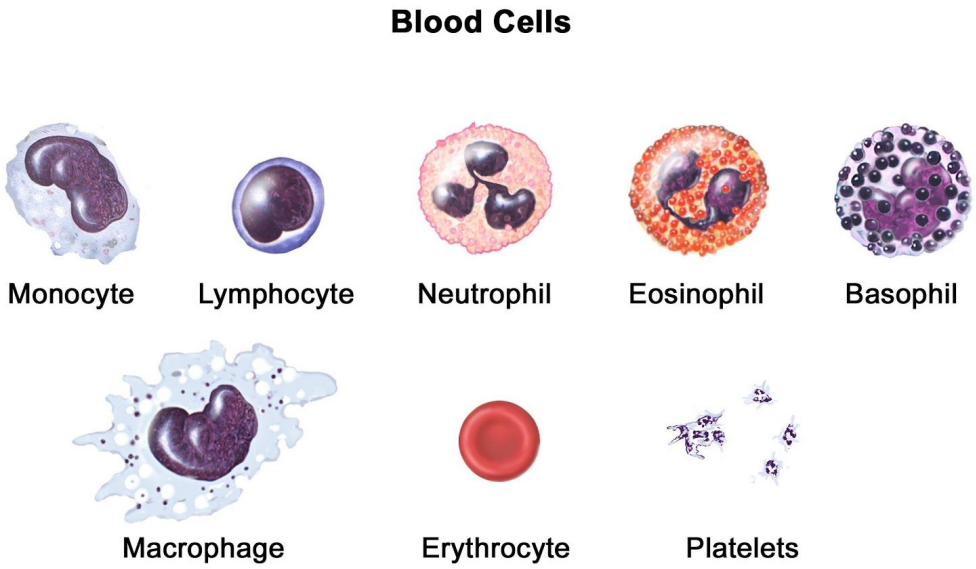
Capillaries are the smallest and thinnest of the blood vessels in the body and also the most common. They can be found running throughout almost every tissue of the body and border the edges of the body's avascular tissues. Capillaries connect to arterioles on one end and venules on the other.

Veins and Venules

Veins are the large return vessels of the body and act as the blood return counterparts of arteries. Because the arteries, arterioles, and capillaries absorb most of the force of the heart's contractions, veins and venules are subjected to very low blood pressures. Veins rely on gravity, inertia, and the force of skeletal muscle contractions to help push blood back to the heart. To facilitate the movement of blood, some veins contain many one-way valves that prevent blood from flowing away from the heart.

The Makeup of Blood

The average human body contains about 4 to 5 liters of blood. Blood transports many substances through the body and helps to maintain homeostasis of nutrients, wastes, and gases. Blood is made up of **red blood cells, white blood cells, platelets, and liquid plasma.**

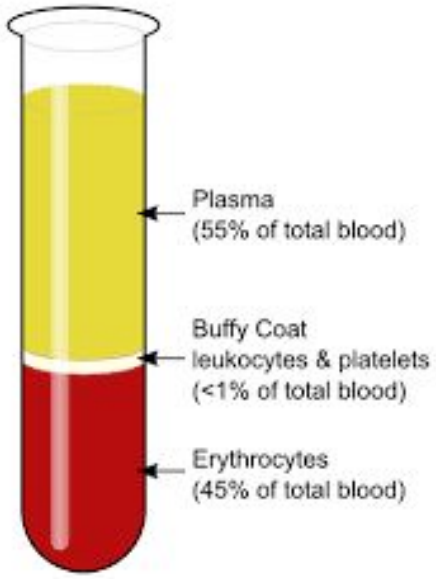


Red Blood Cells

Red blood cells, also known as erythrocytes, are by far the most common type of blood cell and make up about 45% of blood volume. Erythrocytes are produced inside of red bone marrow from stem cells at the astonishing rate of about 2 million cells every second. The shape of erythrocytes is biconcave—disks with a concave curve on both sides of the disk so that the center of an erythrocyte is its thinnest part. The unique shape of erythrocytes gives these cells a high surface area to volume ratio and allows them to fold to fit into thin capillaries. Immature erythrocytes have a nucleus that is ejected from the cell when it reaches maturity to provide it with its unique shape and flexibility. The lack of a nucleus means that red blood cells contain no DNA and are not able to repair themselves once damaged. Erythrocytes transport oxygen in the blood through the red pigment hemoglobin. **Hemoglobin** contains iron and proteins joined to greatly increase the oxygen carrying capacity of erythrocytes. The high surface area to volume ratio of erythrocytes allows oxygen to be easily transferred into the cell in the lungs and out of the cell in the capillaries of the systemic tissues.

White Blood Cells

White blood cells, also known as leukocytes, make up a very small percentage of the total number of cells in the bloodstream, but have important functions in the body's immune system. There are two major classes of white blood cells: **granular leukocytes** and **agranular leukocytes.** Granular leukocytes -- they are better known as granulocytes -- are part of the innate immune system and have somewhat non specific, broad-based activity. The agranular leukocytes are massing granules: tiny sacs that contain various enzymes, compounds and other components that are used to defend against pathogens, reduce inflammation and destroy cells.



Platelets

Also known as **thrombocytes**, platelets are small cell fragments responsible for the clotting of blood and the formation of scabs. Platelets form in the red bone marrow from large megakaryocyte cells that periodically rupture and release thousands of pieces of membrane that become the platelets. Platelets do not contain a nucleus and only survive in the body for up to a week before macrophages capture and digest them.

Plasma

Plasma is the non-cellular or liquid portion of the blood that makes up about 55% of the blood's volume. Plasma is a mixture of water, proteins, and dissolved substances. Around 90% of plasma is made of water, although the exact percentage varies depending upon the hydration levels of the individual. The proteins within plasma include **antibodies and albumins**. Antibodies are part of the immune system and bind to antigens on the surface of pathogens that infect the body. Albumins help maintain the body's osmotic balance by providing an isotonic solution for the cells of the body. Many different substances can be found dissolved in the plasma, including glucose, oxygen, carbon dioxide, electrolytes, nutrients, and cellular waste products. The plasma functions as a transportation medium for these substances as they move throughout the body.

Understanding blood pressure

Your blood pressure is recorded as two numbers, such 123/72. These numbers are measured in mmHG (millimeters of mercury) and represent:

- **Systolic blood pressure** (the upper number) — indicates how much pressure your blood is exerting against your artery walls when the heart beats.

- **Diastolic blood pressure** (the lower number) — indicates how much pressure your blood is exerting against your artery walls while the heart is resting between beats.

BLOOD PRESSURE CATEGORY	SYSTOLIC mm Hg (upper number)		DIASTOLIC mm Hg (lower number)
NORMAL	LESS THAN 120	and	LESS THAN 80
ELEVATED	120 – 129	and	LESS THAN 80
HIGH BLOOD PRESSURE (HYPERTENSION) STAGE 1	130 – 139	or	80 – 89
HIGH BLOOD PRESSURE (HYPERTENSION) STAGE 2	140 OR HIGHER	or	90 OR HIGHER
HYPERTENSIVE CRISIS (consult your doctor immediately)	HIGHER THAN 180	and/or	HIGHER THAN 120

Typically, more attention is given to **systolic blood pressure (the top number) as a major risk factor for cardiovascular disease** for people over 50. In most people, systolic blood pressure rises steadily with age due to the increasing stiffness of large arteries, long-term build-up of plaque and an increased incidence of cardiac and vascular disease.

Yoga and the Cardiovascular System

Unfortunately, there is not a lot of scientific research specifically related to yoga's effect on the body. But we do know how exercise improves the body's overall functioning, as well as the importance of the breath for stress levels and parasympathetic response.

Know that **during exercise,** the heart compensates for the muscles' greater needs for oxygen by:

- Increasing heart rate
- Increasing ejection fraction
- Increasing stroke volume
- Increasing cardiac output

Over time, as the body continues to exercise multiple times throughout the week, **the cardiovascular system improves by:**

- Increasing plasma volume
- Increasing red cell mass
- Increasing total blood volume
- Improving blood pressure
- Increasing stroke volume
- Increasing cardiac output
- Improved cholesterol

Combining what we already know about breathing rate and the nervous system, we can see how the enhanced PNS effect of yoga improves our overall cardiovascular conditioning:

Parasympathetic phase	**Sympathetic Phase**
Exhalation	Inhalation
Bronchi constrict	Bronchi dilate
Carbon dioxide transfers out of bloodstream	Oxygen transfers into bloodstream
Heartbeat rate decreases	Heartbeat rate increases
Arterial pressure decreases	Arterial pressure increases
Arterial blood flow decreases	Arterial blood flow increases
Arterial relaxation/elastic contraction	Arterial constriction/elastic distention
Peripheral arterial pressure decreases	Peripheral arterial pressure increases
Venous blood flow decelerates	Venous blood flow accelerates
Venus reservoirs empty	Venous reservoirs fill

One meta-analysis found that yoga reduces heart disease risk as well as or better than most exercise. Long-term clinical trials have shown that a yogic lifestyle could reverse heart disease.

"When you experience the vibration of your breath and you truly recognize the vibratory quality of everything you encounter, when you feel constant change in all that is going on around you right now, then you have deep insight into the meaning of life." - Richard Freeman, The Mirror of Yoga

The Respiratory System

First, take a deep breath…. Didn't that feel nice?

The breath is the most important in our yoga practice. It is relaxing, it's an important odometer for the body, and it's our primary connection to the world around us. From a physiological perspective, our breath is part of our respiratory system.

The Basics

The human respiratory system is a series of organs responsible for taking in oxygen and expelling carbon dioxide. The primary organs of the respiratory system are **lungs**, which carry out this exchange of gases as we breathe.

Red blood cells collect the oxygen from the lungs and carry it to the parts of the body where it is needed. During the process, the red blood cells collect the carbon dioxide and transport it back to the lungs, where it leaves the body when we exhale.

The human body needs oxygen to sustain itself. In fact every cell in your body needs to breathe. A decrease in oxygen is known as **hypoxia** and a complete lack of oxygen is known as **anoxia**. These conditions can be fatal; after about four minutes without oxygen, brain cells begin dying, which can lead to brain damage and ultimately death.

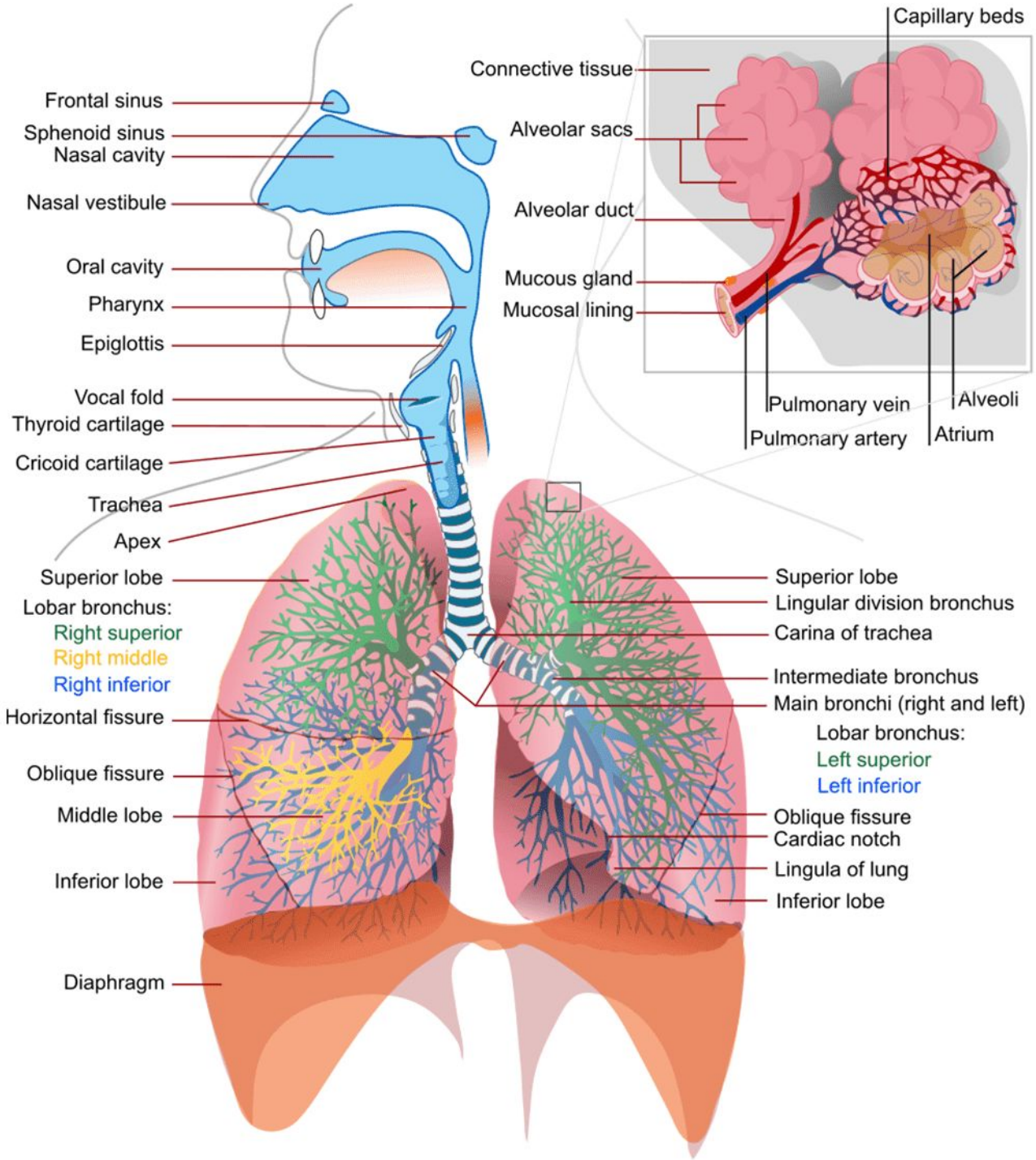
In humans, the average rate of breathing depends on age. A newborn's normal breathing rate is about 40 times each minute and may slow to 20 to 40 times per minute when the baby is sleeping. For adults, the average resting respiratory rate for adults is 12 to 16 breaths per minute. Physical exertion also has an effect on respiratory rate, and healthy adults can average 45 breaths per minute during strenuous exercise

The Pathway of Air

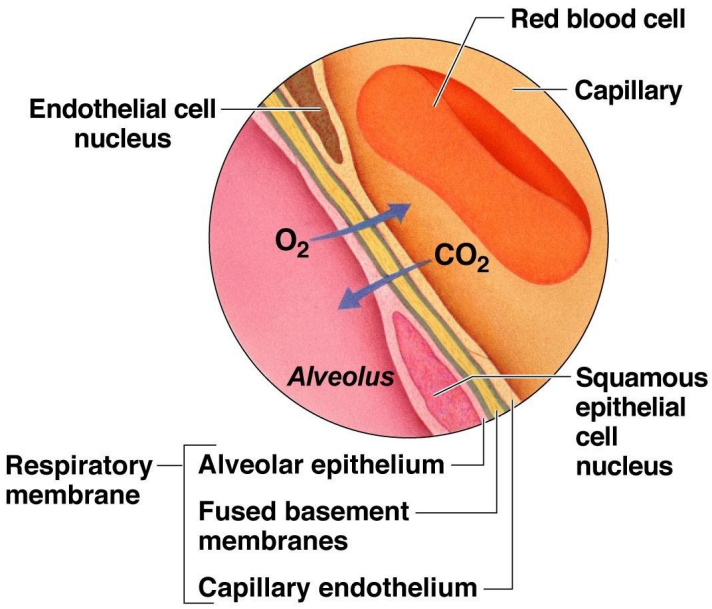
Our airways begin at the nose and mouth. Air is pulled backward in the nose past the **hard and soft palates**, where it makes a 90 degree turn and enterals a funnel-shaped region, the **pharynx**. From there is continues downward into the **larynx**, which is the organ for phonation and whose vocal cords vibrate to create sound.

Below the larynx air passes into the **trachea**, the right and left **primary bronchi**, and then into the two lungs.

Each lungs consists of **10 bronchopulmonary segments** that are served individually by **secondary bronchi**. The secondary bronchi in turn divide into **tertiary bronchi** and smaller subdivisions (**bronchioles**) that collectively compose the **bronchial tree**. The terminal bronchioles of the bronchial tree in turn open to the tiny **alveoli**, giving a microscopic view of the lungs and the appearance of a delicate lacy network.



The respiratory membrane separates air within the alveoli from the **blood** within pulmonary capillaries. It consists of the alveolar wall, the capillary wall, and their basement membranes. The respiratory membrane is very thin (less than 0.5 mm).



Pulmonary volumes

The amount of air in the lungs can be subdivided into **four volumes and four capacities.**

Respiratory (lung) volumes:

1. **Tidal volume (TV)** is the amount of air that can be inhaled and exhaled during one normal breathing cycle (about 500 ml for men & women).
2. **Inspiratory reserve volume (IRV)** is the amount of air that can be forcibly inhaled beyond a tidal inhalation (about 3,000 ml for men & 2,000 ml for women).
3. **Expiratory reserve volume (ERV)** is the amount of air that can be forcibly exhaled beyond a tidal exhalation (about 1200 ml for men & 700 ml for women).
4. **Residual Volume (RV)** – the amount of air remaining in the lungs after an ERV (about 1,200 ml in men & women).

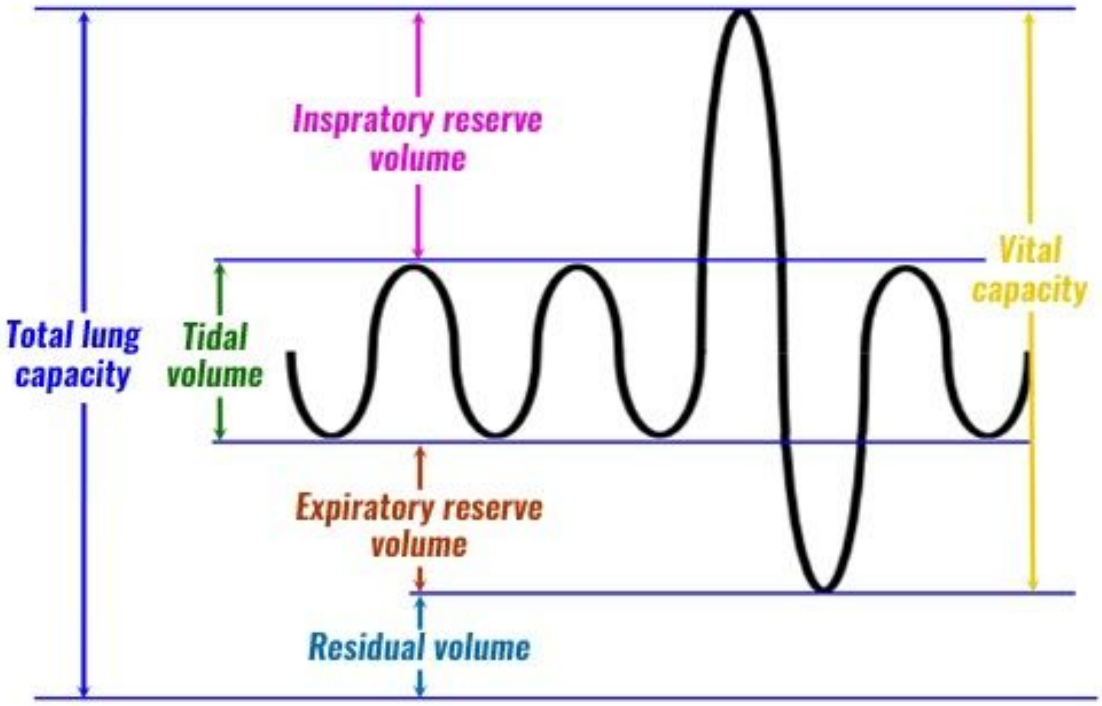
Respiratory capacities are found by adding together two or more respiratory volumes.

1. **Inspiratory capacity** = TV + IRV.
2. **Functional reserve capacity** = ERV + RV.
3. **Vital capacity** = TV + IRV + ERV.
4. **Total lung capacity** = RV + VC.

Yoga and the Respiratory System

It may be surprising for many first time yoga students to learn that they are breathing incorrectly. Fortunately, through intentionally focusing on the breath in our pranayama and asana practices, we can all learn how to breathe more fully and completely.

Pranayama practices like **kapalabhati** have been shown to increase vital capacity, increase expiratory

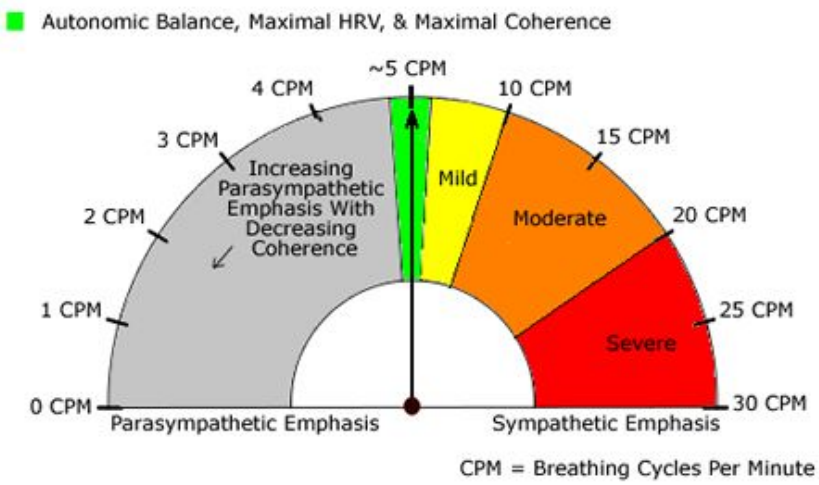


reserve volume, and increase maximal minute ventilation. We also strengthen our respiratory muscles through more active pranayama.

Yoga and Heart Rate Variability

Yoga trains our body to breathe at its most optimal levels. For adults in the state of rest or semi-activity, optimal synchrony between **heart rate variability (HRV)** and breathing rhythms occurs at a specific frequency, this being 1 cycle in ~12 seconds, or 5 cycles in ~1 minute.

When operating at this pace, **cardiopulmonary efficiency and effectiveness are maximized** and in keeping with the fundamental underlying autonomic nervous system rhythm. Cardiopulmonary operation at this rhythm is characterized by relatively low average heartbeat rate, maximized heart rate variability amplitude, and maximized heart rate variability coherence.



Yoga teaches us about balance and harmony. We do not want to breathe too fast and stimulate our stress response, but we do not want to breathe too slowly either and deprive our body of the essential oxygen that it needs.

Feelings of love and compassion are associated with an increase in HRV, and when we feel insecurity, anger, or frustration, our HRV decreases, becoming more smooth and regular. As any yoga practitioner will tell you (and you may also have discovered), once we learn to breathe correctly, our entire world transforms.

"We humans have known since time immemorial something that science is only now discovering: our gut feeling is responsible in no small measure for how we feel. We are "scared shitless" or we can be "shitting ourselves" with fear. If we don't manage to complete a job, we can't get our "ass in gear." We "swallow" our disappointment and need time to "digest" a defeat. A nasty comment leaves a "bad taste in our mouth." When we fall in love, we get "butterflies in our stomach." Our self is created in our head and our gut—no longer just in language, but increasingly also in the lab."
— Giulia Enders, Gut: The Inside Story of Our Body's Most Underrated Organ

The Digestive System

Finally, let us examine another large body of organs that intimately connects to the nervous system: **the Digestive System.**

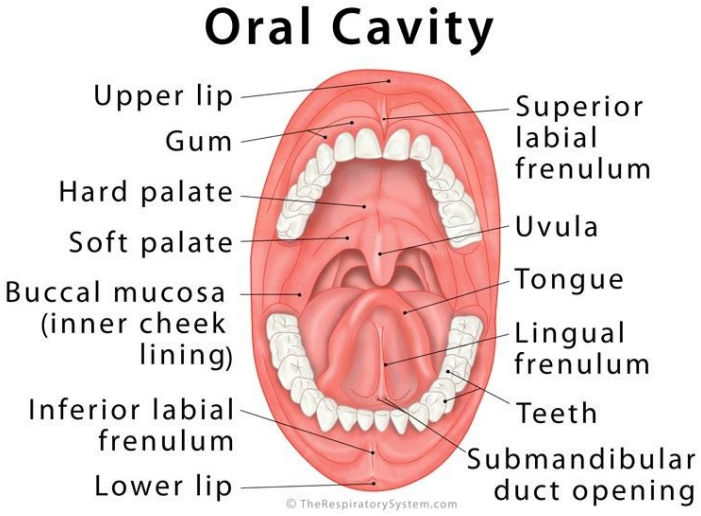
The Basics

The digestive system is **a group of organs working together** to convert food into energy and basic nutrients to feed the entire body. Food passes through a long tube inside the body known as the alimentary canal or the gastrointestinal tract (GI tract). The **alimentary canal** is made up of the **oral cavity, pharynx, esophagus, stomach, small intestines, and large intestines.**

In addition to the alimentary canal, there are several important accessory organs that help your body to digest food, but do not have food pass through them. Accessory organs of the digestive system include **the teeth, tongue, salivary glands, liver, gallbladder, and pancreas.**

Oral Cavity:

- **Mouth** Food begins its journey through the digestive system in the mouth, also known as the oral cavity. Inside the mouth are many accessory organs that aid in the digestion of food—the tongue, teeth, and salivary glands. Teeth chop food into small pieces, which are moistened by saliva before the tongue and other muscles push the food into the pharynx.

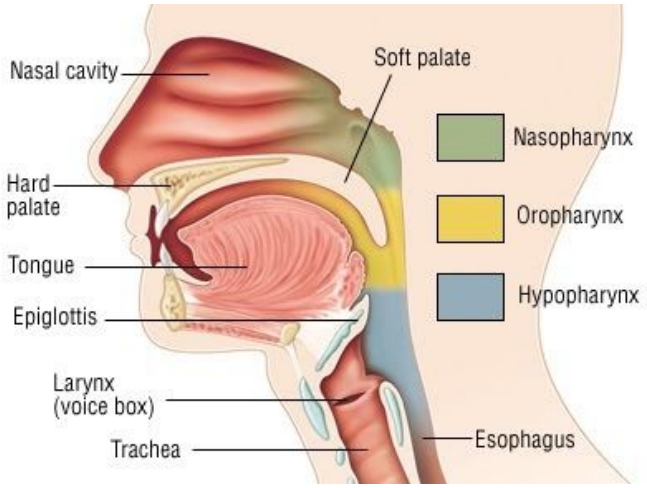


- **Teeth**. The teeth are 32 small, hard organs found along the anterior and lateral edges of the mouth. Each tooth is made of a bone-like substance called dentin and covered in a layer of enamel—the hardest substance in the body. Teeth are living organs and contain blood vessels and nerves under the

dentin in a soft region known as the pulp. The teeth are designed for cutting and grinding food into smaller pieces.

- **Tongue**. The tongue is located on the inferior portion of the mouth just posterior and medial to the teeth. It is a small organ made up of several pairs of muscles covered in a thin, bumpy, skin-like layer. The outside of the tongue contains many rough papillae for gripping food as it is moved by the tongue's muscles. The taste buds on the surface of the tongue detect taste molecules in food and connect to nerves in the tongue to send taste information to the brain. The tongue also helps to push food toward the posterior part of the mouth for swallowing.

- **Salivary Glands**. Surrounding the mouth are 3 sets of salivary glands. The salivary glands are accessory organs that produce a watery secretion known as saliva. Saliva helps to moisten food and begins the digestion of carbohydrates. The body also uses saliva to lubricate food as it passes through the mouth, pharynx, and esophagus.

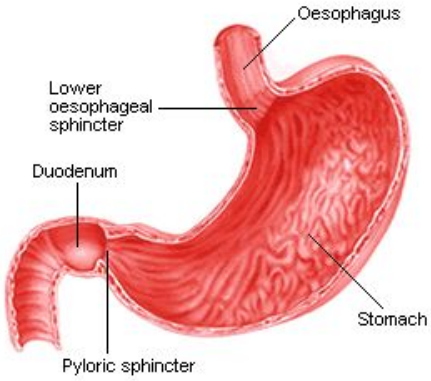


Pharynx

The pharynx, or throat, is a funnel-shaped tube connected to the posterior end of the mouth. The pharynx is responsible for the passing of masses of chewed food from the mouth to the esophagus. The pharynx also plays an important role in the respiratory system, as air from the nasal cavity passes through the pharynx on its way to the larynx and eventually the lungs. Because the pharynx serves two different functions, it contains a flap of tissue known as the epiglottis that acts as a switch to route food to the esophagus and air to the larynx.

Esophagus

The esophagus is a muscular tube connecting the pharynx to the stomach that is part of the upper gastrointestinal tract. It carries swallowed masses of chewed food along its length. At the inferior end of the esophagus is a muscular ring called the lower esophageal sphincter or cardiac sphincter. The function of this sphincter is to close of the end of the esophagus and trap food in the stomach.



Stomach

The stomach is a muscular sac that is located on the left side of the abdominal cavity, just inferior to the diaphragm. In an average person, the stomach is about the size of their two fists placed next to each other. This major organ acts as a storage tank for food so that the

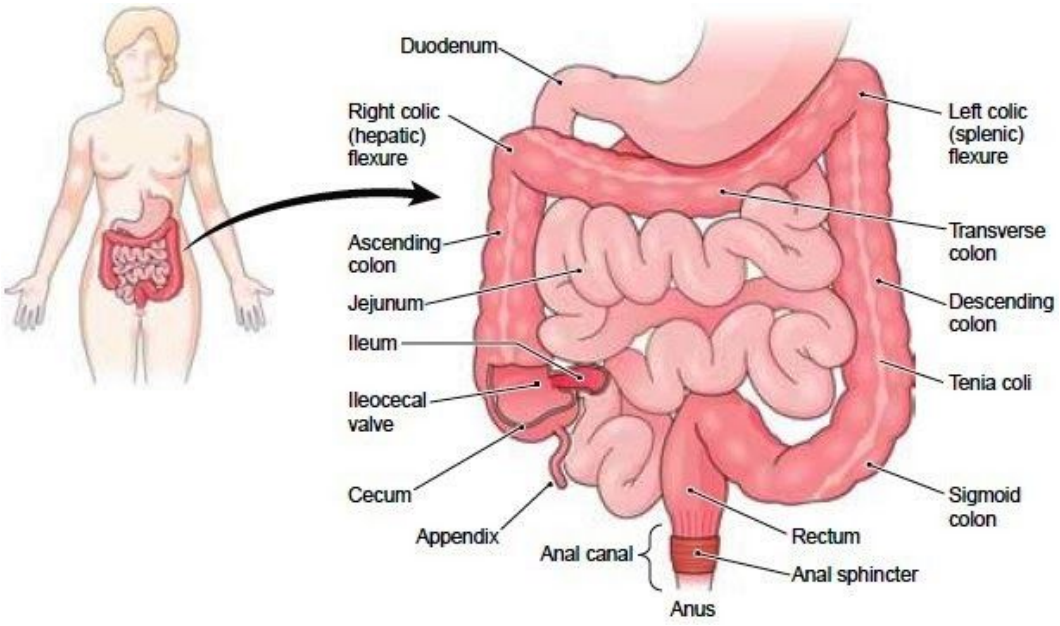
body has time to digest large meals properly. The stomach also contains hydrochloric acid and digestive enzymes that continue the digestion of food that began in the mouth.

Small Intestine

The small intestine is a long, thin tube about 1 inch in diameter and about 10 feet long that is part of the lower gastrointestinal tract. It is located just inferior to the stomach and takes up most of the space in the abdominal cavity. The entire small intestine is coiled like a hose and the inside surface is full of many ridges and folds. These folds are used to maximize the digestion of food and absorption of nutrients. By the time food leaves the small intestine, around 90% of all nutrients have been extracted from the food that entered it.

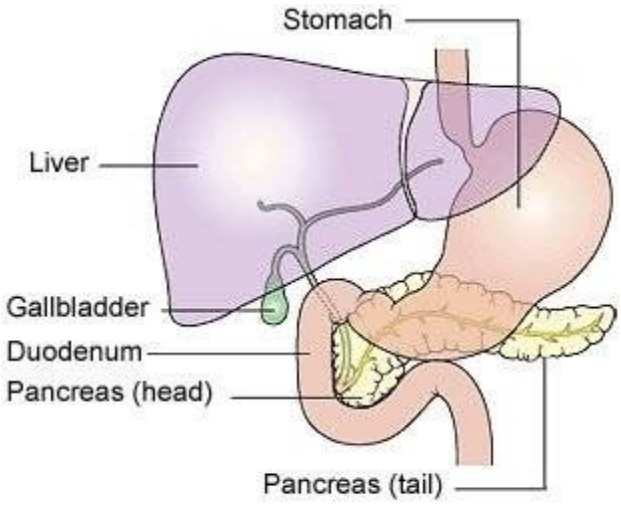
Large Intestine

The large intestine is a long, thick tube about 2.5 inches in diameter and about 5 feet long. It is located just inferior to the stomach and wraps around the superior and lateral border of the small intestine. The large intestine absorbs water and contains many symbiotic bacteria that aid in the breaking down of wastes to extract some small amounts of nutrients. Feces in the large intestine exit the body through the anal canal.



The three main accessory organs in digestion include the liver, gallbladder and pancreas.

- **Liver** The liver is a roughly triangular accessory organ of the digestive system located to the right of the stomach, just inferior to the diaphragm and superior to the small intestine. The liver weighs about 3 pounds and is the second largest organ in the body. The liver has many different functions in the body, but the main function of the liver in digestion is the production of bile and its secretion into the small intestine.



- **Gallbladder** The gallbladder is a small, pear-shaped organ located just posterior to the liver. The gallbladder is used to store and recycle excess bile from the small intestine so that it can be reused for the digestion of subsequent meals.

- **Pancreas** The pancreas is a large gland located just inferior and posterior to the stomach. It is about 6 inches long and shaped like short, lumpy snake with its "head" connected to the duodenum and its "tail" pointing to the left wall of the abdominal cavity. The pancreas secretes digestive enzymes into the small intestine to complete the chemical digestion of foods.

Digestive System Physiology

The digestive system is responsible for taking whole foods and turning them into energy and nutrients to allow the body to function, grow, and repair itself. **The six primary processes** of the digestive system include:

- Ingestion of food
- Secretion of fluids and digestive enzymes
- Mixing and movement of food and wastes through the body
- Digestion of food into smaller pieces
- Absorption of nutrients
- Excretion of wastes

Ingestion

The first function of the digestive system is ingestion, or the intake of food. The mouth is responsible for this function, as it is the orifice through which all food enters the body. The mouth and stomach are also responsible for the storage of food as it is waiting to be digested. This storage capacity allows the body to eat only a few times each day and to ingest more food than it can process at one time.

Secretion

In the course of a day, the digestive system secretes around 7 liters of fluids. These fluids include saliva, mucus, hydrochloric acid, enzymes, and bile. Saliva moistens dry food and contains salivary amylase, a digestive enzyme that begins the digestion of carbohydrates. Mucus serves as a protective barrier and lubricant inside of the GI tract. Hydrochloric acid helps to digest food chemically and protects the body by killing bacteria present in our food. Enzymes are like tiny biochemical machines that disassemble large macromolecules like proteins, carbohydrates, and lipids into their smaller components. Finally, bile is used to emulsify large masses of lipids into tiny globules for easy digestion.

Mixing and Movement

The digestive system uses 3 main processes to move and mix food:

- **Swallowing**. Swallowing is the process of using smooth and skeletal muscles in the mouth, tongue, and pharynx to push food out of the mouth, through the pharynx, and into the esophagus.
- **Peristalsis**. Peristalsis is a muscular wave that travels the length of the GI tract, moving partially digested food a short distance down the tract. It takes many waves of peristalsis for food to travel from the esophagus, through the stomach and intestines, and reach the end of the GI tract.
- **Segmentation**. Segmentation occurs only in the small intestine as short segments of intestine contract like hands squeezing a toothpaste tube. Segmentation helps to increase the absorption of nutrients by mixing food and increasing its contact with the walls of the intestine

Digestion

Digestion is the process of turning large pieces of food into its component chemicals. Mechanical digestion is the physical breakdown of large pieces of food into smaller pieces. This mode of digestion begins with the chewing of food by the teeth and is continued through the muscular mixing of food by the stomach and intestines. Bile produced by the liver is also used to mechanically break fats into smaller globules. While food is being mechanically digested it is also being chemically digested as larger and more complex molecules are being broken down into smaller molecules that are easier to absorb. Chemical digestion begins in the mouth with salivary amylase in saliva splitting complex carbohydrates into simple carbohydrates. The enzymes and acid in the stomach continue chemical digestion, but the bulk of chemical digestion takes place in the small intestine thanks to the action of the pancreas. The pancreas secretes an incredibly strong digestive cocktail known as pancreatic juice, which is capable of digesting lipids, carbohydrates, proteins and nucleic acids. By the time food has left the duodenum, it has been reduced to its chemical building blocks—fatty acids, amino acids, monosaccharides, and nucleotides.

Absorption

Once food has been reduced to its building blocks, it is ready for the body to absorb. Absorption begins in the stomach with simple molecules like water and alcohol being absorbed directly into the bloodstream. Most absorption takes place in the walls of the small intestine, which are densely folded to maximize the surface area in contact with digested food. Small blood and lymphatic vessels in the intestinal wall pick up the molecules and carry them to the rest of the body. The large intestine is also involved in the absorption of water and vitamins B and K before feces leave the body.

Excretion

The final function of the digestive system is the excretion of waste in a process known as defecation. Defecation removes indigestible substances from the body so that they do not accumulate inside the gut. The timing of defecation is controlled voluntarily by the conscious part of the brain, but must be accomplished on a regular basis to prevent a backup of indigestible materials.

Yoga and the Digestive System

Yoga helps our digestive system through three main ways: reducing stress, physical manipulation, and all the positive results that stem from mindful eating.

Reducing Stress

Chronic stress causes chronic problems in the digestive system. The reduced stress from our yoga practice helps our digestive system run smoothly.

Physical Manipulation

Food needs to pass through the digestive system quickly and efficiently. All of the twists, turns, backbends and forward folds we do in our asana practice help move the food forward through our intestines.

Slower Metabolism

Yoga can help the body become more efficient with less energy. A reduction in stress will also prevent the body from holding on to fat.

Mindful eating

The mindful movement we practice on our yoga mat directly translates to mindful eating at the dinner table. By slowing down and taking the time to taste and savor our food, we eat less and enjoy it more. By learning to take care of our body and what our body needs, we eat better and feel more nourished.

Mind-body Connection

The more in touch we are with our bodies, and checking in with how our body feels, we gain a deeper understanding of how the food we put into our bodies affects our overall well-being. We begin to eat less of the foods that make us feel tired and heavy, we eat more of the food that helps us feel spacious and free.

Of course, the greatest effect that yoga has on the digestive system is through **following a yogic diet**. This topic can be explored later on in the course or on one's own.