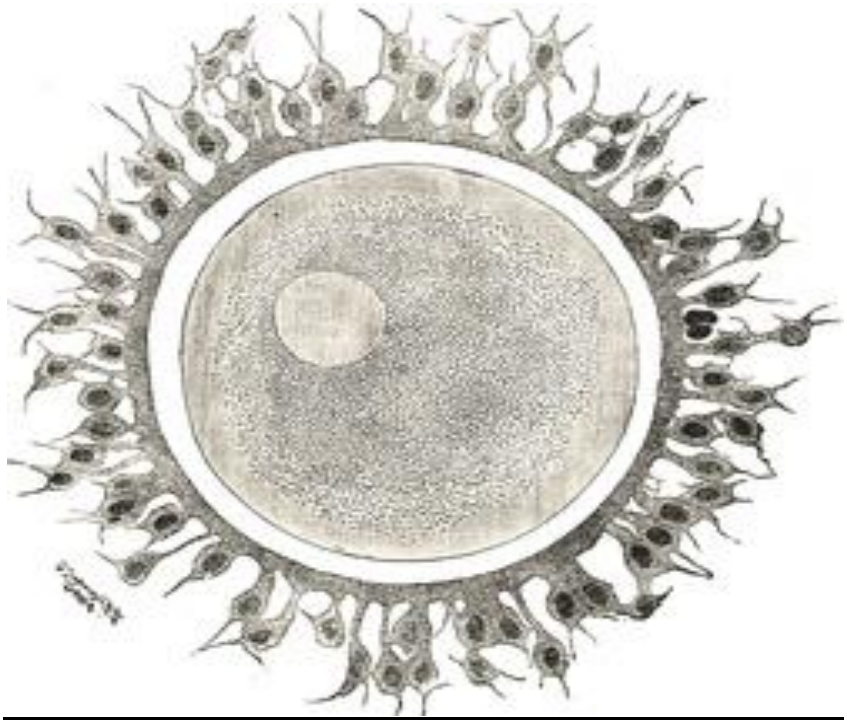
Anatomy and Physiology for Yoga



A beginner's manual

Foreword: this manual has been designed to be studied in conjunction with lectures, power point and pictoral information presented by Lisa Fitzpatrick

Anatomy and Physiology for Yoga

This information is an overview of a vast subject which can take many years to learn and integrate into your practice. The more we know about the body, the more tools we have to deepen our experience of yoga. Applying this subject to your own practice of yoga is most important. When this information makes sense to you in your practice, then you can share it with others with confidence and integrity.

What is Anatomy?

Anatomy is *structure*.

Anatomy is the science of understanding the different structures that make up the body. It is everything you can see and touch on the body. If the body were a computer system, anatomy is the hardware.

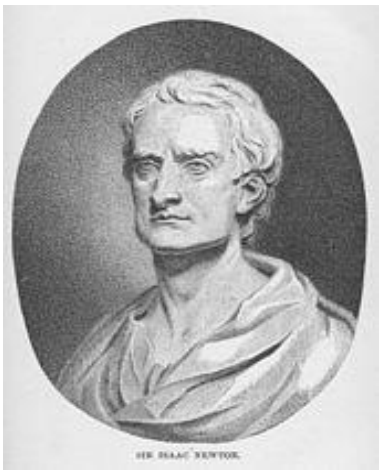
What is Physiology?

Physiology is *function.* Physiology comes from the Greek *physiologia* meaning 'knowledge'. Physiology is the science of understanding how the different structures of the body interact and function. Processes like breathing, balance and movement are physiological. If the body were a computer system, physiology is the software.

The Western Scientific Model

The Western Scientific Model of the body is a relatively modern science of understanding the body which breaks the body into its physical components. It is based on measurable and tangible evidence. This model is influenced by the theories of Isaac Newton (1642-1727) which laid the foundation for classical mechanics. The mechanistic view of the body allows for a dissection of the body without considering the whole. With the development of Quantum Physics, the understanding of the body is becoming more holistic in nature.

The content of these lectures is based on the Western Scientific model. However, the Yogic and Ayurvedic and Chinese Medicine Models of the body are more ancient systems of understanding which approach the body from holistic and energetic perspectives. Understanding the Western Scientific model enhances your ability to communicate with other health practitioners about the body and to understand specific medical conditions your students may have.



Isaac Newton

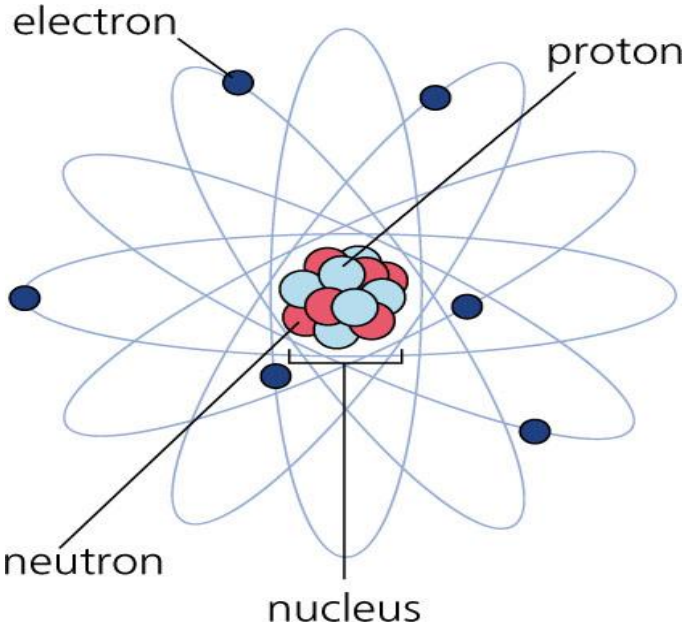
Why Learn Anatomy and Physiology for Yoga Teaching?

- to inspire us to become more precise and skilful, knowledge-able and safe yoga teachers
- to deepen our appreciation of injury and its causes
- to prevent injury and to enable correct adjustment and positioning during asana teaching and practice
- to increase our understanding of the health benefits of yoga
- to increase confidence, awareness and compassion towards our students
- to increase our understanding about movement, giving us the skills to teach safe transitions in and out of postures.
- to enhance our communication with others. Knowledge of anatomy and physiology can help you speak proficiently with other health practitioners using medical terms and to be familiar with medical conditions experienced by yoga students.
-to deepen our awareness about our own bodies and enhance our practice

The Cell

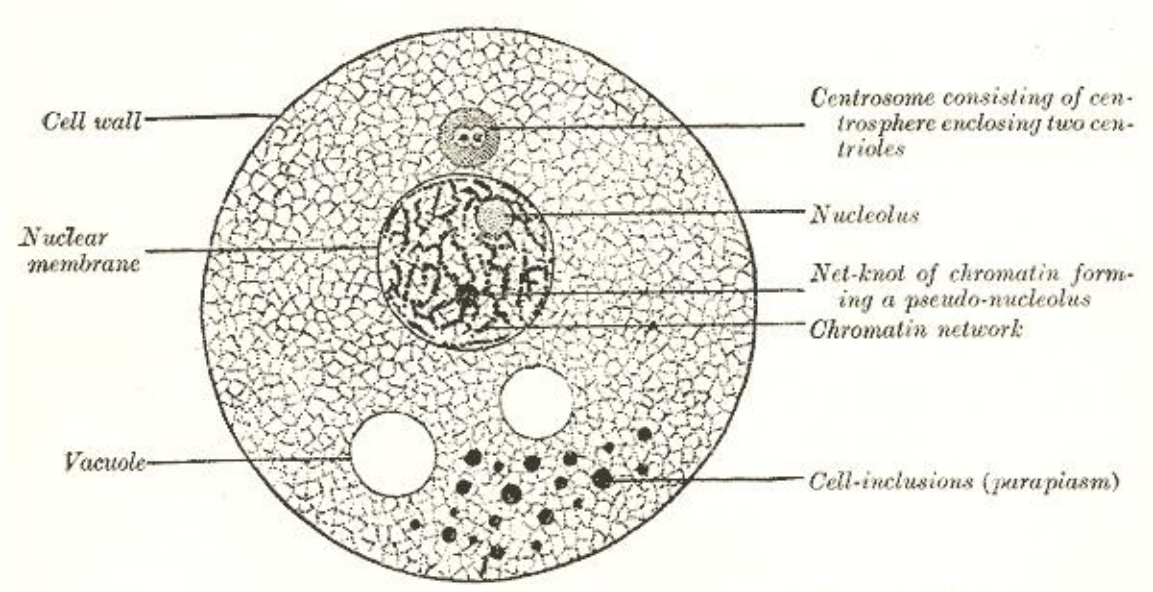
The basic building block of the body, on a microscopic level, is the cell. Cells are the basic structural and functional units of all living things. There are 50 trillion cells in the human body which work like a community to handle the body's functions. Each cell has its own complex arrangement of organic molecules and water within a semi-permeable membrane. However, like all matter, cells can be broken down into atoms which are a cluster of protons and neutrons with a swirl of electrons circulating and vibrating around them. All physical matter is comprised of this energetic configuration. Cells mainly contain Hydrogen (H), Carbon (C), Oxygen (O), Nitrogen (N), Phosphorous (P) and

Sulphur (S). Cells are generally 80% water (H_2O), 15% protein and 5% minerals and lipids (fats). The activities of a cell constitute all of the basic life processes of the greater organism. For example, a cell can ingest nutrients, excrete waste, break down materials, breathe, move and become excitable. Hence, the health of a single cell reflects the health of the larger organism and provides information about the larger organism it represents.



The **mitochondria** are small power plants located inside cells. These are responsible for harnessing energy by combining with oxygen and food molecules to make ATP *adenosine triphosphate* – our basic fuel source for all activities. Mitochondria are more densely clustered where action is required such as the muscles, brain and heart. We are able to increase the number of mitochondria when we practice yoga by strengthening our muscles.

The balance of molecules in a cell depend upon its location and function in the body. For example, a nerve cell has a very different appearance to a skin cell. However, we can influence the health of our cells through our diet, our movements and our mental processes. Living consciously through our yoga practice can help us to support healthy bodies on a cellular level. Bearing in mind how much water is required, adequate hydration levels are an essential part of good health.



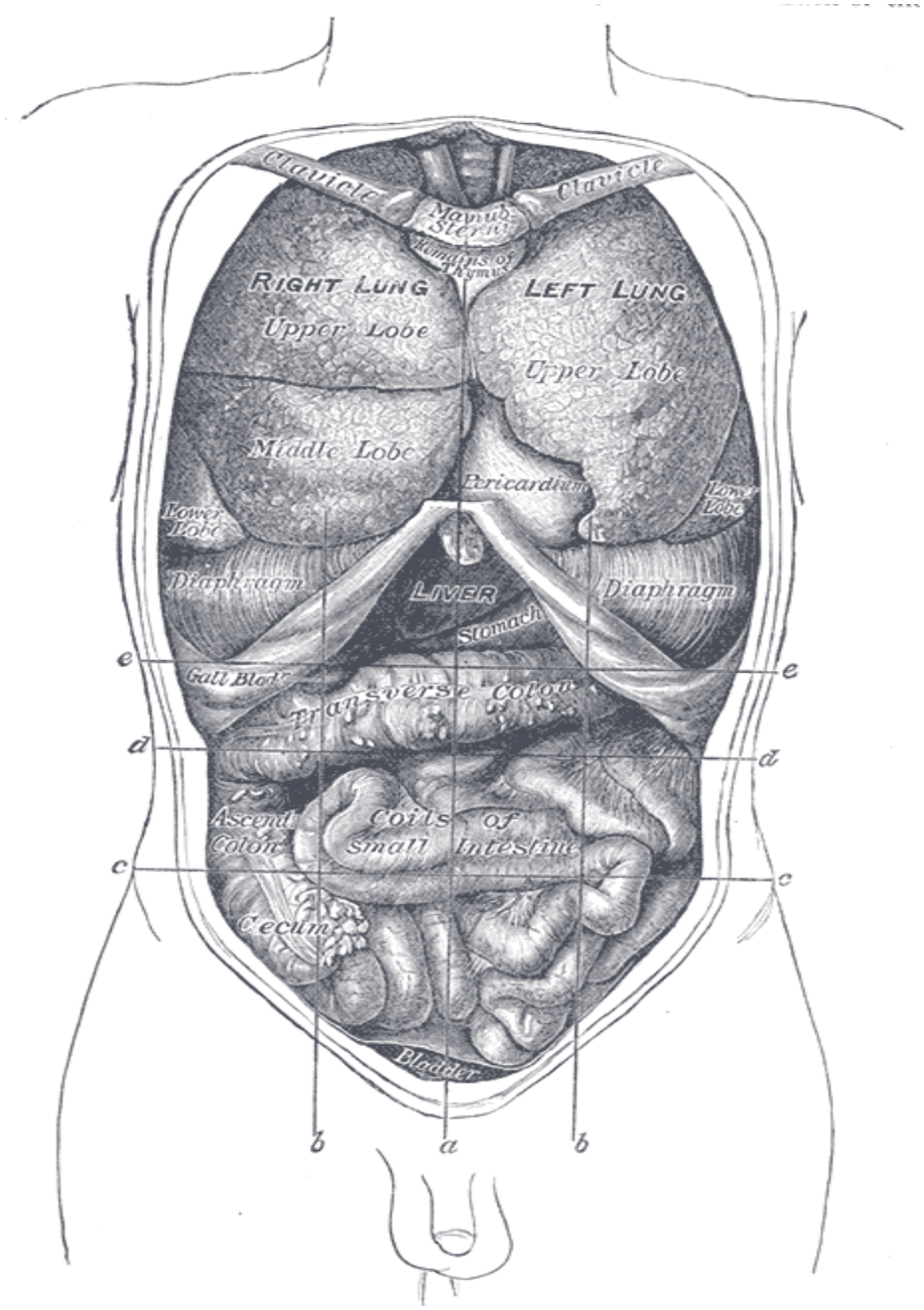
The Cell

The nucleus of the cell is contained inside a nuclear membrane in the centre of the cell. This contains all the genetic information relevant to the organism through the DNA. The nucleus was always thought to be the brain of the cell. However with the research of Bruce Lipton, it has been found to hold more of a reproductive function. Lipton's research outlined in his revolutionary book *The Biology of Belief* has confirmed that the effects of the environment (which includes thoughts and feelings) have a huge role to play in the health of the cell. This research is bridging the gap between our mechanical understanding of the body and the energetic nature of the body.

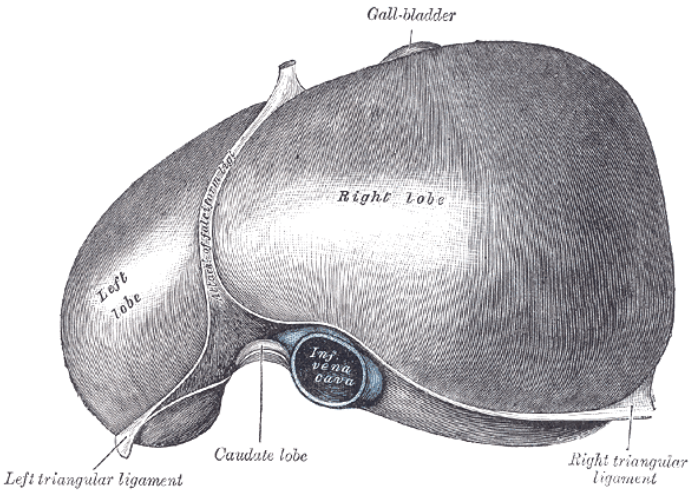
Tissues

Like-minded cells cluster together to form tissues. Functional groups of tissues work together to form organs. There are four major tissue types in the body-
(1) epithelial – skin and linings of organs and blood vessels (2) muscle – movement (3) nervous - communication (4) connective – connectivity (this includes bone, cartilage, ligaments, tendons, joint capsule, blood).

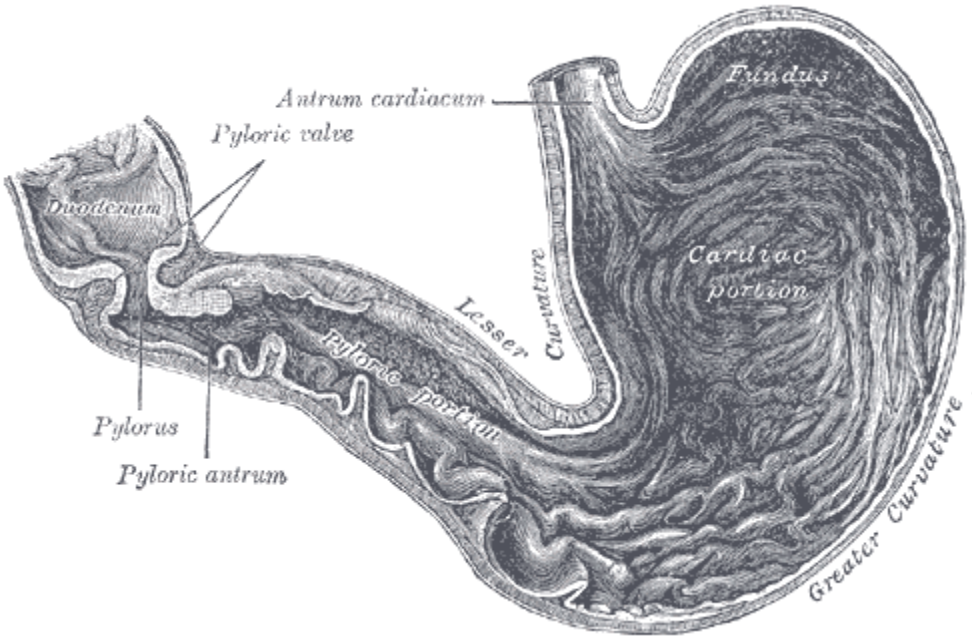
Major Organs and Functions Knowing the function and location of the organs allows an understanding of how asana affect the organs



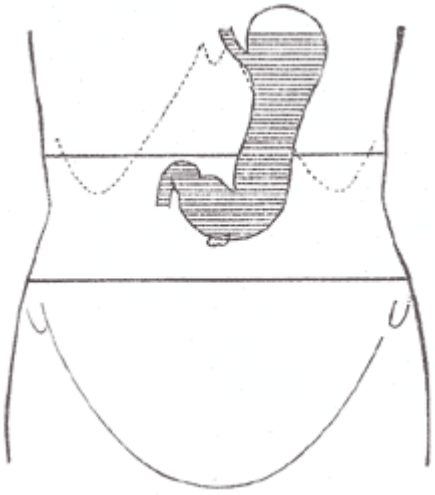
Liver - a large dome shaped organ located on the front, right side of the abdomen, under the rib cage. Important for detoxification, digestion of fats, proteins and carbohydrates, nutrient storage and breakdown of hormones.



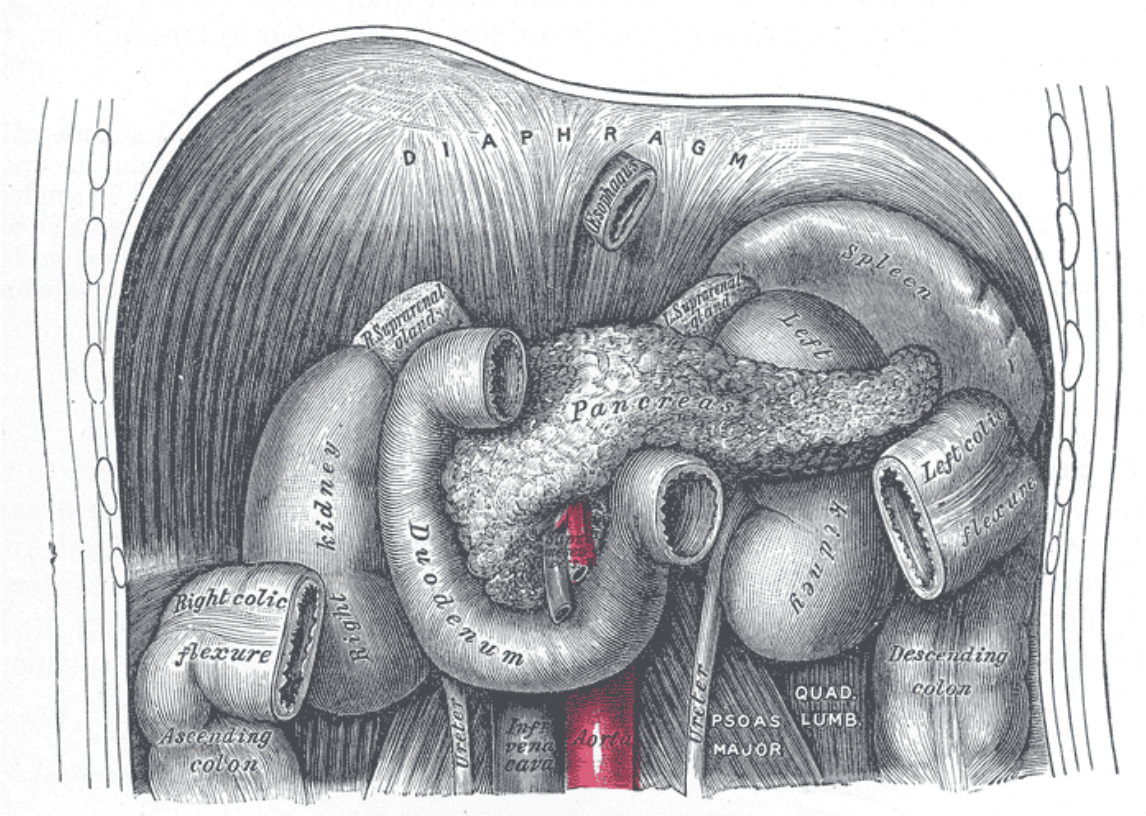
Stomach - under the rib cage on the left side of the abdomen. Responsible for chemical digestion of food and can fit an average of one litre of food or fluid inside.



A moderately full stomach – location in the body below

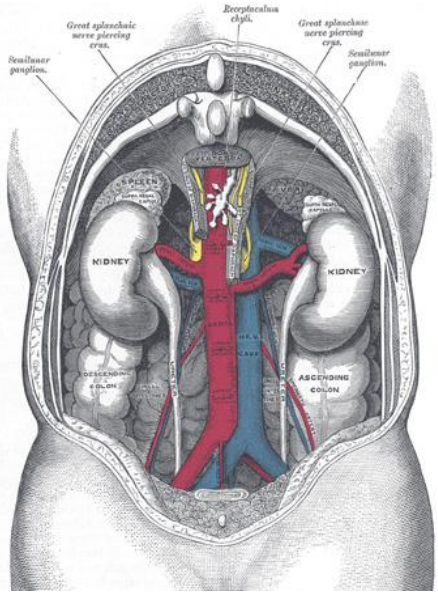


Pancreas – moulded around the stomach. Secretes digestive enzymes and blood sugar regulating hormones.

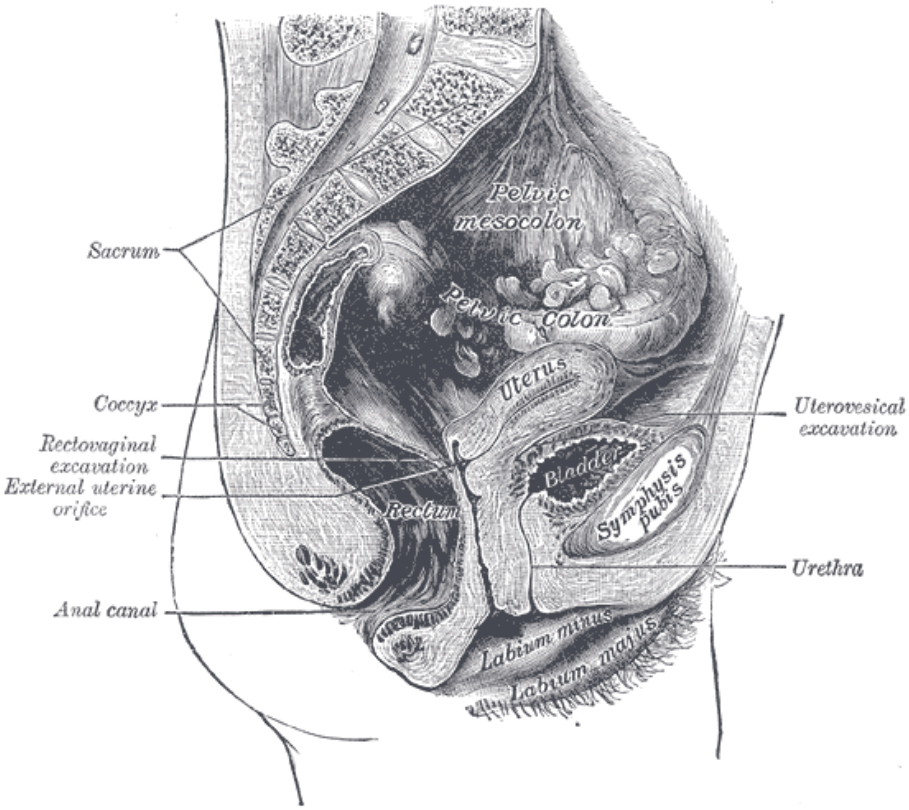


Gall Bladder – behind the liver. This collects the bile produced by the liver

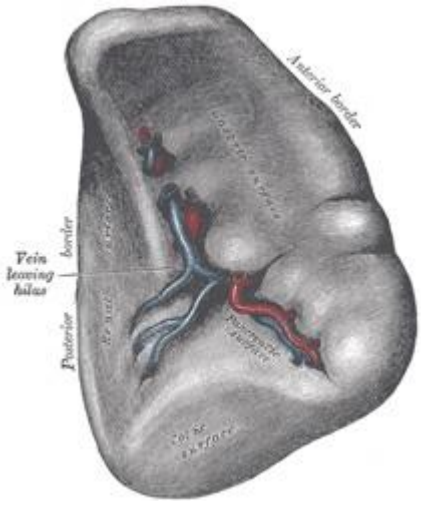
Kidneys – paired organs protected by the lower rib cage at the back. Filters fluids and sends the excess to the bladder



Bladder – located behind the pubic bone, the bladder collects and empties fluid from the body

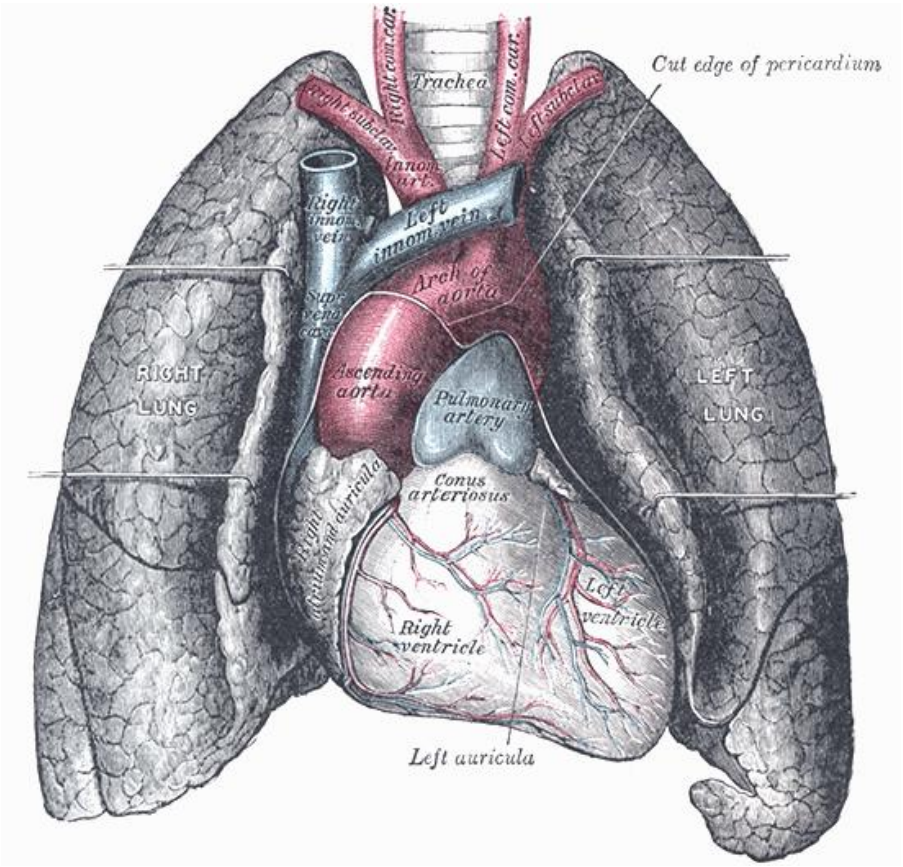


Spleen – under the ribs on the left side, this helps to destroy bacteria and recycle red blood cells

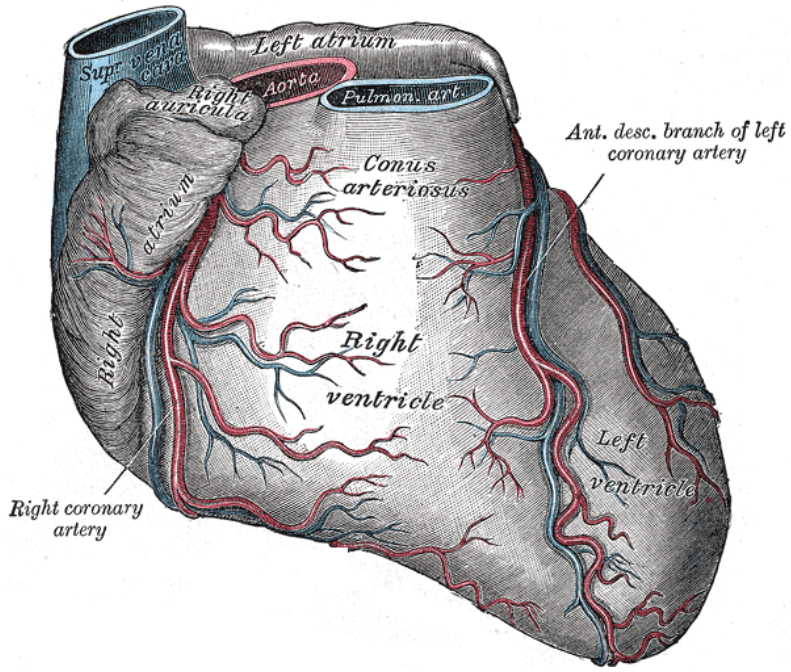


The visceral (organ) surface of the spleen

Lungs – paired organs inside the rib cage responsible for our intake of oxygen and prana (lifeforce)



Heart – a fist sized organ in the centre left chest essential for the circulation of blood through the body



Small Intestine – behind abdominal wall, this assists the digestion and absorption of food
Large Intestine – curled beneath the small intestine, this organ assists digestion, absorption and elimination of food

The Organs in Yoga

Asana involving twists are particularly beneficial to the major abdominal organs of the body. Twists such as Parivrtta Parsvakonasana and Jathara Parivartanasana help to squeeze the digestive organs, assisting them to flush out waste products and stimulating the digestive process. Release of the twist then allows nutrient-rich circulation through the organs. Asana may also help to open the rib cage to assist full expansion of the lungs. Stimulation of the parasympathetic nervous system with forward bends enhances the digestive process and supports the immune system.

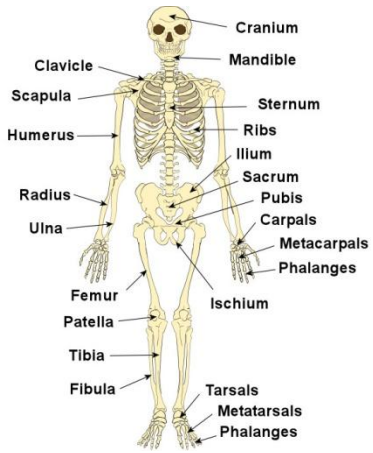
The Eleven Systems

Organs which work together to perform similar functions form the major systems of the body. In the Western Scientific Model, there are 11 systems in the body each with its own set of organs and functions.

1. Skeletal – the axial and appendicular skeleton.

Functions – support, protection, mineral storage, movement, blood cell production, energy storage.

Weightbearing asana help to strengthen bones.



2. Muscular – skeletal, cardiac and smooth muscle

Functions – movement

Asana lengthens and strengthens muscles.

3. Respiratory – nose, pharynx, larynx, bronchi, bronchioles, lungs

Functions – exchange of carbon dioxide and oxygen, regulation of acid/alkali balance in the body

Pranayama provides a tool for conscious breath awareness and enhanced respiratory function.

4. Nervous – brain, spinal cord, nerves, ganglia, special sense organs

Functions – homeostasis: maintains balance in the body by regulating and co-ordinating activities and detecting changes in the environment of the body.

Yoga utilizes the nervous system to enhance conscious awareness and learning

5. Cardiovascular – heart, blood vessels, blood

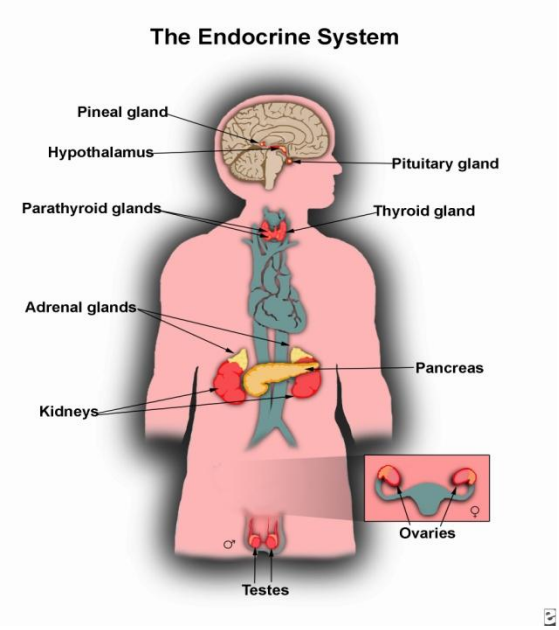
Functions – the transport of nutrients, gases and hormones to the body's tissues

Inversion postures take gravitational pressure off the heart

6. Endocrine (hormonal) – hypothalamus, pituitary gland, thyroid gland, parathyroid gland, adrenal gland, kidney, pancreas, testes, ovaries, thymus gland, pineal gland

Functions – regulation and co-ordination of many functions such as hormonal secretions, metabolism and bone density.

Asana provides various stimulating experiences for the endocrine system. The Chakra locations largely correlate with the locations of the major glands of the body. For example the heart chakra is in the same region as the thymus gland.



7. Digestive – mouth, salivary glands, pharynx, larynx, oesophagus, stomach, intestines (large and small), liver, gall bladder, pancreas

Functions – digestion and absorption of nutrients, water and salt

Asana involving trunk twisting such as Jathara Parivartansana stimulates the digestive system

8. Integumentary - skin and nails, hair and glands

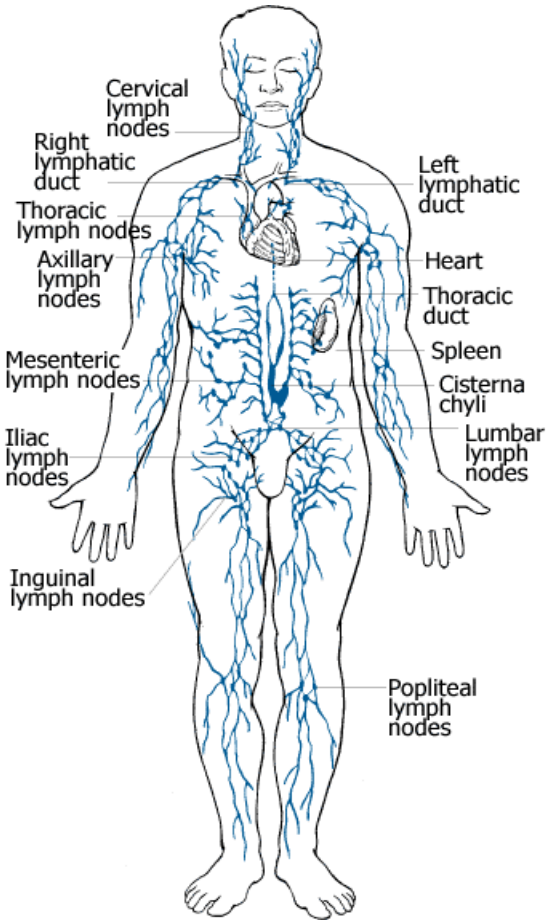
Functions: protection from foreign invaders, sensations (touch, pain, temperature), immunity, excretion, blood reservoir, vitamin D synthesis, thermal regulation

Asana enhances circulation to the skin by stimulating blood flow

9. Lymphatic – bone, lymph vessels and nodes, spleen, thymus, lymphoid tissue

Functions - foreign invader defence, return of cellular fluid to the bloodstream, formation and differentiation of white blood cells

Bandha activation, inversions and active muscular contractions during asana help to stimulate the flow of lymph by creating internal pressure gradients



The Lymphatic System

10. Urinary – kidneys, ureters, urethra, bladder,

Functions - regulation of plasma composition through controlled excretion of organic wastes, salts and water. Adequate fluid intake (2litres/day) ensures the well-being of this system for yoga practice.

11. Reproductive – male: testes, penis, ducts and glands

female: ovaries, uterine tubes, uterus, vagina, mammary glands

Functions – male: production of sperm, transfer of sperm to female

female: production of eggs, nutritive environment for embryo

Stimulation of the parasympathetic nervous system with meditation and forward bending (inward focused poses) may enhance fertility by encouraging blood flow to the abdomen.

The Nervous System

The primary role of the nervous system is to maintain balance, harmonizing all the systems. This balance is known as **homeostasis**. Greek – *homeos*= same *stasis*=standing still.

Patanjali's Yoga Sutras teach that yoga is about the nervous system -

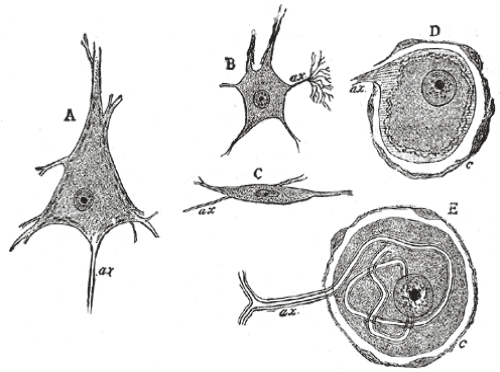
Yogas citta vrtti nirodah

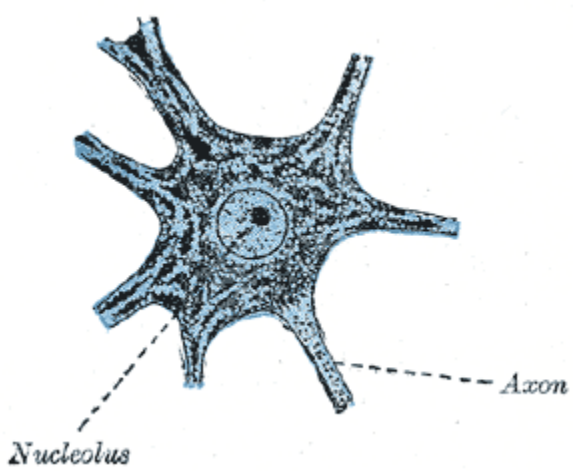
Translated, this means – yoga is experienced in that mind which has ceased to identify itself with its vacillating waves of perception.

The nervous system is divided into two parts

1. the central nervous system (CNS) – the brain and spinal cord
2. the peripheral nervous system (PNS) – any nerves outside the brain and spinal cord as well as the autonomic nervous system (ANS). The enteric nervous system (ENS) is a division of the ANS.

Neurons are the main cells of the nervous system, responsible for both receiving information from various structures of the body and sending impulses to affect the functions of the body.

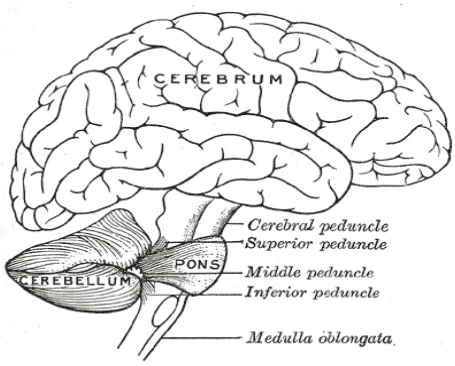




Neurons come in various shapes and sizes depending upon their location in the nervous system.

The Central Nervous System (CNS)

The brain is made up of billions of nerve cells (neurons) and support cells. Although the brain is only 2% of the body weight, it consumes 20-30% of the energy supply. Certain areas of the brain have specialized functions such as speech, hearing, memory, emotion and movement.



There are 2 sides of the brain which are able to work almost independently. Yoga helps balance the left and right sides of the brain.

i) the left hemisphere – affects the right side of the body and relates to the **Ha** or masculine side of nature -intellectual, reasoning, mathematics, spoken and written language, numerical ability, scientific skills and linear thought.

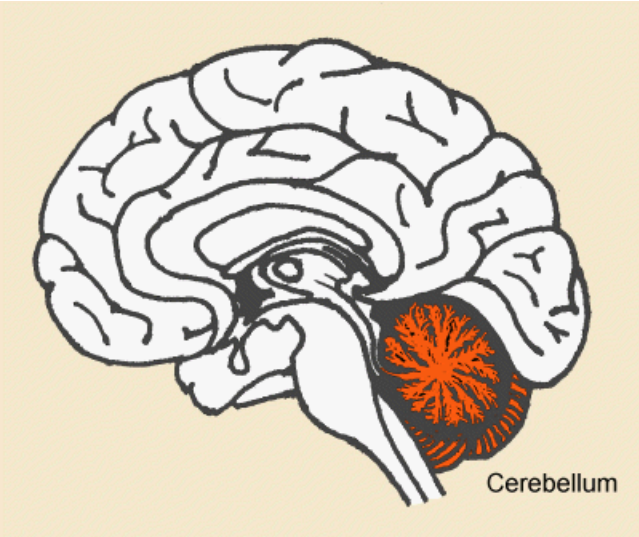
ii) the right hemisphere – affects the left side of the body, relates to the **Tha** or female side of nature - creativity, imagination, intuition, artistic awareness, space and pattern perception, insight and imagination.

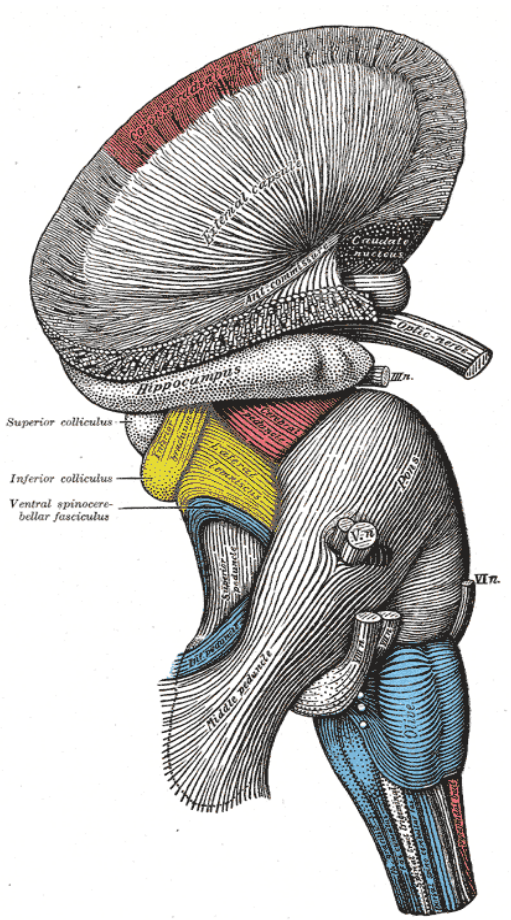
The hemispheres are connected by the corpus callosum which becomes well developed in yoga by asana which involve crossing the midline of the body (for example Jathara Parivartanasana and Parivritta Parsvakonasana) and balancing poses (such as Vrksasana).

Scientific research has shown that the nervous system can be influenced by experiences which shape and change the functions of various parts of the brain, a phenomenon known as neuroplasticity. The more varied our experiences, the greater these changes are.

The Cerebellum

This is a cauliflower shaped aspect of the brain, known as the 'lesser' brain which is responsible for balance, smooth integration of movement, posture and regulation of muscle tone. This is an essential structure for the deep, automatic responses to asana which allow us to keep our balance and our body awareness in space.





The Brainstem

The brainstem is the lowest part of the brain connecting the brain to the spinal cord. Regulates heart beat, blood pressure, breathing, swallow reflex, vomit reflex and coughing reflex.

The Spinal Cord

The spinal cord is a thin extension of the brain, living inside the vertebral canal (spine). It is 45cm in length on average and carries sensory and motor information to and from the body to the brain.

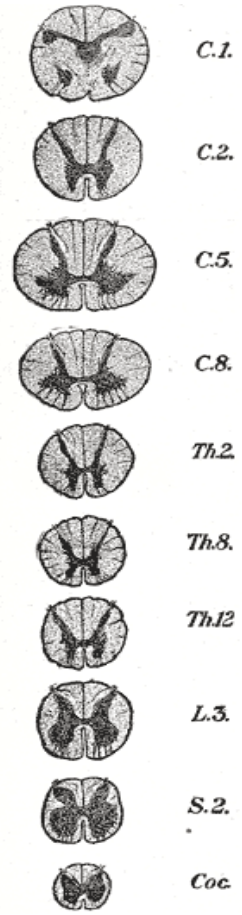


Diagram showing a cross-section the medulla spinalis (spinal cord) at different levels of the spine

Asana such as Halasana and Salamba Sarvangasana gently stretch the spinal cord.

The Meninges

The brain and spinal cord are encased in 3 layers of protective tissue known as meninges. The meninges cushion the CNS within the bony casing of the skull and vertebral column.

The Cerebrospinal Fluid

The CNS is suspended within the meninges and further cushioned by cerebrospinal fluid (CSF). The CSF provides nutrients, cushioning and shock absorption and helps remove metabolic waste from the CNS. Marjariasana, twists and spinal movement during asana help to pump the CSF throughout the CNS.

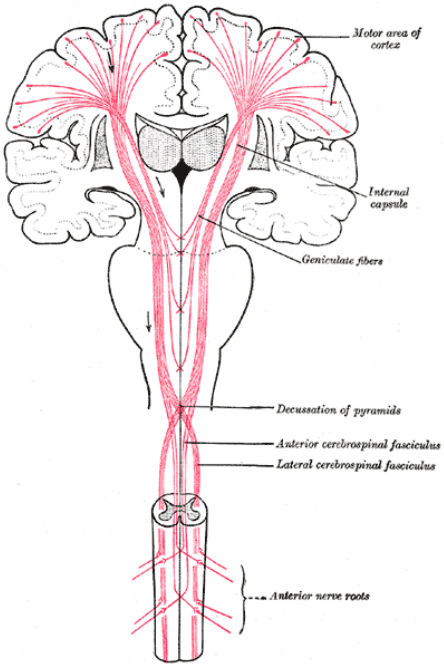
The Peripheral Nervous System (PNS)

The PNS consists of all the nerves outside the CNS. It exits the spine between the arches of the vertebrae and consists of 31 pairs of nerves. Nerves have many different functions both motor and sensory, leading to skin, muscles, organs and other tissues.

Nerves generate electrical impulses therefore they are wrapped in a myelin sheath and insulated with fat cells.

Nerves form bundles known as plexuses – located at the cervical, brachial, lumbar and sacral levels of the spine.

Nerve impulses send information from the nerve in the PNS to the spinal cord and brain during asana to give feedback about the body's position in space, level of flexibility, alignment and balance.



Connections from brain to spinal cord

The Autonomic Nervous System (ANS)

A branch of the PNS is the Autonomic Nervous System (ANS). The ANS is divided into the sympathetic nervous system (SNS) and the parasympathetic nervous system (PSNS).

All subconscious activities within the body are directed by the Autonomic Nervous System such as organ control, heart rate and blood pressure.

The SNS relates to emergency and stressful situations – the 'fight or flight' response. When activated, the SNS increases heart rate, blood pressure and respiratory rate. It increases the blood flow to muscles to activate them which results in less blood flow to the digestive organs.

The PSNS relates to a relaxation response which results in decreased heart rate, blood pressure and respiratory rate. Blood flow to the digestive organs increases, immunity and fertility are enhanced. The 'rest and digest' response.

Ideally, we should spend a majority of our time in the PSNS but unfortunately due to stress, many people spend more time in the SNS. Yoga techniques such as meditation, savasana, certain types of pranayama and gentle asana (especially restorative asana and forward bends) greatly enhance the PSNS response.

The Relaxation Response

Discovered by Herbert Benson (professor at Harvard and founder of the Mind/Body Institute) – occurs when the PSNS predominates. Two factors elicit the Relaxation Response- 1. The mind focuses on something repetitive (yantra, mantra, knitting, walking, asana 2. a conscious attempt is made to let go of all other thoughts – only need the intention not necessarily the full state of letting go in order to experience the physiological change.

The Enteric Nervous System (ENS)

Also known as the 'second brain' the ENS is comprised of aspects of the ANS and lives inside the abdomen where large numbers of nerve cells co-ordinate digestive functions and give us intuitive or 'gut' feelings.

Dristhi

The optic nerve is the largest nerve entering the brain aside from the spinal cord. A restful and meditative yoga practice can be obtained when the eyes are kept as still as possible throughout the yoga practice.

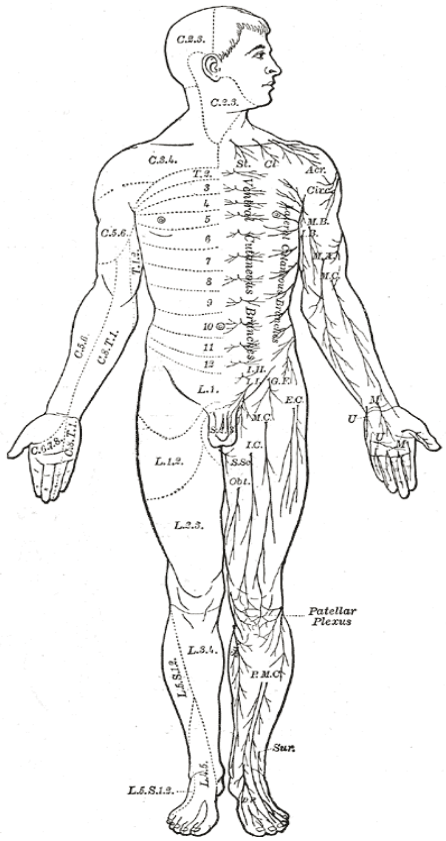
Utilising the Nervous System during Asana

Reflexes – a response to a change (stimulus) in the internal or external environment and an attempt by the nervous system to quickly restore homeostasis (to protect the body).

Myotatic Stretch Reflex- A slight change in muscle length will activate receptors in a muscle belly known as muscle spindles. This reflex needs to be minimized by moving slowly into asana and allowing time for the nervous system and muscular system to adjust to changes in the muscles otherwise it has the potential to shorten muscles and limit stretch.

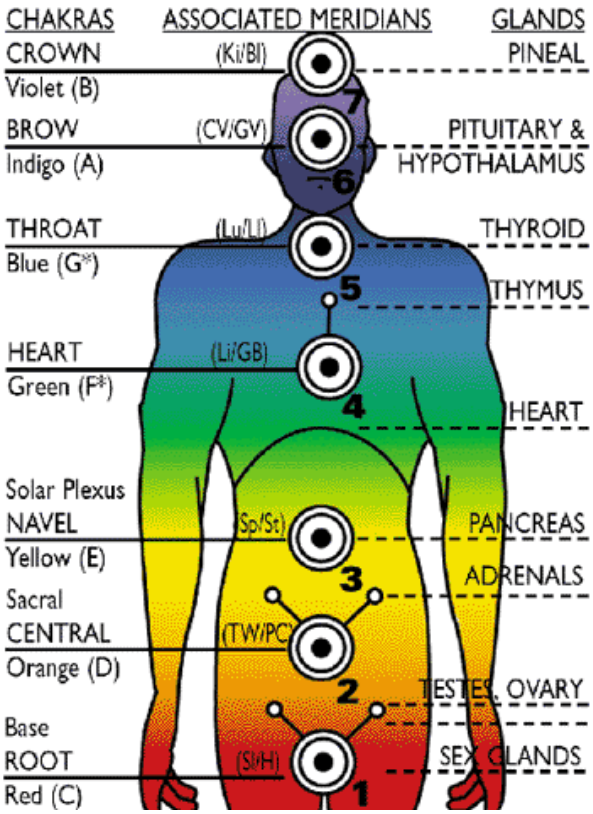
Reciprocal Inhibition Reflex – When we contract a muscle (agonist) its opposing muscle (antagonist) will relax.

Inverse Myotatic Stretch Reflex – Golgi Tendon Organs lie in the junction between tendons and muscle belly, and these enable relaxation of a muscle to protect it from damage due to excess tension. Each asana needs to be held for a period of time in order for the lengthening and relaxation of the muscle to occur. Muscles to be stretched may also be actively contracted prior to being stretched to enhance their relaxation and utilize this reflex further (a technique known as **PNF** or proprioceptive neuromuscular facilitation).



The Endocrine System

All functions of the body are co-ordinated and balanced by the nervous system and the endocrine system. The endocrine system secretes chemical substances (hormones) and delivers them to affect cells via the circulatory system. Hormones influence cell function slowly to assist in maintaining balance in the body. The functions of hormones are diverse such as regulating metabolism, immunity and reproduction. Hormones are co-ordinated by the hypothalamus, an area in the midbrain. Endocrine glands include the pituitary, pineal and parathyroid glands. The yogis believed in an energetic system of the body known as the chakras. The endocrine glands correlate with many of the major chakra locations in the body.



Movement Terms

There are 3 planes of the body. To understand movement, we always start with the body in the Western Anatomical Position which is similar to Tadasana with the palms facing the thighs. Knowing the scientific terms for movement helps enormously to learn muscle actions.

1. Frontal Plane: Front (anterior) and back (posterior) of the body are divided.

abduction is movement laterally- away from the midline.

adduction is movement towards the midline of the body.

Medial- a point relatively close to the midline. i.e. The collarbone is medial to the shoulder

Lateral- a point relatively far away from the midline i.e. The shoulder is lateral to the collarbone

2. Sagittal Plane

Left and right sides of the body are divided by the sagittal plane

Flexion- decreases the angle across a joint.

Extension- increases the angle across a joint

3. Transverse or Horizontal Plane

Superior- 'upper direction/headwards ie the head is superior to the chest

Inferior- 'lower than' i.e. the feet are inferior to the hips

Rotation- twisting around vertical axis, movement in the transverse plane.

Proximal- on a limb a point closer to the body i.e the shoulder is proximal to the wrist

Distal- on a limb a point relatively further away from the body i.e. The ankle is distal to the hip

Lateral- external rotation- a movement which rotates a body part outwards/laterally

Medial- Internal rotation- a movement which rotates a body part inwards towards the midline/medially.

Pronation- turn the forearm and palm to a posterior positioning

supination- turn the forearm and palm to an anterior positioning

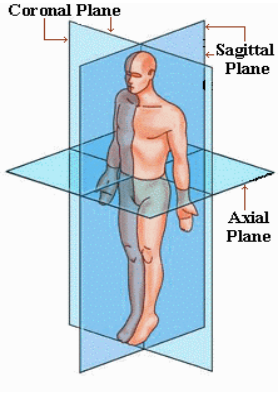
elevation- to lift the shoulder girdle

depression- to lower the shoulder girdle

protraction- to move forward

retraction- to move back

ankles – plantar flexion – to point the toes away



dorsiflexion- to draw the toes towards the shin

inversion- to turn the soles of the feet inwards

eversion- to turn the soles of the feet away from each other.

The Skeletal System

The human skeletal system consists of

1. The axial skeleton (80 bones) – includes the skull, spine, ribs and sternum
2. The appendicular skeleton (126 bones) – includes the upper and lower limbs, hands and feet bones, hip and shoulder girdles.

Purpose of Bone

Bones serve to support and protect the body. They are essential for movement, providing attachment points for the muscles. Bones also provide a place for mineral storage, energy storage and blood cell production which occurs in the bone marrow.

The Nature of Bone

Bone is a living tissue, constantly being built, torn down and rebuilt. Bones contain blood vessels, nerves and live cells. There are two types of bone tissue- **compact bone**, which forms a dense outer layer and **spongy bone**, which creates a honey-comb inner structure for stability without weight. Bone is 50-75% mineral such as calcium (most common), magnesium, phosphorous and silica and also contains water. Periosteum is the dense membrane surrounding bone which supports bone growth. Certain bones also contain bone marrow, a site of blood cell production and rich in fat. Cartilage is a white, shiny substance found on the ends of bone to reduce friction between joining bones.

Wolff's Law

Bone elements will place or displace themselves in the direction of stress and will increase or decrease their mass to reflect the amount of stress placed upon them. Thus, yoga has the potential to alter bone mass and shape depending upon the alignment of force placed upon the bones during asana. We can literally re-shape our bones with asana but need to be careful to practice good alignment in order for the alterations to be safe and symmetrical.

Joints

Bones join to other bones to form joints. Not all joints move, such as the joints between skull plates. However, freely moving joints are known as **synovial joints.** All synovial joints have the following in common:

A joint space, cartilage, synovial membrane, synovial fluid, fibrous joint capsule and supporting ligaments.

Joint Types

There are many different types of joints which create different types of movement. Major joints are the ball and socket (i.e. the hip and shoulder) – these allow for a large range of movements to occur at the joint, hinge (i.e. the elbow), gliding (i.e. finger joints) and ellipsoid (i.e. the wrist).

Fascia

Immediately deep to the skin is a layer of connective tissue known as fascia. It also separates muscles into compartments and contains a network of veins and lymphatics. It

is interconnected throughout the body and contributes to the flexibility of the body providing a matrix for allowing intercellular communication.

Joint Range of Motion (ROM)

Range of motion at the joints is dependent upon individual flexibility and genetics. Restrictions in range may be from **compression** which is where bone limits bone at a joint and **tensile** which is where soft tissue structures limit range (these may include ligaments, joint capsule, tendon/muscle length, nervous tension, fascial restriction). The structure of joints varies enormously amongst individuals (i.e. the hip socket or *acetabulum* is shallow in some people and very deep in others hence limiting the hip flexibility).

The Spine

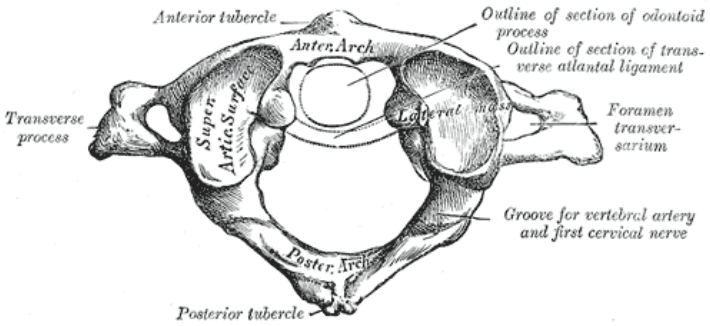
The spine is divided into 4 divisions which include the cervical spine (7 vertebrae), thoracic spine (12 vertebrae), lumbar spine (5 vertebrae) and sacrum = *sacred* (1 bone consisting of 5 fused vertebrae). The coccyx forms the tip of the sacrum or tailbone (4 fused bones) and is shaped like a cuckoo's beak.

Curves

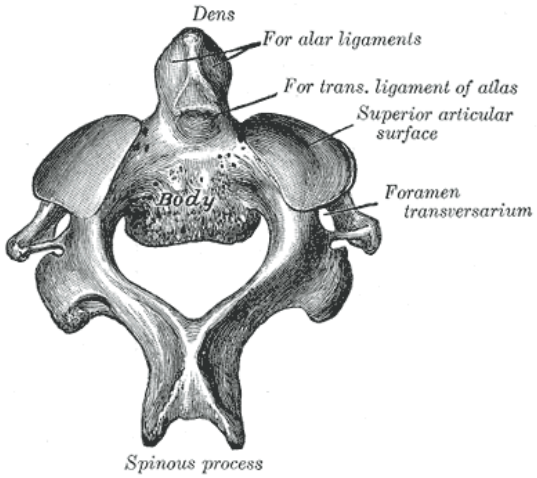
The primary curves of the spine form at birth to create a rounding out to the back (the spinal position seen in child pose). This is known as kyphosis. As a baby develops and learns to lift the head, this creates the inward facing cervical curve. Later, the sitting posture develops which introduces the inward facing lumbar curve. The cervical and lumbar curves are known as secondary curves or **lordosis.**

Spinal Vertebrae

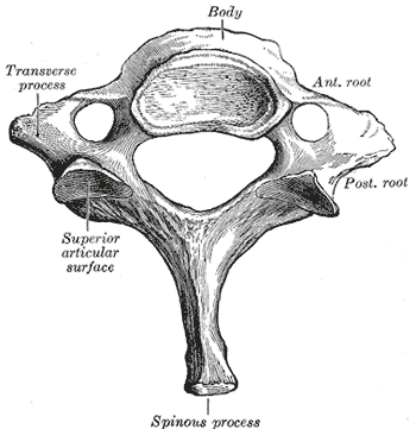
Every vertebrae has a vertebral body which supports the body weight along the vertebral column. Every vertebrae protects the spinal cord inside the spinal canal. The canal is formed at the front by the vertebral bodies and at the back by the vertebral arches. Vertebrae are stabilized in place by a series of ligaments connecting each level of the spine. There are differences in the shape of vertebrae depending upon their location. For example, cervical vertebrae have smaller bodies and more horizontal joints allowing greater freedom of movement where-as lumbar vertebrae have large vertebral bodies for greater weight-bearing support and allow less movement.



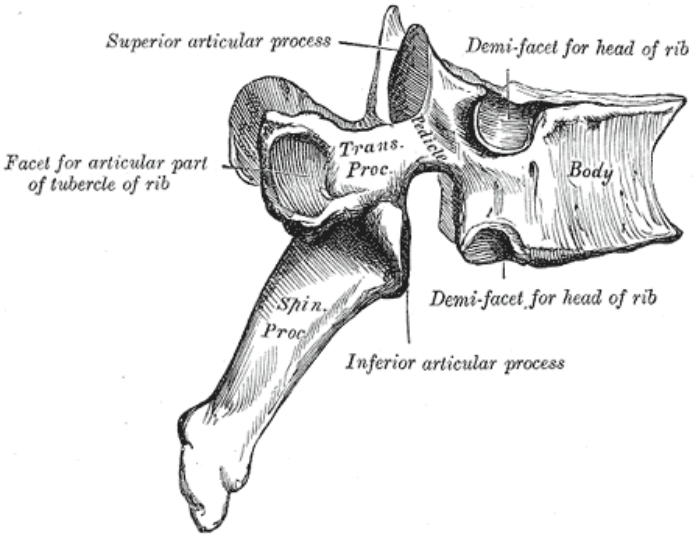
The first cervical vertebra – or atlas



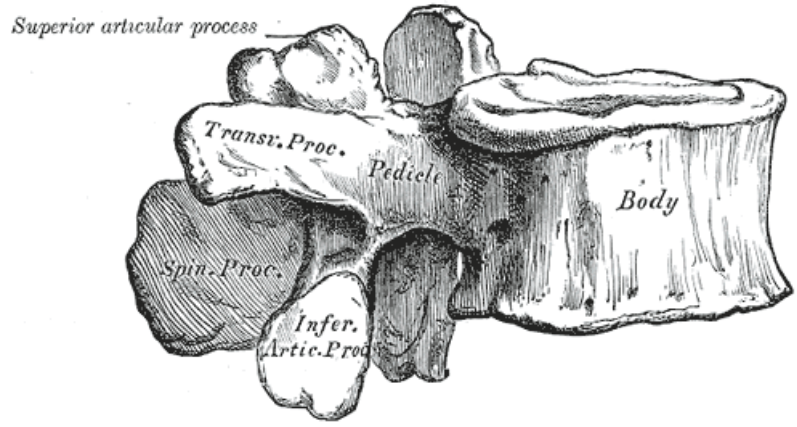
The second cervical vertebra – or axis



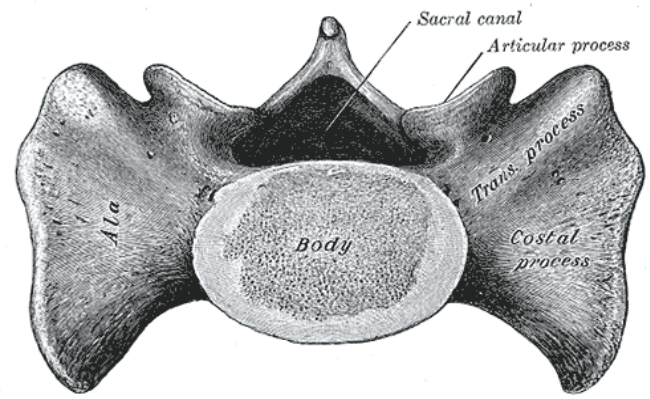
The seventh cervical vertebra



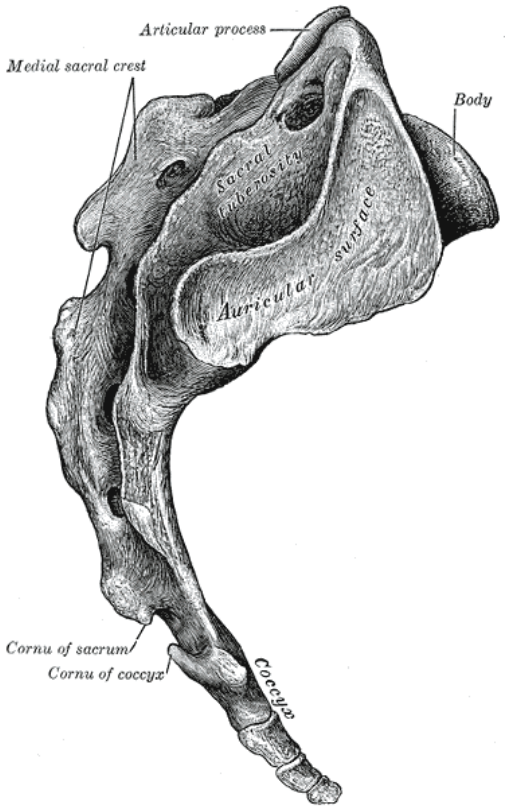
A thoracic vertebra – note the specialized areas for articulation of the ribs



A lumbar vertebra – note the thick heavy vertebral body



The base of the sacrum (seen from superior perspective)



Lateral view of the sacrum

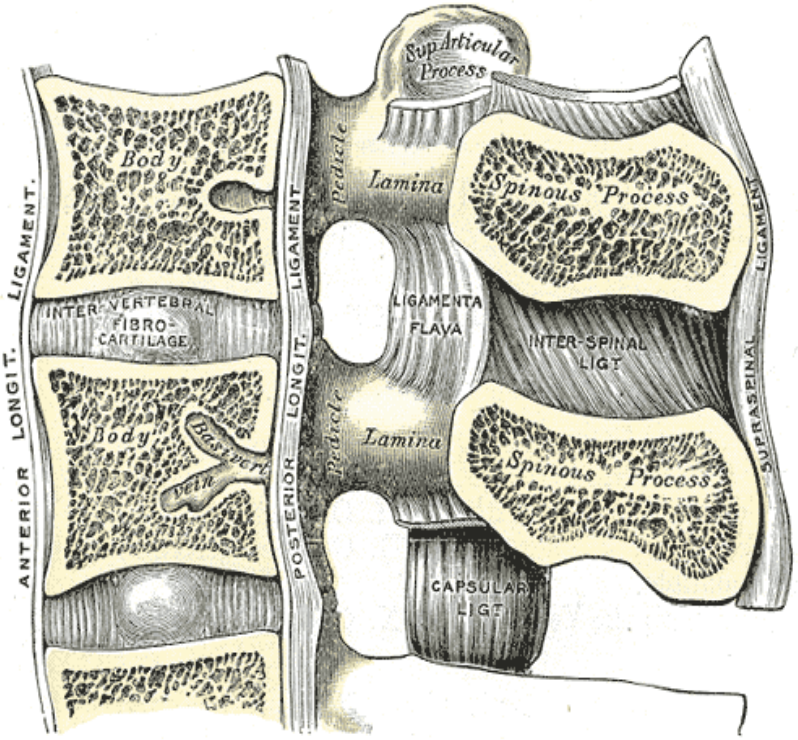
Intervertebral Discs

Each vertebra is separated from the next by an intervertebral disc which is a cushion-like cartilaginous structure. This disc has tough outer fibres (*annulus fibrosis)* and a squishy soft centre (*nucleus pulposis*). This structure allows for shock absorption and reduces friction between the bones of the spine.

Injuries involving the intervertebral disc can occur with excessive forward flexion such as Paschimottanasana and Uttanasana if the spine isn't maintained in good alignment or if a teacher adjusts a student too forcefully into a forward bend.

Intervertebral discs are prone to damage with heavy lifting and twisting which causes shear forces to create micro tears in the cartilaginous *annulus fibrosis.*

Years of poor posture, misuse and mal-alignment of the spine creates areas of weakness which may be highlighted when a student begins a yoga practice. Great care towards alignment is essential for preservation of the integrity of the spine.



All levels of the spine are protected by ligamentous reinforcements. A section of the Lumbar spine (above) protected by large, tough ligaments

The Muscular System

Please see the accompanying manual *'50+ Essential Muscles of Iyengar Yoga'* **by Lisa Fitzpatrick**

Functions

(i) provide movement

(ii) to support and stabilize joints and organs hence regulating organ volume

(iii) thermogenesis – approx. 85% of the heat generated in the body comes from muscle activity

(iv) generation of pressure gradients – when a muscles contracts it creates a high pressure area and assists with circulation of energy (blood, fluid and nutrients).

Types

(i) skeletal muscle – moves the skeleton and works against gravity with voluntary control. During asana this is the type of muscle used.

(ii) smooth muscle – regulates involuntary activity such as BP and digestion. Some yogis may gain voluntary control over this type of muscle after years of practice.

(iii) cardiac muscle – specialized muscle to cope with the continual pumping action of the heart

The Physiology of Muscle

Muscles have the characteristics of excitability, contractility, extensibility and elasticity which are all controlled by the Nervous System. Muscle tension is generated by an electrochemical signal which travels along a nerve and connects to a muscle via the neuromuscular junction point.

Muscles only pull they do not push. Every muscle has at least one opposing muscle. For example, the hamstrings are opposed by the quadriceps. Opposing muscles reduce tension. For example, a contraction of the quadriceps will reduce tension in the hamstrings facilitating greater length in the hamstrings. During Paschimottanasana – activation of the quadriceps enables a greater relaxation through the hamstrings and deepens the movement.

Tendons

Tendons are made of strong fibrous cords of connective tissue which extend out from the ends of muscle to attach muscle to bone.

Ligaments

Ligaments are inflexible bands of connective tissue which attach bone to bone around joints. They are joint structures not connected to muscle and do not have any contractile or movement ability.

Muscles

Major muscles of the body, their location and function in asana, may be enjoyed visually by reading *The Key Muscles of Hatha Yoga* by Ray Long. There are approximately 700 muscles in the body. Some of the major muscle groups relevant to yoga asana are listed below. Please note this is a very brief summary. In order to learn the muscles it is helpful to take a sensory approach as follows-

(1) hear the muscle name, action and location (origin and insertion)
(2) locate (see) the muscle on a picture or person
(3) palpate the muscle on a person/self
(4) functionally orientate the muscle into active asana. Experience the muscle actively contract as well as lengthen.

Muscles of the Lower Body

Ilio-Psoas – at the front of the hip. Consists of 2 muscles – Iliacus and Psoas. Flexes the hip. i.e. the lifted leg in Utthita Padangusthasana

Gluteus Maximus – at the back of the hip, forming the buttock. Extends the hip. i.e. Dhanurasana

Gluteus Medius and Minimus – deep in the hip underneath gluteus maximus. Abducts and internally rotates the hip i.e. upper leg in Ardha Chandrasana.

Tensor Fascia Lata – the most superficial muscles on the outer thigh. Flexes, internally rotates and abducts the hip. i.e. stabilizes the upper leg in Ardha Chandrasana

The Adductors – form the fleshy bulk of the inner thigh consisting of 5 muscles (Adductor Longus, Adductor Brevis, Adductor Magnus, Gracilis and Pectineus). Adducts the hip. i.e. the hips in Gomukhasana

External Rotators – deep in the back of the pelvis underlying the gluteals. This group consists of Obturator Internus and Externus, Piriformis, Quadratus Femoris, Gemelli Superior and Inferior. These externally rotate the hip. i.e. the hip position in Baddha Konasana

Sartorius – long straplike muscle originating from the ASIS (front pelvic bony prominence – anterior superior iliac spine) attaching to the inside of the knee. Flexes, abducts and externally rotates the hip hence the 'taylor muscle'.

Muscles of the Knee

Quadriceps Femoris – large muscle on the front of the thigh. A group of 4 muscles consisting of Rectus Femoris, Vastus Medialis, Vastus Lateralis and Vastus Intermedius. Extends the knee such as Trikonasana (front leg). Rectus Femoris assists Iliopsoas to flex the hip. i.e. Navasana

Hamstrings – forms the bulk behind the thigh. Consists of 3 muscles- Biceps Femoris, Semi Membranosus and Semi Tendonosis. Flexes the knee i.e. the flexed knee in Marichyasana III. Assists Gluteus Maximus to extend the hip i.e. Salabhasana

Muscles of the Ankle

Anterior Tibials – at the front of the shin. Dorsiflexes the ankle. i.e. the raised ankle in Utthita Hasta Padangusthasana

Gastrocnemius & Soleus – form the calf muscle. Plantarflexes the ankle. i.e. the starting position of the ankles in Bakasana

Muscles of the Trunk

Erector Spinae – runs up and down all levels of the spine at the back. Extends the spine. i.e. the spine in Urdhvadhanurasana

Quadratus Lumborum – lies deep to erector spinae over the lumbar spine. Extends the lumbar spine i.e. Urdhvadhanurasana

Latissimus Dorsi – forms the bulk of muscle at the back. Draws the chest forward and open, stabilizing the trunk in Ardho Mukha Svanasana. Also draws the arm down and towards the body

The Abdominals – there are 4 muscles which make up the abdominals and they all work together to protect the lumbar spine by creating a band of support at the front lower torso. They also have specific functions-

i. Transversus Abdominus – deepest layer forming the front of the abdomen. Draws the whole belly inwards, compressing the abdomen. i..e Navasana

ii. Internal Oblique – located on each side of the centerline of the abdomen. Has diagonal fibres. Draws the opposite shoulder forward and bends trunk to the side. i.e. assists twist of trunk in Parvrtta Trikonasana

iii. External Oblique – superficial to the internal oblique. Draws the same side shoulder forward. i.e. assists the twist of the trunk in Parvrtta Parsvakonasana

iv. Rectus Abdominus – a long flat muscle on the front, centre of the abdomen. Flexes the trunk forward. i.e Utthanasana

Sternocleidomastoid (SCM) – located on both sides of the front of the neck. Flexes the neck forward and draws the chin down. One side activated will turn the face to the opposite side. i.e. in Utthita Trikonasana the lower SCM is active when turning the face to look up.

Muscles of the Upper Body

Trapezius – runs between the scapula and the spine from the occiput of the skull to the lowest thoracic vertebrae (T12). Retracts the shoulder blades. Upper fibres elevate the shoulder i.e. Urdhvadhanurasana. Middle fibres retract the shoulders i.e. Bhujangasana. Lower fibres depress the shoulder. i.e. Bakasana.

Rhomboids (major and minor) – run deep to trapezius muscles. Retract the shoulder blades. i.e. Bhujangasana

Serratus Anterior – forms finger-like projections on the front of the ribcage. Protracts the shoulders to oppose the trapezius and rhomboid groups. i.e. engaged in Plank and Chaturanga

Rotator Cuff - a group of muscles consisting of Supraspinatus, Infraspinatus, Subscapularis and Teres Minor which run from the scapula to the top of the humerus (upper arm). Stabilises the shoulder girdle and rotates the upper arm. i.e. stabilizes the weightbearing shoulder in Vasisthana

Deltoids (anterior, lateral, posterior) – forms the bulk of the outer shoulder. The anterior (front) portion flexes the shoulder i.e. arm lift in Utkatasana and Virabhadrasana I. The lateral portion abducts the shoulders i.e. Virabhadrasana II. The posterior portion extends the shoulders i.e. shoulders in Salabhasana

Pectoralis Major and Minor – form the front of the chest. Adducts the shoulders i.e. Gomukhasana. Stabilises the upper body in Chaturanga Dandasana

Muscles of the Arm

Triceps Brachii – on the back of the upper arm. Extends the elbow. i.e. the elbows in Urdhva Mukha Svanasana (up-face dog).

Biceps Brachii – on the front of the upper arm. Flexes the elbow. i.e. the elbows in Salamba Sarvangasana

Pronator Teres – on the forearm, pronates the forearms in pinchu mayurasana

Wrist Flexors – run from the inner forearm to the hand. Consists of several muscles. Flexes the wrists and fingers. i.e. engaged in Paschimottanasana by flexing the fingers to hold the feet to deepen the forward bend.

Wrist Extensors – run from the lateral/outer forearm to the hand. Extends the wrist and fingers. i.e. Namaste hands in prayer position.

Injury Management and Prevention

See the accompanying manual *Prevention and Management of Common Yoga Injuries* by Lisa Fitzpatrick

Always ask students if they have any injuries that need attention - ask them if they know how to manage their injury. Recognise potential injuries but never try to diagnose or give advice unless you are qualified. Good to delegate to a health professional- ie a doctor, a PT or even a massage therapist

Ask permission before touching someone who is injured. If someone appears seriously injured you may need to make emergency call i.e aneurism or cardiac arrest. Always delegate to a professional if in doubt.

Signs and symptoms of an injury- swelling, pain, blue or grey skin near injury, coolness compared to other side, numbness/pins and needles

RICE management

Rest the part and avoid activity or weightbearing

Ice – use ice packs over first 48hours

Compression- supportive compression bandages help keep swelling down

Elevation- preferably above the level of the heart

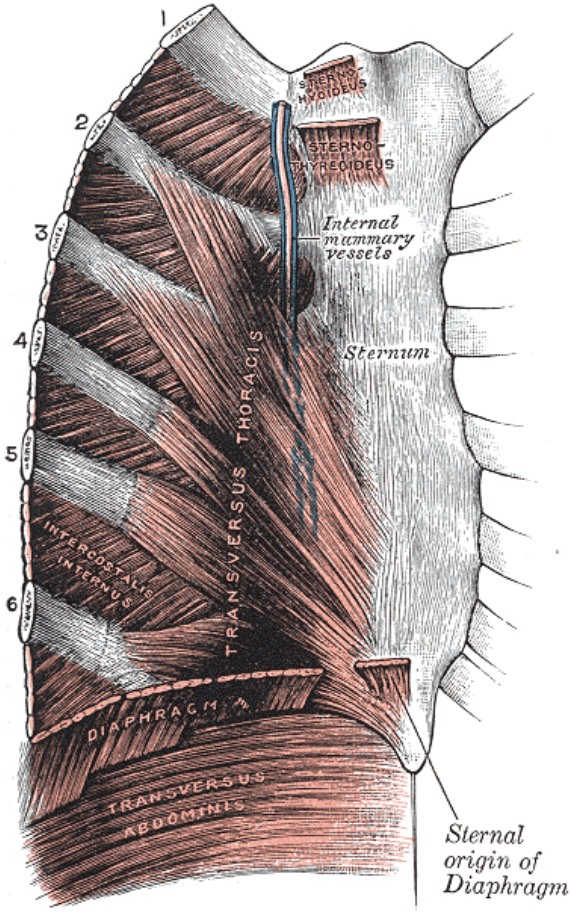
Sometimes a person will need crutches until they are able to see their doctor- usually hire at the chemist

The Breathing Body

Breathing is essential to the functioning of all other systems in the body. Breathing is a highly important part of a yoga practice, said to bring prana (or lifeforce) into the body. Inhalation is essential to carry Oxygen (O2) to the cells. Cells require energy and O2 to carry out all physiological functions such as muscle function, thought processes, immunity etc. The production of energy is known as **metabolism.** Exhalation assists in the removal of waste products i.e. Carbon Dioxide (CO2).

Important muscles of breathing are -

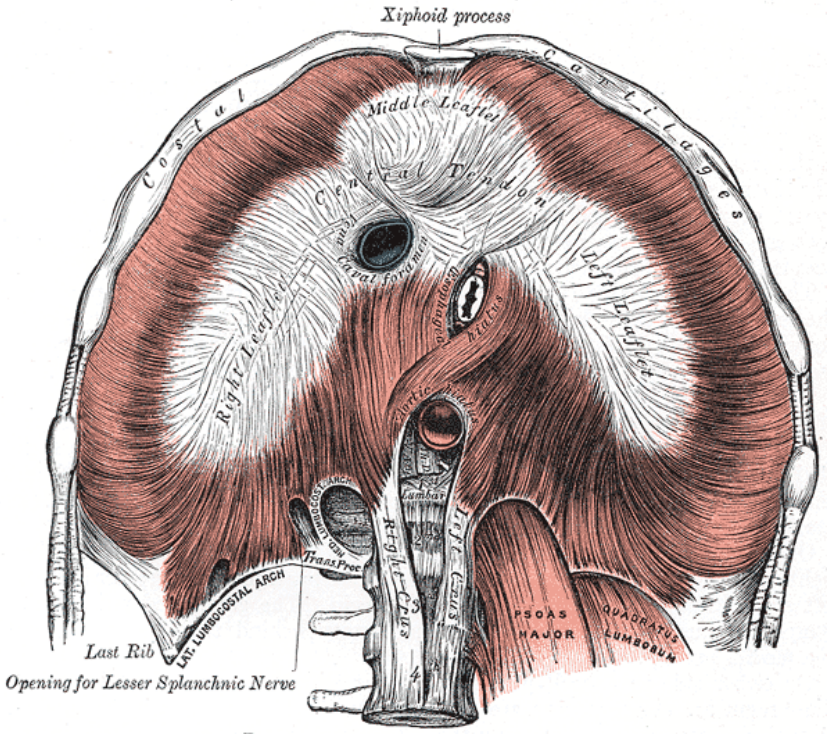
i. Internal Intercostals – located between the ribs, drawing the ribs together for exhalation



ii. External Intercostals – located between the ribs, lifting the ribs apart for inhalation – expansion

iii. The Diaphragm – the most important muscle for breathing attaches to the bottom of the rib cage and is like an open umbrella, with its point extending halfway up into the rib cage. The amount of movement of the diaphragm may be increased through conscious breathing practices such as pranayama. The diaphragm descends on the inhalation and ascends on the exhalation. It separates the heart and lungs in the thoracic cavity from the abdominal cavity

and the digestive organs.



On average, we take 12 breaths per minute during relaxed, normal breathing.

Structure of the Respiratory System

The respiratory system is divided into 2 systems –

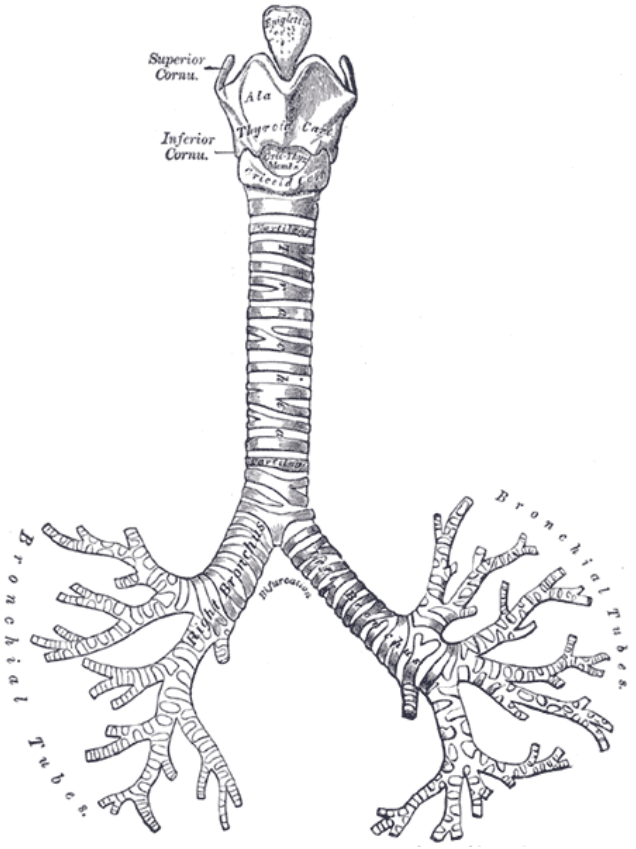
i. **the upper respiratory tract** – the nose and pharynx (throat)

The nose is divided in half by a nasal septum containing nasal conchae (groove-like passageways) which help circulate the air over the mucous membranes. The mucous membranes warm and humidify the air to prepare it for the lungs. Tiny hair-like projections known as cilia line the respiratory tract, protecting it from foreign bodies. Smell receptors line the top of the nasal cavity. Breathing through the mouth bypasses these important protective properties of the nose. The nose leads into the pharynx at the back of the mouth, the passageway for air and food.

ii. **The lower respiratory tract** – the larynx (voice box), trachea (windpipe), bronchii and lungs.

The trachea at the front of the neck is lined with cartilage. It divides into the two primary bronchii at the 5th thoracic vertebrae. The bronchii then divide into secondary bronchii and tertiary bronchii and then smaller sized tubes (bronchioles). This division of tubules gives the appearance of an upside down tree 'the bronchial tree'. The lungs are cone

shaped paired organs inside the ribcage. Each lung is divided into lobes – 2 lobes in the left side and 3 lobes in the right.



Alveoli

The lungs are not just balloons of air with a flat surface. They consist of millions of bubbles of air, like tiny grapes, called alveoli. Alveoli serve to increase the surface area available to absorb oxygen and release CO2. Through the membrane of the alveoli, oxygen is absorbed straight into the tiny capillaries which absorb it and transport it around the body through the circulatory system. The average lung volume is 5-6 litres. There is always a certain amount of air in the respiratory tract at all times, even after a full exhalation, to keep the airways open. This is known as residual volume.

Waste elimination

The breath eliminates more waste by weight over a 24 hour period than any other function, followed by waste elimination through the skin, faeces and urine.

Breath and the Nervous System

Backbends such as Urdhva Dhanurasana activate the front of the chest, stimulating the sympathetic nervous system (SNS).

Front bends such as Paschimottanasana activate the back of the body, stimulating the parasympathetic nervous system (PSNS).

Types of Breath

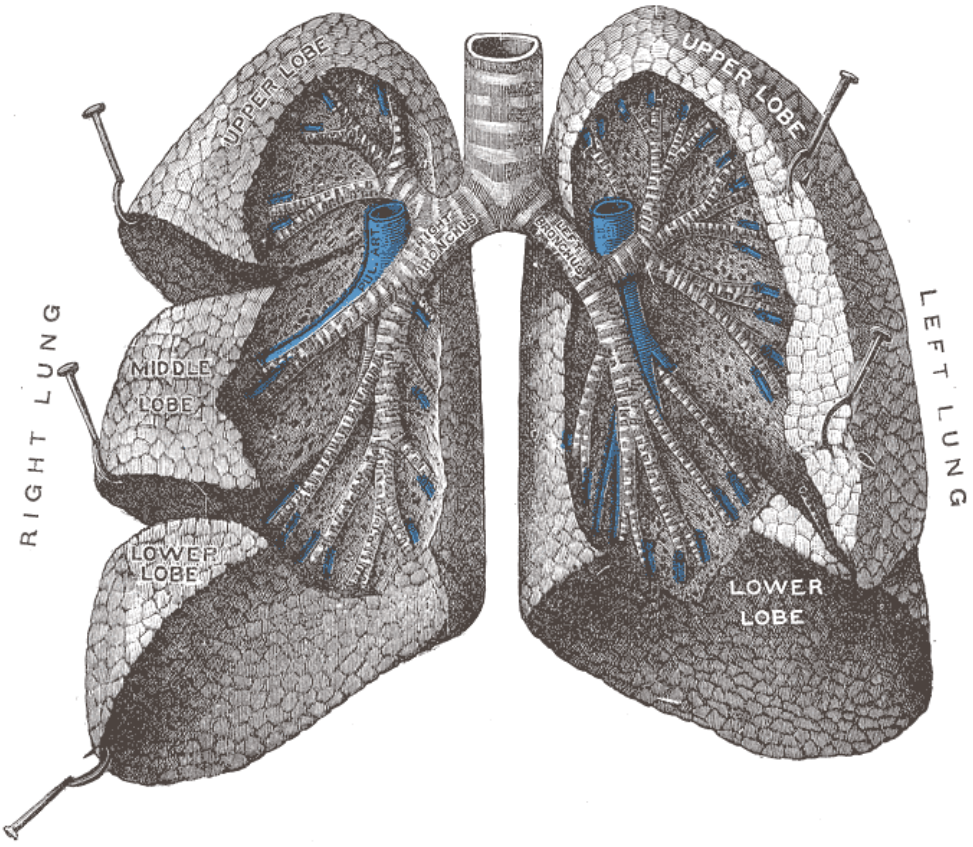
i. the abdominal breath – the diaphragm moves downwards and the waist expands, but the ribcage and chest stays quite static, inducing relaxation.

ii. the thoracic breath- the abdomen is held static and the diaphragm and intercostals lift the ribs on the inhale. This is a stimulating type of breath, activating the SNS.

iii. full and complete breath (yogic breath) – a combination of both the abdominal and thoracic breaths. This is beneficial for increasing lung capacity and ensuring a correct breathing pattern.

The Nadis

Nadis are the energetic pathways through which prana moves into our systems. Ida nadi connects to the left nostril and travels to ajna chakra, coiling through the chakras to the base of the spine and into the left genital. Ida relates to the parasympathetic nervous system and right brain functions, the female side. Pingala nadi connects to the right nostril and travels to ajna chakra, coiling through the chakras to the base of the spine and into the right genital. Pingala relates to the sympathetic nervous system and left brain functions, the male side. Shushumna nadi is the central nadi conducting the energy once the flow of ida and pingala and the breath in the nostrils is balanced. Nadi shodhana is a pranayama practice which alternates the flow of air and prana between the left and right sides, balancing the nervous system.



The Lungs

The Cardiovascular System

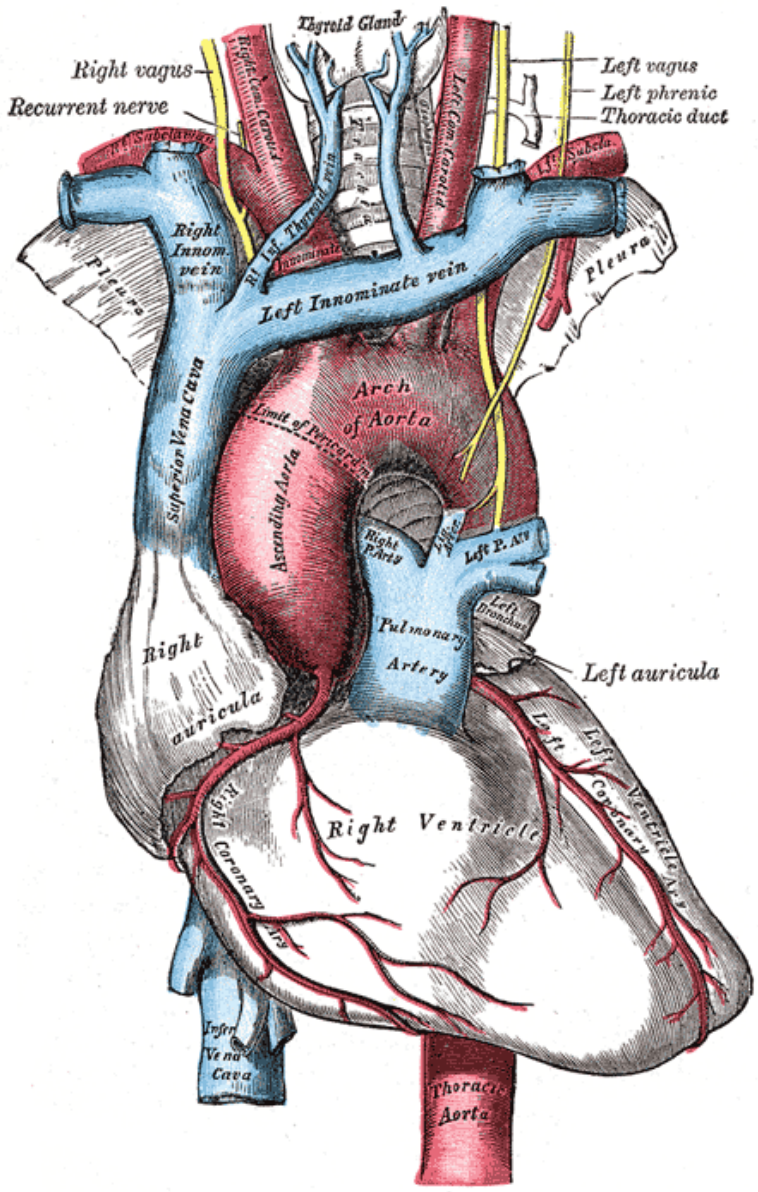
The cardiovascular system consists of the heart and blood vessels such as arteries and veins. It is responsible for the distribution and delivery of oxygen from the lungs and nutrients from the digestive system. It also assists the transport of waste metabolic products away from cells. Everything the cells and systems of the body need to function properly is delivered to them via the cardiovascular system.

The circulatory system consists of everything in the cardiovascular system as well as the lymphatic system which manages metabolic waste and plays a role in our immunity.

The Heart

The heart is a cone shaped, hollow organ with 4 chambers. It is the size of an average fist, about 300g in weight. It sits between the lungs, pointing to the left of the midline. The left lung has one less lobe to accommodate the heart. Cardiac muscle, which has extra energy cells to help it pump endlessly, comprises the bulk of the heart. Coronary arteries branch around the heart and provide it with its high oxygen demand, to keep pumping 24 hours a day without rest.

There are 4 chambers inside the heart – the right atrium and ventricle and the left atrium and ventricle. These chambers form a double pump. One pump pushes de-oxygenated blood from the heart to the lungs. The other pump delivers oxygen-rich blood to the body.



The Blood

On average, males have 5-6 litres, females have 4-5 litres of blood. Blood cells are produced in the red bone marrow of the humerus, femur, sternum, ribs, vertebrae, pelvis and cranium. There are 5 million red blood cells in one drop of blood. Blood transports the oxygen from the lungs, nutrients from the gastro-intestinal tract, hormones from the endocrine system and metabolic waste for excretion.

Arteries

Blood vessels leading away from the heart are arteries. These carry oxygen-rich blood which creates their red colour, have strong muscular walls and enable fast delivery of oxygen and nutrients to tissues. Arteries divide many times into increasingly smaller

vessels, becoming arterioles and finally capillaries. Capillaries are so fine that only a single file of blood cells can pass through them. Capillaries allow oxygen from the blood to enter cells and allow for used carbon dioxide to be returned to the circulatory system.

Veins

Once capillaries have allowed oxygen from the blood to enter the cells (and carbon dioxide to be released), they turn into veins. This is blue blood as it is de-oxygenated. Veins increase in size until they flow back into the heart to enable the blood to be re-oxygenated by the lungs. Veins have lower blood pressure and less muscular walls than arteries. They rely upon one-way valves to aid the transport of blood.
The health of the blood vessels can be supported with protein, magnesium, vitamin C and bioflavonoids. Inversions assist in returning the venous blood flow to the heart.

Circulation Map

Once the blood has delivered its oxygen supply to the body, it returns to the heart via the venous circulation (veins). It arrives at the **right atrium**, the collection chamber of the heart. The right atrium pushes the blood to the **right ventricle** (through the tricuspid valve) during the heart's contraction. The right ventricle then pushes the blood out to both lungs during the next contraction of the heart. The lungs bring in fresh oxygen and release carbon dioxide. Freshly oxygenated blood is then collected in the **left atrium** of the heart. The heart's contraction pumps blood from the left atrium into the **left ventricle**. The left ventricle is the strongest chamber of the heart. It pushes the blood out to the rest of the body via the aorta. Fresh blood supplies the heart first, then it travels through the aorta to the body. Blood also flows to the digestive system which is a separate circulation route.
Asana assists in the circulation of the blood to every cell in the body by creating high and low pressure areas during muscular contractions which aid in the distribution of the blood.

Blood pressure

Each contraction of the heart squeezes out a pressurized volume of blood into the circulation. This travels through the arteries in a wave and is kept pressurized by the muscle tension in the artery walls. Blood vessels are decreasing in size as they distribute through the body which adds to the pressure in the system. A certain level of pressure is maintained in the arteries to maintain continual blood flow.

Average blood pressure is 120/80 mmHg. 120 is the contractive force of the left ventricle (the systolic pressure). 80 is the resting pressure inside the aorta (the diastolic pressure).

Breath holding during asana can increase blood pressure and cause hernias. Continual breathing during asana prevents internal pressure build up.

Yoga and the Cardiovascular System

Pranayama has a direct influence on the ability of the blood to absorb oxygen. Asana, meditation and pranayama are able to train the nervous system, muscular system and respiratory system to benefit the heart and blood pressure (BP).

Inversions

Inversions place extra pressure on the upper body, including the heart and blood vessels in the head and upper limbs. Regular practice can slowly build up muscular strength in the blood vessel walls to ensure inversions are safe. In standing, blood pressure in the head may be approximately 90/60 mmHg. However, in an inverted posture such as Adho Mukha Vrksasana (handstand) the blood pressure in the head may increase to approximately 150/120mmHg due to gravitational forces drawing the blood downwards towards the head. Anyone with high blood pressure must approach inversions with care.

Baroreceptors

Pressure receptors in the arteries of the neck are called baroreceptors. These measure BP. During inversions, increased pressure in the head is registered in these receptors via a feedback loop to the brain. The CNS responds by lowering the BP to lessen cardiac output – a response called reflex hypotension. Being well aligned, especially around the cervical spine during inversions is important to ensure the venous return from the head to the heart is not compromised by postural constriction.

The Lymphatic System

The human body has a water content of around 70%. Every tissue, including bone, consists of a high percentage of water. The lymphatic system manages fluid away from the tissues via specific vessels known as lymphatic vessels. Filtering stations known as lymph nodes are built into the lymphatic vessels where the fluid (known as lymph) may take care of unwanted toxic material and viruses and bacteria. The lymphatic system does not have a pump so it relies upon gravity and muscular support to transport and move lymph. Asana works to assist pump lymph which in turn assists the immune system. Twists, forward bends and inversions all help to move lymph.

The Immune System

The immune system is present in the lymphatic system and the endocrine system. White blood cells (WBCs) are also called lymphocytes and come from bone marrow, B lymphocytes, or from the thymus gland (known as T-lymphocytes). WBCs identify harmful substances then secrete enzymes to break down these substances for elimination from the body. Stress and nutrition greatly affect the immune system. Asana, pranayama and meditation, when practiced correctly, have been found to enhance the functioning of the immune system and decrease stress.

Conclusion

The topic of Anatomy and Physiology is so vast we must accept that we may only grasp a small portion of it each time we study. With ongoing and consistent effort as well as practical application to our yoga practice, this subject will gradually integrate into our way of being and bear fruit for us. It is also important to know which resources to refer to in order to access information when it is needed. See bibliography to follow…

Namaste

Lisa Fitzpatrick

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