



A Guide to Anatomy & Physiology

Essential information to help you
learn and apply the basics of A&P

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Introduction

It is of primary importance for the therapist to have a good knowledge of Anatomy & Physiology (A&P) so that treatments can be targeted effectively and undue harm cannot be caused to the client. It is also helpful to have this knowledge so that the therapist does not make any current medical conditions worse.

This guide provides students with essential A&P knowledge, to ensure that they are able to practice with an awareness of how the body's systems and physiology function to obtain the best possible outcome for the treatment and to recognise important contra-indications as and when they present from clients.

Biology is the study of life. One of its goals is to discover the unity and the patterns that underlie the diversity of organisms.

This reference guide will give people who have an interest in the inner workings of the human body the chance to learn about its functions and structure. The word Anatomy has Greek origin, as do many anatomical terms and phrases originating from more than 1500 years ago. Anatomy, which means 'cutting open', is the study of internal and external structures of the body and the physical relationship among the body parts. In contrast, physiology is the study of how living organisms perform their vital functions.

Anatomy in the human body determines how you look at things and what you see. Based on your degree of structural detail, anatomy can be divided into Gross (macroscopic) anatomy and microscopic anatomy.

Gross (Macroscopic) Anatomy

Gross Anatomy involves the examination of relatively large structures and features usually visible with an unaided eye. There are many types of gross anatomy:

- Surface anatomy is the study of general form and superficial markings
- Regional anatomy focuses on the anatomical organization of specific areas of the body such as the head, neck or trunk.
- Systematic anatomy is the study of the structure of organ systems, which are groups of organs that function together in a coordinated manner. Examples include the skeletal system composed of bones, the muscular system made up of muscles and the cardiovascular system consisting of the heart, blood and vessels, which distribute oxygen and nutrients around the body.
- Developmental anatomy describes the changes in form that occur between conception and physical maturity.
- Clinical anatomy includes a number of subspecialties important in clinical practice. Examples of this include medical anatomy, radiographic anatomy and surgical anatomy.

Microscopic Anatomy

Microscopic anatomy deals with structures that cannot be seen without magnification and thus the boundaries of microscopic anatomy are established by limitations of equipment required. With a dissecting microscope, you can see basic details of cell structure, with an electronic microscope you can see individual molecules that are only a few nanometers across.

Physiology is the study of the function of anatomical structures; human physiology is the study of the human body. These functions are complex and more difficult to examine than most anatomical structures.

Cell physiology is the study of functions of cells and considers events of chemical and molecular levels – both chemical processes within cells and chemical interactions between the cells. Special physiology is the study of specific organs.

Systemic physiology includes all aspects of the functioning of a specific organ system. Examples of systemic systems are cardiovascular, respiratory and reproductive physiology. Pathological physiology is the study of effects of diseases on organ or system functions.

Introduction to cells

- Contemporary cell theory incorporates several basic concepts:
- Cells are the building blocks of all plants and animals
 - Cells are produced by the division of pre-existing cells
 - Cells are the smallest units that perform all vital physiological functions
 - Each cell maintains homeostasis at the cellular level and;
 - Homeostasis at the tissue, organ, organ system and organism level reflect the combined and coordinated actions of many cells.

Cytology is the study of cellular structure and function of cell biology. The human body contains two types of cells: sex cells (sperm and oocytes) and somatic cells (all other cells).

The cell membrane functions include physical isolation, regulation of exchange with the environment and structural support. A typical cell is surrounded by extracellular fluid and the cell’s outer layer is called cell membrane or plasma membrane.

The nucleus is the control centre of cellular operations, which is surrounded by a nuclear envelope. It controls the direction of synthesis of specific proteins, using information stored in chromosomes.

The System Overview

The Integument System

The Integument System protects against environmental hazards such as controlling body temperature

Organ/ Component	Primary Functions
Cutaneous Membrane: Epidermis Dermis	Cover surfaces, protects deeper tissues Nourishes epidermis, provides strength, contains glands
Hair follicles Hair Sebaceous glands	Produces hair, innervation provides sensation, provides protection for head Secrete lipid coating that lubricates hair shaft and epidermis
Sweat glands	Produce perspiration for evaporative cooling
Nails	Protect and stiffen distal tips of digits
Sensory receptors	Provides sensations of touch, pressure, temperature and pain
Subcutaneous layer	Stores lipid, attaches skin to deeper structures

The Skeletal System

The Skeletal System provides support, protects tissues, stores minerals and forms blood

Organ/Component	Primary Functions
Bones, Cartilages and Joints	Supports, protects soft tissue, bones store minerals
Axial skeleton (skull, vertebrae, ribs, sternum, sacrum, cartilages and ligaments)	Protects brain, spinal cord, sense organs and soft tissues of thoracic cavity; Supports the body weight over lower limbs
Appendicular skeleton (supporting bones, cartilages and ligaments of the limbs)	Provides internal support and positioning of the limbs; supports and moves the axial skeleton
Bone marrow	Acts as a primary site of blood cell production (red blood cells, white blood cells); stores lipid reserves

The Muscular System

The Muscular System provides movement and locomotion; provides support and generates heat

Organ/Component	Primary Functions
Skeletal muscles (700)	Provides skeletal movements, control entrance and exit of digestive tract, produce heat, support skeletal position, protect soft tissue
Axial muscles	Support and position axial skeleton
Appendicular muscles	Support, move and brace limbs
Tendons, aponeuroses	Harness forces of contraction to perform specific tasks

The Nervous System

The Nervous System directs immediate response to stimuli, usually by coordinating the activities of the other organ systems

Organ/Component	Primary Functions
Central Nervous System (CNS)	Acts as a control centre for nervous system; processes information, provides short term cover over activities of other systems
Brain	Performs complex integrative functions; controls both voluntary and autonomic activities
Spine	Relays information to and from brain; performs less-complex integrative functions, directs many simple involuntary functions
Peripheral Nervous System (PNS)	Links CNS with other systems and with sense organs

The Endocrine System

The Endocrine System directs long term changes in other organ systems

Organ/Component	Primary Functions
Pineal glands	May control timing of reproduction and set day-night rhythms
Pituitary glands	Controls other endocrine glands; regulates growth and fluid balance
Thyroid glands	Controls tissue metabolic rate; regulates calcium levels
Parathyroid glands	Regulate calcium levels (with thyroid)
Thymus	Controls maturation of lymphocytes
Adrenal glands	Adjust water balance, tissue metabolism, cardiovascular and respiratory systems
Kidneys	Control red blood cell production and assist in calcium regulation
Pancreas	Regulates blood glucose levels
Gonads Testes	Support male characteristics and reproductive functions
Ovaries	Support female characteristics and reproductive functions

The Cardiovascular System

The Cardiovascular System – transport cells and dissolved materials including nutrients, wastes and gases

Organ/Component	Primary functions
Heart	Propels bloods; maintain blood pressure
Blood vessels Arteries Capillaries	Distribute blood around the body Carry blood from heart to capillaries Permit diffusion between blood and interstitial fluids
Veins	Return blood from capillaries to heart
Blood	Transports oxygen, carbon dioxide and blood cells; delivers nutrients and hormones, removes waste products, assists in temperature regulation and defense against disease

The Lymphatic System

The Lymphatic System – defends against infection and diseases; returns tissue fluid to the bloodstream

Organ/Component	Primary Functions
Lymphatic vessels	Carry lymph (water and proteins) and lymphocytes from peripheral tissues to veins of the cardiovascular system
Lymph nodes	Monitor the composition of lymph; macrophages engulf pathogens; stimulates immune response
Spleen	Monitors circulating blood; macrophages engulf pathogens; stimulates immune response
Thymus	Controls development and maintenance of one class of lymphocytes (T cells)

The Respiratory System

The Respiratory System – delivers air to sites where gas exchange can occur between the air and circulating blood

Organ/Component	Primary Functions
Nasal cavities, Para nasal sinuses	Filter, warm, humidify air; detect smells
Pharynx	Conducts air to larynx; is a chamber shared with the digestive tract
Larynx	Protects opening to trachea and contains vocal chords
Trachea and Bronchi	Filters air, traps particles in mucus; cartilages keep airway open
Lungs	Responsible for air movement through volume changes during movements of ribs and diaphragm; includes airways and alveoli
Alveoli	Acts as sites of gas exchange between air and blood

The Digestive System

The Digestive System – processes food, absorbs nutrients, eliminates waste products

Organ/component	Primary Functions
Salivary glands	Provides buffers and lubrication; produce enzymes that begin digestion
Pharynx	Conducts solid foods and liquids to esophagus; is a chamber shared with respiratory tract
Esophagus	Delivers food to stomach
Stomach	Secretes acid and enzymes
Small intestine	Secretes digestive enzymes, buffers and hormones; absorbs nutrients
Liver	Secretes bile; regulates nutrient composition of blood
Gallbladder	Stores bile for release into small intestine
Pancreas	Secretes digestive enzymes and buffers; contains endocrine cells
Large intestine	Removes water from fecal material; stores wastes

The Urinary System

The Urinary System - Eliminates excess water, salts and waste products

Organ/Component	Primary Functions
Kidneys	Form and concentrate urine; regulate blood pH and ion concentrations; perform endocrine functions
Ureters	Conduct urine from kidneys to urinary bladder
Urinary bladder	Stores urine for eventual elimination
Urethra	Conducts urine to exterior

The Male Reproductive System

The Male Reproductive System

Organ/ Component	Primary Functions
Testes	Produce sperm and hormones
Accessory Organs Epididymis Ductus deferens (sperm duct)	Act as sites of sperm maturation Conducts sperm between epididymis and prostate gland
Seminal vesicles Prostate gland	Secrete fluid that makes up much of the volume of semen Secretes fluid and enzymes
Urethra	Conducts semen to exterior
External genitalia Penis	Contains erectile tissue; deposits sperm in the vagina of the female; produces pleasurable sensations during sexual activities
Scrotum	Surrounds the testes and controls their temperature

The Female Reproductive System

The Female Reproductive System

Organ/Component	Primary Functions
Ovaries	Produces oocytes and hormones
Uterine tubes	Deliver oocyte or embryo to uterus; normal place for fertilisation
Uterus	Site of embryonic development and exchange between maternal and embryonic bloodstreams
Vagina	Site of sperm deposition; acts as birth canal during delivery; provides passageway for fluids during menstruation
External Genitalia Clitoris Labia	Contains erectile tissue; produces pleasurable sensations during sexual activities
Mammary glands	Produce milk that nourishes newborn infant

The Integumentary System

The skin is an ever-changing organ that contains many specialised cells and structures. The skin functions as a protective barrier that interfaces with a sometimes-hostile environment. It is also very involved in maintaining the proper temperature for the body to function well. It gathers sensory information from the environment, and plays an active role in the immune system in protecting us from disease. Understanding how the skin can function in these many ways starts with understanding the structure of the three layers of skin - the epidermis, dermis, and subcutaneous tissue.

The Integumentary system consists of two major components: the cutaneous membrane or skin and the accessory structures. The cutaneous membrane has two components; Epidermis (superficial epithelium) and Dermis (underlying area of connective tissues). The accessory structures include hair, nails and multi-cellular exocrine glands. These structures are located primarily in the dermis and protrude through the epidermis to the skin surface.

The integument does not work in isolation. An extensive network of blood vessels branches through the dermis and sensory receptors that monitor touch, pressure, temperature and pain, provides information to the CNS. The loose connective tissue of the subcutaneous layer is known as superficial fascia or hypodermis, which separates the integument from the deep fascia around other organs such as muscles and bones.

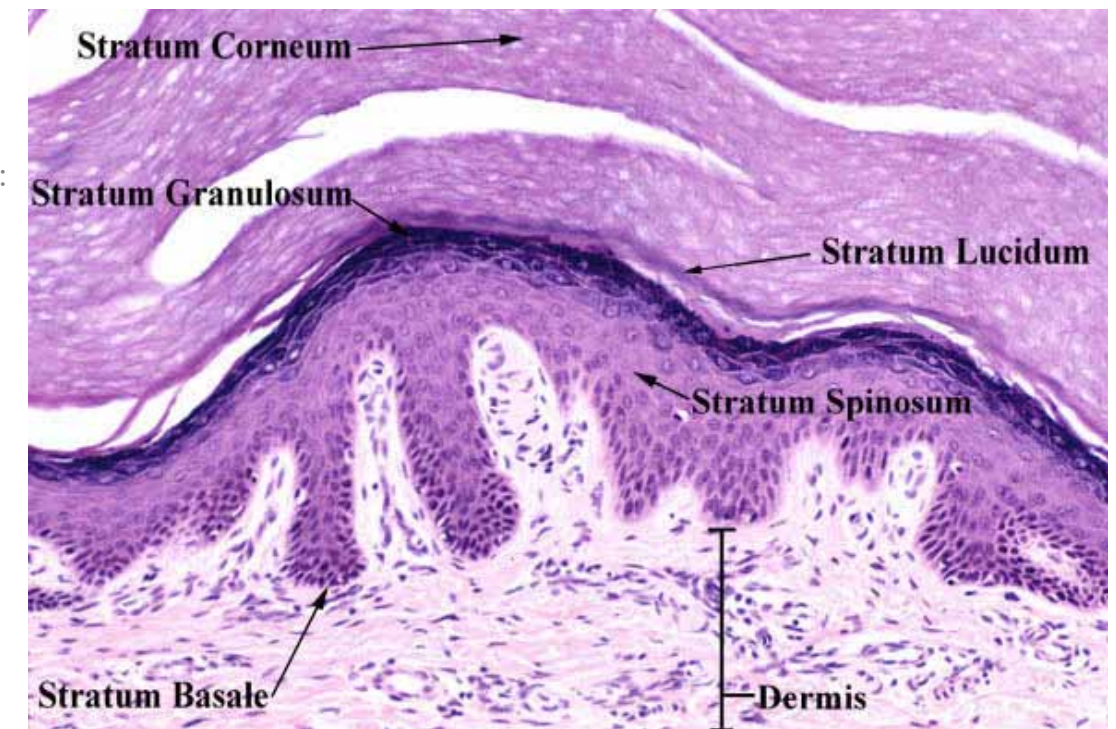
Epidermis

The epidermis is the outer layer of skin. The thickness of the epidermis varies in different types of skin. It is the thinnest on the eyelids at .05 mm and the thickest on the palms and soles at 1.5 mm.

The epidermis contains 5 layers.

From bottom to top the layers are named:

- Stratum Basale
- Stratum Spinosum
- Stratum Granulosum
- Stratum Lcidum
- Stratum Corneum



The bottom layer, the stratum basale, has cells that are shaped like columns. In this layer the cells divide and push already formed cells into higher layers. As the cells move into the higher layers, they flatten and eventually die. The stratum basale is the bottom layer of keratinocytes in the epidermis and is responsible for constantly renewing epidermal cells. This layer contains just one row of undifferentiated columnar stem cells that divide very frequently. Half of the cells differentiate and move to the next layer to begin the maturation process. The other half stay in the basal layer and divide over and over again to replenish the basal layer.

Cells that move into the stratum spinosum layer (also called prickle cell layer) change from being columnar to polygonal. In this layer the cells start to synthesize keratin.

The cells in the stratum granulosum, or granular layer, have lost their nuclei and are characterized by dark clumps of cytoplasmic material. There is a lot of activity in this layer as keratin proteins and water-proofing lipids are being produced and organized.

The stratum lucidum layer is only present in thick skin where it helps reduce friction and shear forces between the stratum corneum and stratum granulosum.

The top layer of the epidermis, the stratum corneum, is made of dead, flat skin cells that shed about every 2 weeks.

Specialised Epidermal Cells

There are three types of specialized cells in the epidermis.

- The Melanocyte produces pigment (melanin)
- The Langerhans' cell is the frontline defence of the immune system in the skin
- The Merkel's cell's function is not clearly known

Dermis

The dermis also varies in thickness depending on the location of the skin. It is .3 mm on the eyelid and 3.0 mm on the back. The dermis is composed of three types of tissue that are present throughout - not in layers. The types of tissue are:

- Collagen
- Elastic tissue
- Reticular Fibres

Layers of the Dermis

The two layers of the dermis are the papillary and reticular layers.

The upper, papillary layer contains a thin arrangement of collagen fibres.

The lower, reticular layer is thicker and made of thick collagen fibres that are arranged parallel to the surface of the skin.

Specialised Dermal Cells

The dermis contains many specialized cells and structures.

- The hair follicles are situated here with the erector pili muscle that attaches to each follicle.
- Sebaceous (oil) glands and apocrine (scent) glands are associated with the follicle. This layer also contains eccrine (sweat) glands, but they are not associated with hair follicles.
- Blood vessels and nerves course through this layer. The nerves transmit sensations of pain, itch, and temperature.
- There are also specialized nerve cells called Meissner's and Vater-Pacini corpuscles that transmit the sensations of touch and pressure.

Subcutaneous Tissue

The subcutaneous tissue is a layer of fat and connective tissue that houses larger blood vessels and nerves. This layer is important in the regulation of temperature of the skin itself and the body. The size of this layer varies throughout the body and from person to person.

The skin is a complicated structure with many functions. If any of the structures in the skin are not working properly, a rash or abnormal sensation is the result.

When the skin is exposed to sunlight, modified cholesterol in the dermis produces vitamin D, which helps the body to absorb calcium for healthy bones.

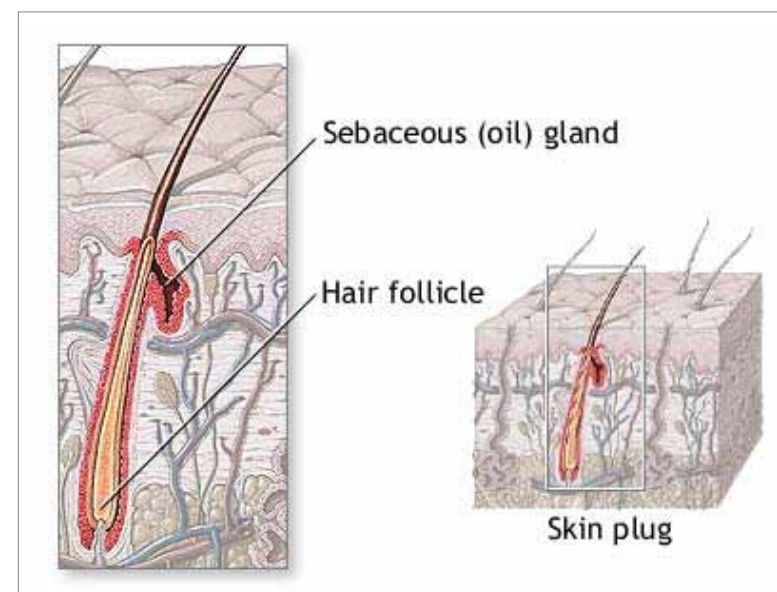
Hair is much more complicated than it appears. It helps transmit sensory information and creates gender identity. Hair is often important to the appearance of men and women. There is hair on all the major visible surfaces of the body. It is also the only body structure that is completely renewable without scarring.

Hair Origin

A developing foetus has all of its hair follicles formed by week 22. At this time there are 5 million follicles on the body. One million of those are on the head, and 100,000 are on the scalp. This is the largest number of follicles we will ever have - follicles are never added during life. As the size of the body increases as we grow older, the density of the hair follicles on the skin decreases.

Hair Anatomy

Hair has two separate structures - the follicle in the skin and the shaft we see.



Follicle - The follicle is a stocking-like structure that contains several layers with different jobs. At the base of the follicle is a projection formed like sticking a finger in the bottom of a stocking and pushing it in a small amount. This projection is called a papilla and it contains capillaries, or tiny blood vessels, that feed the cells.

The living part of the hair is the bottom part of the stocking surrounding the papilla called the bulb. This bottom part is the only part fed by the capillaries. The cells in the bulb divide every 23 to 72 hours, faster than any other cells in

the body

The follicle is surrounded by two sheaths - an inner and outer sheath. These sheaths protect and mould the growing hair shaft. The inner sheath follows the hair shaft and ends below the opening of a sebaceous (oil) gland, and sometimes an apocrine (scent) gland.

The outer sheath continues all the way up to the gland. A muscle called an erector pili muscle attaches below the gland to a fibrous layer around the outer sheath. When this muscle contracts, it causes the hair to stand up.

The sebaceous gland is important because it produces sebum which is a natural conditioner. More sebum is produced after puberty. The sebum production decreases in women throughout their lives. The production also decreases in men, but not as much as in women.

Shaft - The hair shaft is made up of dead, hard protein called keratin in three layers. The inner layer is called the medulla and may not be present. The next layer is the cortex and the outer layer is the cuticle. The cortex makes up the majority of the hair shaft. The cuticle is formed by tightly packed scales in an overlapping structure similar to roof shingles. Most hair conditioning products attempt to affect the cuticle. There are pigment cells that are distributed throughout the cortex and medulla giving the hair its characteristic colour.

Hair Growth Cycle

Hair on the scalp grows about .3-.4 mm/day or about 6 inches per year. Unlike other mammals, hair growth and loss is random and not seasonal or cyclic. At any given time, a random number of hairs will be in various stages of growth and shedding. There are three stages of hair growth: catagen, telogen, and anagen.

Catagen - The catagen phase is a transitional stage and 3% of all hairs are in this phase at any time. This phase lasts for about 2-3 weeks. During this time growth stops and the outer root sheath shrinks and attaches to the root of the hair. This is the formation of what is known as a club hair.

Telogen is the resting phase and accounts for 10-15 per cent of all hairs. This phase lasts for about 100 days for hairs on the scalp and much longer for hairs on the eyebrow, eyelash, arm and leg. During this phase the hair follicle is completely at rest and the club hair is completely formed. Pulling out a hair in this phase will reveal a solid, hard, dry, white material at the root. About 25- 100 telogen hairs are normally shed each day.

Anagen is the active phase of the hair. The cells in the root of the hair are dividing rapidly. A new hair is formed and pushes the club hair up the follicle and eventually out. During this phase the hair grows about 1 cm every 28 days. Scalp hair stays in this active phase of growth for 2-6 years. Some people have difficulty growing their hair beyond a certain length because they have a short active phase of growth. On the other hand, people with very long hair have a long active phase of growth. The hair on the arms, legs, eyelashes, and eyebrows have a very short active growth phase of about 30-45 days explaining why they are so much shorter than scalp hair.

Hair Shape

The amount of natural curl a hair has, is determined by its cross-sectional shape. Hair that is most similar to a circle is straight and hair that is flattened and elliptical is curly or kinky. The more circular the shaft is, the straighter it is. The more elliptical the shaft is, the curlier or kinkier the hair. The cross-sectional shape also determines the amount of shine the hair has. Straighter hair is shinier because sebum from the sebaceous gland can travel down the hair more easily. The kinkier the hair, the more difficulty the sebum has travelling down the hair, therefore the more dry or dull the hair looks.

Nails

The nail body of a nail covers the nail bed. Nail production occurs at the nail root which is overlaid by the cuticle. The free edge of the nail extends over the hypochium.

Summary

To summarise, here are the structures within the dermis that enhance the skin's function: Blood vessels supply nutrients to the dividing cells in the basal layer and remove any waste products. They also help maintain body temperature by dilating and carrying more blood when the body needs to lose heat from its surface; they narrow and carry less blood when the body needs to limit the amount of heat lost at its surface.

Specialised nerves in the dermis detect heat, cold, pain, pressure and touch and relay this information to the brain. In this way the body senses changes in the environment that may potentially harm the body.

Hair follicles are embedded in the dermis and occur all over the body, except on the soles, palms and lips. Each hair follicle has a layer of cells at its base that continually divides, pushing overlying cells upwards inside the follicle. These cells become keratinised and die, like the cells in the epidermis, but here form the hair shaft that is visible above the skin. The colour of the hair is determined by the amount and type of melanin in the outer layer of the hair shaft.

A sebaceous (oil) gland opens into each hair follicle and produces sebum, a lubricant for the hair and skin that helps repel water, damaging chemicals and micro-organisms (germs). Attached to each hair follicle are small erector pili muscle fibres. These muscle fibres contract in cold weather and sometimes in fright; this pulls the hair up which pulls on the skin with the result being goosebumps.

Sweat glands occur on all skin areas, each person has more than 2 million. When the body needs to lose heat these glands produce sweat (a mix of water, salts and some waste material such as urea). Sweat moves to the skin's surface via the sweat duct, and evaporation of this water from the skin has a cooling effect on the body.

The Skeletal System



The skeletal system is the structure and framework on which the body depends for its many systems. It includes bones of the skeleton and the cartilages, ligaments and other connective tissues that stabilize or connect the bones. The function of the skeleton system provides support, storage of minerals and lipids, blood cell production, protection and leverage.

Support

The skeleton is the framework of the body; it supports the softer tissues and provides points of attachment for most skeletal muscles.

Protection

The skeleton provides mechanical protection for many of the body's internal organs, reducing risk of injury to them. For example, cranial bones protect the brain, vertebrae protect the spinal cord, and the ribcage protects the heart and lungs.

Skeletal muscles are attached to bones, therefore when the associated muscles contract they cause bones to move.

Production of Blood Cells

In the red bone marrow inside some larger bones, blood cells are produced.

Storage of Chemical Energy

With increasing age some bone marrow changes from 'red bone marrow' to 'yellow bone marrow'. Yellow bone marrow consists mainly of adipose cells, and a few blood cells. It is an important chemical energy reserve.

There are two types of bone tissue: compact and spongy. The names imply that the two types of differ in density, or how tightly the tissue is packed together. There are three types of cells that contribute to bone homeostasis.

Osteoblasts are bone-forming cells, osteoclasts resorb or break down bone, and osteocytes are mature bone cells. Equilibrium between osteoblasts and osteoclasts maintains bone tissue.

Compact Bone

Compact bone consists of closely packed osteons or haversian systems. The osteon consists of a central canal called the osteonic (haversian) canal, which is surrounded by concentric rings (lamellae) of matrix.

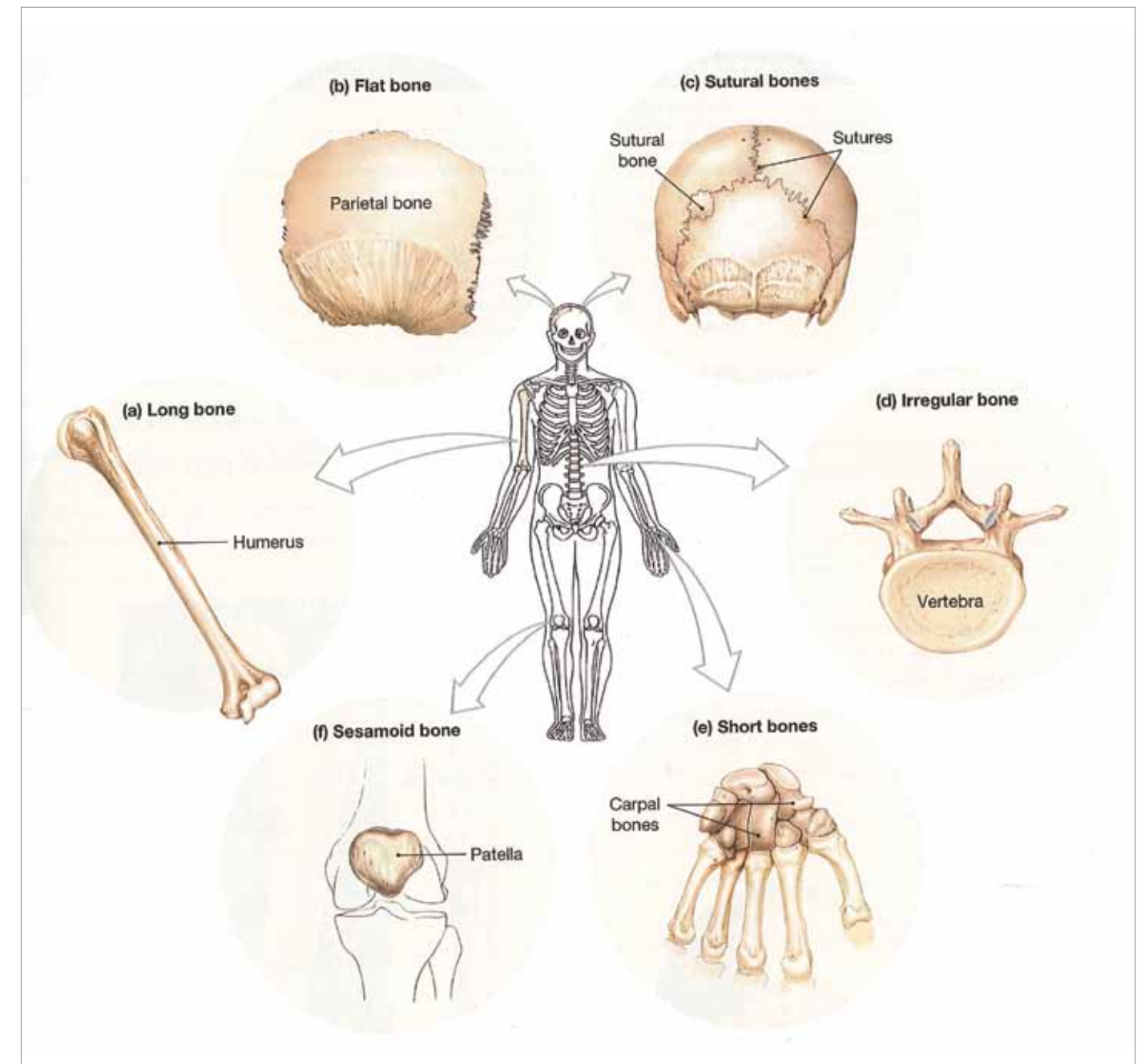
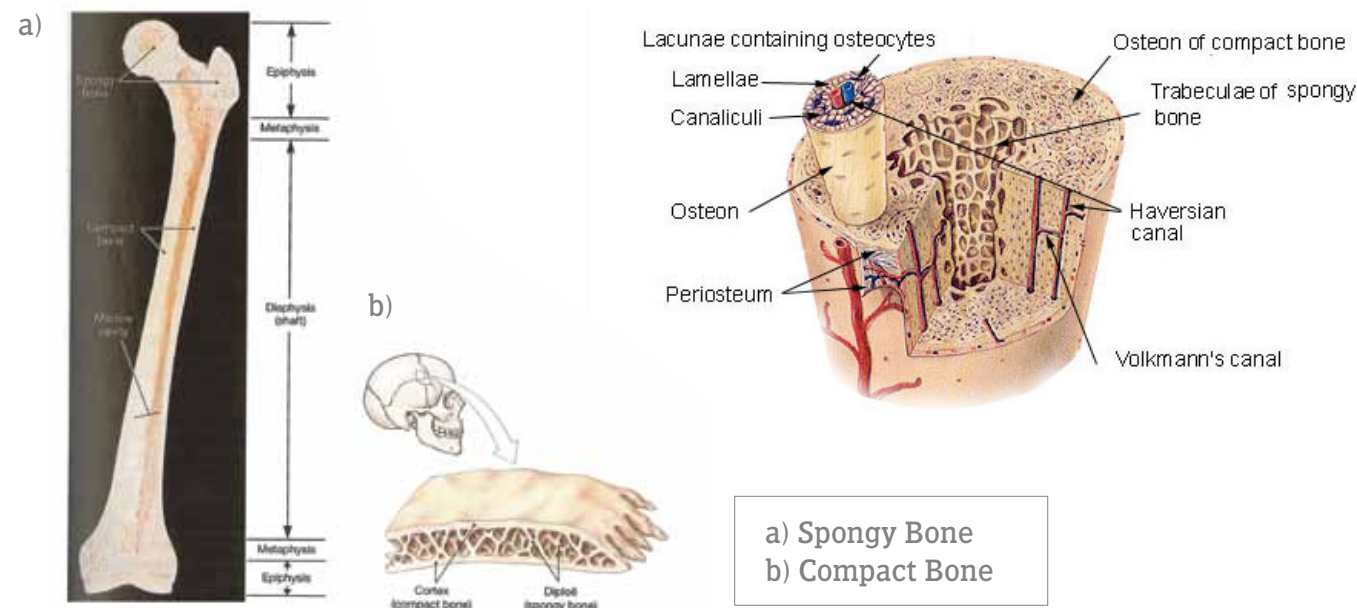
Between the rings of matrix, the bone cells (osteocytes) are located in spaces called lacunae. Small channels (canaliculi) radiate from the lacunae to the osteonic (haversian) canal to provide passageways through the hard matrix. In compact bone, the haversian systems are packed tightly together to form what appears to be a solid mass. The osteonic canals contain blood vessels that are parallel to the long axis of the bone. These blood vessels interconnect, by way of perforating canals, with vessels on the surface of the bone.

Spongy (Cancellous) Bone

Spongy (cancellous) bone is lighter and less dense than compact bone. Spongy bone consists of plates (trabeculae) and bars of bone adjacent to small, irregular cavities that contain red bone marrow.

The canaliculi connect to the adjacent cavities, instead of a central haversian canal, to receive their blood supply. It may appear that the trabeculae are arranged in a haphazard manner, but they are organized to provide maximum strength similar to braces that are used to support a building. The Bones grow from their ends (extremities). Under normal circumstances bones stop growing when one reaches their late teens or early twenties.

Bone marrow produces stem cells, such as erythrocytes (red blood cells) and leucocytes (white blood cells).



a) Long bones

These have greater length than width and consist of a shaft and a variable number of endings (extremities). They are usually somewhat curved for strength. Examples include femur, tibia, fibula, humerus, ulna and radius.

b) Flat bones

These have a thin shape/structure and provide considerable mechanical protection and extensive surfaces for muscle attachments. Examples include cranial bones (protecting the brain), the sternum and ribs (protecting the organs in the thorax), and the scapulae (shoulder blades).

c) Sutural bones

These are classified by their location rather than by their shape. They are very small bones located within the sutural joints between the cranial bones. The number of sutural bones varies considerably from person to person, therefore these are un-named bones.

d) Irregular bones

These have complicated shapes and so cannot be classified into any of the above (shape-based) categories. Their shapes are due to the functions they fulfill within the body e.g. providing major mechanical support for the body yet also protecting the spinal cord (in the case of the vertebrae). Examples include the vertebrae and some facial bones.

e) Short bones

These are roughly cube-shaped and have approximately equal length and width. Examples include ankle and wrist bones.

f) Sesamoid bones

These develop in some tendons in locations where there is considerable friction, tension, and physical stress. They may therefore form in the palms of the hands and the soles of the feet, however their presence and quantity varies considerably from person to person. Examples common to everyone include the patellae (kneecaps).

The skull is the bony structure of the head. The skull supports the structures of the face and protects the head against injury.

The skull can be subdivided into two parts: the cranium and the mandible. A skull that is missing a mandible is only a cranium; this is the source of a very commonly made error in terminology.

Protection of the brain is only one part of the function of a bony skull. For example, a fixed distance between the eyes is essential for stereoscopic vision, and a fixed position for the ears helps the brain to use auditory cues to judge direction and distance of sounds. In some animals, the skull also has a defensive function (e.g. horned ungulates); the frontal bone is where horns are mounted. In humans, the adult skull is normally made up of 22 bones. Except for the mandible, all of the bones of the skull are joined together by sutures, rigid articulations permitting very little movement. Eight bones form the neurocranium (braincase)—including the frontal, parietals, occipital bone, sphenoid, temporals and ethmoid—a protective vault surrounding the brain.

The skull contains the sinus cavities, which are air-filled cavities lined with respiratory epithelium, which also lines the large airways.

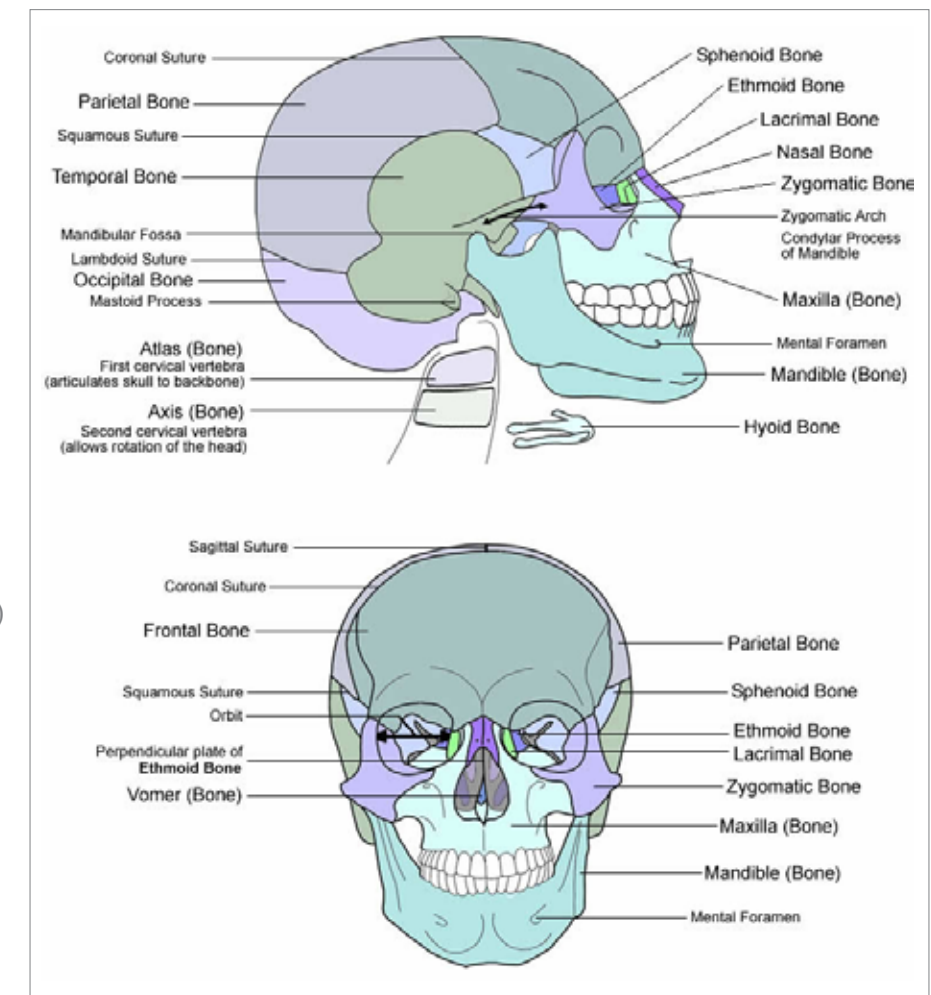
There are 22 bones of the Skull, which include:

8 Cranial Bones

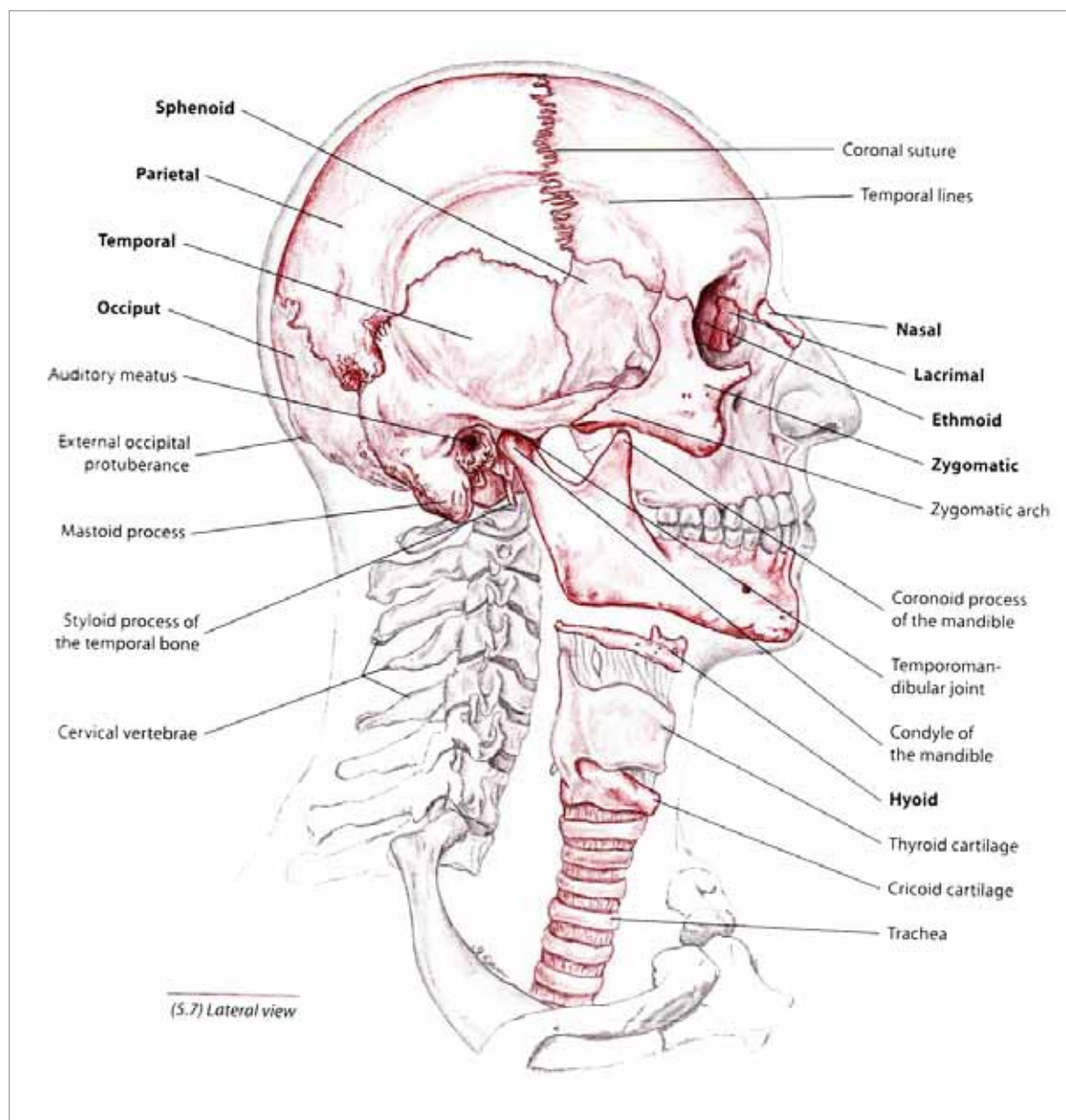
- 1 x Ethmoid Bone
- 1 x Frontal Bone
- 1 x Occipital Bone
- 2 x Parietal Bones
- 1 x Sphenoid Bone
- 2 x Temporal Bones

14 Facial Bones

- 2 x Inferior Nasal Conchae
- 2 x Lacrimal Bones
- 1 x Mandible
- 2 x Maxillae (pl.); Maxilla (sing.)
- 2 x Nasal Bones
- 2 x Palatine Bones
- 1 x Vomer
- 2 x Zygomatic Bones



Bony structure of head



The spine

Understanding the fundamental anatomy and function of the spine is key to understanding injuries to and diseases of the spine.

The spine has several special roles in the human body. Its functions are:

- To protect the spinal cord (which connects nerves to the brain);
- To provide the support needed to walk upright;
- To enable the torso to bend;
- To support the head.

When viewed from the side, the spine has a natural "S" curve.

The main sections of the Spine

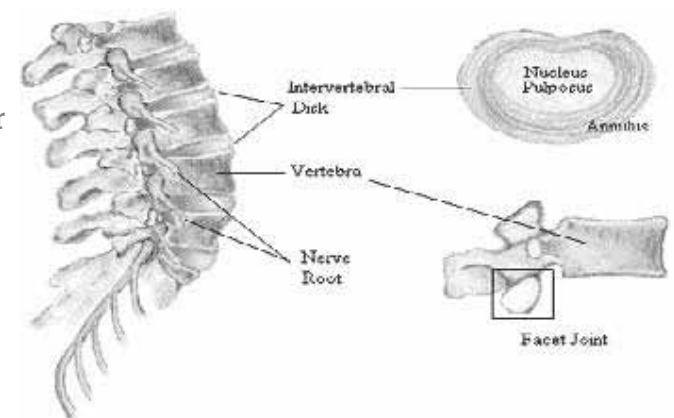
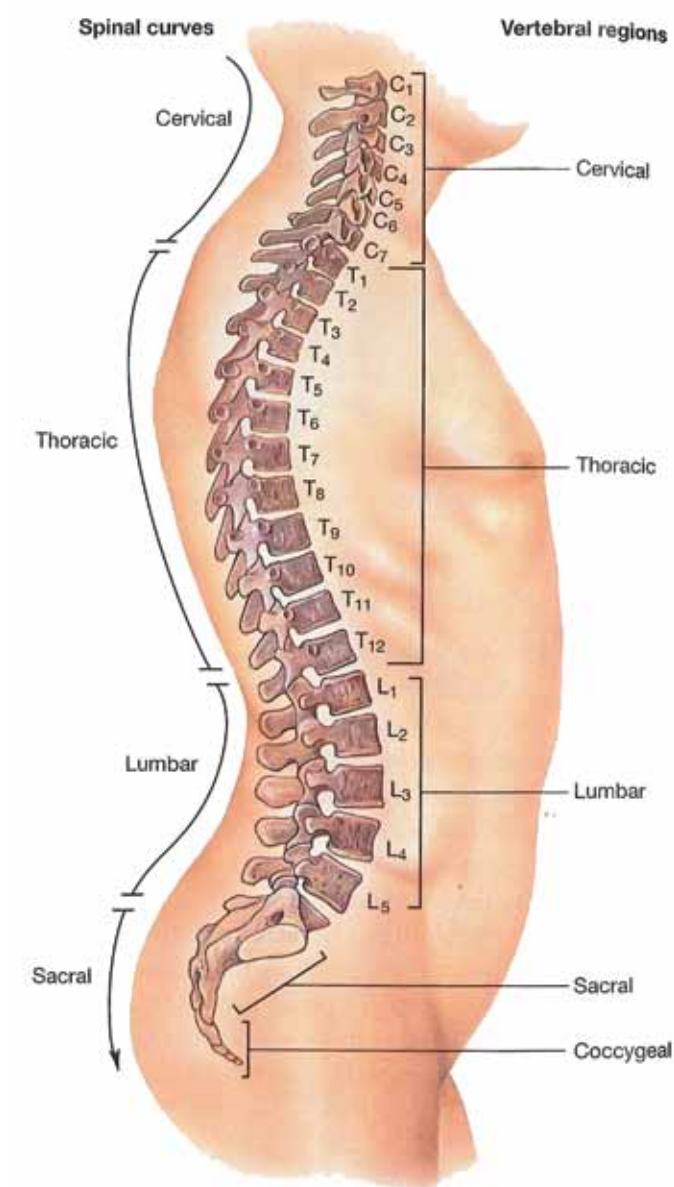
Cervical - commonly referred to as the neck. There are seven cervical vertebrae (doughnut-shaped bones) that connect the skull to the rest of the spine.

Thoracic - The spine's thoracic section begins at the shoulders and extends down to the end of the rib cage. There are 12 vertebrae in the upper back, with shock-absorbing discs between them. Scoliosis commonly affects the thoracic section of the spine.

Lumbar - The lumbar section, or lower back, has five vertebrae. These vertebrae, separated by discs, are the largest in the spine. The lumbar section is also a common location for scoliosis to occur.

Sacrum - There are five vertebrae that join together to form the sacrum, a wedge-shaped part of the spine that rests at the top of the pelvis.

Coccyx - often referred to as the tailbone, consists of four vertebrae.



Glossary of terms associated with the anatomy of the spine:

Vertebrae - The spine has 33 doughnut-shaped bones called vertebrae. Each vertebra is assigned a letter and a number that identifies its location in the spine.

Discs - Between each pair of vertebrae is a spongy cartilage, or disc.

- Intervertebral discs act as shock-absorbing cushions.
- Spongy disks are located between the vertebrae.

Spinal cord - nerve tissue that extends from the brain and is protected by the spine. It carries information between the body and the brain via the nerve roots.

Nerve root - the main nerve branch off the spinal cord, leaving the spine through openings between the vertebrae at the level of the disc.

Facet joint - paired joints which attach the rear section of one vertebra to those above and below.

Sacroiliac joint - where the sacral spine attaches to the pelvis.

Tendon - tough fibrous tissue which attaches muscle to bone.

Ligament - tough fibrous tissue which attaches bone to bone which provides joint stability.

The shoulder girdle connects the upper limbs with the thorax and consists of four bones:

- Two Clavicles (known as the collar bones)
- Two Scapulae (known as the shoulder blades)

The clavicle is a doubly curved short bone that connects the arm (upper limb) to the body (trunk), located directly above the first rib. It acts as a shunt to keep the scapula in position so the arm can hang freely. Medially, it articulates with the manubrium of the sternum (breast-bone) at the sternoclavicular joint. At its lateral end it articulates with the acromion process of the scapula (shoulder blade) at the acromioclavicular joint. It has a rounded medial end and a flattened lateral end.

From the roughly pyramidal sternal end, each clavicle curves laterally and posteriorly for roughly half its length. It then forms a smooth posterior curve to articulate with a process of the scapula (acromion). The flat, acromial end of the clavicle is broader than the sternal end. The acromial end has a rough inferior surface that bears prominent lines and tubercles. These surface features are attachment sites for muscles and ligaments of the shoulder.

The clavicle serves several functions:

- It serves as a rigid support from which the scapula and free limb are suspended. This arrangement keeps the upper limb (arm) away from the thorax so that the arm has maximum range of movement.
- Covers the cervicoaxillary canal (passageway between the neck and arm), through which several important structures pass.
- Transmits physical impacts from the upper limb to the axial skeleton.

Even though it is classified as a long bone, the clavicle has no medullary (bone marrow) cavity like other long bones. It is made up of spongy (cancellous) bone with a shell of compact bone. It is a dermal bone derived from elements originally attached to the skull.

**Anterior View****Lateral View****Posterior View**

The Scapula

The Scapula has two surfaces, three borders, three angles and three projections.

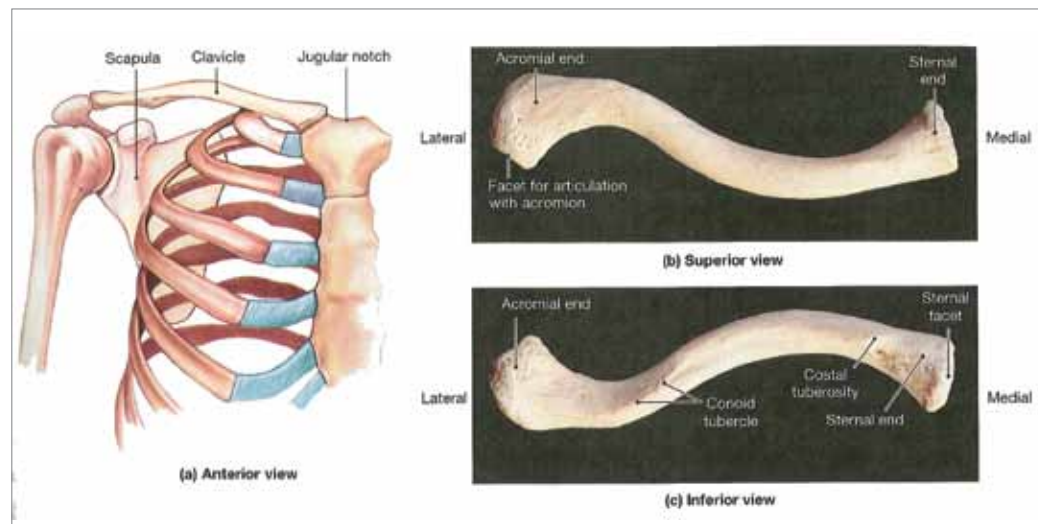
The anterior (front) side of the scapula shows the fossa subscapularis (subscapular fossa) to which the subscapularis muscle attaches. In animals, this side is referred to as medial or costal (since it faces the ribs and the middle part of the animal) and also shows the facies serrata, for the insertion of the ventral (anterior) serratus muscle.

The posterior surface (lateral in animals) of the scapula is divided by a bony projection, the spina scapulae (opposite to the fossa subscapularis) into the supraspinous fossa and the infraspinous fossa. This projection is called the spine of the scapula. It begins flat at the base of the shoulder bone, ascends in distal direction to its peak at about the middle of the scapula.

For humans the spine of the scapula runs into a forward pointing hook called acromion, which continues past the main part of the bone.

Another hook-like projection comes off the lateral angle of the scapula, and is called the coracoid process. The end of this hook is the site of attachment of many muscles, such as the coracobrachialis muscle.

Near the base of the coracoid process, so also on the lateral angle, there is a depression called the glenoid cavity. This forms the socket that the head of the humerus articulates with. The scapula also articulates with the clavicle, via the acromion process (the acromioclavicular joint).



Bones of the upper limbs

The following bones are considered to be part of the upper limb:

- Clavicle - the only bone that directly articulates with the trunk
- Scapula
- Humerus
- Radius
- Ulna
- Carpal bones
- Metacarpals
- Phalanges

The **humerus** is a long bone in the arm or forelimb that runs from the shoulder to the elbow. Skeletally, it fits between the scapula and the ulna, and consists of the following three sections:

- Upper extremity of humerus
- Body of humerus
- Lower extremity of humerus

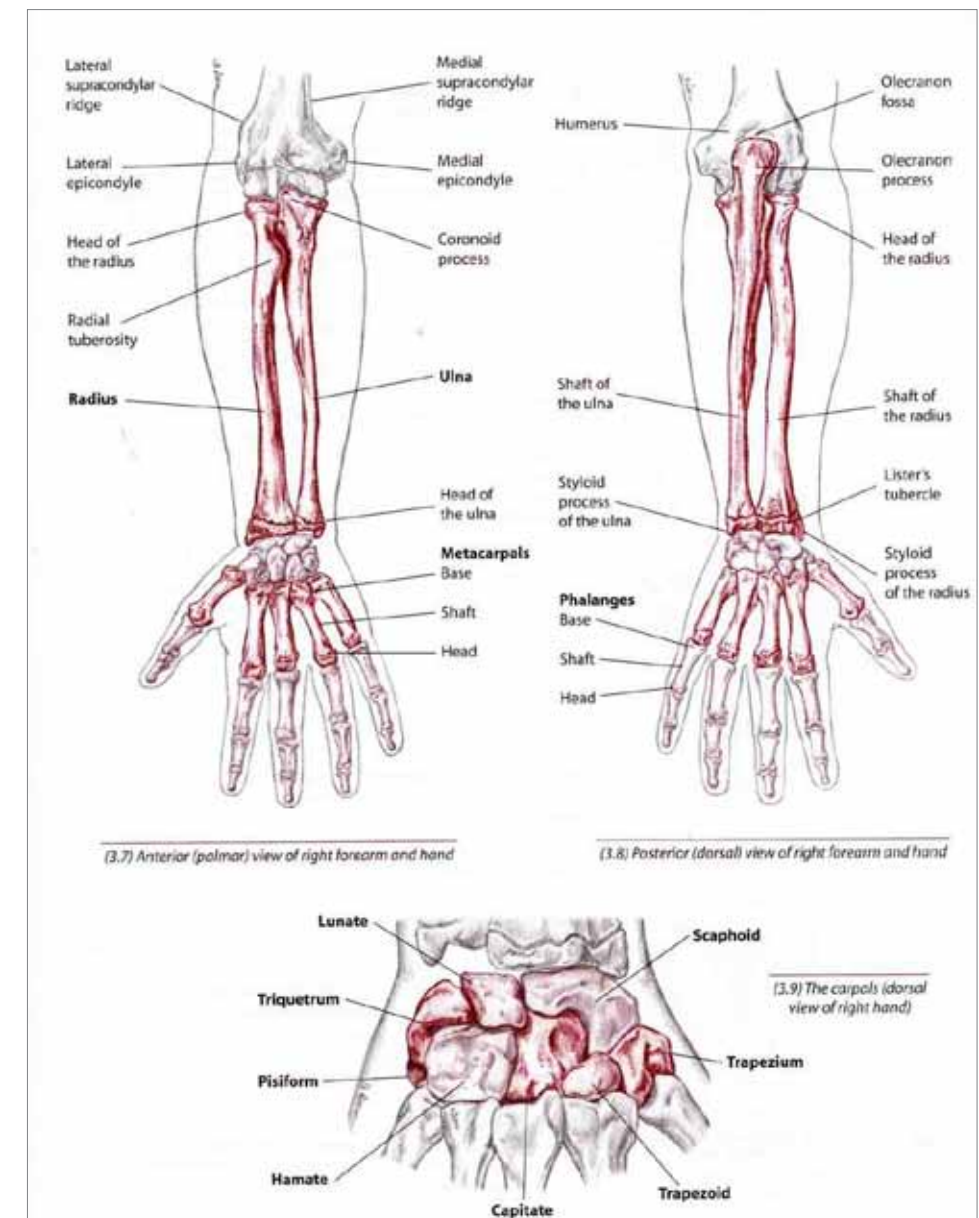
Muscle attachments

A variety of muscles attach to the humerus, enabling movement at the elbow and at the shoulder. The rotator cuff muscles attach at the proximal end of the humerus, allowing for the movement of the arm at the shoulder. Some of the forearm muscles, such as pronator teres and the flexors and extensors of the wrist, attach to the distal end.

The Radius & Ulna are the two long bones of the forearm and the bones are allowed to pass over each other because they are bound by a fibrous ring to allow a 'rotating' movement.

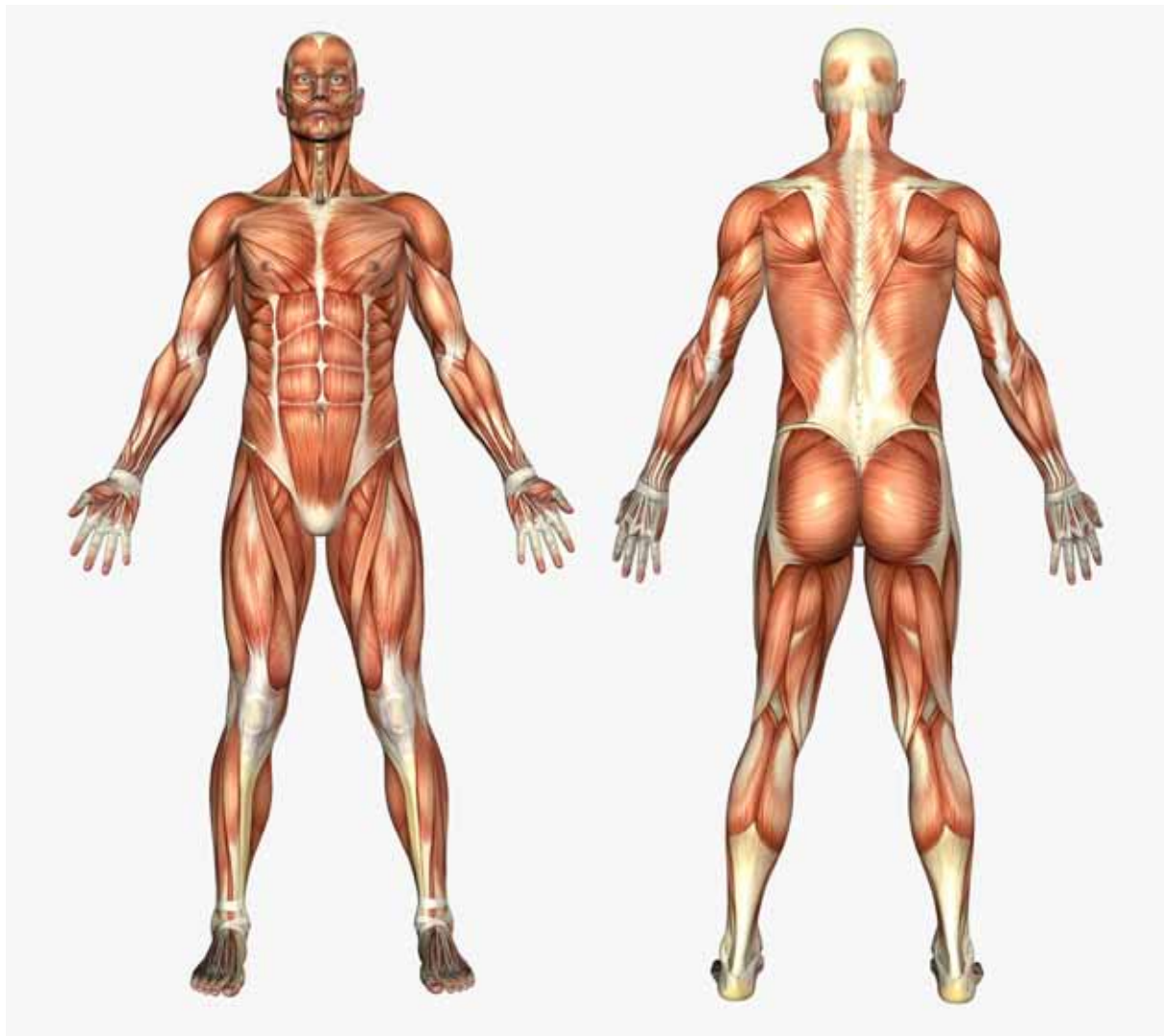
The ulna is on the side where the little finger is located and the radius is located on the thumb side of the forearm.

The forearm allows for a supination movement and a pronation movement, which means that the arm can rotate so that the thumb can be closer to the body or rotate so that it is lateral to the body. The Carpals, Metacarpals and the Phalanges are the bones of the wrist, hand and fingers.



The Muscular System

The human body contains more than 650 individual muscles, which are attached to the skeleton; this provides the pulling power for us to move around. The main job of the muscular system is to provide movement for the body. The muscular system consists of three different types of tissue: Skeletal, Cardiac & Smooth muscles. Each of these different tissues has the ability to contract, which allows body movements and functions. There are two types of muscles in the muscular system - they are 'Voluntary' (muscles we can control by ourselves) and 'Involuntary' (not under our control) muscles. The heart (cardiac muscle) is an example of involuntary muscle.



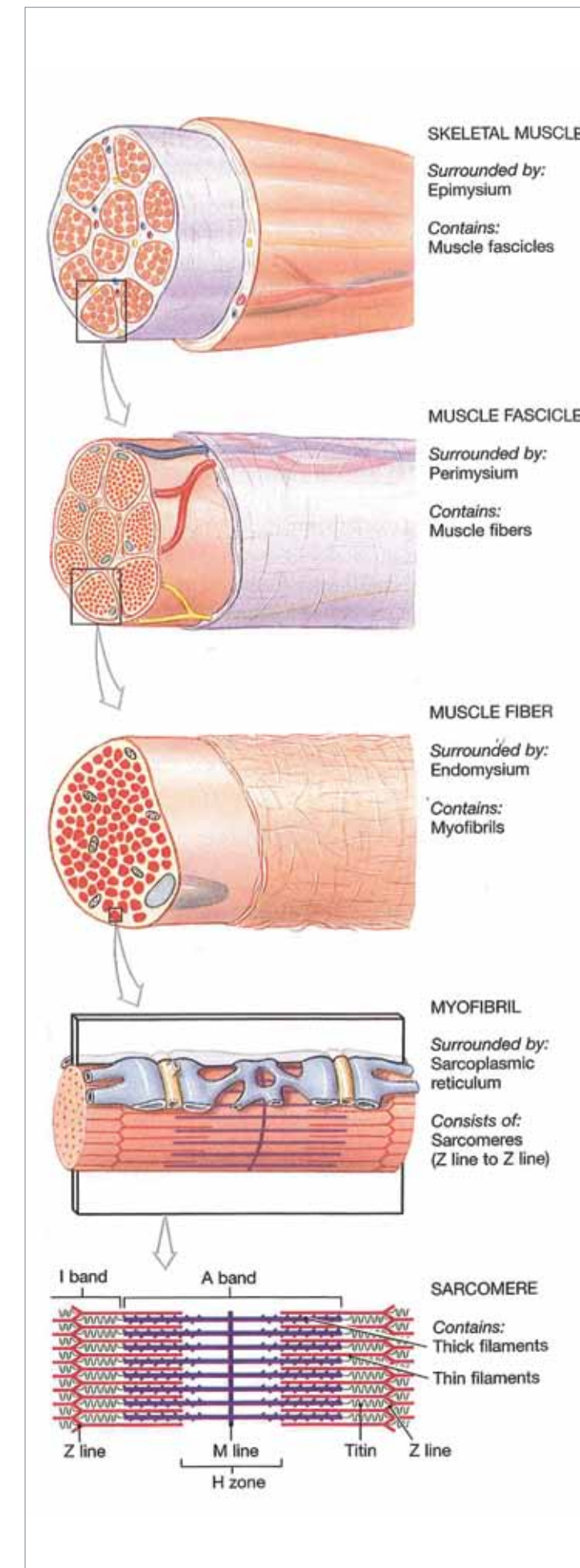
Skeletal Muscles

Skeletal muscle makes up about 40 per cent of an adult's body weight. It has stripe-like markings, or striations. Skeletal muscles are composed of long muscle fibres. Many of the skeletal muscle contractions are automatic. However we still can control the action of the skeletal muscle; for this reason skeletal muscle is 'voluntary' muscle.

These muscles function in pairs or groups, each having the opposite function of the other. In other words muscles that flex the forearm. For example, this must be complemented by muscles that extend the same structure. One end of each muscle is generally termed the origin, the other the

insertion, and the muscle mass itself is sometimes referred to as the belly.

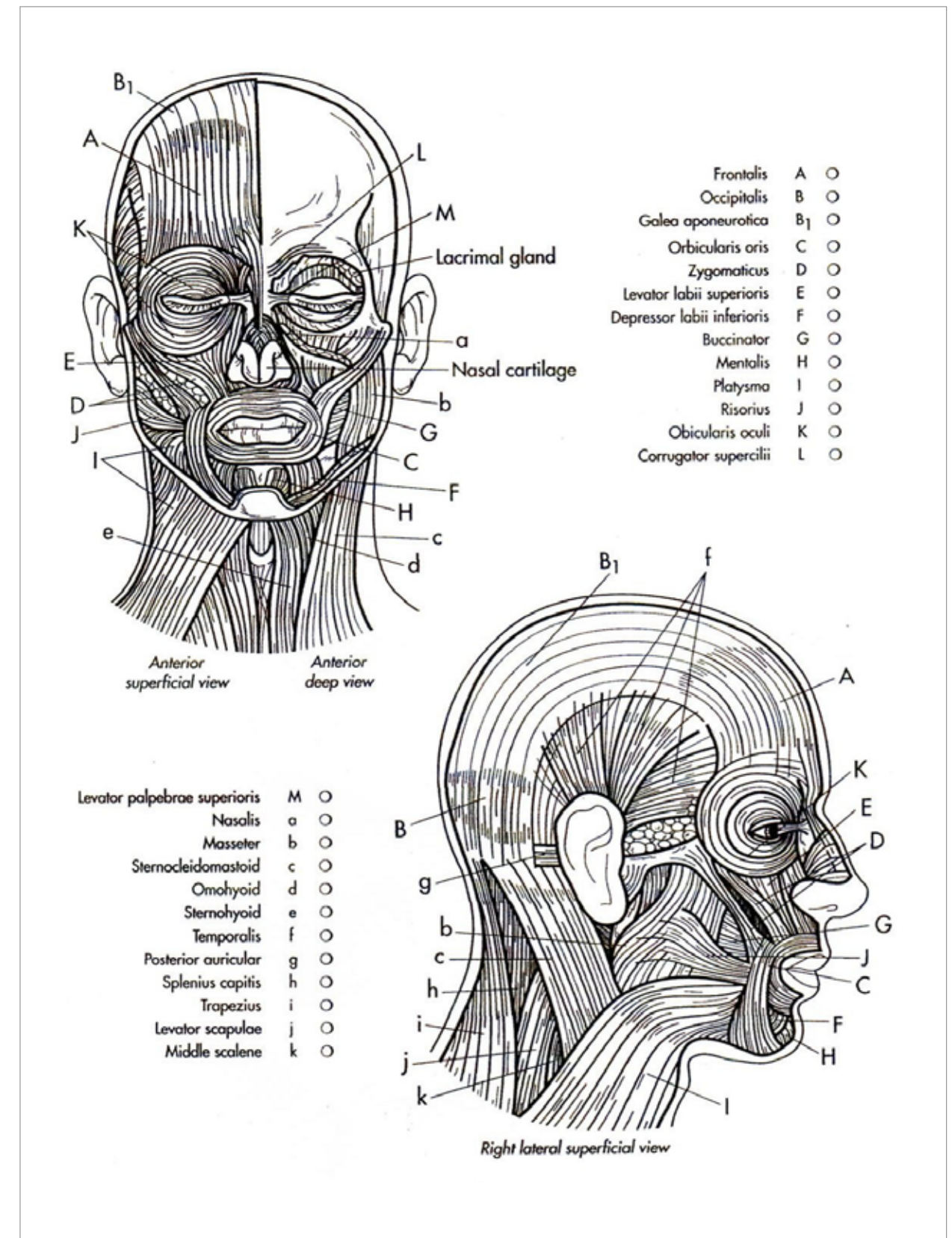
- Origin: the end of the muscle that is relatively stationary during contraction.
- Insertion: the end of the muscle that moves toward the origin during contraction.



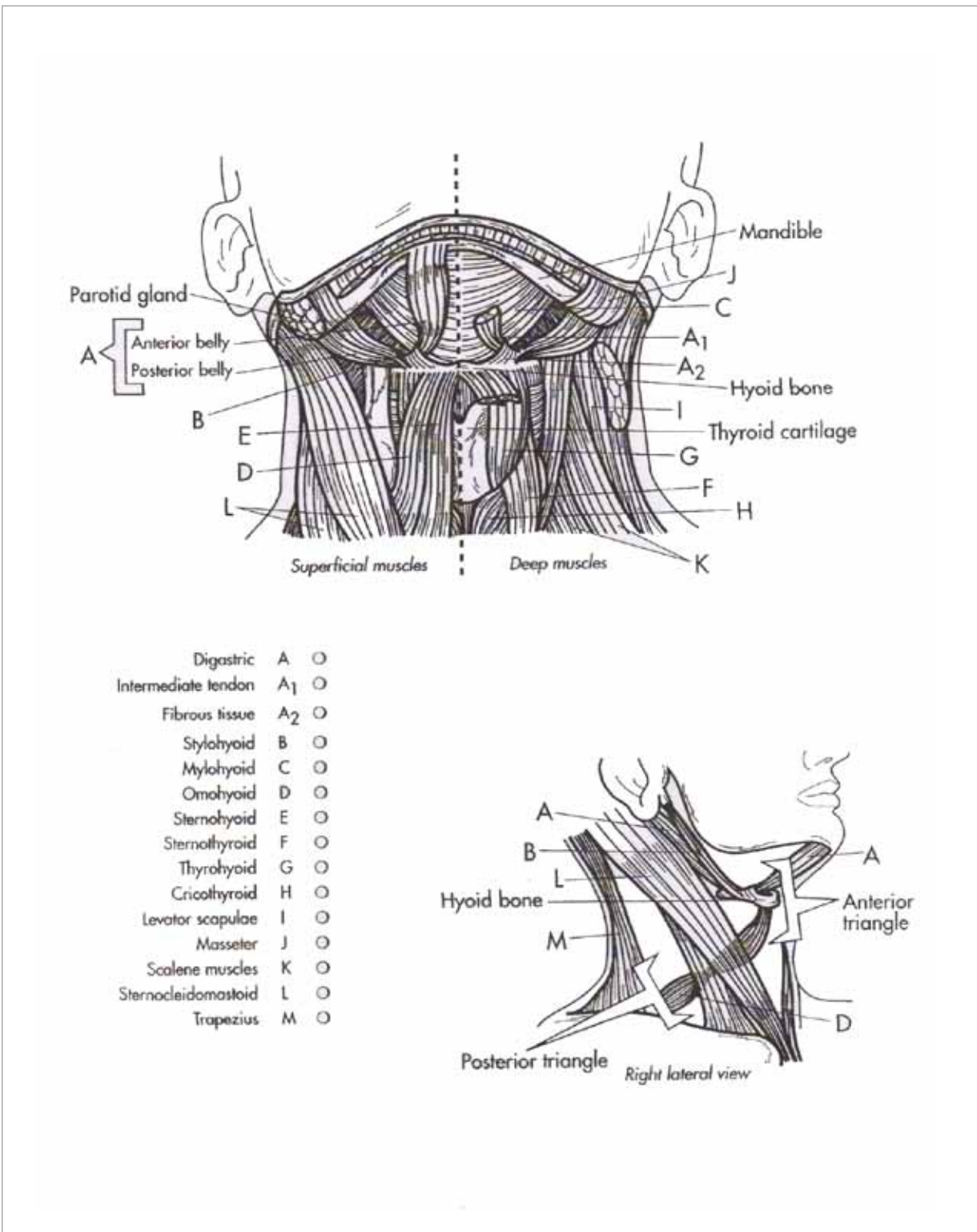
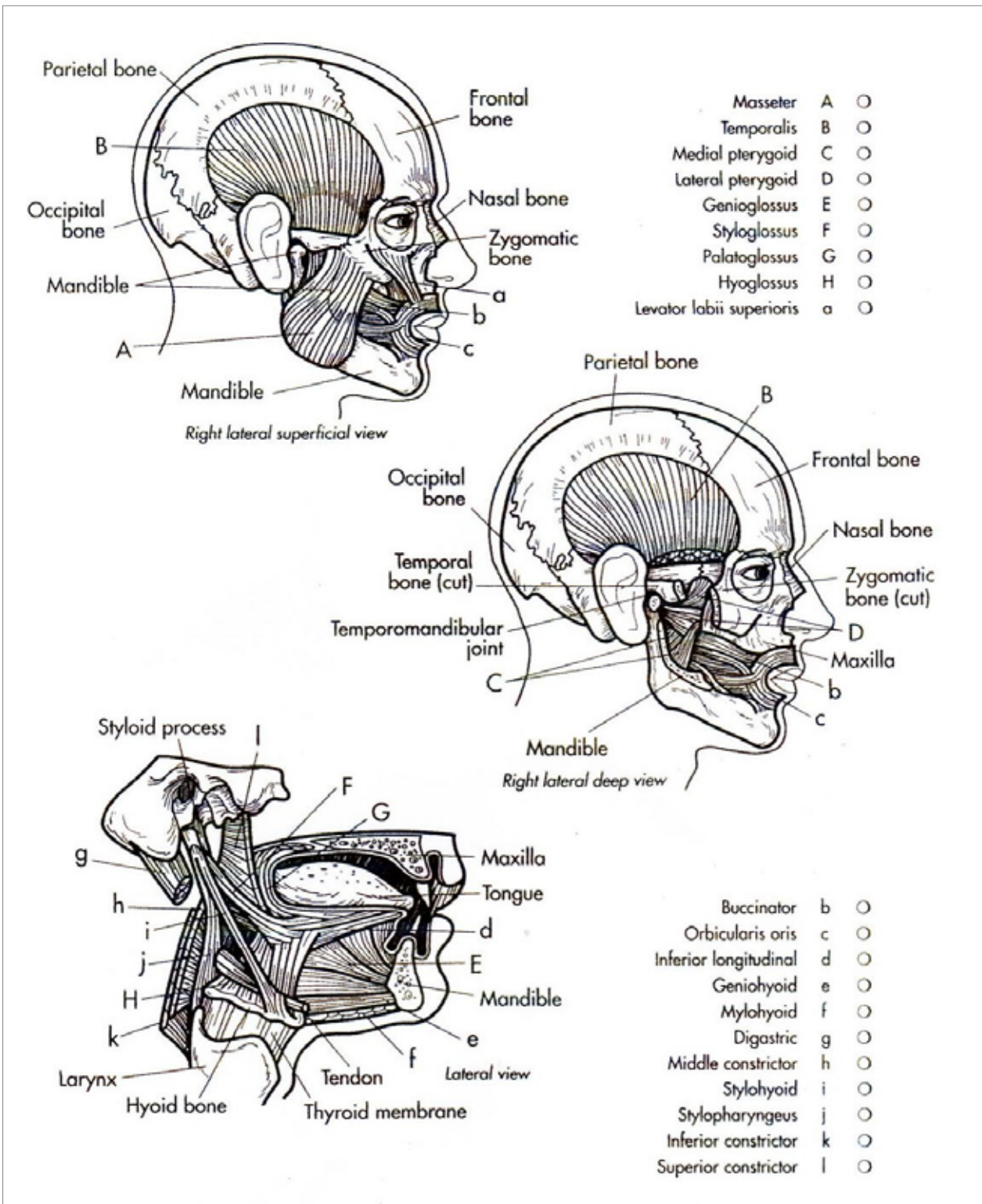
Location, Action & Expression

Muscle	Location	Action	Expression
Frontalis	forehead	pulls scalp forwards raises eyebrows horizontal wrinkles across forehead	surprise
Occipitalis	back of head	moves scalp at back of head	
Orbicularis oculi	surrounds eyes	opens and closes the eyelid wrinkles skin around the eyes	winking
Corrugator	extends along the line of eyebrows	draws eyebrows together (downwards and inwards) causes vertical wrinkles between brows	frown
Procerus	covers top of nose	compresses nostrils	annoyance
Nasalis	tip of nose	opens and closes lips presses them forwards	anger
Orbicularis oris	surrounds mouth	draws corners of mouth outwards compresses cheeks	pout, kiss, doubt
Risorius	extends diagonally from corners of mouth	draws corners of mouth outwards compresses cheeks	smiling, grinning
Buccinator	inside of cheeks - lies between upper and lower jaw	compresses cheeks helps chewing movements	blowing
Zygomaticus	extends from zygomatic bone to angle of mouth	lifts corner of mouth upwards and backwards	smiling, laughing
Mentalis	chin	lifts skin of chin lifts lower lip outwards causing chin to wrinkle	doubt
Masseutte	cheek area - extends from zygomatic bone to angle of jaw	clenches the teeth, closes and raises the lower jaw when muscle loses its tone produces jowls	
Temporalis	fan-shaped muscle of side of head in front of ear (extends from temporal bone to the mandible)	raises the jaw to close the mouth and draw it backwards as it helps with mastication	
Platysma	side of neck and chin	draws corners of mouth downwards and backwards causing skin to wrinkle	fear, shock

Muscles of Jaw and Tongue



Muscles of Neck and Oral Cavity



Cardiac Muscle

Cardiac muscle is like skeletal muscle in that it is striated and multinucleate, and like smooth muscle in that the nuclei are centrally located and many cells are required to span the length of the muscle. Cardiac muscle is the tissue that makes up the wall of the heart - it is called the Myocardium; it is under control of the autonomic nervous system. The cardiac muscle is a special type of muscle, not only because it is attached together instead of attached to bone, but because it has 2 distinct differences from other muscle tissue, these are:

- it has a 'branch' like structure
- it has something called intercalated discs between each cell. This structure assists the rapid transmission of electrical impulses throughout the heart. The heart beats by electrically charged muscular contractions which makes it unique.

How does the heart muscle contract and cause a heartbeat?

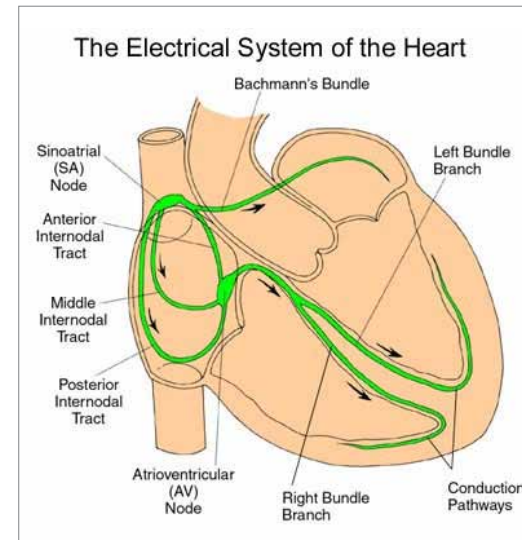
The heart has a natural pacemaker that regulates the pace or rate of the heart. It sits in the upper portion of the right atrium and is a collection of specialized electrical cells known as the SINUS or SINO-ATRIAL (SA) node.

Like the spark-plug of an automobile it generates a number of "sparks" per minute. Each "spark" travels across a specialized electrical conduction pathway (see diagram below) and stimulates the muscle wall of the four chambers of the heart to contract (and thus empty) in a certain sequence or pattern.

The upper chambers or atria are first stimulated. This is followed by a slight delay to allow the two atria to empty. Finally, the two ventricles are electrically stimulated.

In an automobile, the number of sparks per minute generated by a spark plug is increased when you press the gas pedal or accelerator; this revs up the motor.

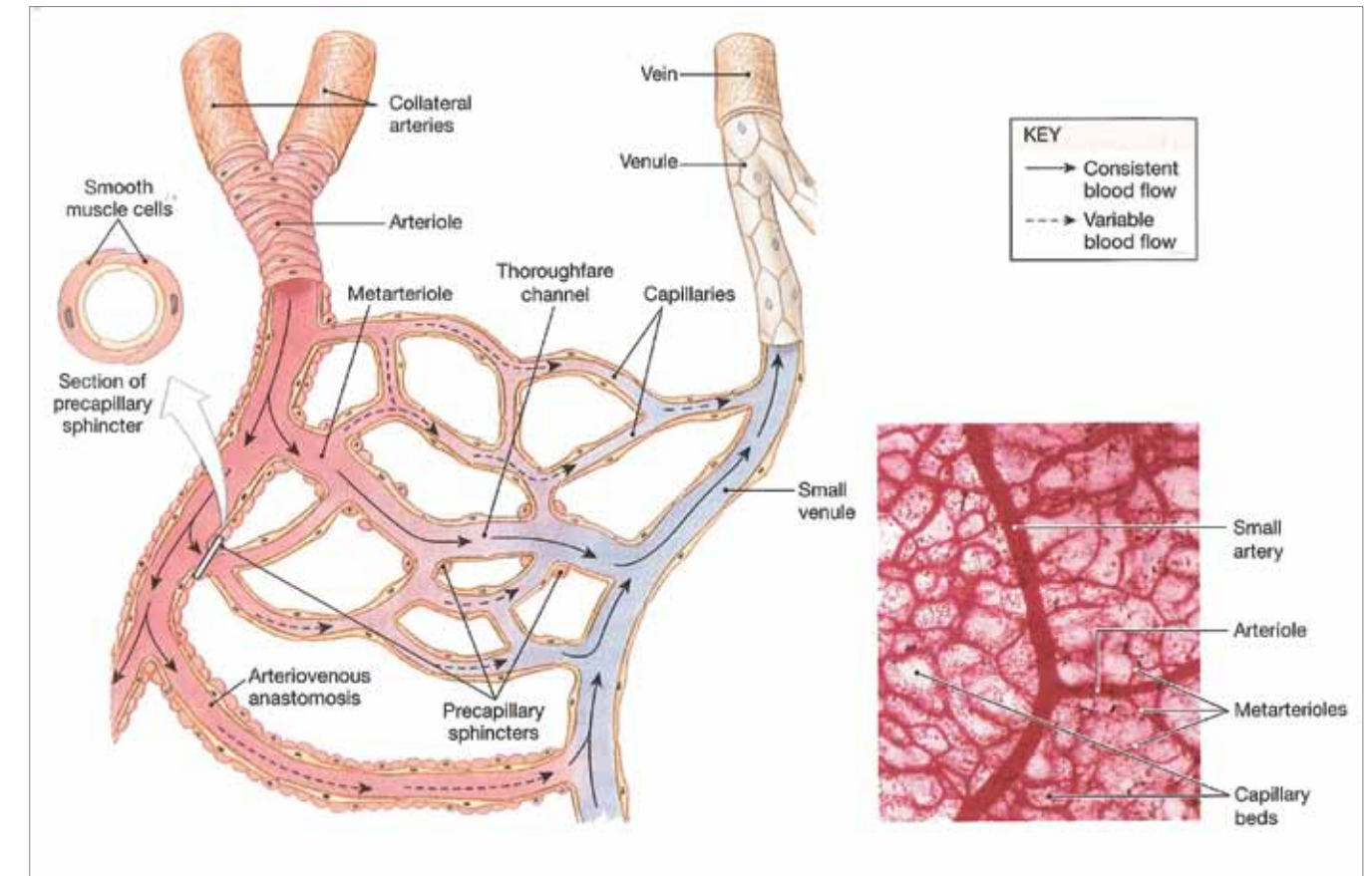
In the heart's case, adrenaline acts as a gas pedal and causes the sinus node to increase the number of sparks per minute, which in turn increases the heart rate. The release of adrenaline is controlled by the autonomic nervous system. The heart normally beats at around 72 times per minute and the sinus node speeds up during exertion, emotional stress, fever, etc. or whenever our body needs an extra boost of blood supply. In contrast, it slows down during rest or under the influence of certain medications.



Smooth Muscles

Much of our internal organs are made up of smooth muscles. They are found in the urinary bladder, gallbladder, esophagus and stomach, arteries, and veins. The smooth muscles are controlled by the nervous system and hormones. We cannot consciously control the smooth muscle; for this reason they are classed as 'involuntary' muscles.

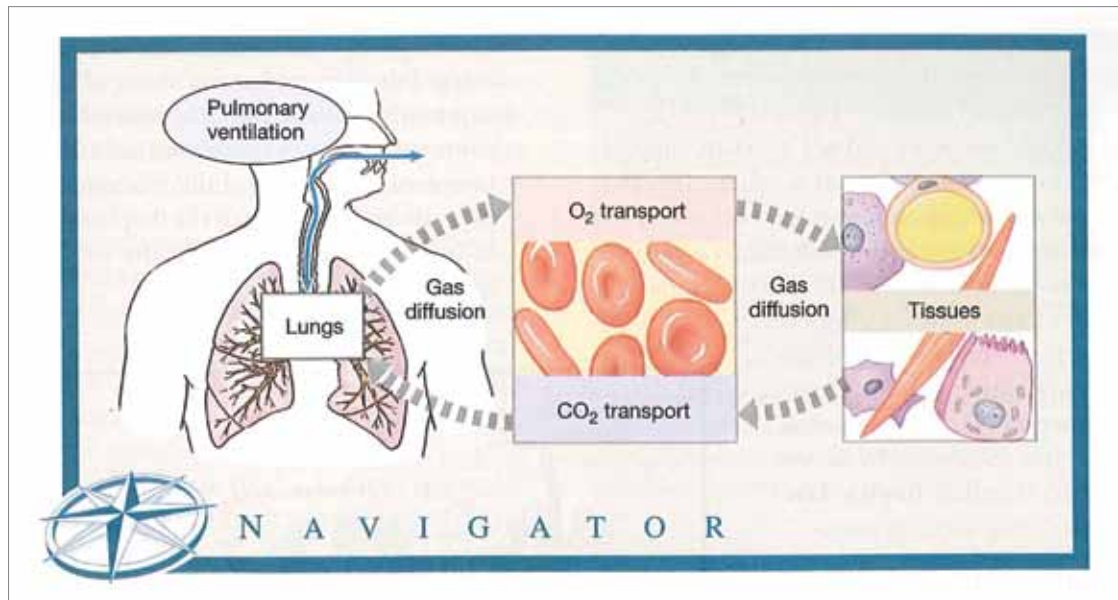
Examples of smooth or involuntary muscles found in the esophagus and stomach as part of the digestive system.



The Respiratory System

The primary functions of the respiratory system are two-fold:

- To supply the blood with Oxygen so that 'oxygenated' blood can perfuse cells all over the body with oxygen
- To remove the waste product of respiration within each cell – Carbon Dioxide



The respiratory system does this through breathing. When we breathe, we inhale oxygen into the respiratory system and we exhale carbon dioxide. This exchange of gases is the respiratory system's means of getting oxygen to the blood and waste carbon dioxide out.

The Respiratory system is composed of:

- The Trachea (windpipe or airway) which is connected to the mouth via the larynx
- The Bronchi which divide into 2 smaller tubes from the Trachea and connect to each Lung
- The Lungs themselves are filled with tiny airways and air sacs (called Alveoli)
- The Diaphragm, which is the large dome shaped muscle underneath the ribcage and contracts upwards and downwards

The average adult's lungs contain about 600 million of these spongy, air-filled sacs (alveoli) that are surrounded by capillaries. The inhaled oxygen passes into the alveoli and then diffuses through the capillaries into the arterial blood. Meanwhile, the waste-rich blood from the veins releases its carbon dioxide into the alveoli. The carbon dioxide follows the same path out of the lungs when you exhale.

The diaphragm's job is to help pump the carbon dioxide out of the lungs and pull the oxygen into the lungs. As the diaphragm contracts and relaxes, breathing takes place. When the diaphragm contracts, oxygen is pulled into the lungs; when the diaphragm relaxes, the lungs compress carbon dioxide out of the lungs. This exchange of gases happens in collaboration with the circulatory system.

Gaseous exchange takes place in the alveoli. There are some 300 million alveoli in two adult lungs. These provide a surface area of some 160 m² (almost equal to the singles area of a tennis court and 80 times the area of our skin).

Breathing

Breathing

In mammals, the diaphragm divides the body cavity into the:

- abdominal cavity, which contains the viscera (e.g. stomach and intestines) and;
- thoracic cavity, which contains the heart and lungs

The inner surface of the thoracic cavity and the outer surface of the lungs are lined with pleural membranes which adhere to each other. If air is introduced between them, the adhesion is broken and the natural elasticity of the lung causes it to collapse. This can occur from trauma, and it is sometimes induced deliberately to allow the lung to rest. In either case, 're-inflation' occurs as the air is gradually absorbed by the tissues. Because of this adhesion, any action that increases the volume of the thoracic cavity causes the lungs to expand, drawing air into them.

The mechanics of breathing

- air enters the nostrils
- passes through the nasopharynx,
- the oral pharynx
- through the glottis
- into the trachea

During inspiration (inhaling):

- The external intercostal muscles contract, lifting the ribs up and out.
- The diaphragm contracts, drawing it down – air is drawn in.

During expiration (exhaling):

- These processes are reversed and the natural elasticity of the lungs returns them to their normal volume and we breathe out. At rest, we breathe 15-18 times a minute exchanging about 500 ml of air.

In more vigorous expiration:

- The internal intercostal muscles draw the ribs down and inward. The wall of the abdomen contracts pushing the stomach and liver upward.

Under these conditions, an average adult male can flush his lungs with about 4 litres of air at each breath. This is called the vital capacity. Even with maximum expiration, about 1200 ml of residual air remain.

The table (see right) shows what happens to the composition of air when it reaches the alveoli. Some of the oxygen dissolves in the film of moisture covering the epithelium of the alveoli. From here it diffuses into the blood in a nearby capillary. It enters a red blood cell and combines with the haemoglobin therein.

At the same time, some of the carbon dioxide in the blood diffuses into the alveoli from which it can be exhaled.

Composition of atmospheric air and expired air in a typical subject.

Note that only a fraction of the oxygen inhaled is taken up by the lungs.

Component	Atmospheric air (%)	Expired air (%)
N ₂ (plus inert gases)	78.62	74.9
O ₂	20.85	15.3
CO ₂	0.03	3.6
H ₂ O	0.5	6.2
Total	100.0	100.0

Central Control of Breathing

The rate of cellular respiration (and hence oxygen consumption and carbon dioxide production) varies with level of activity. Vigorous exercise can increase by 20-25 times the demand of the tissues for oxygen. This is met by increasing the rate and depth of breathing.

It is a rising concentration of carbon dioxide — not a declining concentration of oxygen — that plays the major role in regulating the ventilation of the lungs. The concentration of CO₂ is monitored by cells in the medulla oblongata. If the level rises, the medulla responds by increasing the activity of the motor nerves that control the intercostal muscles and diaphragm.

However, the carotid body in the carotid arteries does have receptors that respond to a drop in oxygen. Their activation is important in situations (e.g., at high altitude in the unpressurized cabin of an aircraft) where oxygen supply is inadequate but there has been no increase in the production of CO₂.

Local Control of Breathing

The smooth muscle in the walls of the bronchioles is very sensitive to the concentration of carbon dioxide. A rising level of CO₂ causes the bronchioles to dilate. This lowers the resistance in the airways and thus increases the flow of air in and out.

The function of the circulatory system is to transport nutrients, oxygen from the lungs and water to all parts of the body. In reverse it transports away the carbon dioxide as a by-product of respiration in the blood cells to the lungs for exhalation (see Respiratory System) – the system comprises of:

The Heart – a muscular pump, which beats on average and at rest, around 72 times per minute in a normal, healthy adult

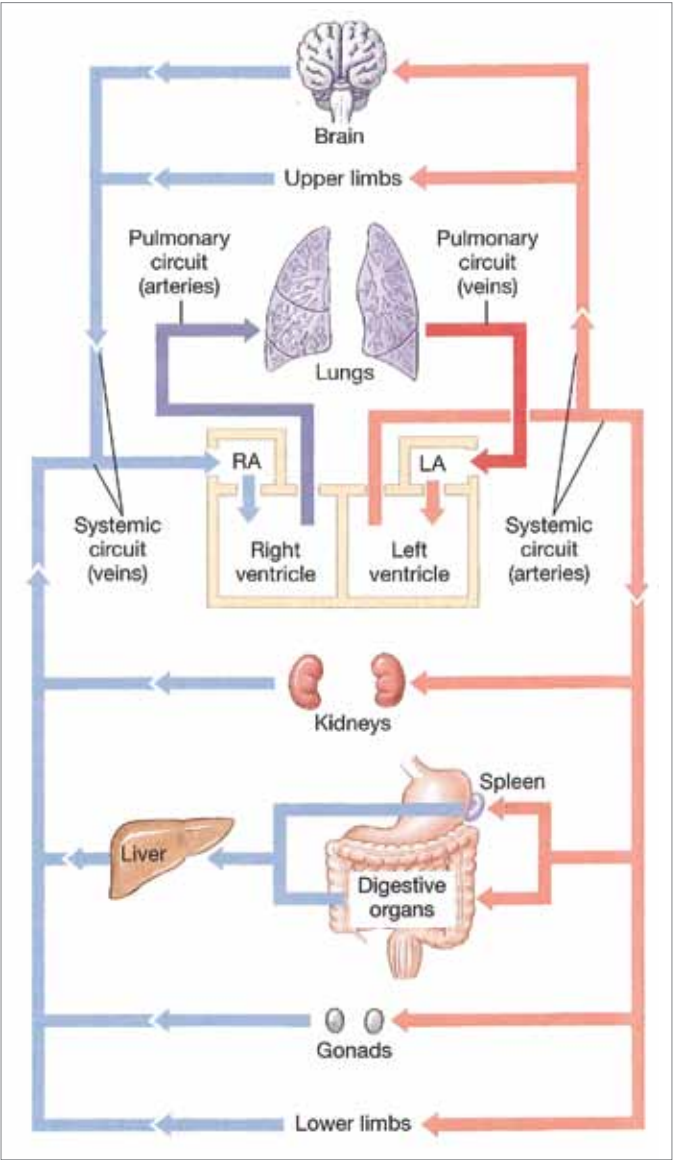
The Arteries - carry oxygenated blood away from the heart to the body

The veins - return de-oxygenated (containing carbon dioxide) blood from the body back to the heart and onwards to the lungs to rid itself of Carbon dioxide and to be reoxygenated

Red blood cells carry oxygen and carbon dioxide around the body.

- White Blood cells** (lymphocytes, and phagocyte cells)
- The lymphocytes are concerned with the body's immune system.
 - The phagocyte cells are further subdivided into the Granulocyte & Monocyte cells, and their function is to break down any foreign particles and microorganisms, and protect against infection.

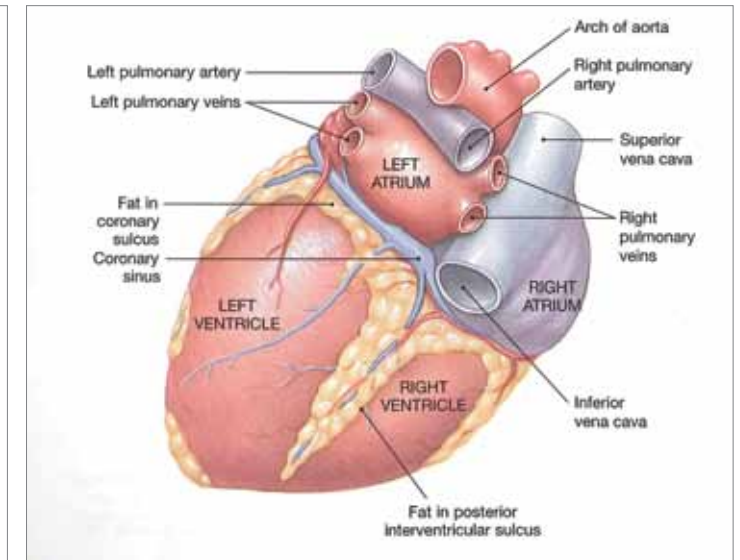
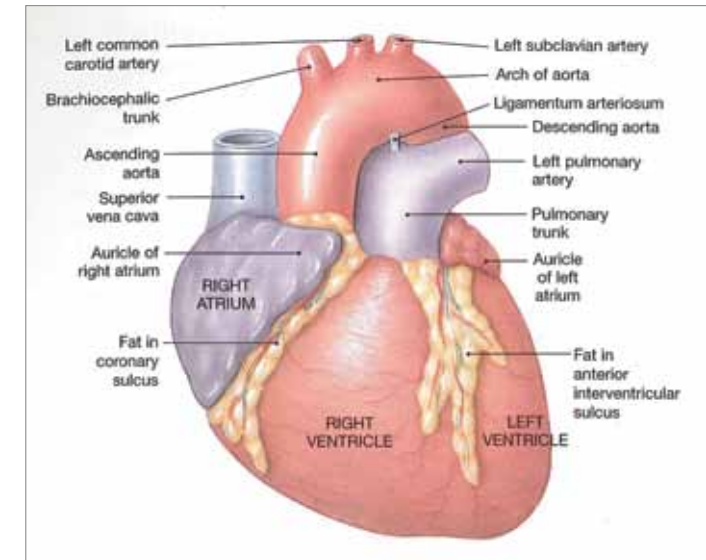
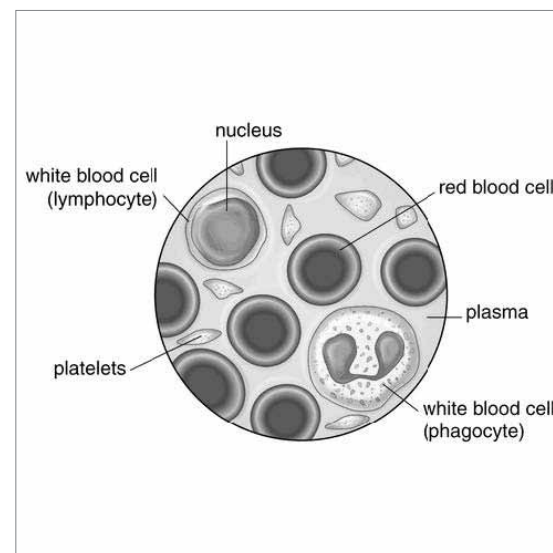
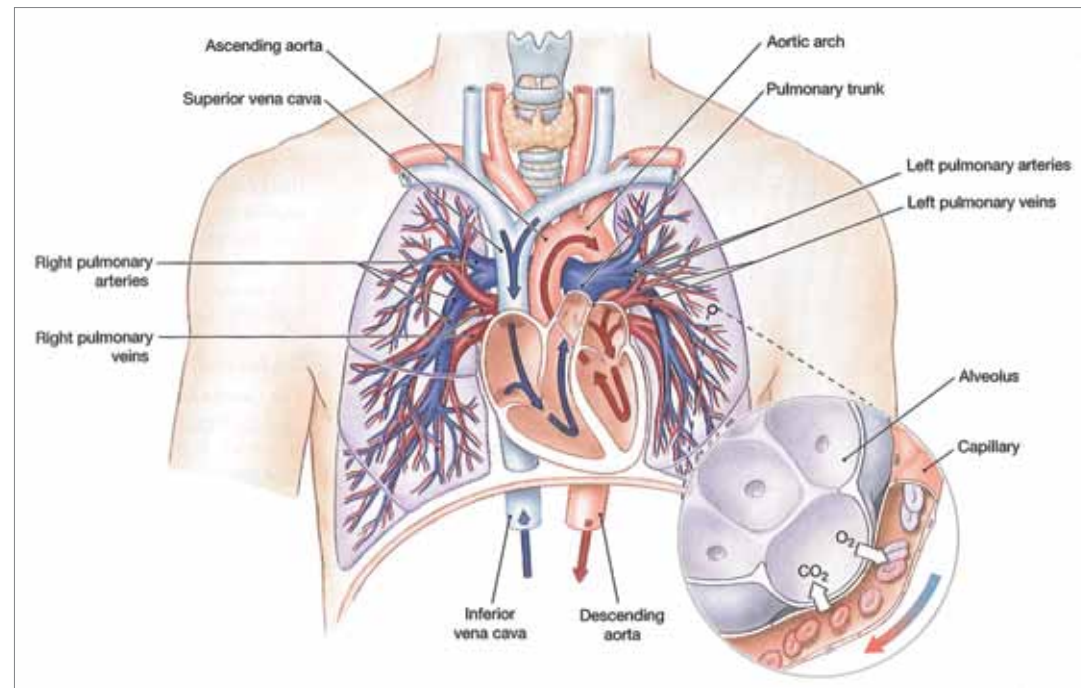
Platelets
Fragments of old red blood cells called Platelets; the platelets form blood clots when we cut ourselves;



The flow of Blood through the Circulatory System via the Lungs and Heart – remember that the blood flows to all vital organs such as the brain in the head area, Liver, Stomach, etc through specialised arteries and veins. The Red blood in the diagram is oxygenated, meaning that it is full of fresh oxygen from the Pulmonary element of the circulatory system. The Blue coloured blood represents de-oxygenated blood – meaning that oxygen has been used by the body and carbon dioxide as a waste product of respiration has been removed.

The Capillaries are very tiny blood vessels, which interact between the arteries and the veins. They act as an exchange system for digested food and oxygen between the blood and the body cells, and from body cells to the blood when transporting waste. For example, muscles need oxygen to function as well as glucose and amino acids. Muscles expand and contract, and the blood takes the correct proportions of sodium potassium and calcium salts to the muscles for this process.

The Pulmonary (or lung) element of circulation is important, as the lungs have to re-oxygenate the blood. This re-oxygenated blood is drawn into the left side of the heart, and is then transported out into the blood or circulatory system.



The heart muscle is a very efficient pump that delivers blood, oxygen and nutrients to your body.

Right side

First the oxygen-depleted blood enters the heart through two large veins, the inferior and superior vena cava and then flows into the right atrium. From the right atrium, it passes through the tricuspid valve and then into the right ventricle. The blood is then pumped through the pulmonary valve and into the lungs.

Once in the lungs, carbon dioxide is removed and oxygen is added to the blood.

Left side

The pulmonary vein empties oxygen-rich blood, from the lungs, into the left atrium. From here, the blood flows from the atrium into your left ventricle through the open mitral valve and finally, it is pumped through the aortic valve into the aorta - the blood vessel that feeds all of the other parts of your body.

When the ventricles are full, the mitral and tricuspid valves close. This prevents blood from flowing backward into the atria while the ventricles contract (squeeze) or “pump.” This pattern is repeated continuously throughout your life, causing blood to flow continuously to the heart, lungs and other parts of the body.

How does the heart beat?

The atria and ventricles work together by alternately contracting (squeezing) and relaxing to pump blood through your heart. The heartbeat is triggered by electrical impulses that travel down a special pathway through your heart. The electrical system of your heart is the power source that makes this beating possible.

The Lymphatic System

The lymphatic system is a part of the circulatory system entwined with the blood circulation which provides one way for the blood to leave the heart, the arterial system, and two ways for it to return.

The Lymphatic System consists of:

- Lymphatic Vessels – Capillaries, Lymphatics, Nodes & Ducts
- Lymph
- Spleen
- Thymus
- Adenoids
- Tonsils
- Appendix
- Peyer's Patches (found in the small intestine only)

The Lymphatic System's principal functions are to:

- Act as a Drainage System by collecting and returning interstitial fluid, including plasma protein to the blood, thus helping to maintain fluid balance and prevent oedema.
- Remove waste from cells
- Supply nourishment to cells
- Return larger protein molecules back to bloodstream
- Act as a Defence System, Combats infections & generates antibodies by producing lymphocytes.
- Act as a fat absorption system (lipids) from the intestine and transport them to the blood.

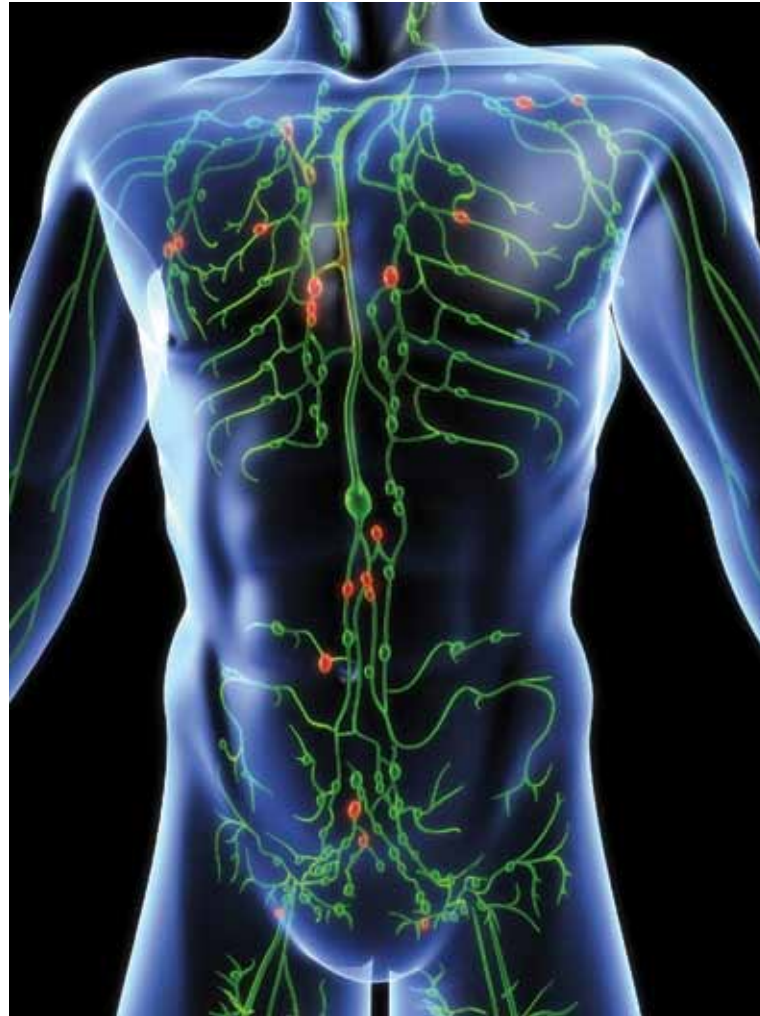
It is also worth noting that:-

- Small amounts of diffuse lymphatic tissue are found in virtually every organ of the body.
- In addition, the spleen and the thymus gland are considered to be lymphatic tissue.

What is Lymph?

Blood travels to and from the body tissues. A derivative of blood plasma, known as interstitial fluid, escapes from the blood capillaries and delivers nutrients such as oxygen, glucose, proteins. Interstitial fluid then collects carbon dioxide, lactic acid and other waste products. However, not all can pass through the capillary walls due to high pressure inside the capillaries. The fluid that is left behind is picked up by lymphatic capillaries. Once interstitial fluid enters a lymph capillary, it is referred to as lymph.

Fluid and dissolved substances are continually being filtered out of the blood. Approximately 90 per cent of this tissue fluid moves back into the blood capillaries and carried away as part of the venous blood. The other 10 per cent is drained by the lymphatic capillaries that surround the blood capillaries.



Lymphatic Vessels

Lymphatic vessels are found throughout the body, in parallel with the capillary system. The vessels are as small in diameter as the capillaries, and the nodes are about the size of a pea. If you picture a string with knots tied in it along its length, the string is the lymph vessel, and the knots are the lymph nodes.

If the pathways become congested, damaged or severed, then fluids and toxins can build up in the connective tissue and eventually cell pathology may begin. Cellular oxygenation and nourishment is reduced, as is waste elimination. Toxins eventually penetrate the cells and create the symptoms of chronic disease. So lymph drainage can enhance recovery rates, by moving out toxins and wastes, boosting immunity and oxygenation, and reducing inflammation.

The lymphatic circulation as a drainage system

The lymphatic system has neither a heart nor arteries to move lymph around the body. Its microscopic dead-end capillaries extend into most tissues, paralleling the blood capillaries. It's job is maintaining fluid balance to:

- Collect excess interstitial fluid and return it to the blood (approximately 3 litres daily).
- Return plasma proteins to the blood. Segments of the lymphatic vessels located between its valves contract rhythmically, propelling the lymph along. The rate of these contractions is related to the volume of fluid in the vessel - the more fluid, the more rapid the contractions, and the more rapid the contractions, the more fluid that is able to move.

This means that when a person is dehydrated, there is not enough fluid volume to move throughout the system. When this happens, debris and foreign particles, mainly viruses and bacteria, are able to proliferate because they are not being phagocytized and washed away.

The three main types of lymphatic vessels are:

Lymph capillaries – these are microscopic tubes located between cells

Lymph capillaries resemble blood capillaries somewhat, but differ in important ways.

Whereas a blood capillary has an arterial and a venous end, a lymph capillary has no arterial end. Instead, each lymph capillary originates as a closed tube. Lymph capillaries also have a larger and more irregular lumen (inner space) than blood capillaries and are more permeable.

The wall of a lymph capillary is constructed of endothelial cells that overlap one another. When fluid outside the capillary pushes against the overlapping cells, they swing slightly inward-like a swinging door that moves in only one direction. Fluid inside the capillary cannot flow out through these openings.

Lymph capillaries branch and interconnect freely and extend into almost all tissues of the body except the CNS (Central Nervous System) and the avascular tissues such as the epidermis and the cartilage.

Lymphatics

These resemble blood-conducting veins but have thinner walls and relatively larger lumen; they also contain more valves.

In the skin, lymphatics are located in subcutaneous tissue and follow same paths as veins.

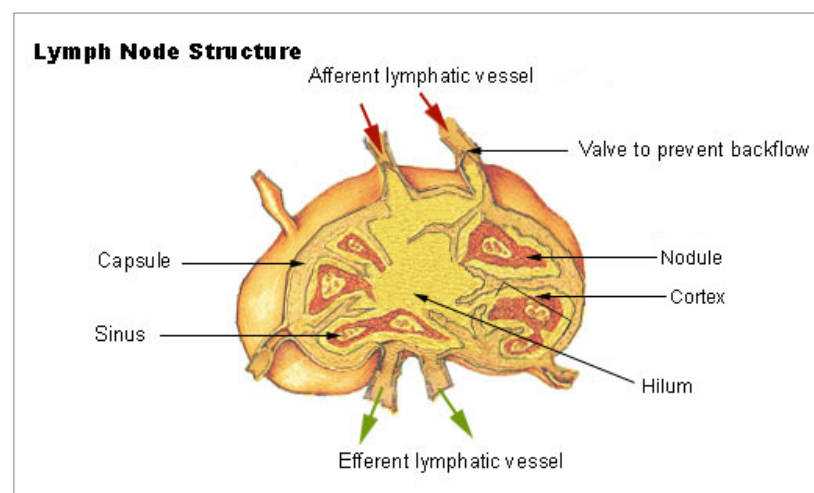
In the viscera (organs in the 3 major cavities of the body), lymphatics generally follow arteries and form plexuses (networks) around them.

Lymph Nodes

Lymph nodes are found all over the body and are connected by a network of tiny lymphatic vessels. The lymph nodes you are most likely to notice are in the neck, armpit and groin. The number of lymph nodes varies from one part of the body to another, in some parts there are very few whereas under each arm there may be between 20 and 50 nodes.

Functions of lymph nodes - Filtering and Phagocytosis

- Lymph is filtered by the reticular and lymphoid tissue as it passes through lymph nodes.
- Particulate matter may include microbes, dead and live phagocytes containing ingested microbes, cells from malignant tumours, worn out and damaged tissue cells, and inhaled particles.
- Organic material is destroyed in the lymph nodes by macrophages and antibodies.
- Some inorganic inhaled particles cannot be destroyed by phagocytosis. These remain inside the macrophage either causing no damage or destroying it.
- Material not filtered off and dealt with in one lymph node passes on to the next and so on. Thus by the time the lymph reaches the blood it has usually been cleaned of all impurities such as cell debris and foreign bodies.
- In some instances where phagocytation is incomplete the node may swell. Swelling of lymph nodes is often an indication of an infection. You may well have experienced swollen cervical lymph nodes. These often accompany a sore throat due to streptococcal infection. Infections in almost any part of the body may result in swelling and tenderness of the lymph nodes associated with that part of the body.
- Similar cells are also found elsewhere in the body, eg: Liver, Bone Marrow, spleen, Brain, Lungs and subcutaneous tissue.



Structure of Lymph Nodes

- Lymph nodes have a surrounding capsule of fibrous tissue which dips down into the node substance forming partitions, or trabeculae.
- The main substance of the node consists of reticular and lymphatic tissue containing many lymphocytes and macrophages.
- As many as four or five afferent lymph vessels may enter a lymph node while only one efferent vessel carries lymph away from the node.
- Each node has a concave surface called the hilum, where an artery enters a vein and the efferent lymph vessel leaves. The large numbers of lymph nodes are situated in strategic positions throughout the body, in deep and superficial groups.
- All the small and medium-sized lymph vessels open into lymph nodes which are situated in strategic positions throughout the body. The lymph drains through a number of nodes, usually 8 to 10, before returning to the blood. These nodes vary considerably in size: some are as small as a pinhead and the largest are about the size of an almond.
- Lymphatics leaving lymph nodes are called efferent lymph vessels and conduct lymph toward the shoulder region.
- Large lymphatics that drain groups of lymph nodes are often called lymph trunks.

Lymphatic Circulation

As previously mentioned, the Lymphatic system is a subdivision of the Circulatory system; however, there is no Heart in the Lymphatic system to move Lymph around the Lymphatic vessels, and so flow is maintained by:

- Pressure caused by Arterial pulse; remember, in the viscera (organs in the 3 major cavities of the body), lymphatics generally follow arteries and form plexuses (networks) around them.
- Negative pressure in the thorax during inspiration of air whilst breathing – this draws lymph into the thoracic duct and expiration forces lymph into the Subclavian veins.
- Larger lymph vessels having muscular walls.
- Greater pressure in Lymph capillaries than Blood Capillaries.
- Muscular Movements (in the form of exercise).
- Valves in the Lymphatics and Lymph capillaries.
- Artificial compression from outside the body such as manual lymphatic drainage massage techniques.

The Lymphatic Pathway:

Lymph capillaries ⇒ lymphatic ⇒ lymph node ⇒ lymphatic ⇒ Cisterna Chyli ⇒ Thoracic duct

Lymph from the head and neck passes through deep and superficial cervical nodes.

Lymph from the upper limbs passes through nodes situated in the elbow region then through the deep and superficial axillary nodes. Most of the lymph from the breast also passes through the axillary nodes.

Lymph from the pelvic and abdominal cavities passes through many lymph nodes such as parasternal, intercostal, brachiocephalic, mediastinal, tracheobronchial, bronchopulmonary and oesophageal nodes before entering the Cisterna Chyli.

Lymphatics from the lower portion of the body also converge to the Cisterna Chyli. The Cisterna Chyli extends for about 6 centimetres just to the right of the abdominal aorta. At the level of the twelfth thoracic vertebra, the Cisterna Chyli narrows and becomes the thoracic duct.

The lymph from the lower limbs drains through deep and superficial nodes including Popliteal nodes and Inguinal nodes before draining into the Cisterna Chyli also.

The Lymphatic Circulation as a Defence System

- Lymphocytes and Macrophages are found in the tissues of the Lymph Nodes:
- Macrophages remove bacteria and other foreign matter & debris such as worn out and damaged tissue cells and inhaled particles.
 - Lymphocytes are added to the lymph as it flows through the sinuses of a lymph node. Thus the lymph leaving the node is both cleaner of debris and richer in lymphocytes.

Macrophages

Macrophages are made from Monocytes, from the blood stream and are the largest of the white blood cells – they make up around 3 to 8 per cent of the total white blood cell volume.

The term ‘macrophage’ comes from the Greek meaning “big eater”. These cells are responsible for the cleanup and elimination of pathogens, dead cells and cellular debris in the body.

Lymphocytes

Lymphocytes are a type of white blood cell in the immune system. By their appearance under the light microscope, there are two broad categories of lymphocytes, namely the large granular lymphocytes and the small lymphocytes. Most, but not all large granular lymphocytes are more commonly known as the natural killer cells (NK cells). The small lymphocytes are the T cells and B cells. Lymphocytes play an important and integral role in the body’s defenses.

There are three major types of lymphocytes, T cells, B cells and natural killer (NK) cells

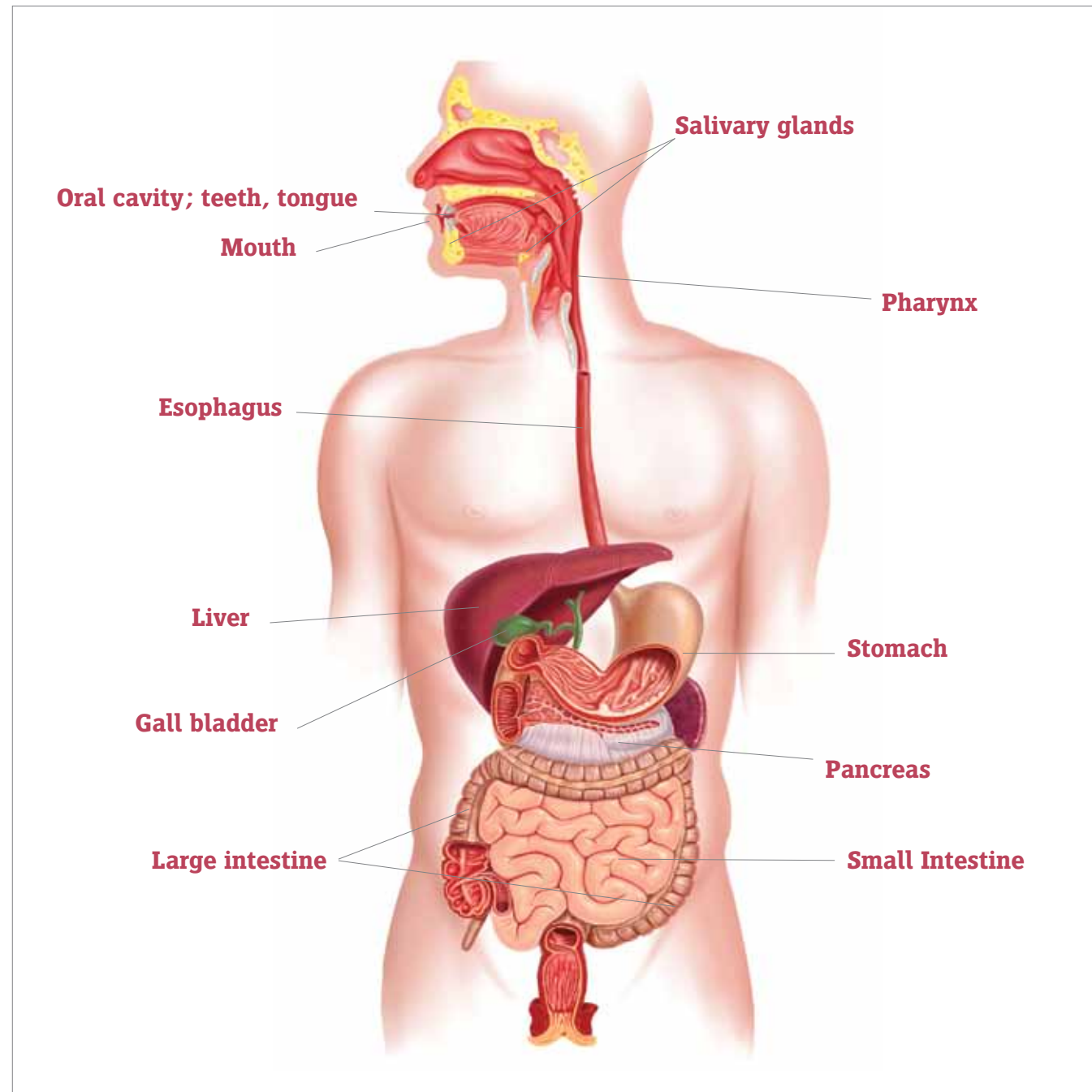
- **NK cells**
NK cells are a part of innate immune system and play a major role in defending the host from both tumours and virally infected cells.
- **T cells and B-cells**
The function of T cells and B cells is to recognize specific “non-self” antigens, during a process known as antigen presentation. Once they have identified an invader, the cells generate specific responses that are tailored to maximally eliminate specific pathogens or pathogen infected cells. B cells respond to pathogens by producing large quantities of antibodies which then neutralize foreign objects like bacteria and viruses.

In response to pathogens some T cells, called helper T cells produce cytokines that direct the immune response whilst other T cells, called cytotoxic T cells, produce toxic granules that induce the death of pathogen infected cells.

Following activation, B cells and T cells leave a lasting legacy of the antigens they have encountered, in the form of memory cells. Throughout the lifetime of an animal these memory cells will “remember” each specific pathogen encountered, and are able to mount a strong response if the pathogen is detected again.

Role of the lymphatic system in fat absorption and transport

Small quantities of very small fatty acids are able to directly enter the intestinal capillaries of the villi of the small intestine and hence enter the blood stream in this way. Lymphatic vessels drain these fats in the form of Lymph from the Gastro Intestinal tract, via Lymph capillaries, also known as Peyer’s Patches. As fats are absorbed by the capillaries, they take on a ‘milky’ appearance, known as ‘Chyle’. This is then transported to the venous blood of the left subclavian vein via the thoracic duct and the Cisterna Chyli.



The digestive system is a series of hollow organs joined in a long, twisting tube from the mouth to the anus. Inside this tube is a lining called the mucosa. In the mouth, stomach, and small intestine, the mucosa contains tiny glands that produce juices to help digest food.

Two solid organs, the liver and the pancreas, produce digestive juices that reach the intestine through smaller tubes. In addition, parts of other organ systems (for instance, nerves and blood) play a major role in the digestive system.

Why is digestion important?

When we eat such things as bread, meat, and vegetables, they are not in a form that the body can use as nourishment. Our food and drink must be changed into smaller molecules of nutrients before they can be absorbed into the blood and carried to cells throughout the body. Digestion is the process by which food and drink are broken down into their smallest parts so that the body can use them to build and nourish cells and to provide energy.

How is food digested?

Digestion involves the mixing of food, its movement through the digestive tract, and the chemical breakdown of the large molecules of food into smaller molecules. Digestion begins in the mouth, when we chew and swallow, and is completed in the small intestine. The chemical process varies somewhat for different kinds of food.

Movement of food through the system

The large, hollow organs of the digestive system contain muscle that enables their walls to move. The movement of organ walls can propel food and liquid and also can mix the contents within each organ. Typical movements of the esophagus, stomach, and intestine are called peristalsis. The action of peristalsis looks like an ocean wave moving through the muscle. The muscle of the organ produces a narrowing and then propels the narrowed portion slowly down the length of the organ. These waves of narrowing push the food and fluid in front of them through each hollow organ.

The first major muscle movement occurs when food or liquid is swallowed. Although we are able to start swallowing by choice, once the swallow begins, it becomes involuntary and proceeds under the control of the nerves.

The esophagus is the organ into which the swallowed food is pushed. It connects the throat above with the stomach below. At the junction of the esophagus and stomach, there is a ring-like valve closing the passage between the two organs. However, as the food approaches the closed ring, the surrounding muscles relax and allow the food to pass.

The food then enters the stomach, which has three mechanical tasks to do. First, the stomach must store the swallowed food and liquid. This requires the muscle of the upper part of the stomach to relax and accept large volumes of swallowed material. The second job is to mix up the food, liquid, and digestive juice produced by the stomach. The lower part of the stomach mixes these materials by its muscle action. The third task of the stomach is to empty its contents slowly into the small intestine.

Several factors affect emptying of the stomach, including the nature of the food (mainly its fat and protein content) and the degree of muscle action of the emptying stomach and the next organ to receive the contents (the small intestine). As the food is digested in the small intestine and dissolved into the juices from the pancreas, liver, and intestine, the contents of the intestine are mixed and pushed forward to allow further digestion.

Finally, all of the digested nutrients are absorbed through the intestinal walls. The waste products of this process include undigested parts of the food, known as fibre, and older cells that have been shed from the mucosa. These materials are propelled into the colon, where they remain, usually for a day or two, until the faeces are expelled by a bowel movement.

Production of Digestive Juices

The glands that act first are in the mouth—the salivary glands. Saliva produced by these glands contains an enzyme that begins to digest the starch from food into smaller molecules.

The next set of digestive glands is in the stomach lining. They produce stomach acid and an enzyme that digests protein. One of the unsolved puzzles of the digestive system is why the acid juice of the stomach does not dissolve the tissue of the stomach itself. In most people, the stomach mucosa is able to resist the juice, although food and other tissues of the body cannot.

After the stomach empties the food and juice mixture into the small intestine, the juices of two other digestive organs mix with the food to continue the process of digestion. One of these organs is the pancreas. It produces a juice that contains a wide array of enzymes to break down the carbohydrate, fat, and protein in food. Other enzymes that are active in the process come from glands in the wall of the intestine or even a part of that wall.

The liver produces yet another digestive juice—bile. The bile is stored between meals in the gallbladder. At mealtime, it is squeezed out of the gallbladder into the bile ducts to reach the intestine and mix with the fat in our food. The bile acids dissolve the fat into the watery contents of the intestine, much like detergents that dissolve grease from a frying pan. After the fat is dissolved, it is digested by enzymes from the pancreas and the lining of the intestine.

Absorption and Transport of Nutrients

Digested molecules of food, as well as water and minerals from the diet, are absorbed from the cavity of the upper small intestine. Most absorbed materials cross the mucosa into the blood and are carried off in the bloodstream to other parts of the body for storage or further chemical change. As already noted, this part of the process varies with different types of nutrients. How is the digestive process controlled?

Hormone Regulators

A fascinating feature of the digestive system is that it contains its own regulators. The major hormones that control the functions of the digestive system are produced and released by cells in the mucosa of the stomach and small intestine. These hormones are released into the blood of the digestive tract, travel back to the heart and through the arteries, and return to the digestive system, where they stimulate digestive juices and cause organ movement.

The hormones that control digestion are Gastrin, Secretin, and Cholecystokinin (CCK):

- Gastrin causes the stomach to produce an acid for dissolving and digesting some foods. It is also necessary for the normal growth of the lining of the stomach, small intestine, and colon.
- Secretin causes the pancreas to send out a digestive juice that is rich in bicarbonate. It stimulates the stomach to produce pepsin, an enzyme that digests protein, and it also stimulates the liver to produce bile.
- CCK causes the pancreas to grow and to produce the enzymes of pancreatic juice, and it causes the gallbladder to empty.

Additional hormones in the digestive system regulate appetite:

- Ghrelin is produced in the stomach and upper intestine in the absence of food in the digestive system and stimulates appetite.
- Peptide YY is produced in the Gastro-intestinal (GI) tract in response to a meal in the system and inhibits appetite. Both of these hormones work on the brain to help regulate the intake of food for energy.

Nerve Regulators

Two types of nerves help to control the action of the digestive system. Extrinsic (outside) nerves come to the digestive organs from the unconscious part of the brain or from the spinal cord. They release a chemical called Acetylcholine and another called adrenaline. Acetylcholine causes the muscle of the digestive organs to squeeze with more force and increase the “push” of food and juice through the digestive tract. Acetylcholine also causes the stomach and pancreas to produce more digestive juice. Adrenaline relaxes the muscle of the stomach and intestine and decreases the flow of blood to these organs.

Even more important, though, are the intrinsic (inside) nerves, which make up a very dense network embedded in the walls of the oesophagus, stomach, small intestine, and colon. The intrinsic nerves are triggered to act when the walls of the hollow organs are stretched by food. They release many different substances that speed up or delay the movement of food and the production of juices by the digestive organs.

The Central Nervous System

The nervous system is a highly specialized network in the Human body, whose principal components are nerves called neurons.

These are the core components of both the central nervous system & peripheral nervous system. Neurons are sensors that send electric messages to the Central Nervous System which send the electric messages back to the neurons telling them how to react - the messages are finally sent back directly to the brain. These messages travel at a usual pace of 100 meters per second.

Neurons are interconnected to each other in complex arrangements, and have the property of conduction - meaning that they can communicate using electrochemical signals within the nervous tissue and most of the other tissues. Thus, neurons coordinate multiple functions in organisms. Nervous systems are found in many multi-cellular animals.

The human nervous system can be observed both with gross anatomy, (which describes the parts that are large enough to be seen with the plain eye,) and microanatomy, (which describes the system at a cellular level.)

The CNS represents the largest part of the nervous system, including the brain and the spinal cord. The CNS is contained within the dorsal cavity, with the brain within the cranial cavity, and the spinal cord in the spinal cavity. The CNS is covered by the meninges. The brain is also protected by the skull, and the spinal cord is also protected by the vertebrae. The nervous system can be connected into many systems that can function together. The nervous system is, on a small scale, primarily made up of neurons. However, glial cells also play a major role.

(Brain & Spinal cord) and the Peripheral Nervous System

Sensory neurones receive stimuli from organs and receptors in the skin and transmit their impulse to the spinal cord and Brain – examples of sensory stimuli are: feeling heat or something hot, such as hot water as well as pain, taste, smell and eyesight and hearing.

Motor Neurones conduct impulses away from the brain and spinal cord for example to a muscle to instruct it to do something such as moving the arm (via the muscle contraction or relaxation).

There are also association or mixed neurones which link sensory and motor neurones together – these are complex pathways and interpret incoming messages, decide what to do about them and send out instructions to the body in response.

Glial cells do not conduct electrical impulses (as opposed to neurons, which do). The glial cells surround neurons and provide support for them and insulation between them. Glial cells are capable of extensive signaling in response to a diversity of stimuli. Bidirectional communication exists between glial cells and neurons, and between glial cells and vascular cells

Glial cells are the most abundant cell types in the central nervous system. There are three types of glial cells: astrocytes, oligodendrocytes, and microglia. Astrocytes are concerned with neurotransmission and neuronal metabolism. Oligodendrocytes are involved in the production of myelin, the insulating material around neurons, and microglia are part of the immune system.

This is quite literally a huge mass of nervous tissue and is the main communication centre of the nervous system. The brain consists of various areas which control specific human functions – these are:

The cerebrum

The cerebrum directs the conscious or volitional motor functions of the body. These functions originate within the primary motor cortex and other frontal lobe motor areas where actions are planned. Damage to motor areas of cortex can lead to certain types of motor neuron disease. This kind of damage results in loss of muscular power and precision rather than total paralysis. The cortex has a number of functional areas – these are:

- Sensory areas to receive sensory impulses from sensory neurones (see neurones above) such as vision, hearing, touch, taste and smell.
- Motor areas which connect to voluntary muscles all over the body.
- Association areas which consist of remembered information from the past to enable decisions to be made with conscious thought.

The Thalamus

A relay and interpretation area for sensory impulses apart from olfaction (smell)

The hypothalamus

This area controls many important functions and regulates the autonomic nervous system and the endocrine (glandular) systems of the body, as it governs the pituitary gland. It controls hunger, thirst, temperature regulation as well as anger, aggression sleep and sexual behaviour amongst other things.

The Pituitary Gland

Is situated beneath the Hypothalamus (see above) and is the master gland in the Endocrine system.

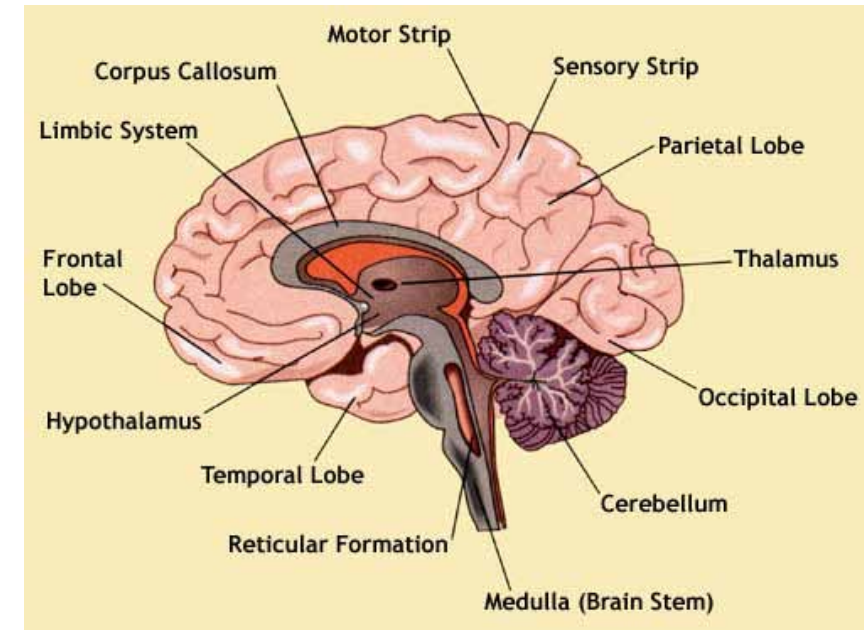
The Pineal Gland - This area is attached to the upper portion of the Thalamus (see above) and is involved with regulation of something called Circadian rhythms. These are repeated activities in the body such as regulation of sleep and sleep patterns – it is also thought to regulate moods.

The Cerebellum

This area gives the brain its characteristic cauliflower shape and is located posterior to the cranium, beneath the Cerebrum. It is concerned with muscle tone, balance and co-ordination of muscle movements.

The Brain Stem - is divided into 4 main structures:

- The mid-brain which contains main nerve pathways both in and out of the brain. It also co-ordinates certain visual and auditory functions such as eye movements.
- The Pons which relays messages from the cerebral cortex to the spinal cord
- The Medulla Oblongata which is considered to be the most vital area as it is a continuation of the spinal cord and controls vital functions such as the stimulus for the heart to beat and heart rate, stimulus to breathe and intestinal functions for digestion.
- The spinal cord is an extension of the brain stem which extends from an opening in the base of the skull and down to the second Lumbar vertebrae. It relays impulses to and from the brain via sensory and motor neurones



The peripheral nervous system acts as a connector to the central nervous system. The part of the peripheral nervous system known as the somatic nervous system is comprised of cranial nerves and spinal nerves. The nerves of the somatic nervous system supply the muscular system and external receptors. It is this part of the body that remains in control to enable movement.

A person's sense of touch, taste, sight, sound and smell are controlled by the somatic nervous system. Also, the somatic nervous system is what causes the body to feel heat, cold, and pain. It also controls involuntary actions such as blinking.

There are 31 pairs of spinal nerves which pass out of the spinal cord, between the vertebrae and have branches to link it to the sensory and motor neural functions of the body. Each of the spinal nerves are numbered and labelled according to the area of the spine they emerge from; there are:

- 8 cervical nerves
- 12 thoracic nerves
- 5 lumbar nerves
- 5 sacral nerves
- 1 coccygeal nerve

Each nerve is divided into several branches, forming a network (or plexus) of nerves to different parts of the body. The cranial nerves lead to and from the brain and control feelings and functions of areas and parts of the face and head, including muscles, eyes, ears, nose and mouth.

The nerves are listed as follows: Cranial Nerve:	Major Functions:
Olfactory	• smell
Optic	• vision
Oculomotor	• eyelid and eyeball movement
Trochlear	• innervates superior oblique • turns eye downward and laterally
Trigeminal	• chewing • face & mouth touch & pain
Abducens	• turns eye laterally
Facial	• controls most facial expressions • secretion of tears & saliva • taste
Vestibulocochlear	• hearing
(auditory)	• equilibrium sensation
Glossopharyngeal	• taste • senses carotid blood pressure
Vagus	• senses aortic blood pressure • slows heart rate • stimulates digestive organs taste
Spinal Accessory	• controls trapezius & sternocleidomastoid
	• controls swallowing movements
Hypoglossal	• controls tongue movements

The second part of the peripheral nervous system is the autonomic nervous system, or visceral nervous system. The autonomic system controls and regulates the body internally. The autonomic nervous system is comprised of the sympathetic and parasympathetic nervous systems. Cranial nerves make up the parasympathetic nervous system.

The autonomic nervous system conveys impulses to from the sensory organs to the brain. This part of the peripheral nervous system is in control when the body is at rest. It is also the part of the nervous system that regulates internal processes such as increased and decreased heart rates as a response to stimuli, secretion of digestive fluids, and the body’s reaction to stress.

The Sympathetic and Parasympathetic Nervous system

Sympathetic and parasympathetic divisions typically function in opposition to each other. But this opposition is better termed complementary in nature rather than antagonistic. For an analogy, one may think of the sympathetic division as the accelerator and the parasympathetic division as the brake. The sympathetic division typically functions in actions requiring quick responses. The parasympathetic division functions with actions that do not require immediate reaction.

The main actions of the parasympathetic nervous system are summarized by the phrase “rest and repose” or “rest and digest” (in contrast to the “fight-or-flight” of the sympathetic nervous system).

Summary

The sympathetic nervous system prepares the body for expending energy and dealing with emergency situations – commonly known as ‘fight or flight’, including:

- Increased Heart and Respiration rates
- Inhibited salivation
- Decrease digestion and Gastro-Intestinal activity
- Stimulation of adrenal and sweat glands
- Dilation of blood vessels
- Pupil dilation.

The parasympathetic nervous system balances the action of the sympathetic nervous system by working to conserve energy and create conditions needed for rest or sleep, including:

- Resting Heart Rate & Respiratory Rate
- Constriction of blood vessels
- Increased digestion
- Pupil constriction
- Stimulated salivation

The Benefits of Massage to the Various Systems of the Body

General benefits of massage therapy:

- Massage feels good and it is a pleasurable experience
- Massage increases the body's self-awareness and sensitivity
- Massage reduces stress, tension and anxiety levels
- Massage calms the nervous system and has a balancing effect
- Massage relaxes, focuses and clears the mind
- Massage helps to improve and maintain posture
- Massage helps to fulfill the need for a caring and nurturing touch
- Massage encourages self-esteem and a general feeling of well-being
- Massage increases awareness of the whole being connection and improves your emotional awareness



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