



My@Campus

Learner Guide

PAP1 – Part A – Anatomy and Physiology



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Unit introduction

Welcome to the **PAP1 – Part A – Anatomy and Physiology** cluster of units. A cluster of units is a group of units that are clustered together to achieve a set of learning outcomes.

The name given to this cluster of units is PAP1. Below is a list of the units contained within this cluster of units:

- **SISFFIT004** Incorporate anatomy and physiology principles into fitness programming

Before you begin please read through the following frequently asked questions.

What is the full name of the course award I am working for?

Successful completion of this course can count towards several qualifications. Check your registration details for the qualification you are working towards.

How much work is involved?

Whichever qualification you are working towards will have a number of units of competency you are required to complete.

We recommend that, to successfully meet the requirements of each cluster of units for this course, you plan to complete one cluster of units of study per month. You will receive your personalised study plan two weeks after your enrolment date. This study plan is a structured plan which allocates a manageable study timeframe, with the allocation of additional months at the end of your study period.

This will enable you to read through the materials, undertaking a range of activities which focus on this cluster of units. Then you will be ready for the final assessments at the end of this cluster of units.

If I get stuck or need help, what is available?

The Technical Panel is available to support you during business hours, from Monday to Friday (excluding public holidays). You may book a phone coaching session with a Technical Advisor by emailing your questions to fitness.support@aipt.edu.au. One of the Technical Advisors will respond to you within two business days. In the meantime, whilst you are waiting for a response, we recommend that you continue working through your cluster of units learning and activities.

Aim: What is this cluster of units about, and what will be expected of me?

SISFFIT004

This unit describes the performance outcomes, skills, and knowledge required to incorporate an understanding of the human body structure and physiology into fitness instruction, programming, and provision of fitness advice.

This unit applies to fitness instructors who work in a variety of fitness locations such as fitness, leisure, and community centres. These individuals typically work independently with some level of autonomy in a controlled environment. Work is performed according to relevant legislation and organisational policies and procedures.

No occupational licensing, certification, or specific legislative requirements apply to this unit at the time of publication.

Learning objectives: What should I be able to do, when I have successfully achieved this cluster of units?

We are working with you to support you in developing your competence in the following areas:

SSIFFIT004

- I. Consolidate understanding of anatomy and physiology.
- II. Apply knowledge to own professional practice.
- III. Maintain and update knowledge of anatomy principles.

What kind of work will I have to undertake and complete?

This is an online learning course, which is different from learning in the traditional classroom. You can work at your own pace, refer to your own past experiences and seek support, when needed. Each time you read and complete a set of information, save that work and return to it, if you wish to revise or review, at any time. Work through one module at a time. It will take time to adapt to online learning, so be fair to yourself, and allow yourself time to get used to this new and exciting way of developing your skills and knowledge!

How many modules are in this course?

There are **six** modules to be completed within this course. They are:

1. Organisation of the human body
2. Skeletal system
3. Musculoskeletal system
4. Nervous system
5. Cardiorespiratory system
6. Digestive system

How are the modules presented?

Each module will provide you with an introduction and overview of information.

When do I get assessed?

You will submit your assessments at the end of this cluster of units. You can of course ask for help before or during your studies if you wish. Please feel free to read through the assessments at any time.

How will I be scored/assessed?

The Assessor is looking for a demonstration of your competence in this cluster of units. There are four assessment items for each cluster of units. Each of the four assessment items must be assessed as 'Satisfactory'. If any assessment item is assessed as 'Not Yet Satisfactory', this means that the item does not meet the cluster of units standards/requirements. You will then be required to review and resubmit the assessment item/s. The Assessor will provide comments for you for the purpose of assisting in revising and reviewing your submission to meet cluster of units standards and criteria. Professional AIPPT assistance is also available for you, on request.

The final assessment outcome of the cluster of units will recognise you to be 'Competent' in each of the individual units that make up this cluster of units. This can only be confirmed when all four assessment items are assessed as "Satisfactory". You will not be deemed "Competent", until all four assessment items are separately assessed as "Satisfactory". This is the basis on which all vocational (work-based) training is assessed. Please note that neither scores nor grades are issued to candidates within the competency-based assessment process.

How will I know the difference between learning activities and final assessments?

Within this cluster of units, you will be provided with the following presentations, in this order:

- **General information** – to read through, interpret and understand
- **Final assessment tasks** – are to be found in a separate resource; the Assessment area of My eCampus.

Additional learning aids (subject to availability)

- eLibrary of templates and resources available for you to use
- Video clips to enhance your e-learning (subject to availability)
- Webinars can be organised (subject to availability and numbers)
- Online chat forums are encouraged (subject to availability).

What icons are used throughout the course?

We have included the following icons to identify the different work you are going to undertake:

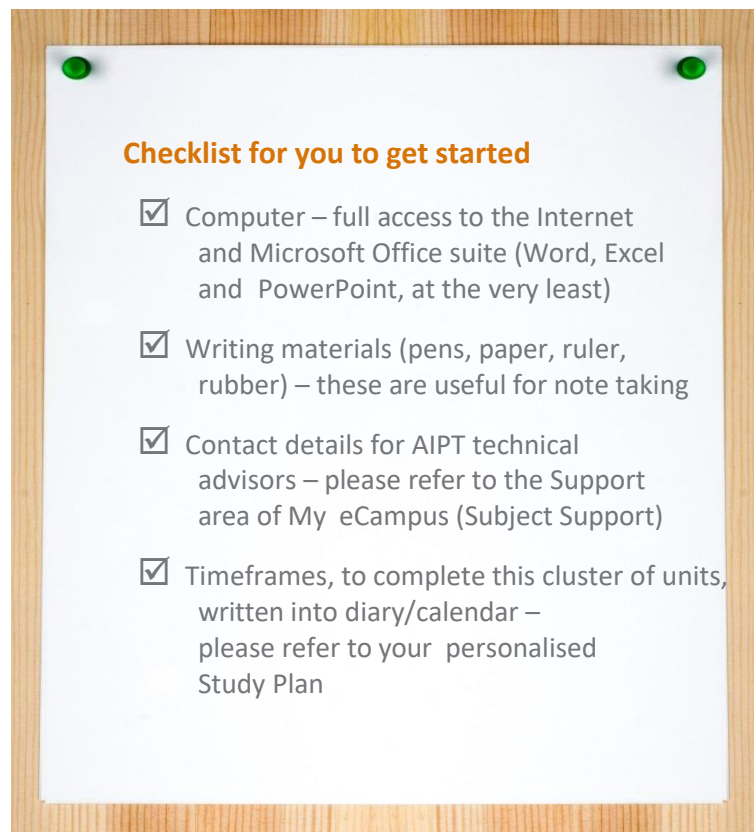
Icons	Icon type	Description
	Prescribed Reading	Courses with prescribed readings require you to have access to a particular text for the duration of the course. This icon represents readings from this text.
	Suggested Reading	These are readings which will add depth and understanding to your course participation.
	Definition	These represent definitions of important terms relevant to this course.
	Reflection	Reflections prompt you to think about certain subject matters. You are being encouraged to draw on your own personal experiences.
	Tip	Hints and tips to assist you in this subject area.
	Video	Videos to support the course content. Watch these short videos to learn more about the topics covered.
	Web	Internet web link to support course content and provide further reading or research opportunities
	Attachment	Attachments are separate documents that are referred to within the Modules. You can download the attachments from the Learning Resources section of this cluster of units in My eCampus.

AIPT is committed to, and continuously reviews, the design and development of their contemporary eLearning tools and resources to support you, in your studies. However, availability of resources will be subject to availability.

Recommendation to make the best use of your time

We recommend that you attempt to complete at least one cluster of units per month. A minimum of 12 hours per month should be set aside in a quiet area where there are minimum interruptions for you. This time is YOUR investment in YOUR learning and, in YOUR success.

Great! I think we are ready to get started. Please work through and complete the following checklist, to ensure you have the tools needed to get started.



To be successful within this cluster of units, we need you to demonstrate your competence. What does that mean for you?

To be competent is to: Demonstrate your skills, knowledge and attributes for completing a task/job to national standards.



Tip

Read through and identify any area/s in which you may wish to undertake personal research prior to commencing your studies.

Remember that AIPT has Technical Advisers who are available to work with you after you have commenced your studies. When contacting them (preferably by email), list the key questions or queries you have. By doing so, you will enable them to assist you in the best possible way. Telephone appointments are also available! Their email address is fitness.support@aipt.edu.au.

So, let's look at the 'competencies' that are to be demonstrated, within this cluster of units.

SSIFFIT004

Performance Evidence	- Effectively use knowledge of the following body systems to improve own instructional practice to plan and instruct at least five different client sessions: - Cardiovascular - Respiratory - Musculoskeletal, with attention to: - Bone strength - Muscle endurance - Muscle strength - Nervous - Digestive - Explain and demonstrate: - The major movements of the body, while identifying major muscles - Actions of major joints during exercise - Relevant information regarding structure and function of skeletal muscle, and process of muscle contraction during exercise - Muscle actions and functions during different types of contractions
Knowledge Evidence	- Anatomical terminology: - Anatomical position - Superior - Inferior - Proximal - Distal - Lateral - Medial - Superficial - Deep - Planes of movement – sagittal, frontal, horizontal - Movement terminology and muscle actions: - Flexion - Extension - Abduction - Adduction - Pronation - Supination - Dorsiflexion - Plantarflexion - Circumduction - Inversion - Eversion - Structural levels of body organisation: - Cells - Tissues - Organs - Organisms

- Functions of major muscles during exercise and movement:
 - Agonist
 - Prime mover
 - Antagonist
 - Synergist
 - Fixator
- Types of muscle contractions:
 - Isotonic – concentric and eccentric
 - Isokinetic
 - Isometric
- Tissue types:
 - Connective
 - Muscle
 - Nervous
 - Epithelial
- Body systems and their interdependence and contribution to a healthy body:
 - Cardiovascular
 - Musculoskeletal
 - Nervous
 - Digestive
 - Respiratory
- Structure and function of:
 - Muscles:
 - Types and classifications
 - Global and local muscular systems
 - Major muscle groups
 - Contractibility and activation
 - Nervous system:
 - Nerves and nerve impulses
 - Reflex arcs and relationship to stretching
 - Role of nervous system in different types of training
 - Skeletal system:
 - Types of bones
 - Major bones
 - Bony landmarks
 - Major joints
 - Cardiovascular system:
 - Heart and blood vessel anatomy
 - Circulation pathways
 - Role of blood
 - Oxygen demands of fitness activities
 - Relationships between exercise intensity and circulatory and ventilator responses
 - Respiratory system:
 - Mechanics of breathing
 - Respiratory volumes and relationships to fitness levels and exercise
- Energy systems, pathways, and substrates and relevant recovery options
- Thermoregulation of the human body:
 - Consideration of the methods of cooling and warming
 - Current environmental conditions

	- Exercises to promote ideal postural alignment and prevent development of pathological postures, with consideration of: - Spinal curves - Muscle balance - Joint alignment
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Standards established to assess you

As you will learn over the course of this cluster of units, to assess any performance requires that a minimal standard or standards (or benchmark) be achieved. This is written into a Performance Criterion.

A Performance Criterion will clearly state WHAT is to be demonstrated for assessment to be successful. The performance criteria for this cluster of units are set by the Australian Qualifications Framework (AQF).

Performance criteria

SSIFFIT004

1. Consolidate understanding of anatomy and physiology	1.1 Source and access information on anatomy and physiology relevant to fitness outcomes. 1.2 Use knowledge of anatomy and physiology in day-to-day professional practice. 1.3 Discuss/explain how understanding of anatomy and physiology contribute to safe/optimum technique and skill development. 1.4 Use a wide range of anatomical terminology relevant to injury prevention and fitness outcomes. 1.5 Identify how anatomical structures respond to physical activity. 1.6 Apply a sound understanding of injury prevention techniques to fitness instruction and programming.
2. Apply knowledge to own professional practice	2.1 Assess ways in which knowledge of anatomy and physiology may be used, adapted, or challenged in instruction and provision of fitness advice. 2.2 Identify current and emerging knowledge of anatomy and physiology relevant to development of own professional practice. 2.3 Modify approach to fitness programming activities and advice as required.
3. Maintain and update knowledge of anatomy principles	3.1 Identify and use opportunities to update and expand own knowledge of anatomy and physiology. 3.2 Monitor response to changes made to own professional practice or instruction. 3.3 Continue to adjust own practice to optimise results.

Module One: Organisation of the human body

SECTION 1 – INTRODUCTION TO ANATOMY AND PHYSIOLOGY

The study of anatomy and physiology centres on discovering the parts of the body and how they function (The Essential Guide to Fitness, 2011). As a fitness professional, it is important to understand the structures and functions of the human body. This is because fitness professionals must be able to include progression into training sessions without causing injury and maximise client results through applying anatomy and physiology training principles.



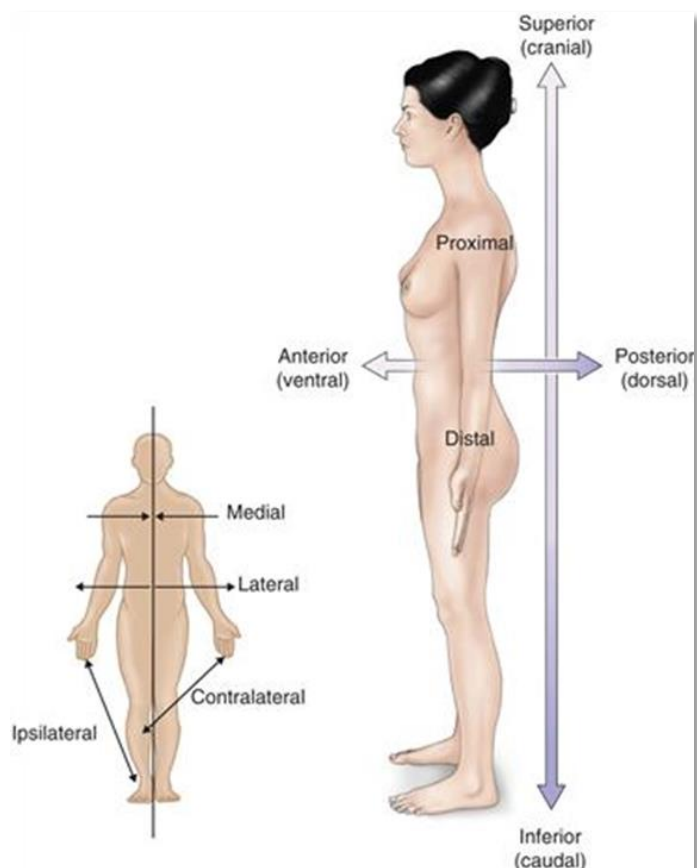
Definition

- **Anatomy** is the study of the bodily structure of humans, animals, and other living organisms. It is the science that deals with the description and organisation of the structure of cells, tissues, and organs that compose systems such as the circulatory, digestive, reproductive, and musculoskeletal system.
- **Physiology** is the study of the function of living organisms. It is the science that deals with the function of cells, tissues, and organs, including the analysis of how the organ tissue performs a certain function.

Anatomical terminology

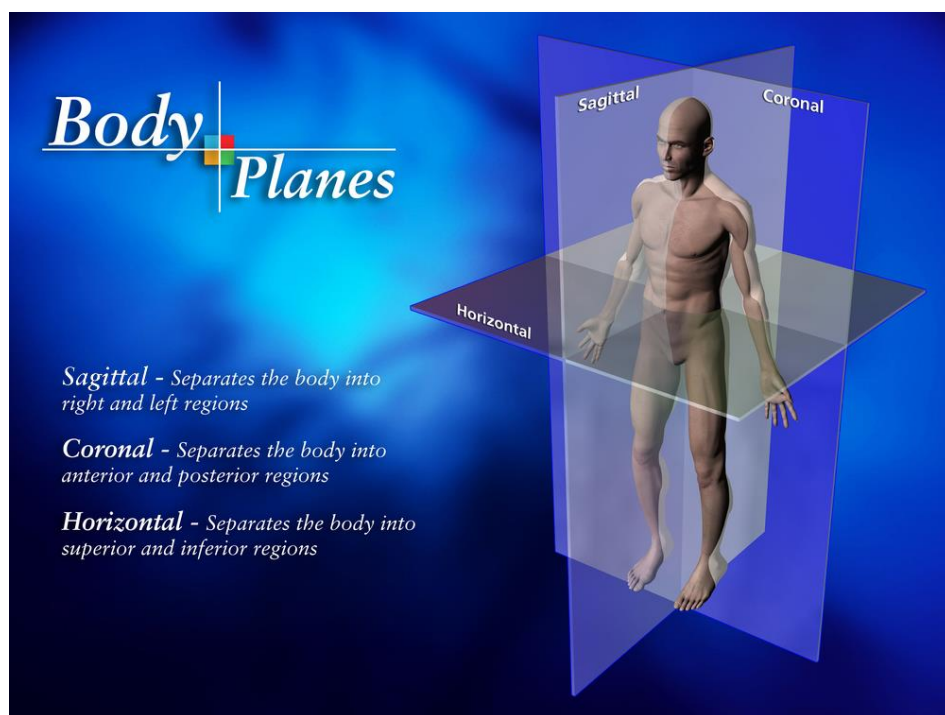
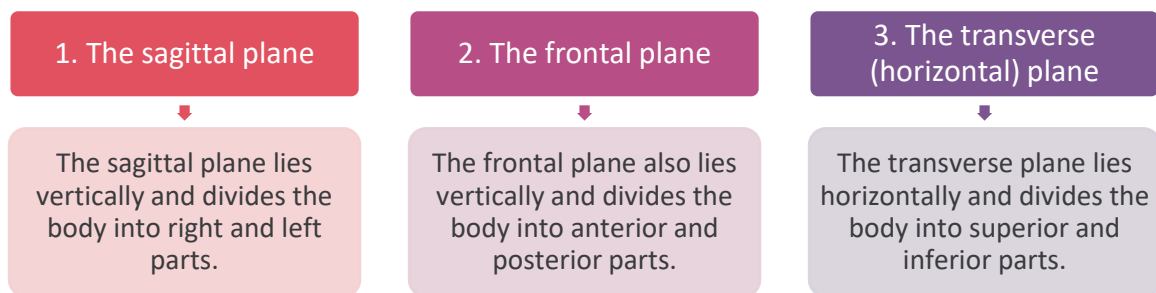
There are several of important terminologies that need to be understood in order to understand the structure and function of the human body. Anatomical position is the first term you will learn in the study of anatomy and physiology, and this describes the position with the body erect, the arms at the sides and the palms forward. The anatomical position is of importance in anatomy because it is the position of reference for anatomical language.

The following table defines each of the important terms relevant to the anatomical position



Term	Definition
Superior	Latin word meaning “above” that is used to refer to what is above something. For example, the elbow is superior to the wrist (in anatomical position).
Inferior	Latin word meaning “below” that is used to refer to what is below it. For example, the wrist is inferior to the elbow (in anatomical position).
Proximal	Closer to the attachment point of a limb. For example, the elbow is proximal to the wrist.
Distal	Further from the attachment point of a limb. For example, the toes are distal to the heel.
Lateral	Away from the mid line of the body. For example, the oblique muscles are lateral to the belly button.
Medial	Towards the mid line of the body. The nose is medial to the ears.
Superficial	Towards the surface of the body. The ribs are superficial to the heart.
Deep	Away from the surface of the body. The bones are deep to the skin.

Human movements are described in three dimensions based on a series of planes and axis. There are three planes of motion that pass through the human body.



Movement terminology

Different joints in the human body have the ability to move in different directions. These movements have standardised terms that all health and fitness professionals use to limit any confusion. These terms are summarised in the following table.

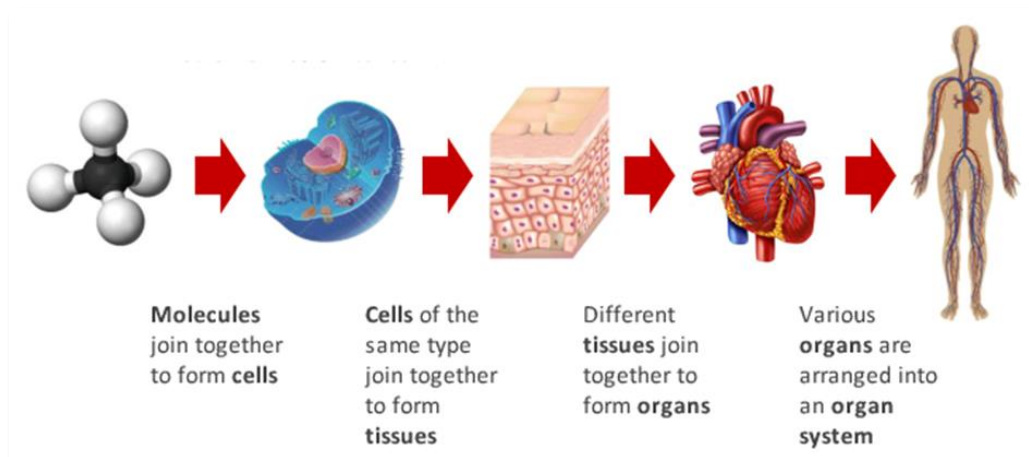
Movement	Definition
Flexion	To decrease the angle at a joint
Extension	To increase the angle at a joint
Lateral/External rotation	Rotate a limb outwards around the long axis of the bone
Medial/Internal rotation	To rotate a limb inwards, around the long axis of a bone
Abduction	To increase the angle of a limb away from the body in a frontal plane
Adduction	To decrease the angle of a limb away from the body in a frontal plane
Circumduction	To allow a joint to perform movement through all possible axes
Inversion	To turn the sole of the foot medially
Eversion	To turn the sole of the foot laterally
Pronation	To turn the palm posterior
Supination	To turn the palm anterior
Horizontal flexion	To decrease the angle at the joint, moving the limb in the horizontal plane
Horizontal extension	To increase the angle at the joint, moving the limb in the horizontal plane
Retraction	Movement towards the midline on the same plane
Protraction	Going away from the midline on the same plane

SECTION 2 – ORGANISATION OF THE HUMAN BODY

Levels of hierarchy

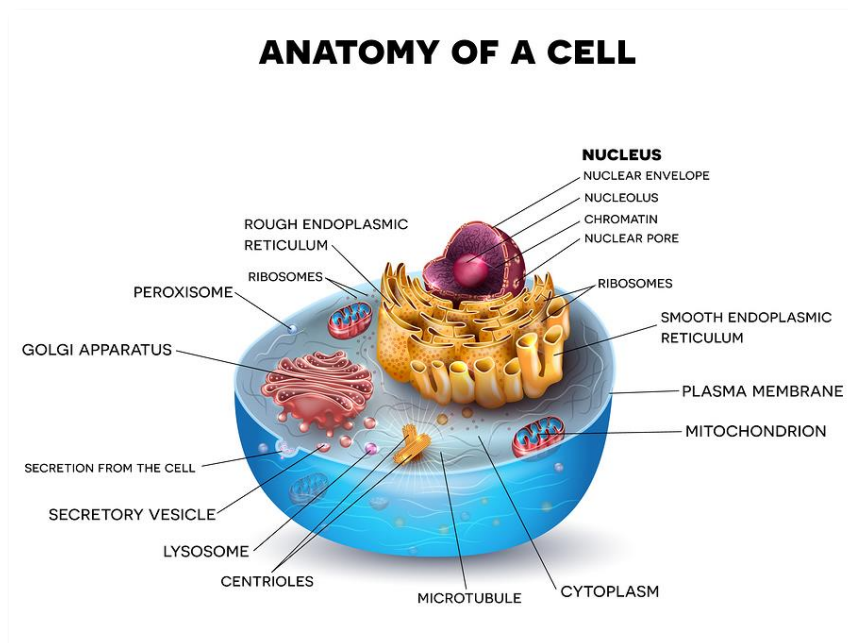
The human body is the entire structure of a human being and has several levels of organisation. Each level uses building blocks that are organised from the smallest (molecules) to the largest (organs) components.

- Molecules join together to form cells
- Cells of the same type join together to form tissues
- Different tissues join together to form organs
- Various organs are arranged into an organ system



Structure	Function	Examples
Molecule	Smallest particle in a chemical element or compound. Molecules are made up of atoms that are held together by chemical bonds.	Water, oxygen, carbon dioxide, sugar (sucrose or glucose), fat (lipid), protein, insulin, adrenaline
Cells	The cell is the basic structural and functional unit of all known living organisms	Muscle cells, fat cells, neurons, bone cells, red blood cells, liver cells
Tissues	A tissue is an ensemble of cells, not necessarily identical but, from the same origin, that together carry out a specific function	Connective, muscle, nervous, epithelial, bone
Organs	Collection of tissues joined in a structural unit to serve a common function	Heart, kidney, liver, stomach
Organ/Body systems	Two or more organs working together in the execution of a specific body function	Nervous, endocrine, digestive, cardiovascular, musculoskeletal

Cell components



- **Nucleus:** controls the cell, often referred to as the “brain” of the cell, contains DNA
- **Nucleolus:** The nucleolus is a structure found in the nucleus of cells.
- **Cell Membrane:** is a biological membrane that separates the interior of all cells from the outside environment and makes up the outer wall of the cell.
- **Mitochondrion:** they generate most of the cell's supply of adenosine triphosphate (ATP), used as a source of chemical energy
- **Cytoplasm:** jelly-like substance filling the cell in which all other organelles are located.
- **Organelles:** small cell components – each have a specific function e.g. Ribosomes, Golgi Complex, and Centrosome.
 - **Ribosome:** serves as the primary site of biological protein synthesis (translation).
 - **Golgi Complex:** packages proteins inside the cell before they are sent to their destination.
 - **Centrosome:** is an organelle that serves as the main microtubule organizing centre.

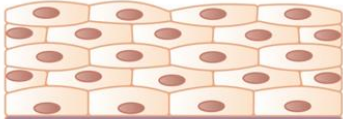
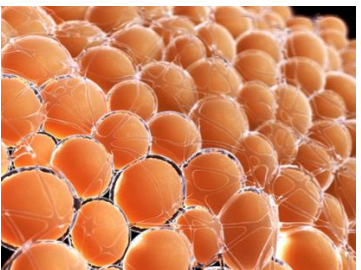
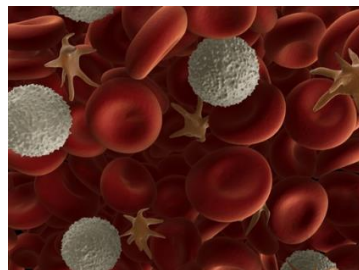
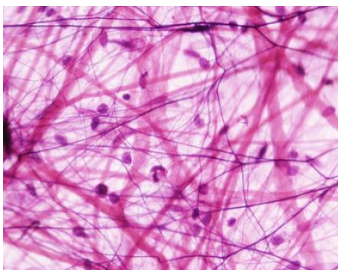
Tissues

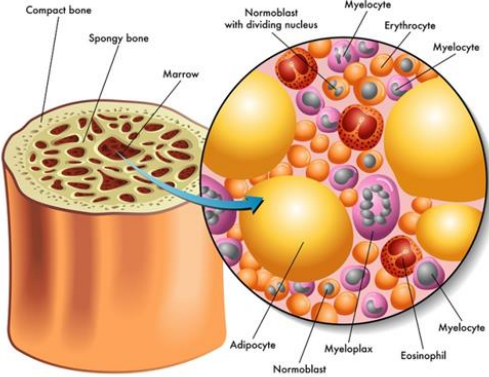
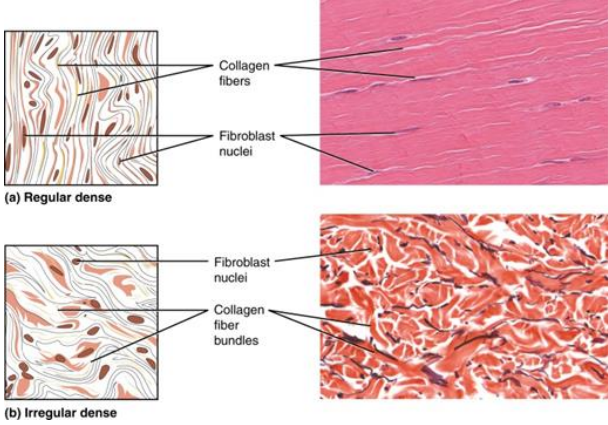
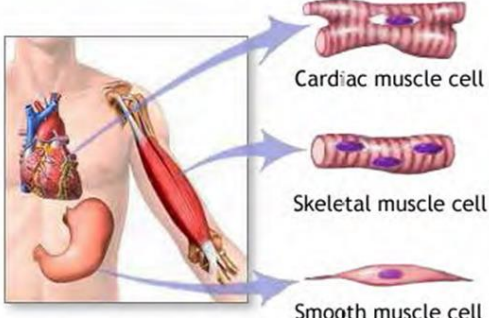


Definition

Tissues are groups of cells from the same origin that look alike and together have the same function.

There are four major types of tissues in the human body:

Tissue	Function	Types		
Epithelial	Lines cavities and surfaces of structures throughout the body. Functions include secretion, selective absorption, protection, trans-cellular transport.	SQUAMOUS EPITHELIUM  Simple squamous epithelium  Stratified squamous epithelium	COLUMNAR EPITHELIUM  Simple columnar epithelium  Stratified columnar epithelium  Pseudostratified columnar epithelium	CUBOIDAL EPITHELIUM  Simple cuboidal epithelium  Stratified cuboidal epithelium
Connective	Found throughout the skeletal system and bind structures together, fill up spaces, provide support and protection, and store fat.	Adipose 	Human Blood 	Loose connective tissue 

		Bone cell 	Dense connective tissue 
Muscular <i>Smooth, Cardiac and skeletal</i>	Muscle tissue is composed of fibres made of actin and myosin proteins, whose interaction is responsible for movement.	 Cardiac muscle cell Skeletal muscle cell Smooth muscle cell	
Nervous	Specialised tissue that forms nerves, brain, and spinal cord. Conduct electrical and chemical messages along cells called neurons.	Dendrites 	Axons 

Organs

When several types of tissues combine and provide a specific purpose or function, they form an organ. Some examples include the heart, liver, blood vessels, kidneys and skin and bone.

Body systems

Systems are groups of organs that join together to carry out a particular function. Examples of body systems are the cardiovascular, skeletal, digestive and nervous systems.



Attachment 1 – Body systems

Please open and read **Attachment 1 – Body systems**.

This attachment provides a diagram and detailed description for each of the body systems.

Attachment(s) for this unit can be found in the *Learning Resources* section of this unit in My eCampus.

The body is very complex and all systems need to perform their correct functions to enable it to work correctly. When one of these systems is disrupted or function diminishes, disorders, illnesses or diseases can result.

What follows is a list of common disorders that can occur in response to disruptions of the different body systems.

Body system	Description of body system	Disorder examples
Circulatory	The circulatory system is composed of the heart and blood vessels. Its primary function is to circulate blood around the body and deliver oxygen and nutrients to the tissue and remove metabolic wastes including carbon dioxide.	Heart disease including coronary artery disease, cardiomyopathy, cardiovascular disease, peripheral vascular disease
Muscular	The muscular system is an organ system consisting of skeletal, smooth and cardiac muscles. It permits movement of the body, maintains posture, and circulates blood throughout the body.	Muscle and tendon strains, muscular dystrophy, metabolic diseases, myotonia
Nervous	The nervous system is a complex collection of nerves and specialized cells known as neurons that transmit signals between different parts of the body.	Epilepsy, stroke, dementia, Alzheimer's disease, Parkinson's disease, multiple sclerosis
Lymphatic	The lymphatic system is a network of tubes throughout the body that drains fluid (called lymph) from tissues and empties it back into the bloodstream. The main roles of the lymphatic system include managing the fluid levels in the body, filtering out bacteria, and housing types of white blood cells.	Tonsillitis, lymphedema
Respiratory	The human respiratory system is a series of organs responsible for taking in oxygen and expelling carbon dioxide. The primary organs of the respiratory system are lungs, which carry out this exchange of gases as we breathe.	COPD including emphysema and chronic bronchitis, asthma
Skeletal	The skeletal system includes all of the bones and joints in the body. The skeletal system also provides attachment points for muscles to allow movements at the joints.	Osteoporosis, postural abnormalities, ligament sprains, osteoarthritis, rheumatoid arthritis, leukaemia, rickets

Module two: The skeletal system

SECTION 1 – BONES AND THE SKELETAL SYSTEM

Bones and bone tissue

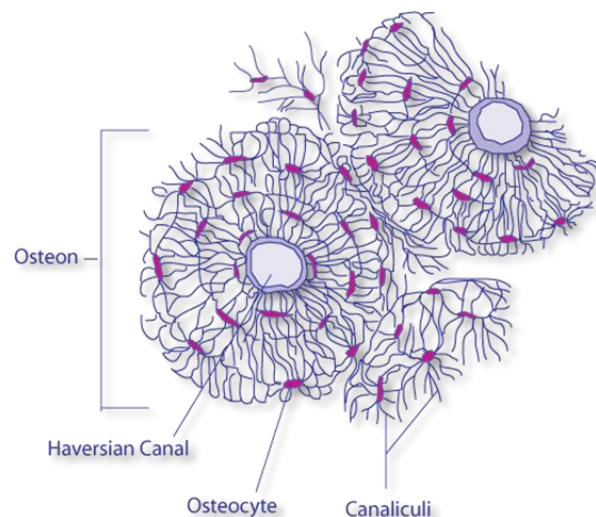
Bone tissue

The Better Health Channel (2012) outlines bone tissue as the major structural and supportive connective tissue of the body.

Bone tissue forms the rigid part of the bone organs that make up the skeletal system.

Organs are made of a collection of tissues joined in a structural unit to serve a common function. Tissues that make up bones include:

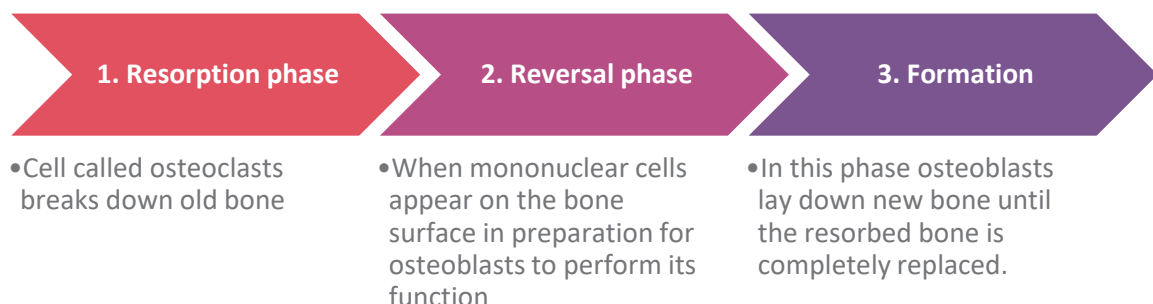
- Osseous tissue
- Connective tissue
- Blood tissue



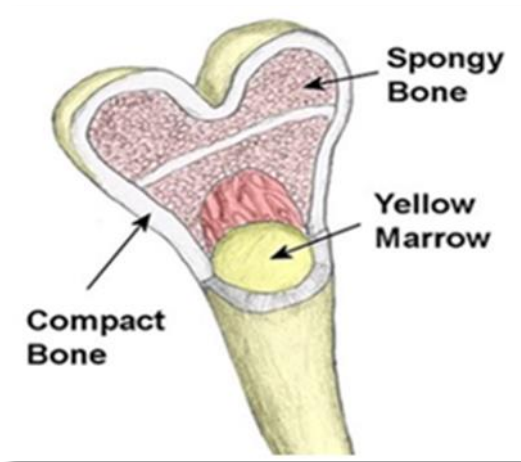
The different layers of bone tissue include:

Periosteum	Compact or dense tissue	Spongy or cancellous tissue	Bone marrow
•The dense, tough outer shell that contains blood vessels and nerves	•The hard, smooth layer that protects the tissue within	•The porous, honeycombed material found inside most bones, which allows the bone to be strong yet lightweight	•The jelly-like substance found inside the cavities of some bones (including the pelvis) that produces blood cells.

Bone metabolism is a complex process called remodelling and it occurs continuously across the ageing process; which is different to that of ossification. The skeleton a metabolically active organ, which undergoes remodelling in three consecutive phases.



Bone tissue is made up of bone cells called osteocytes, embedded in a hard matrix of:



- Calcium salts (for strength)
- Collagen fibres (for flexibility)

Bone tissue can have two appearances:

1. Compact or cortical bone, forms the cortex, or outer shell, of most bones. Compact bone is hard and strong and can surround the medulla cavity to provide strength for the diaphysis of long bones.
2. Spongy or cancellous bone has a higher surface area than compact bone, but is less dense, softer, weaker, and less stiff. It typically occurs at the ends of long bones.

Bone marrow



Definition

Bone marrow is a soft spongy tissue in the cavity of bones. It is the blood cell “factory”. Healthy bone marrow releases blood cells into the blood stream when they are mature and when required (The Better Health Channel, 2012).

Bone marrow may contain fat cells, blood vessels, fluid, and fibrous tissue. Marrow appears yellow and is the primary body site from blood formation. Blood is formed in many bones in babies, but as one ages, blood is mostly formed in the marrow of the vertebrae, humerus, femur, sternum, and ribs.

There are two types of bone marrow:

1. Red bone marrow:

- Site of red blood cell, platelet, and white blood cell production. Red marrow is usually found in flat bones and in the epiphyseal portion of long bones.

2. Yellow bone marrow:

- Storage site for fat. Yellow marrow is found in the hollow inner portion of long bones called the medullary cavity.

Types of bone

Bones provide the structure for our bodies. The adult human skeleton is made up of 206 bones. Bones work with muscles and joints to hold our body together and support freedom and movement. The skeleton supports the body and protects delicate internal organs such as the brain, heart, and lungs. Healthy bones need a balanced diet, regular weight-bearing exercise, and the right levels of various hormones.

Bones in the human body come in many shapes and sizes, which can be categorised into four different types:

Bone	Function	Examples	
Long bone	Consist of compact bone with spongy bone at the ends. They lie in the arms and legs and have a long and thin shape to assist muscles and work as a lever to permit movement.	Femur, tibia, fibula, humerus, radius and ulna	
Flat bones	Are shaped like flat plates, have broad surfaces and their function is protection. They also provide large surfaces for many muscles to attach to.	Ribs, scapulae, sternum and skull bones.	
Short bones	Have a square, cubed shape and provide support, strength and stability.	Wrists, kneecap and ankles	
Irregular bones	Have a shape that does not conform to the above three types. Various functions, including protection of the spinal cord.	Vertebrae, sacrum, coccyx, mandible (jaw bone) and hyoid bone	

Bony landmarks

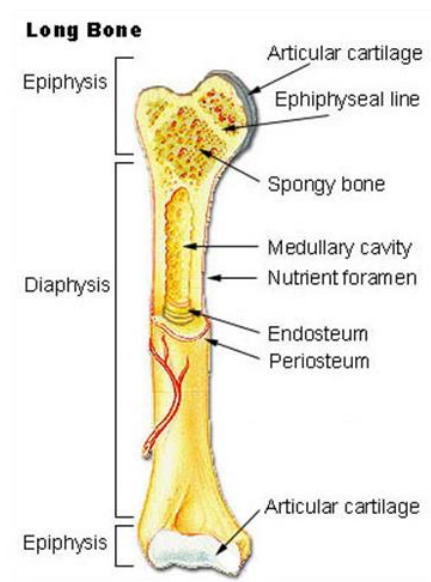
In addition to identification of the major bones of the skeleton, trainers are also required to identify key bony landmarks. This is particularly useful when conducting the screening process, where girth or skinfold measurements may be taken. Some of the key bony landmarks are identified below:

Landmark name	Landmark anatomical description
Acromion	- Bony process of the scapula - It is a continuation of the scapular spine that articulates with the clavicle - It is the most lateral point of the scapula - Required for accurate location of upper arm girth
Inferior Angle of Scapula	- The most inferior point on the scapula where the medial and lateral borders of the scapula meet - Required for locating the subscapular skinfold
Proximal Patella	- The most proximal point of the patella - Required for accurate location of thigh girth measurement
Radiale	- The head of the radius - The most proximal point of the radius - Can be located by feeling for the space between the humerus and radius - Required for accurate location of upper arm girth
Iliac Crest	- Most superior border of the ilium - Required for accurate location of measurement of waist: hip ratio

Bone tissue and structure of long bones

Long bones are very important in regard to exercise prescription. Their structure is detailed in the following image and table.

Structure	Function
Periosteum	The dense, tough outer shell that contains blood vessels and nerves
Compact or dense tissue	The hard, smooth layer that protects the tissue within a bone
Cartilage	Tough, but flexible connective tissue that covers the ends of bones at a joint. It is made of cells, collagen fibres and matrix
Diaphysis	Long shaft component of a bone
Epiphysis	Ends of a long bone. There is a proximal epiphysis, which is the proximal end (that closest to the trunk) and a distal epiphysis, which is at the distal end of the bone (that is further from the attachment point and closest to the hand or foot)
Bone marrow	Jelly-like substance found inside the cavities of some bones (including the pelvis) that produces blood cells
Spongy or cancellous tissue	The porous, honeycombed material found inside most bones, which allows the bone to be strong yet lightweight



Video

Watch this video for more information on the structure of bone:

- [The structure of bone](#) (01:26min)

The Skeleton

Organisation of the skeleton

The human skeleton consists of fused and individual bones that are supported and supplemented by ligaments, tendons, muscles, and cartilage (The Better Health Channel, 2012). The skeleton serves as a scaffold that supports organs, anchors muscle, and protects organs, such as the brain, lungs, and heart.

The human skeleton is divided up into two main sections:





The Axial Skeleton

The axial skeleton consists of around 80 bones along the central axis of the human body. This part of the skeleton consists of the spinal column, ribs, including sternum, and the skull.

The Appendicular Skeleton

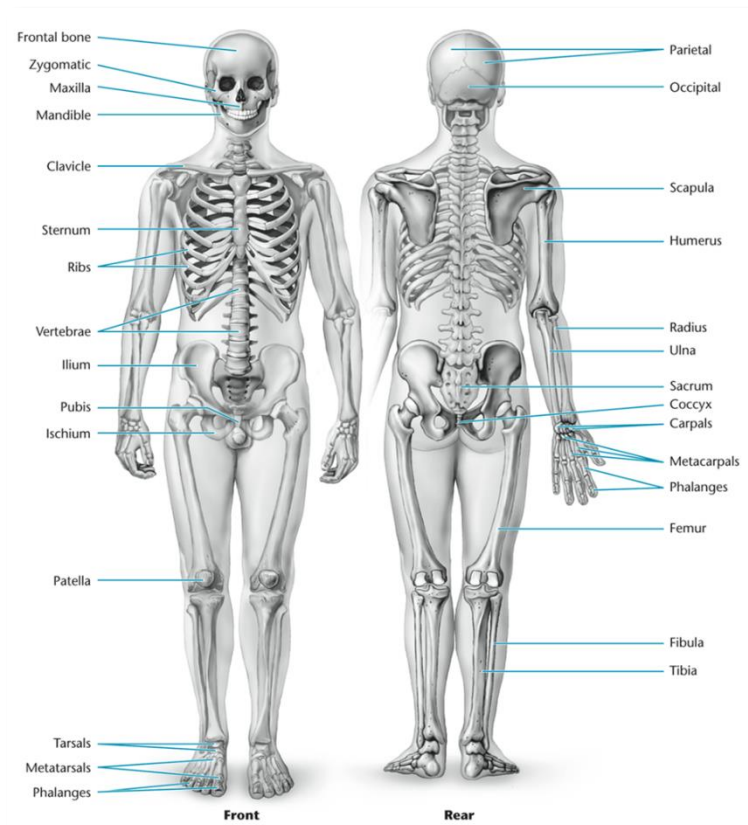
The appendicular skeleton is composed of 126 bones of the human body. Functionally, it is involved in locomotion (lower limbs) of the axial skeleton and manipulation of objects in the environment (upper limbs). The appendicular skeleton consists of the limbs, shoulders, pelvis, hands, and feet.



The Skeleton

The human skeleton has five main functions:

1. Support for the body
2. Provide an attachment point for muscles, which allows movement to occur
3. Protect internal organs
4. Storage place for important minerals, such as calcium
5. Synthesis of blood cells

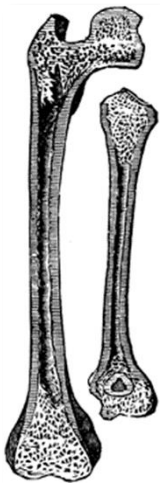
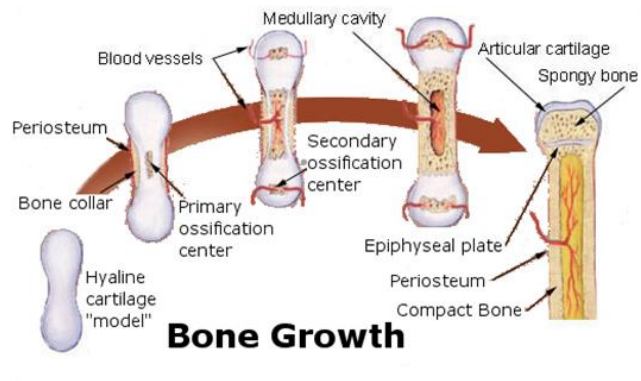


SECTION 2 – BONE GROWTH AND REMODELLING

Bone is not a dormant structure in the human body as it is continually growing and changing. Throughout life, human's bones grow in one of two directions.

Interstitial growth is the process of bone growing in length. This occurs when the cells on the epiphyseal side of the growth plate divide quickly and push the plate away from the diaphysis. This occurs to a great extent in children and adolescents within long bones when the individual is growing. It is important that this area is not injured or placed under too much strain during childhood to ensure growth is not hindered.

Bones can also grow in width and become thicker and stronger; this is known as **appositional growth**. This type of growth can be particularly induced by weight-bearing activities, such as running or resistance training, which stimulates the formation of new bone. Lack of exercise causes bones to weaken.

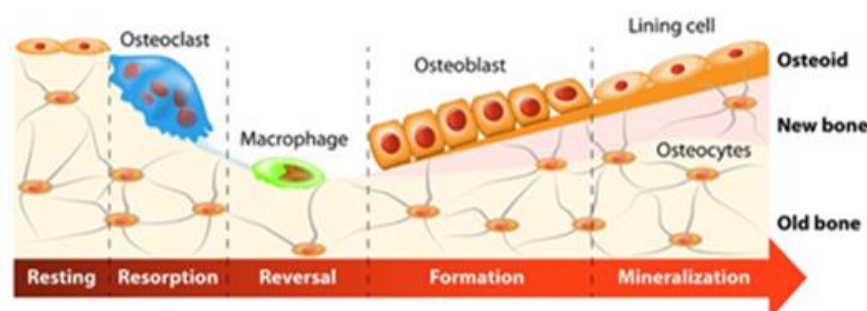


The process of appositional growth can be described by a theory called **Wolff's Law**, which states that bone adapts to the loads that it is placed under. If a bone is exposed to repetitive loading, it will consequently remodel itself to become stronger and thicker to withstand these loads. This occurs during regular resistance training, running, walking, regular jumping, or any activities that put constant stress on bones.

This law also explains what can happen when bones are not loaded on a regular basis. If loading on a bone decreases, the bone will become thinner and weaker. This is common in inactive individuals and in people after a long period of bed rest or immobility, such as post-surgery or injury. Active people can also have weak bones if their chosen method of exercise is non-impact or very low impact, such as swimming or cycling.

Nutrition also has an effect on bone growth, with importance being placed on calcium and vitamin D for bone strength. Alcohol, cigarette smoking, menopause, low body fat, genetics and age negatively affect bone growth, leading to weakened bones.

The bone remodelling process



SECTION 3 – JOINTS

Joint and accessory structures



Definition

A **joint** is described as the part of the body where two or more bones meet to allow movement (The Better Health Channel, 2012).

Joints are described by how much movement they allow.

There are three broad classes of joints:

Joint	Function	Example
Immovable (fibrous joints)	Type of fibrous joint that allows for little or no movement, sometimes called sutures.	Skull
Slightly moveable	Two or more bones are held together so tightly that only limited movement is permitted.	Vertebrae, pubic bone
Freely moving (synovial joints)	- Highly moveable joints and the main focus for fitness professionals as these are what are mostly involved in exercise. - The structure of this joint includes a synovial cavity, which contains synovial fluid to cushion and lubricate the joint, as well as cartilage that covers the ends of the bones and reduces friction.	Knees, shoulders

Cartilage

Cartilage is a tough but flexible connective tissue that covers the ends of bones at a joint. Cartilage is made of up cells, collagen fibres, and matrix. Cartilage is more flexible than bone and is located where bones connect.

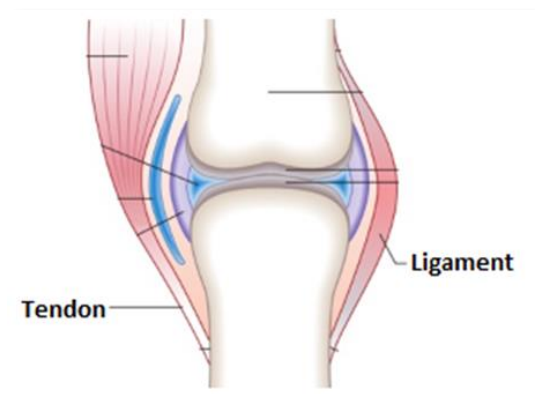
Articular cartilage provides a spongy cushion for the joint. This helps to prevent the joint from being crushed. The articular cartilage can deteriorate, causing such conditions as osteoarthritis, a condition that causes pain and immobility.



Cartilage in the human body	Hyaline cartilage cells
	

Ligaments and tendons

Ligaments help to stabilise joints and are made of dense, regular connective tissue that is organised in a parallel way to create a tough and fibrous band. The main function of a ligament is to connect bone to bone, such as the plantar ligaments under the foot. Examples include the anterior cruciate ligament and the medial collateral ligament – both in the knee. Commonly torn ligaments are those on the lateral aspect of the ankle as a result of an ankle sprain.



Tendons are a tough band of fibrous connective tissue consisting of parallel collagenous fibres that are packed closely together. Tendons join muscle to bone and are able to withstand large amounts of tension. The Achilles tendon is a commonly known tendon that joins the calf muscle to the heel bone.

The following section examines each of the major joints including each movement's terminologies, joint type and range of motion.



Attachment 2 –Joints of the body diagrams

Please open and read **Attachment 2 – Joints of the body diagrams**.

This attachment is a useful resource in visualising how the joints are formed and move.

Attachment(s) for this unit can be found in the *Learning Resources* section of this unit in My eCampus.

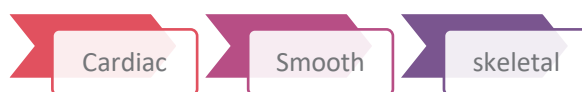
Module three: The muscular system

SECTION 1 – TYPES OF MUSCLES

The muscular system is responsible for producing movement. There are about 600 muscles in the human body. The muscles have a range of functions that include assisting with maintenance of posture and joint stability, pumping blood, and supporting movement.

Muscles work by either contracting or relaxing to cause movement. This movement may be voluntary (movement is made consciously) or involuntary (without conscious awareness).

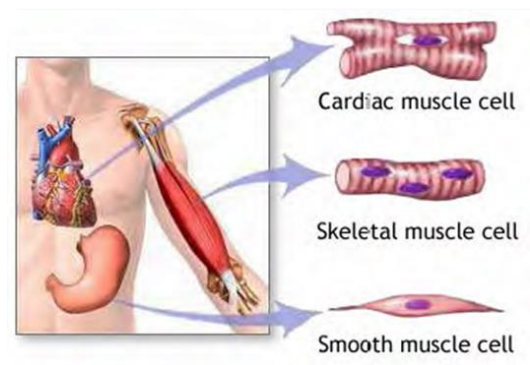
There are three types of muscle tissue:



Cardiac muscle is found in the heart and is under involuntary control, meaning the nervous system makes the heart beat without conscious thought.

A series of diagrams illustrating many of the major **skeletal muscles** in the human body is shown in the next four pages. When viewing the muscles it helps to see alternate images to get different views on muscles and assist with your understanding.

Smooth muscle is located in various internal structures, including the digestive tract, uterus and blood vessels, such as arteries. Smooth muscle is arranged in layered sheets that contract in waves along the length of the structure. Smooth muscle is also under involuntary control as it happens without our conscious awareness.



Attachment 3 – Muscles of the human body diagrams

Please open and read **Attachment 3 – Muscles of the human body diagrams**.

This attachment is a useful resource in visualising where the muscles are located within the body.

Attachment(s) for this unit can be found in the *Learning Resources* section of this unit in My eCampus.



Attachment 4 – Breakdown of the muscles

Please open and read **Attachment 4 – Breakdown of muscles**.

This attachment provides a breakdown of major muscles of the human body, origins and insertions and other important information.

Attachment(s) for this unit can be found in the *Learning Resources* section of this unit in My eCampus.

Skeletal muscle

Structure of skeletal muscle

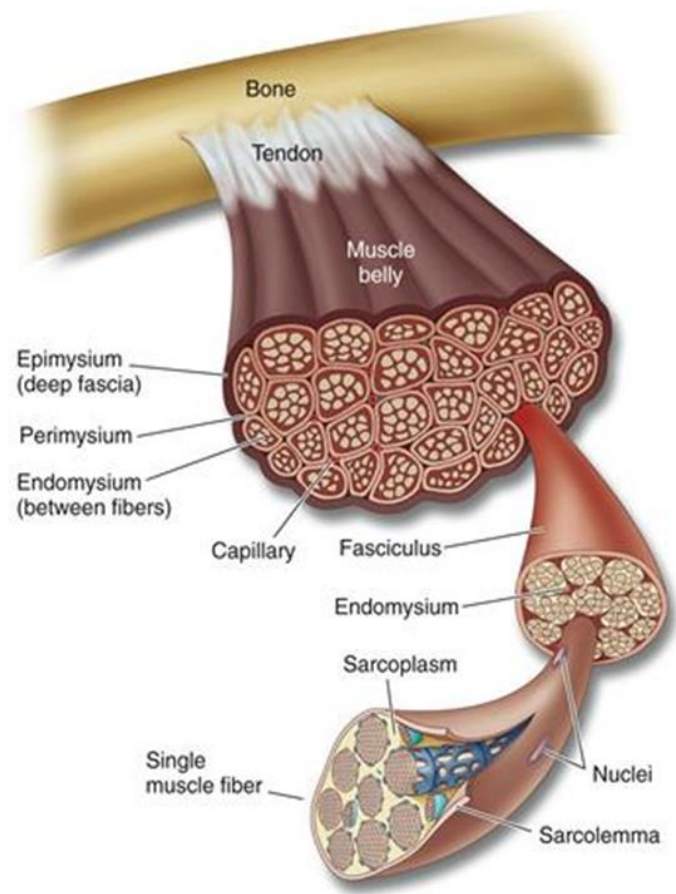
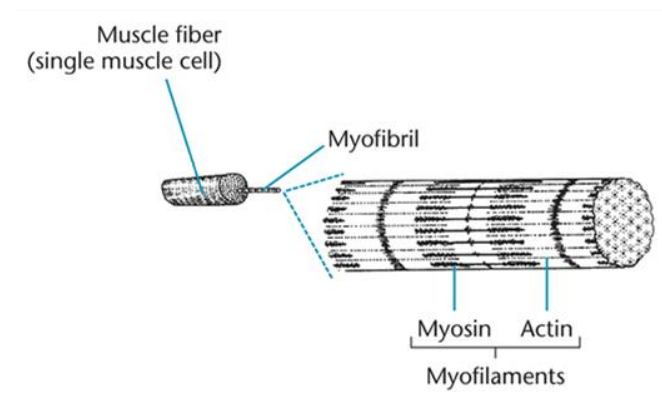
Skeletal muscles are specialised tissue that is attached to bones and allows movement of the skeleton. Together, skeletal muscles and bones are called the musculoskeletal system.

Generally speaking, skeletal muscles are grouped into opposing pairs, such as biceps and triceps on the front and back of the upper arm, and quadriceps and hamstring on the upper thigh, contracting and relaxing when movement occurs under voluntary control (conscious).

Skeletal muscle has certain characteristics that allow it to shorten and lengthen:

- Ability to generate force when stimulated by the nervous system
- Ability to be stretched by the force of movement
- Excitability or the ability to receive and send stimuli via the nervous system (brain and spinal cord)
- Ability to return to their original shape after shortening or lengthening (elastic)

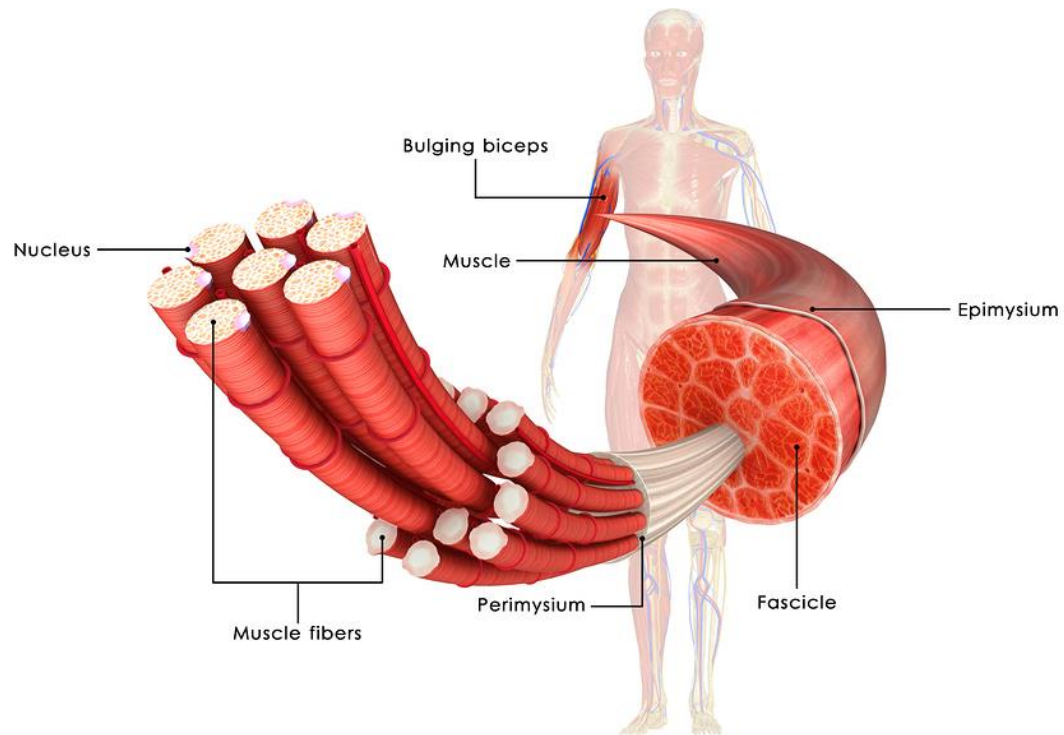
A single muscle cell is called a muscle fibre. Muscle fibres contain contractile filaments that move past each other and change the size of the cell called myofibrils. These consist of myofilaments, comprising of repeating units of proteins called actin and myosin.



Myofibrils contain a specialised protein (myoglobin) and molecules to provide the oxygen and energy required for muscle contraction. Each myofibril contains filaments that fold together when given the signal to contract. This shortens the length of the muscle fibre, which, in turn, shortens the entire muscle if enough fibres are stimulated at the same time.

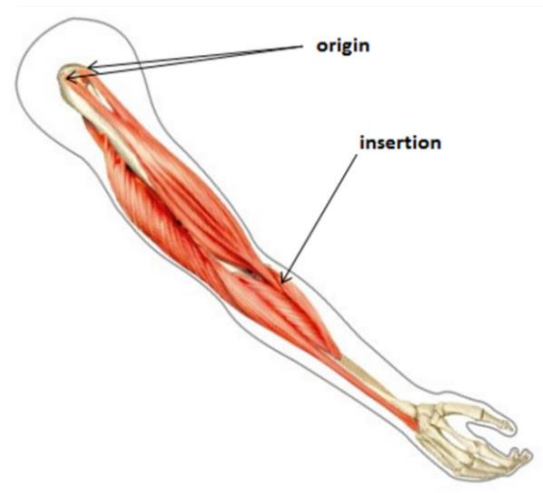
Muscle fibres are bundled together to form a **fascicle**. Many fascicles are bundled together with connective tissue to form a muscle.

The following diagram demonstrates the structure of an entire muscle.



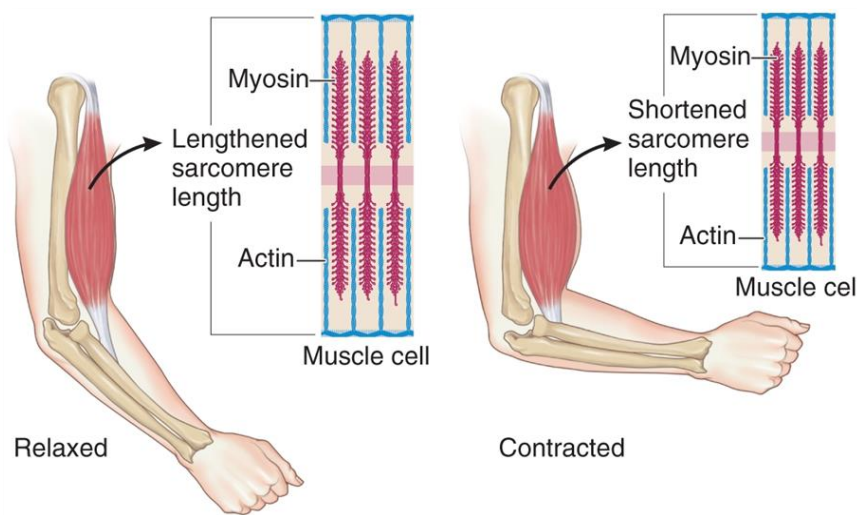
SECTION 2 - MUSCLE ORIGINS, INSERTIONS, AND ACTIONS

Muscles attach to bones via tendons. They attach at two points called the origin and the insertion. The origin is the fixed end not moving during contraction. The insertion is the end attached to the bone that moves during contraction. The movement that the muscle makes is the action. Attachment 4 shows the major muscles of the neck, thoracic, arm, abdomen, lumbar, hip and leg. Each major muscle is shown with its location, origin and insertion and other important information.



Mechanism of movement

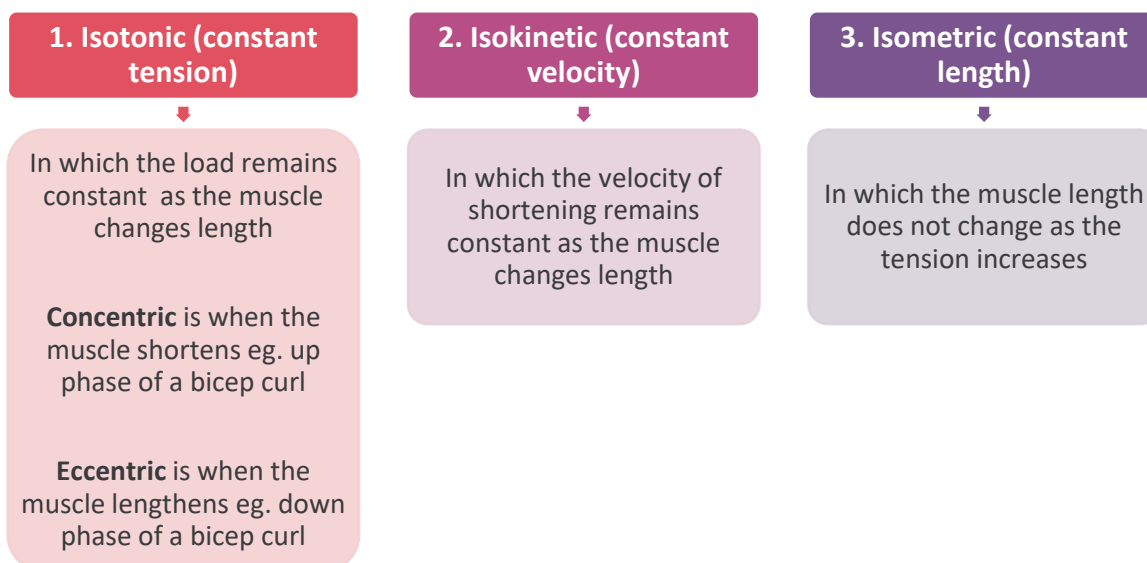
For movement to occur, a muscle needs to contract and shorten. This will then cause movement of the attached joints and bones.



Muscle contraction can be explained by the Sliding Filament Theory, where the actin and myosin proteins “hook” onto each other and slide past one another therefore causing the muscle to shorten.

Types of muscular contraction

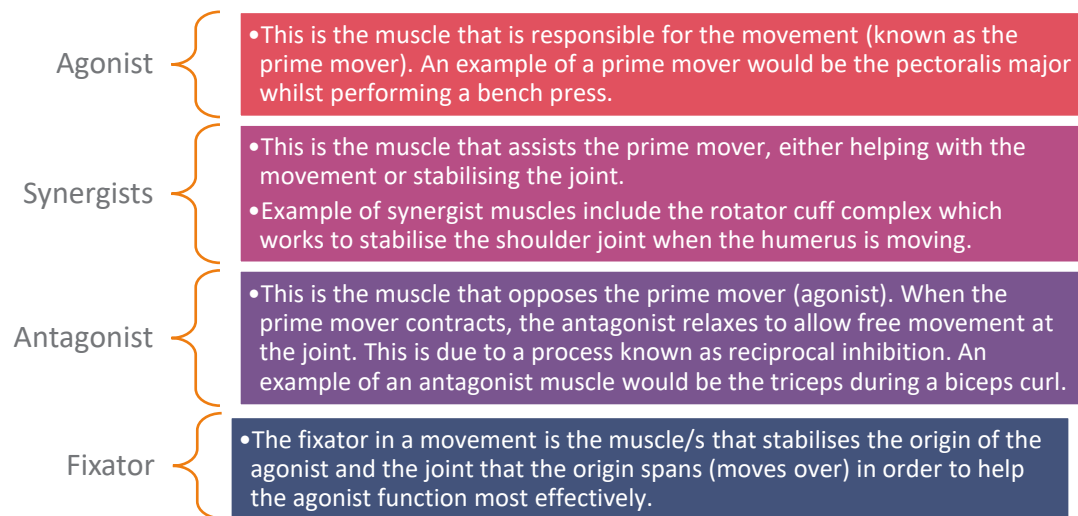
Muscle contraction is the activation of tension-generating sites within muscle fibres. In physiology, muscle contraction does not mean muscle shortening because muscle tension can be produced without changes in muscle length such as holding a heavy book or a dumbbell at the same position. When a person is moving the bone to which the muscle’s insertion is attached, the internal tension is transmitted to the bone as the contractile component stretches and tightens the muscle’s tendon. As a result, the muscle band width shortens when it contracts. There are three types of muscle contraction are:



The “load” is the opposing force exerted on the muscle by the weight of an object. The speed of shortening is inversely proportional to the load. The amount of work accomplished by a contracting muscle equals the magnitude of the load times the distance the load is moved. Many muscles are part of a lever system that amplifies the distance and velocity of the shortening of a muscle at the expense of the muscle having to exert increased force to move a load. The amount of energy consumed by a contracting muscle that is realised as external work varies from 1% to 25%; the remaining energy is converted to heat.

Role of muscles

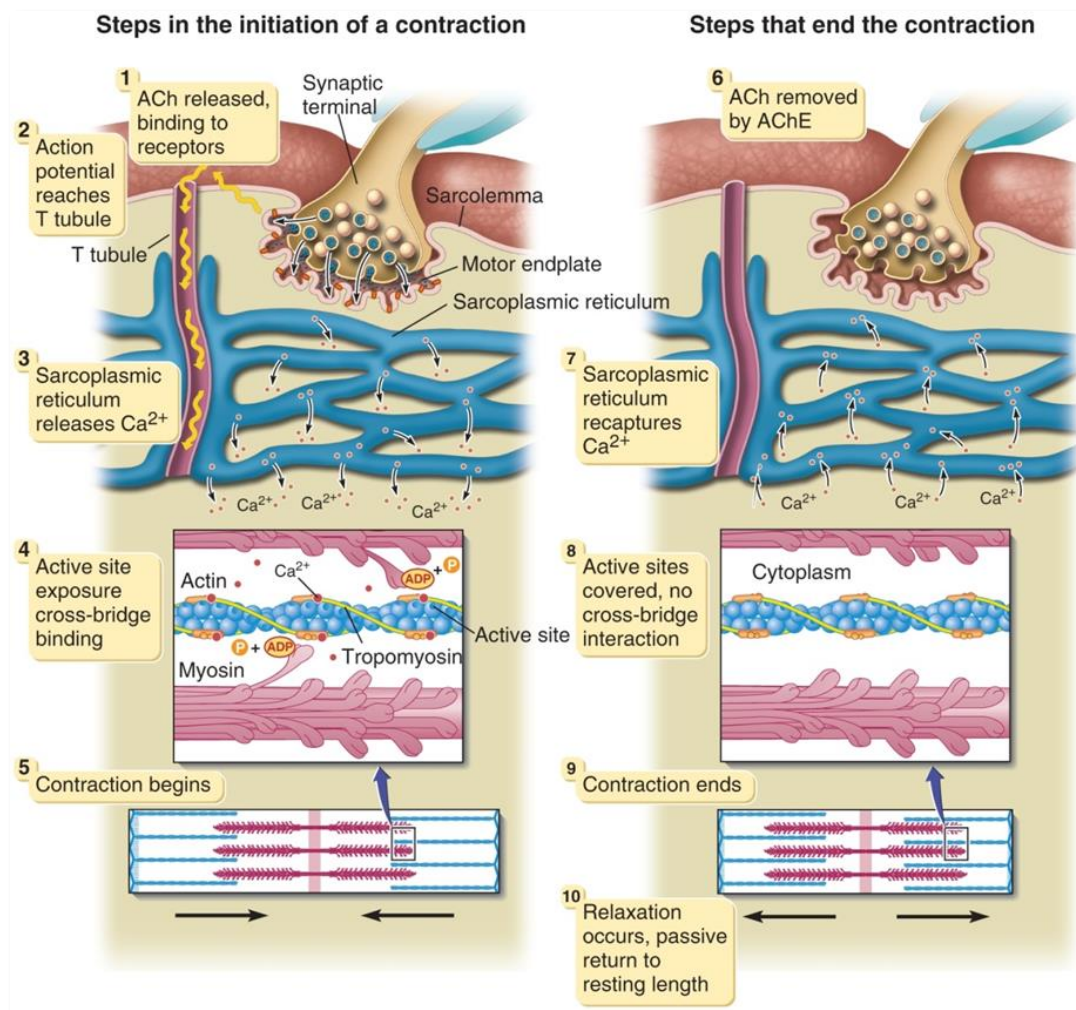
Skeletal muscles do not function on their own; they function as part of a group, with each muscle in the group taking on a different role. These roles include:



Understanding the role that a muscle is playing within a movement or exercise is essential so that correct technique and coaching can be delivered, as well as assisting in exercise selection.

See PAP1- Part B Attachment 4 – Exercise Selection and Movement Terminology for examples of the agonist, synergist, antagonist and fixator muscles in selected exercises.

The following diagrams show the overlap of actin and myosin and the shortened length of the muscle when contracted in comparison to a relaxed state.



Video

Watch these videos for more information on the mechanism of muscle movement:

- [Muscular System, Sliding Filament Theory \(1\)](#) (01:13min)
- [Muscle Contraction: The Cross Bridge Cycle](#)

Muscle movement

In order for movement to occur, the body is involved in a series of chemical reactions to make energy. The human body stores energy in the form of a high energy compound called adenosine triphosphate (ATP). This compound consists of three phosphates and one adenosine group. The removal of one phosphate group — yielding adenosine diphosphate (ADP) — releases the stored energy that can be used for body reactions.



Video

Watch this video for more information on ATP:

- [What ATP is and How it Works](#) (02:45min)

Neural drive

Neural drive is the extent to which the nervous system activates muscles. If neural drive is high, a large amount of motor units are excited producing a large amount of force. This would be during a heavy lift or an explosive activity requiring a high amount of effort. When neural drive is low, less motor units are activated causing less muscle fibres to contract. This produces a weaker contraction, such as when picking up a glass to drink.

The more neural drive, the more muscle fibres are activated and the more force that is exerted.

To further clarify neural drive from another perspective, the rate in which action potentials are received from the brain and CNS is called “Temporal Summation”. Temporal summation is the process by which an increase in the firing frequency of action potentials (or firing frequencies) causes an increase in the amount of force generated by the individual motor unit.

For an example a single action potential when it reaches the muscle fibre is known as a “twitch”

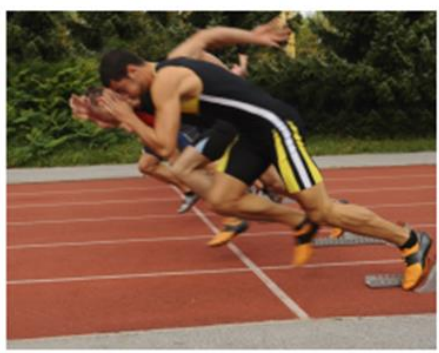
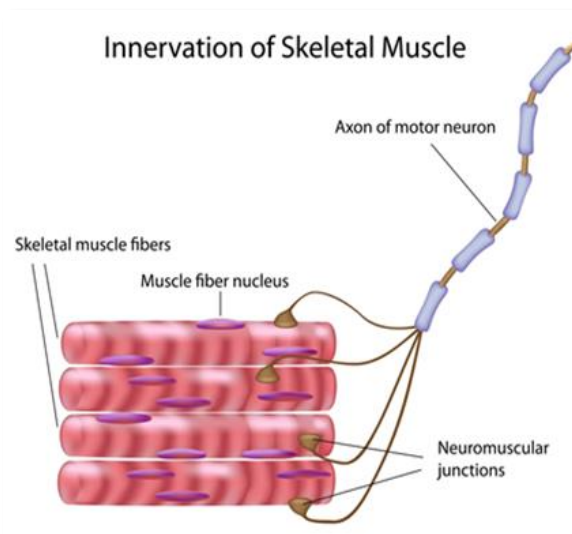
So depending on the rate of the subsequent action potentials will activate the appropriate motor units IE fast twitch fibre motor units or slow twitch fibre muscle units.

SECTION 3 – MUSCLE FIBRE TYPES

Muscle fibres can be classified as predominately fast twitch or slow twitch. The proportion of each muscle fibre in an individual is mostly determined by genetics, however training can play a role in influencing which are dominant.

Fast twitch

Fast-twitch muscle fibres are known as Type II muscle and contract rapidly when activated. These fibres respond to a strong stimulus and are white in colour. Activities containing explosive or high force outputs, mostly anaerobic in nature, recruit fast-twitch muscle fibres. Examples include sprints or high intensity resistance training.



Fast-twitch fibres use anaerobic metabolism to create fuel because they are much better at generating short bursts of strength or speed than slow-twitch fibres, however they fatigue more quickly. Fast-twitch fibres generally produce the same amount of force per contraction as slow-twitch fibres, but they get their name because they are able to fire more rapidly. Having fast twitch fibres can be an asset to a sprinter since they need to quickly generate a lot of force.

Fast-twitch (Type II) muscle fibres produce a rapid and large force during a short period of time relative to ST (Type I) muscle fibres because:

- They have a high capacity of transmitting an electrical signal
- Their cross bridges work faster
- The activity of the enzyme myosin ATPase (responsible for ATP breakdown) is faster
- There is a relative release and use of calcium in the muscle

These fast twitch fibers can be further categorized into Type IIa and Type IIb fibers, which are also known as "fast twitch oxidative" and "fast twitch glycolytic," respectively. Type IIa fibers, or fast oxidative fibers, are used more during sustained power activities such as velocity and are more resistant to fatigue than Type IIB. Type IIb fast-twitch fibers, or fast glycolytic fibres (also known as Type IIx), are recruited for very short-duration high-intensity bursts of power such as maximal and near-maximal lifts and short sprints.



Slow twitch

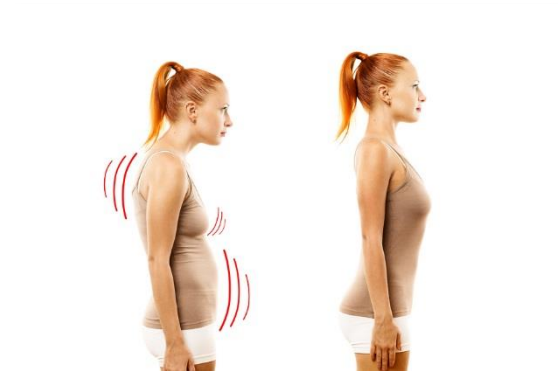


Slow-twitch muscle fibres are called Type I muscle fibres. These fibres contract slower than fast-twitch fibres and respond to a lighter stimulus. As they are used mostly for aerobic activities, slow-twitch fibres are red in colour from the use of oxygenated blood supply. Individuals with a large proportion of slow-twitch fibres will have advantages in long distance aerobic events such as running or swimming.

The slow muscles are more efficient at using oxygen to generate more fuel (ATP) for continuous, extended muscle contractions over a long time. They fire more slowly than fast-twitch fibres and can go for a long time before they fatigue. Therefore, slow-twitch fibres are great at helping athletes run marathons and cycle for hours.

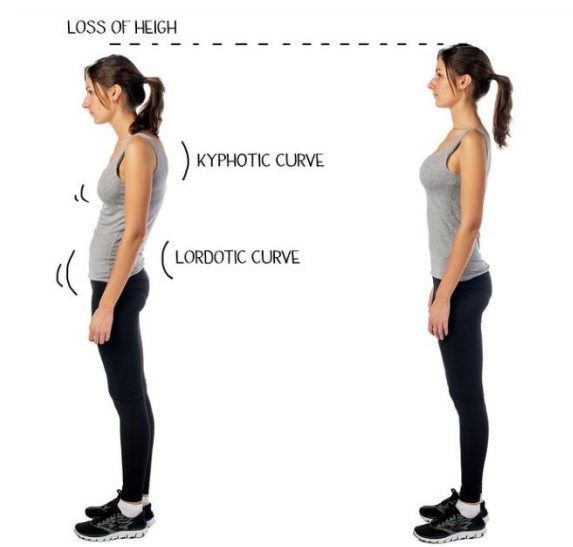
SECTION 4 – POSTURE

The interaction between the skeletal and muscular system controls our posture. Posture refers to the alignment of different parts of the body. The body has a natural shape and curves that may vary slightly, depending on genetics and lifestyle habits. An understanding of 'ideal' posture, variances from this ideal and how to correct postural variances is essential for a fitness instructor to ensure the prescription and delivery of appropriate and safe exercises.



Ideal posture

In order to identify postural variances, we first need to establish a norm to which we can make a comparison. Ideal posture is largely influenced by the position of the spine. A common term or reference point that is used in the fitness industry when providing exercise instruction is 'neutral spine'. This refers to the ideal or natural alignment of the different sections of the spine. It is essential that this is maintained throughout exercise performance as it is in this position that the spine is most effective at bearing weight. Key observational points when determining posture should relate to the alignment of the ear, shoulder, hip, knee and ankle from a lateral view. Ideally, a vertical line should dissect through each of these points.



The spine should display a natural curve of lordosis at the cervical spine and lumbar spine, with a kyphotic curve in the thoracic spine. From an anterior and posterior view, the head should remain forwards, in a neutral position without rotation or lateral flexion. Shoulders should be level, with arms hanging straight by the sides. Similarly, the pelvis and knees should be level, in a neutral position, with the feet parallel to each other.

From the lateral view, a vertical line should dissect through the lobe of the ear and the shoulder joint to the hip. From here the line continues slightly anterior through the

midline of the knee, and slightly anterior to the ankle joint.

Maintaining this ideal posture as much as possible is essential to prevent the development of injuries, particularly during exercise.

Postural variances

Many postural variances exist between individuals. The causes of these variances are determined by genetics, lifestyle habits and muscular imbalances, with either tightness or weakness causing the skeleton to drift from the ideal described above. These imbalances are often as a result of lifestyle habits such as sitting slouched at a desk, or weight bearing through one leg for a prolonged period. Most common postural deviations originate in the spine. These deviations are described below.

Scoliosis

Scoliosis is an abnormal sideways curvature of the spine. This can occur due to genetics or commonly in individuals that participate in activities that place an emphasis on one side of the body or regular rotation, such as racket sports. These activities cause increase tightness and strength on one side of the body, with weakness on the opposing side of the body.

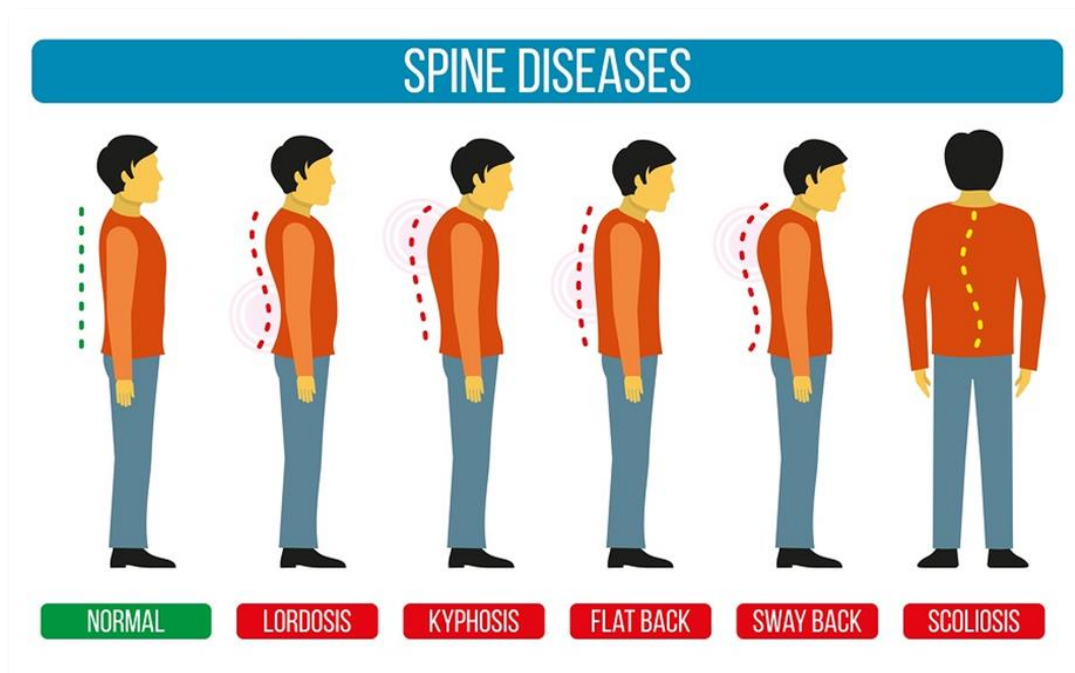
Kyphosis

This refers to the convex curvature of the cervical and thoracic spine regions. An exaggerated kyphotic curve is referred to as hyperkyphosis. This is commonly caused by tightness through the

pectorals and anterior deltoid, with weakness in the rhomboids and posterior deltoids. This will give the shoulders a more rounded appearance, with a humped back.

Lordosis

Lordosis refers to the normal inward curve of the lumbar and cervical spine regions. An exaggerated lordotic curve in the lumbar spine and cervical spine is termed lumbar hyperlordosis. It is caused by tightness in the lower back and hip flexors, with weak and stretched abdominals.



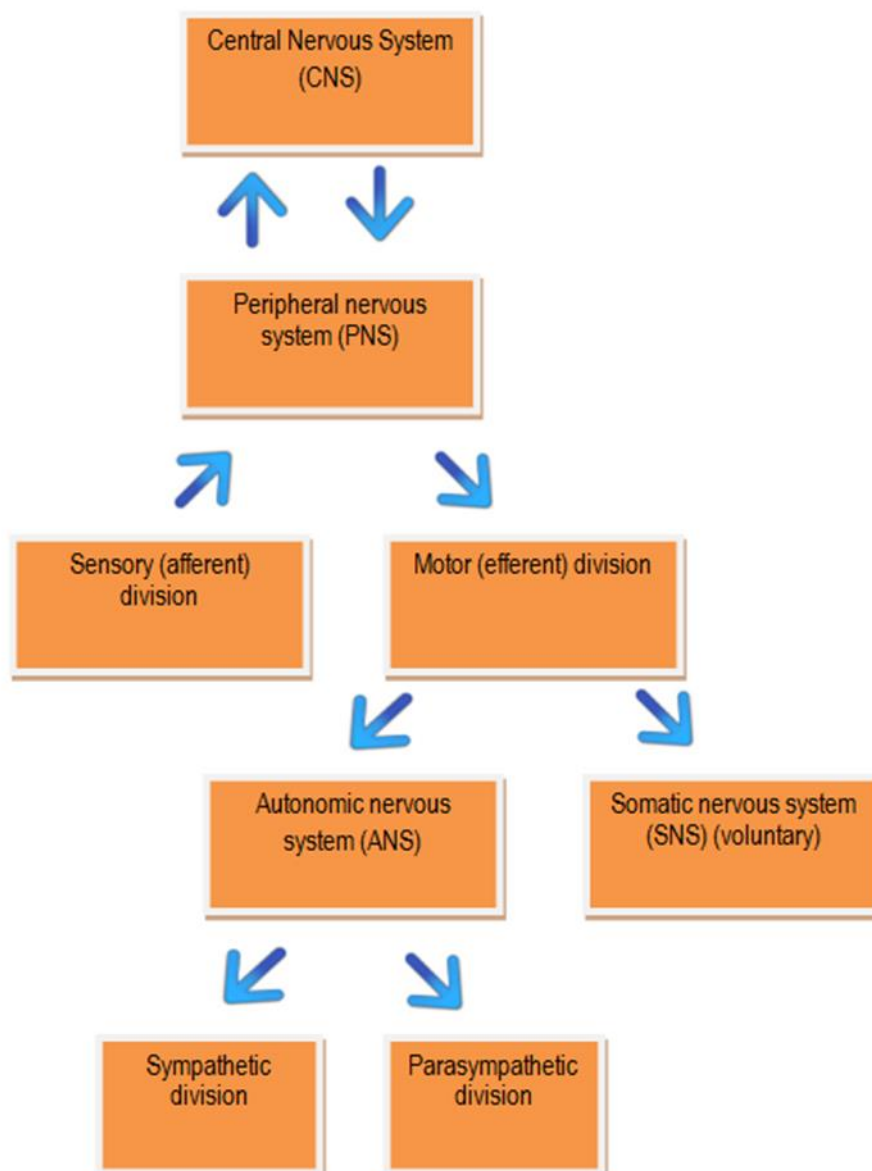
Module four: The nervous system

SECTION 1 – ORGANISATION AND FUNCTION

The nervous system has three major functions, which are all important in the human body (The Better Health Channel 2012). These functions are:

- Monitoring sensory input (information sent into the nervous system from the sensory neurons e.g. muscles)
- Interpreting and deciding how to act upon this sensory information
- Causing a motor output or response

The following diagram illustrates the nervous system anatomy and communication. Upward arrows are representative of sensory communication or afferent fibres. Downward arrows represent motor communication or efferent fibres.

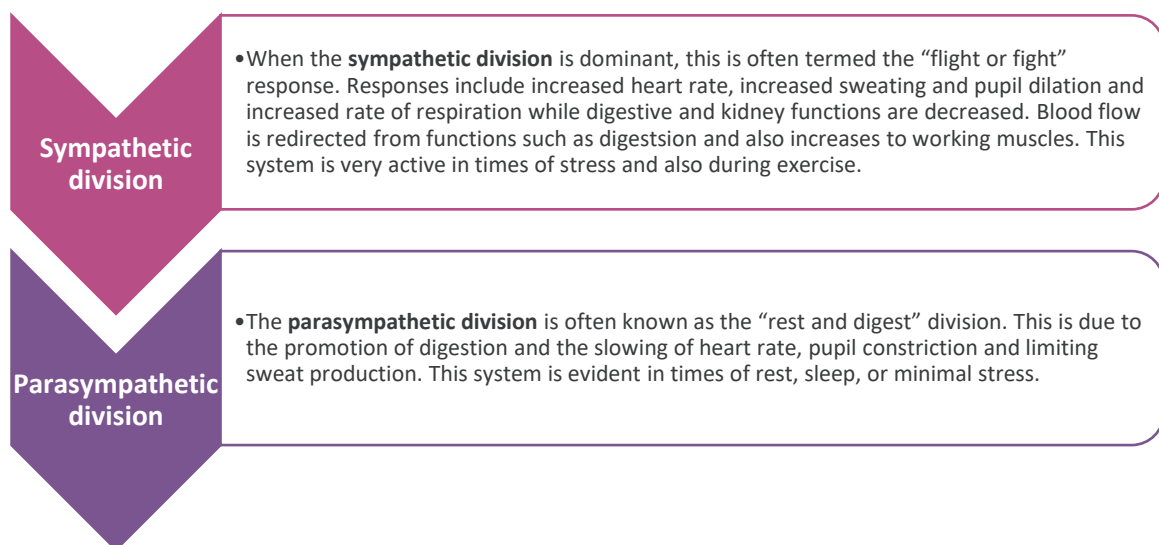


The **central nervous system** (CNS) is responsible for regulating and controlling movement. It is comprised of the brain and spinal cord. Information is sent to the CNS, which on completion of interpreting and sorting is sent to the peripheral nervous system.

The **peripheral nervous system** (PNS) is comprised of the nerves outside of the brain and spinal cord and its main role is to transmit information from the CNS to the rest of the body. The PNS is divided into the somatic nervous system and the autonomic nervous system.

The **somatic nervous system** consists of two types of nerve fibres, sensory and motor neurons. Sensory neurons send sensory information to the CNS (e.g. touch, equilibrium, pain, vision and hearing). Nerve fibres called motor neurons send motor information to skeletal muscle to produce both voluntary and reflex movements which cause skeletal muscles to contract. The muscles required to breathe are also controlled by motor neurons. This system is usually controlled voluntarily however the process of a movement occurring is coordinated subconsciously. For example you don't need to actively coordinate contraction and relaxation of muscles if you want to move from point A to point B but the decision to move is voluntary.

The **autonomic nervous system** is divided into the sympathetic division and parasympathetic division. This system is responsible for controlling smooth muscle, cardiac muscle and glands but not skeletal muscle. The autonomic nervous system works by either increasing or decreasing activity in a given location. In contrast to the somatic system, the autonomic system functions completely involuntarily.



In terms of exercising, both the somatic and autonomic (sympathetic) nervous systems work in conjunction.



Video

Watch this video for more information on the nervous system:

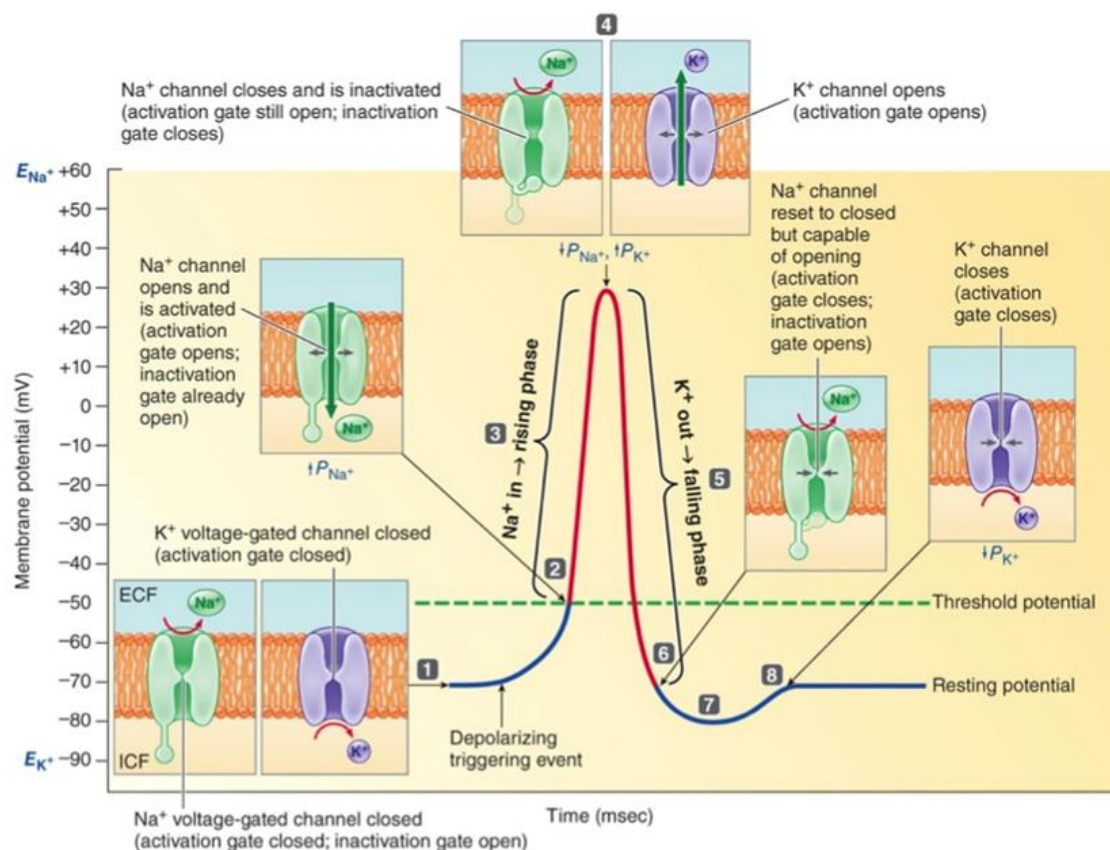
- [The Human Nervous System](#) (09:58min)

SECTION 2 – NERVES AND NERVE IMPULSES

The nerve impulse is the body's quickest way of controlling and maintaining homeostasis. The membrane of a non-conducting neuron is positive outside and negative inside due to the operation of the sodium potassium pump. This difference in charge is called a resting potential and the membrane is said to be polarised.

During an action potential, marked changes in membrane permeability to Na^+ and K^+ take place, therefore permitting rapid refluxes of these ions down their electrochemical gradients. These ion movements carry the "current" responsible for the potential changes that occur during an action potential. The sodium-potassium pump gradually restores the ions that moved during propagation of the action potential to their original location in order to maintain the concentration gradients.

Action potentials take place as a result of the triggered opening and subsequent closing of two specific types of channels: voltage gated Na^+ channels and voltage gated K^+ channels. These permeability changes bring about a brief reversal of membrane potential, with Na^+ influx causing the rising phase (from -70 to $+30$ mV), followed by K^+ efflux causing the falling phase from peak back to resting. The conformational changes in voltage gated sodium channels and potassium channels are demonstrated below along with the events of triggered threshold – shown in figure below. This figure highlights the cellular events associated with the changes in depolarisation and repolarisation, together with the changes in sodium and potassium permeability.



- 1 Resting potential: all voltage-gated channels closed.
- 2 At threshold, Na⁺ activation gate opens and P_{Na^+} rises.
- 3 Na⁺ enters cell, causing explosive depolarization to +30 mV, which generates rising phase of action potential.
- 4 At peak of action potential, Na⁺ inactivation gate closes and P_{Na^+} falls, ending net movement of Na⁺ into cell. At the same time, K⁺ activation gate opens and P_{K^+} rises.
- 5 K⁺ leaves cell, causing its repolarization to resting potential, which generates falling phase of action potential.
- 6 On return to resting potential, Na⁺ activation gate closes and inactivation gate opens, resetting channel to respond to another depolarizing triggering event.
- 7 Further outward movement of K⁺ through still-open K⁺ channel briefly hyperpolarizes membrane, which generates after hyperpolarization.
- 8 K⁺ activation gate closes, and membrane returns to resting potential.

Source: Permeability changes and ion fluxes during an action potential. Sherwood, L. (2013, figure 4-7, p. 96).

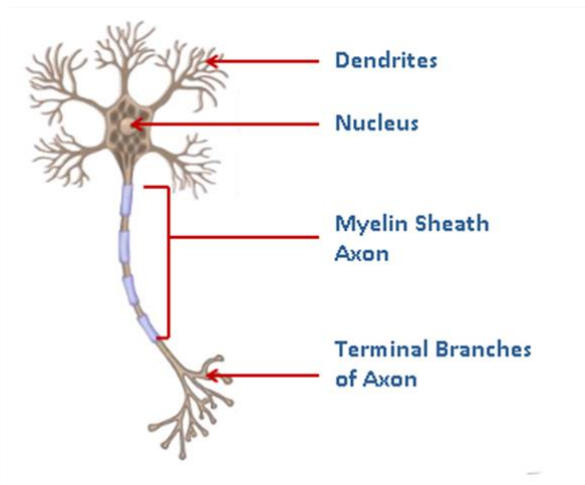
SECTION 3 – MOTOR UNITS AND MUSCLE CONTRACTION

A motor unit is defined as a motor neuron and all the muscle fibres it innervates. When a motor unit is stimulated, the fibres within this motor unit are activated, causing the muscle to contract and movement to occur.

When a motor neuron is activated, all the associated muscle fibres in the motor unit contract simultaneously. Large muscles have many muscle fibres attached to each motor neuron, while small muscles requiring delicate movements have fewer muscle fibres per motor neuron. This is known as the all-or-none principle, as either all fibres in a motor unit are activated or none are activated. Some fibres within a motor unit cannot be activated if others remain un-stimulated.

The force the muscle can generate is dependent on the amount of neural drive. The greater the force required is, the greater number of motor units are activated. This means that if a strong muscular contraction is required, a large amount of neural drive or input is needed. Less neural drive causes less motor units to be activated and a weaker muscle contraction.

A weightlifter performing a lift will require an enormous amount of neural drive to excite as many motor units and muscle fibres as possible to produce the largest amount of force.



Web

The below link is animations of the nerve

- [View Nerve Impulse animation](#)



Video

Watch this video for more information on the nerve impulse:

- [The Nerve Impulse](#) (11min:20sec)

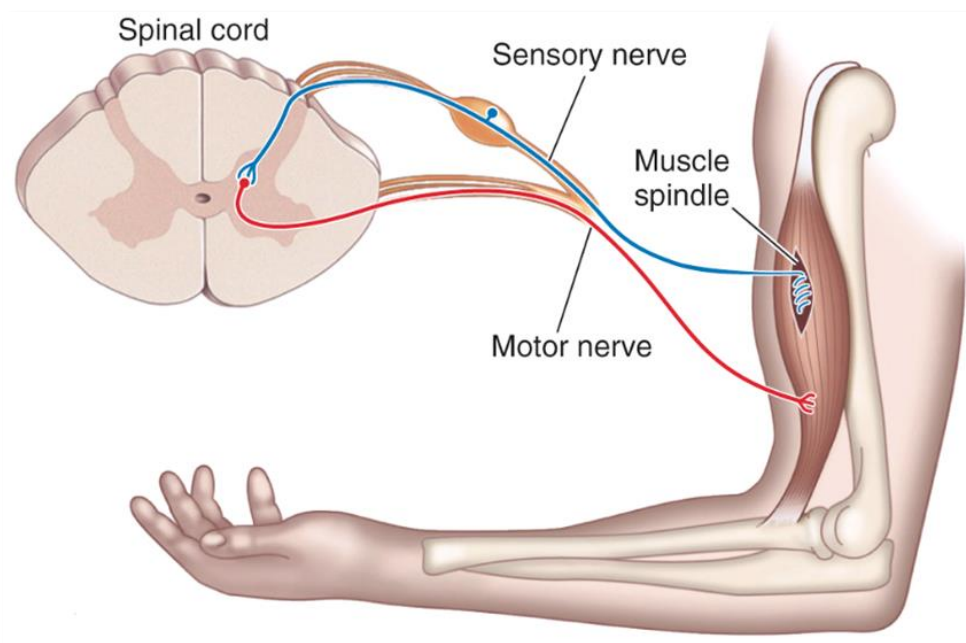
Note: If you choose to complete the quiz below the video, please do not complete the Routing Information and do not email the results.

SECTION 4 – STRETCH REFLEX

A reflex arc is how automatic movements occur within the body. The reflex arc is made up of the following components:

Component	Function
Receptor	Receives the signal for the reflex to start
Sensory/afferent neuron	Part of the special wiring of the nervous system that sends messages from the proprioceptor to the spinal cord
Association neuron	Part of the spinal cord that sorts and organises the information ready to be sent back to the skeletal muscle
Motor/efferent neuron	Neuron that sends messages from the association neuron back to the skeletal muscle
Effector	The part of the body affected by the reflex e.g. muscle

Reflexes are automatic, involuntary reactions to an internal or external stimulus on the body.



The stretch reflex is an automatic response the body has in relation to a stretch stimulus in a muscle. When a muscle spindle is stretched, an impulse is sent to the spinal cord, and this prompts a response that makes the muscle contract. As the message does not have to go to the brain, this happens extremely quickly, almost in an instant. The stretch reflex is a protective measure that prevents muscles tearing by being stretched past their normal range of motion.

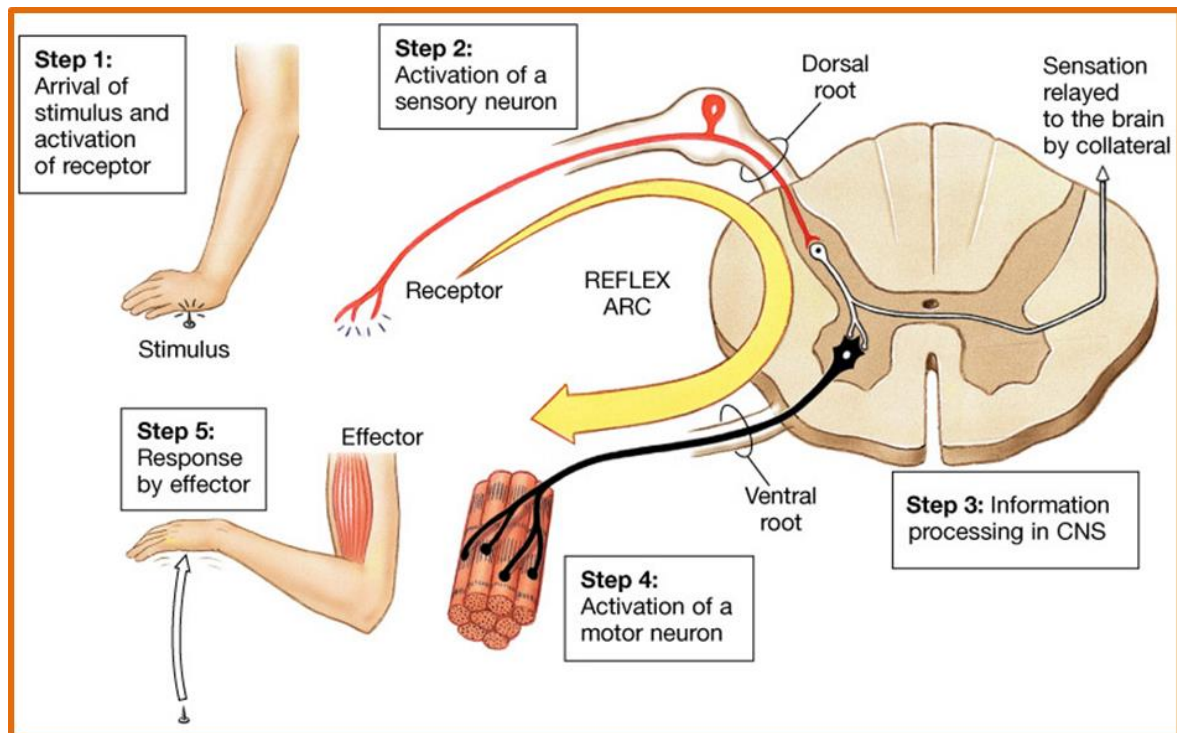


Video

Watch these videos for more information on the stretch reflex:

- [Stretch Reflex BMED](#) (7min:20sec)
- [The Stretch Reflex](#) (4min:47sec)
- [The Reflex Arc](#) (4min:47sec)

A summary of the stretch reflex can be seen in this diagram.



SECTION 5 – ROLE OF NERVOUS SYSTEM IN DIFFERENT TYPES OF TRAINING

The nervous system plays a critical role in regulating cardiovascular responses to acute exercise in humans. In effect, the nervous system promotes an increase in oxygen uptake as a function of increase in heart rate and stroke volume, thus increasing the amount of blood and oxygen to the muscular bed. The activity of the sympathetic nervous system increases during exercise to assist this process as it causes a re-distribution of the circulatory system. At the musculature bed, the sympathetic nervous system causes local vasodilation resulting in increased delivery of blood and oxygen to the muscles. In the peripheral organs (bone, digestive system and kidney's.) the sympathetic nervous system causes vasoconstriction of the blood vessels that deliver blood and oxygen to these organ beds.



Web

To review more detailed information about the response to exercise please review the following paper:

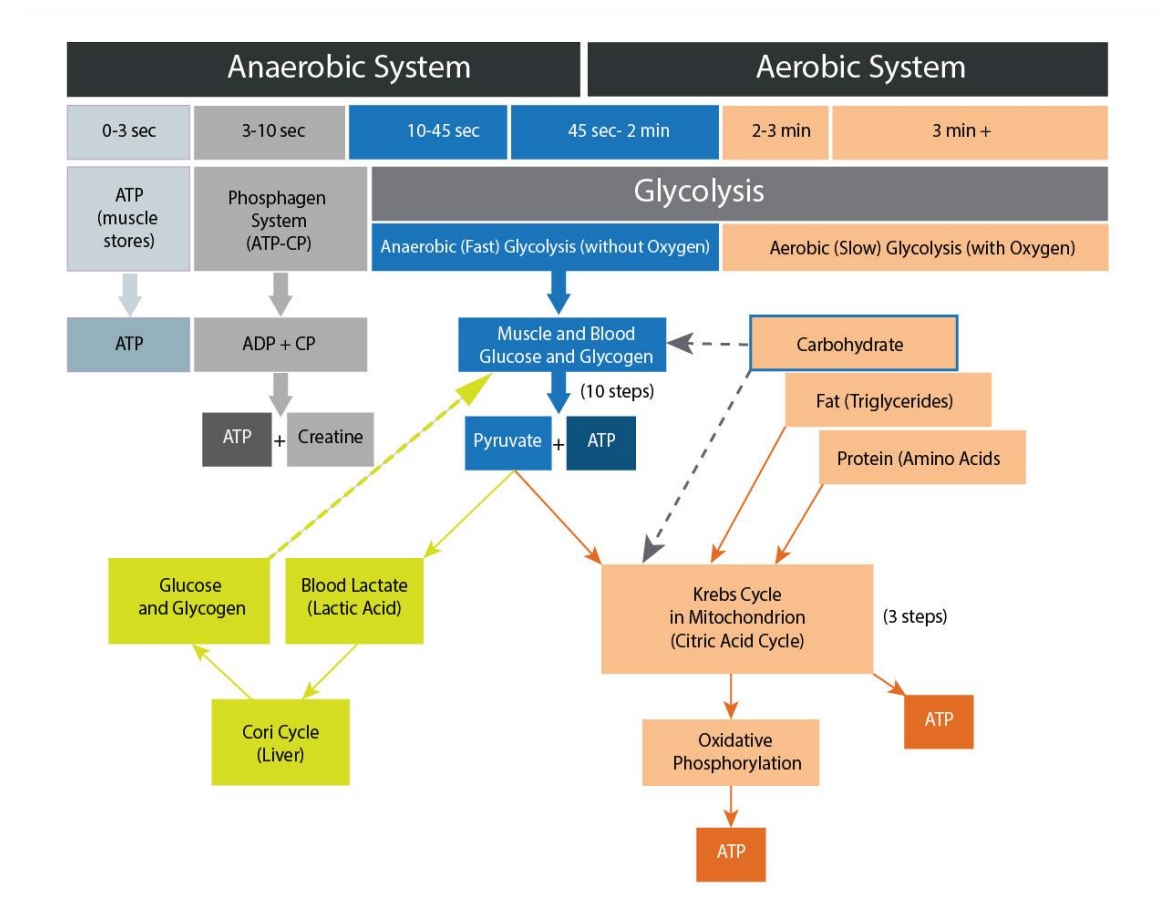
- [Physiological responses to long term exercise](#)

SECTION 6 – ENERGY SYSTEMS

The human body has three different energy systems that provide the body with fuel during different activities. These are the ATP, lactic, and aerobic systems.

A summary of these systems can be seen in the following table.

Energy system	Intensity of exercise	Duration	Recovery time	Fuel source	Limitations and waste
Phosphocreatine (ATP-CP)	Very high	1-10 sec.	30 sec. to 2 min.	Creatine phosphate	Small supply, no waste
Lactic	Moderate to high	Up to 3 min.	20 min. to 2 hrs	Carbohydrate in the form of glycogen or glucose	Lactic acid
Aerobic	Low to moderate	3 min. plus (can be endless with adequate fuel)	Time it takes to replace fuel stores	Carbohydrate, fat, protein	Water and carbon dioxide and lactic acid accumulation



Video

Watch this video for more information on energy systems:

- [Physiology and energy systems](#) (4min:17sec)

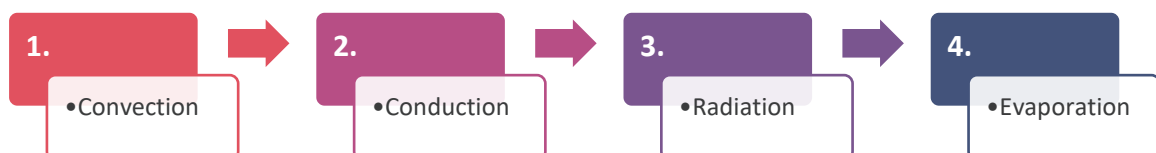
SECTION 7 – THERMOREGULATION

Thermoregulation is a process that allows your body to maintain its core internal temperature.

Thermoregulation is an important aspect of human homeostasis. Most body heat is generated in the deep organs (especially the liver, brain, and heart) and in contraction of skeletal muscles. Humans have been able to adapt to a great diversity of climates, including hot humid and hot arid. High temperatures pose serious stresses for the human body, placing it in great danger of injury or even death. For humans, adaptation to varying climatic conditions includes both physiological mechanisms resulting from evolution and behavioural mechanisms resulting from conscious cultural adaptations.



There are four avenues of heat loss:



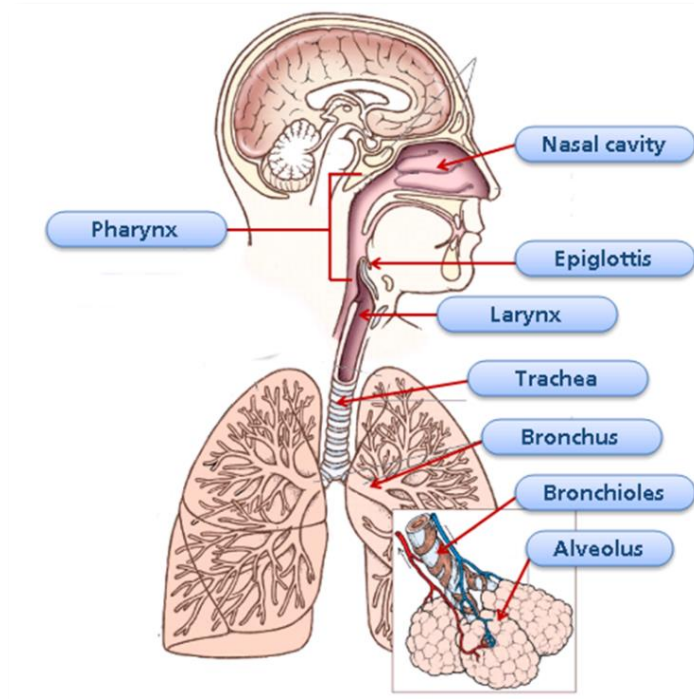
If skin temperature is greater than that of the surroundings, the body can lose heat by radiation and conduction. If the temperature of the surroundings is greater than that of the skin however, the body actually gains heat by radiation and conduction. In such conditions, the only means by which the body can rid itself of heat is by evaporation. Therefore, when the surrounding temperature is higher than the skin temperature, anything that prevents adequate evaporation will cause the internal body temperature to rise. During intense physical activity (e.g. sports), evaporation becomes the main avenue of heat loss.

Module five: The cardiorespiratory system

SECTION 1 – THE RESPIRATORY SYSTEM

Structure of the respiratory system

The respiratory system is made up of the anatomical structures described in the table and represented in the diagram that follow.



Structure	Function
Nasal cavity	Large air-filled space in the nose that conditions (moistens and warms) the air to be received by other areas of the respiratory tract
Epiglottis	A flap of tissue that closes over the trachea when you swallow, so that food does not enter your airway
Pharynx	Connects nose and mouth to the trachea
Larynx	Involved in breathing, sound production, and protecting the trachea against food aspiration
Trachea	Also known as the windpipe, a rigid tube that connects the mouth with the bronchi
Bronchus	Passage of airway in the respiratory tract that conducts air into the lungs
Bronchioles	Passageways by which the air passes through the nose or mouth to the air sacs of the lungs
Alveolus	Tiny, thin-walled air sacs at the end of the bronchiole branches where gas exchange occurs
Diaphragm	Sheet of internal skeletal muscle that extends across the bottom of the rib cage, assisting with inspiration and expiration Separates the thoracic cavity (heart, lungs and ribs) from the abdominal cavity
Intercostal muscles	Groups of muscles that run between the ribs and help form and move the chest wall Involved in the mechanical aspect of breathing.



Web

Visit this website for more information on the respiratory system:

- [Respiratory System](#)

Function of the respiratory system



Definition

The main organ of the respiratory system is the lungs. The lungs breathe in oxygen and breathe out carbon dioxide. This gas exchange is vital to human life.

The function of the respiratory system is to provide the lungs with air from the outside environment. Oxygen can then be extracted from this inspired air and delivered into the blood stream. The respiratory system allows for the removal of carbon dioxide from the blood into the lungs, which can then be expired and expelled from the body.

Mechanics of breathing

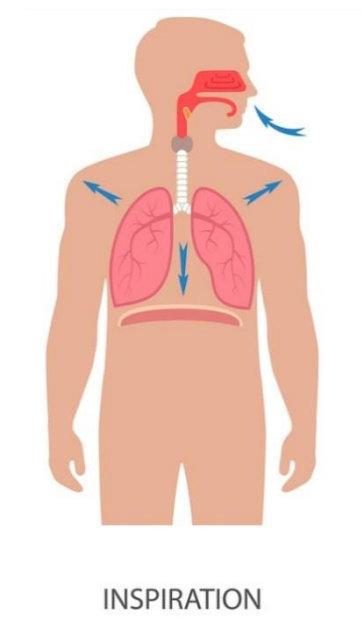
Breathing occurs via two processes: inspiration (breathing in) and expiration (breathing out). This is a passive process, meaning it does not require energy. Rather, air is moved in response to pressure differences between the internal and external environments of the body

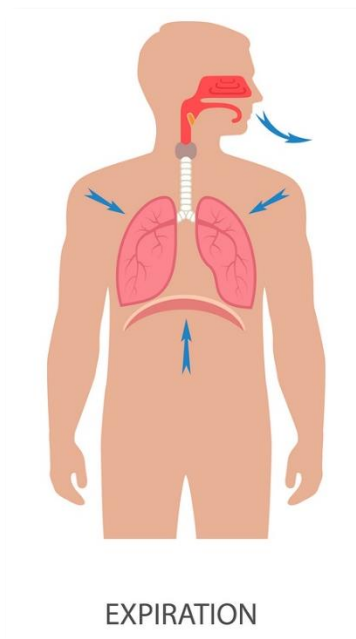
When the diaphragm relaxes and the lung volume is decreased, air travels out of the body. Larger volumes of air are required during physical activity and require additional muscle involvement.

Inspiration

During inspiration the diaphragm and the external intercostal muscles contract causing the diaphragm to flatten and the space within the lungs to increase producing a larger lung volume. When the lung volume is large, there is less pressure in the lungs and therefore air moves into the body

During exercise there is additional muscle recruitment of the scalenes, sternocleidomastoid and pectoralis minor during inspiration. These muscles assist with inspiration by increasing the volume of the thoracic cavity during exercise.





Expiration

Expiration at rest is a passive process in which the diaphragm relaxes and forms a curved shape; this causes the lung cavity to be smaller in size and decreased lung volume. Air and carbon dioxide then move out of the bronchial tubes through the airway and out into the external environment.

During exercise accessory muscle activation is required to help the air escape the lungs. The abdominal muscles and the internal intercostals aid in expiration during exercise by pushing the diaphragm upwards and increasing the internal pressure. In response to the increased internal pressure air is moved out into the external environment.



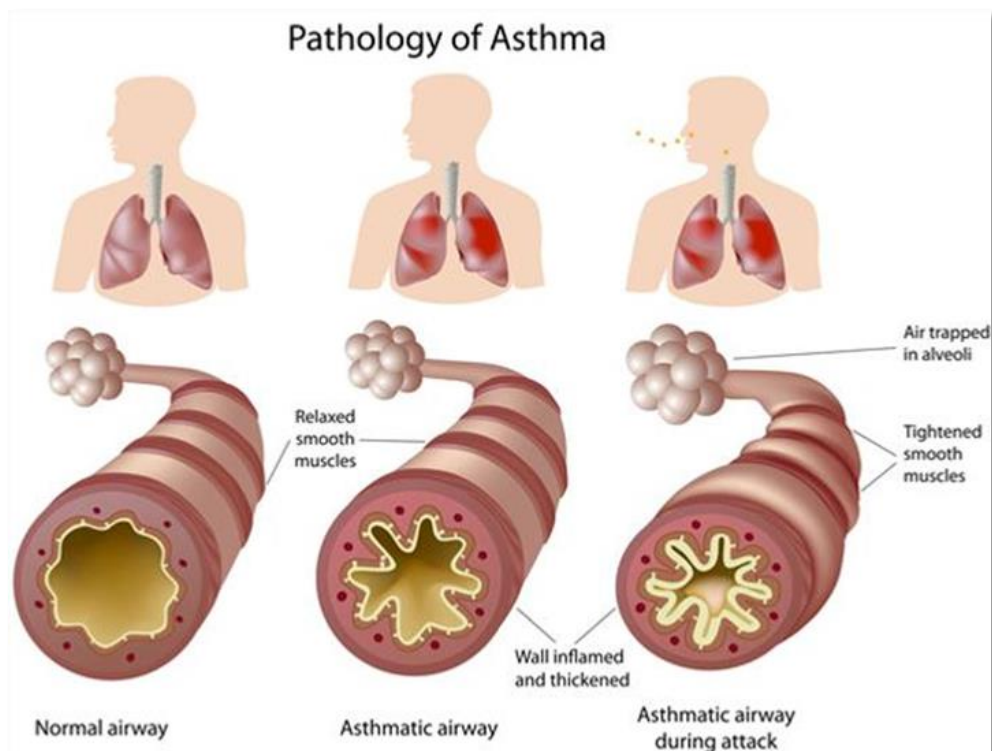
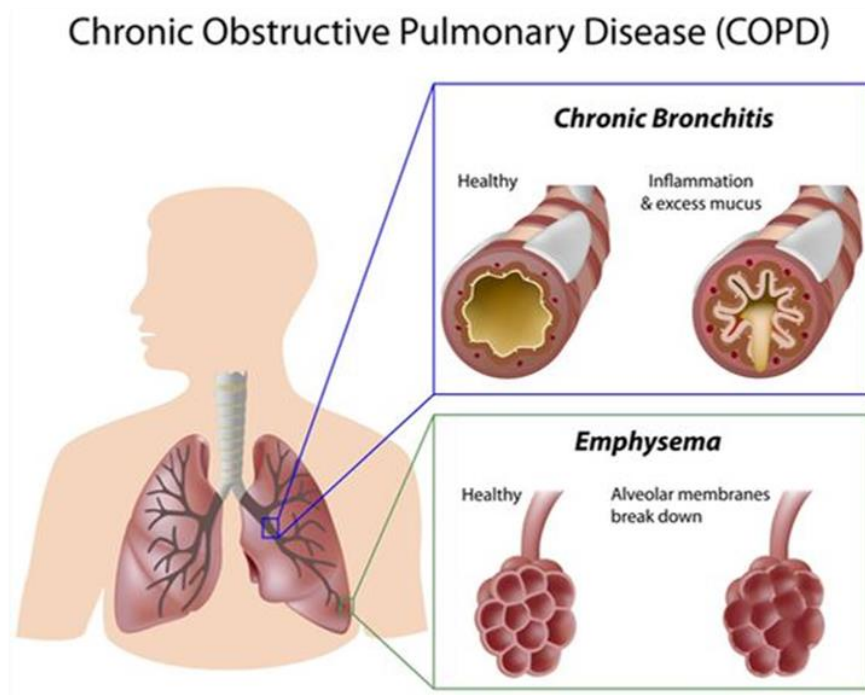
Video

Watch this video for more information on the process of breathing:

- [Human Physiology Respiration](#) (1min:21sec)
- [Respiratory System Introduction – Part 1 \(Nose to Bronchi\) – 3D Anatomy Tutorial](#) (3min:36sec)
- [Respiratory System Introduction – Part 2 \(Bronchial Tree and Lungs\) – 3D Anatomy Tutorial](#) (7min:36sec)
- [The respiratory system](#) (3min:28sec)

Disorders

Some disorders of the respiratory system include:



SECTION 2 – THE CARDIOVASCULAR SYSTEM

Intro to the cardiovascular system

The Better Health Channel (2012) describes the cardiovascular system as being made up of the heart, blood, and blood vessels. The cardiovascular system is one of the major body systems and is primarily responsible for transporting blood and supplying muscles with the required amount of oxygen to perform while exercising and at rest.

The heart, blood, and blood vessels work together to provide nutrients to the cells of the body. This is achieved by using the cardiovascular system to move blood throughout the body and provide cells with oxygen and nutrients, while removing waste. Using the network of arteries, veins, and capillaries, blood carries carbon dioxide to the lungs (for exhalation) and picks up oxygen (for inhalation). This allows muscles to contract and cause movement throughout the body. It is important for humans to maintain a healthy cardiovascular system as blood and blood vessels are crucial to good health.

The Heart

What is the heart?

The heart is a large muscular organ that contracts to pump blood throughout the body. The Heart Foundation (2012) describes the heart as a beating muscle that pumps blood continually to the rest of the body via a network of vessels.

Function of the heart

The functions of the heart are to pump oxygenated blood around the body and to deliver deoxygenated blood and waste products (carbon dioxide) to the lungs.

The heart can beat up to 100,000 times a day, which equates to over three billion heartbeats during an average lifetime!

Size and location of the heart

The heart is about the size of a clenched fist and is located within the ribcage in the thoracic cavity, behind and slightly to the left of the breastbone. The heart weighs between 300g and 450g and is a very complex organ.

Heart at rest and during exercise

At rest, the heart pumps about four to five litres of blood around the body every minute. It also beats approximately 60-80 times per minute for a normal adult. During exercise, contractions (heart rate) and the amount of blood pumped (stroke volume) increases depending on exercise intensity.

Maximum heart rate

Maximum heart rate of the client can be determined by using the equation: $MHR = 220 - \text{age}$.



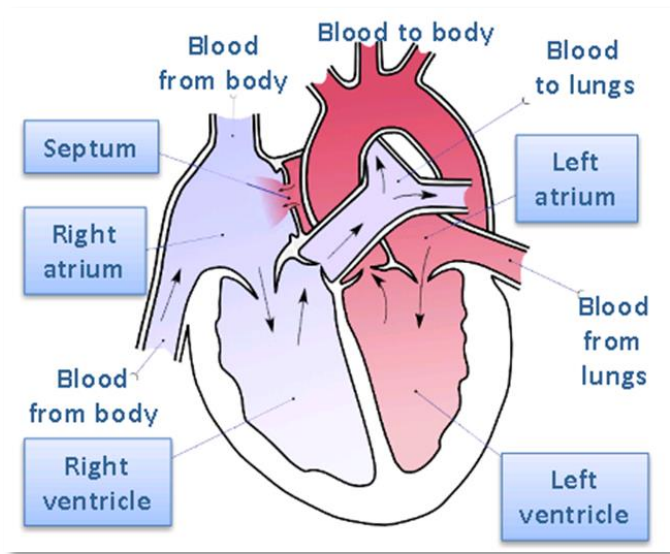
Video

Watch this video to learn how the heart works:

- [Heart anatomy](#) (3min:29sec)

Heart chambers

Within the body, the heart acts as a double pump, with a right and left side. These sides are separated by a muscular wall called the septum (The Better Health Channel, 2012). Each side has a small upper chamber called the “atrium”, which lead into a large lower pumping chamber called a “ventricle”. The ventricles have thicker walls than the atria because they pump blood around the body. The right ventricle circulates blood to the lungs, where it is oxygenated, before travelling to the left side of the heart.



From there, it is pumped around the rest of the body. The right side of the heart therefore contains venous blood and the left side of the heart contains arterial blood.

Oxygen is removed from the blood and utilized as it circulates through and is delivered to the body's organs and tissues. Deoxygenated blood then travels through the right atrium to the right ventricle. The blood is then pumped through the lungs to re-oxygenate. Following this, blood is pumped to the left ventricle via the left atrium where it can then travel out to the body's organs and tissues to provide nutrients and oxygen.

The left ventricle of the heart is larger and the walls are thicker than the right ventricle. This is due to the fact that the left ventricle has to pump the blood further around the body and also against higher pressure compared to the right ventricle.



Video

Watch this video to learn about blood flow of the heart:

- [Heart Anatomy and Blood Flow](#) (3min:40sec)



Web

Visit this website for more information on the circulatory system:

- [Circulatory System](#)

Heart valves

The heart is made up of two main valves that act as doors, controlling the amount of blood, allowing blood to flow through them from the atrium to the ventricle, and keeping blood moving in the correct direction through the heart (The Heart Foundation (2012). As the heart beats, the

valves open and blood is pumped from one chamber to another chamber.

1. •Two Atrioventricular (AV) valves are located between the atria and the ventricles. These are called the Mitral Valve and the Tricuspid Valve.
2. •Two Semilunar (SL) valves are located in the arteries leaving the heart. These are called the Aortic Valve and the Pulmonary Valve.



Video

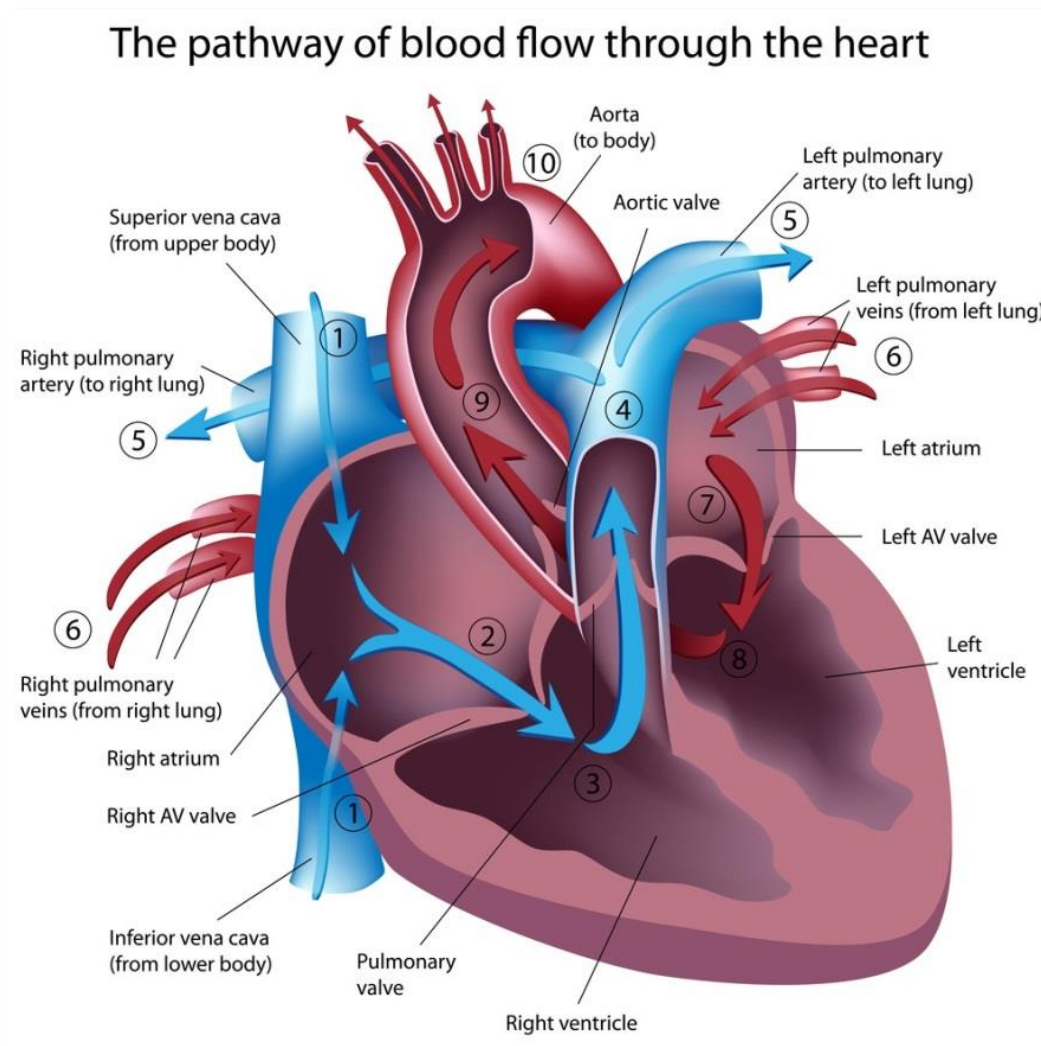
Watch this video to learn about heart valves and their functions:

- [Heart valves](#) (0min:35sec)

Heart vessels

The heart has a number of major vessels which aid the transportation of blood:

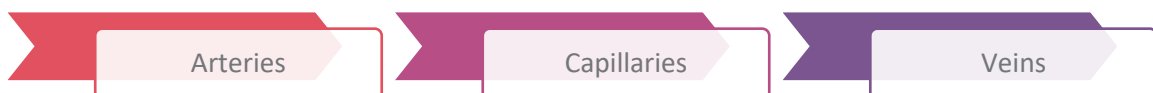
Vessel	Function
Superior vena cava	Carries deoxygenated blood from the upper half of the body to the right atrium
Inferior vena cava	Brings deoxygenated blood from the diaphragm region to the right atrium
Pulmonary arteries	Deoxygenated blood is pumped by the right ventricle into the pulmonary arteries that link to the lungs. These are the only arteries that carry deoxygenated blood.
Pulmonary veins	Return oxygenated blood from the lungs to the left atrium of the heart. These are the only veins in the body carrying oxygenated blood.
Aorta	Largest artery of the body that runs the length of the trunk. Oxygenated blood is pumped into the aorta from the left ventricle. The aorta subdivides into various branches that deliver blood to the upper body, trunk, and lower body
Coronary arteries	The coronary arteries that supply the heart are connected directly to the aorta, which ensures a rich supply of oxygenated blood
Coronary veins	Deoxygenated blood from heart muscle is “dumped” by coronary veins directly into the right atrium



Blood and blood vessels

Blood vessels

Blood vessels are an important part of the circulatory system and are tube-like structures, varied in thickness, which transport blood throughout the body. They are an intricate network of hollow structures that carry blood throughout the body. There are three major types of blood vessels:



Arteries

Arteries include arterioles, capillaries, and venules and carry blood away from the heart. Arteries are responsible for carrying oxygen rich blood to various parts of the body (Essential Guide to Fitness, 2011). Major arteries have thick, muscular walls that can withstand great force and a high pressure of blood as it moves through the body.

Capillaries

Capillaries are much smaller in structure. They join arterioles to venules and veins and allow water, oxygen, carbon dioxide, and nutrient waste exchange between the blood and tissues they reside in.

Capillaries are so small that red blood cells must pass through the vessel in a single file.

Veins

After oxygen has been delivered to working muscles, organs and other required areas of the body, veins are responsible for carrying deoxygenated blood back to the heart. Veins do not have a thick wall like arteries because they do not have to withstand such large pressure. Veins are quite expandable and may carry up to 75 percent of the blood volume at any one time.

Characteristics

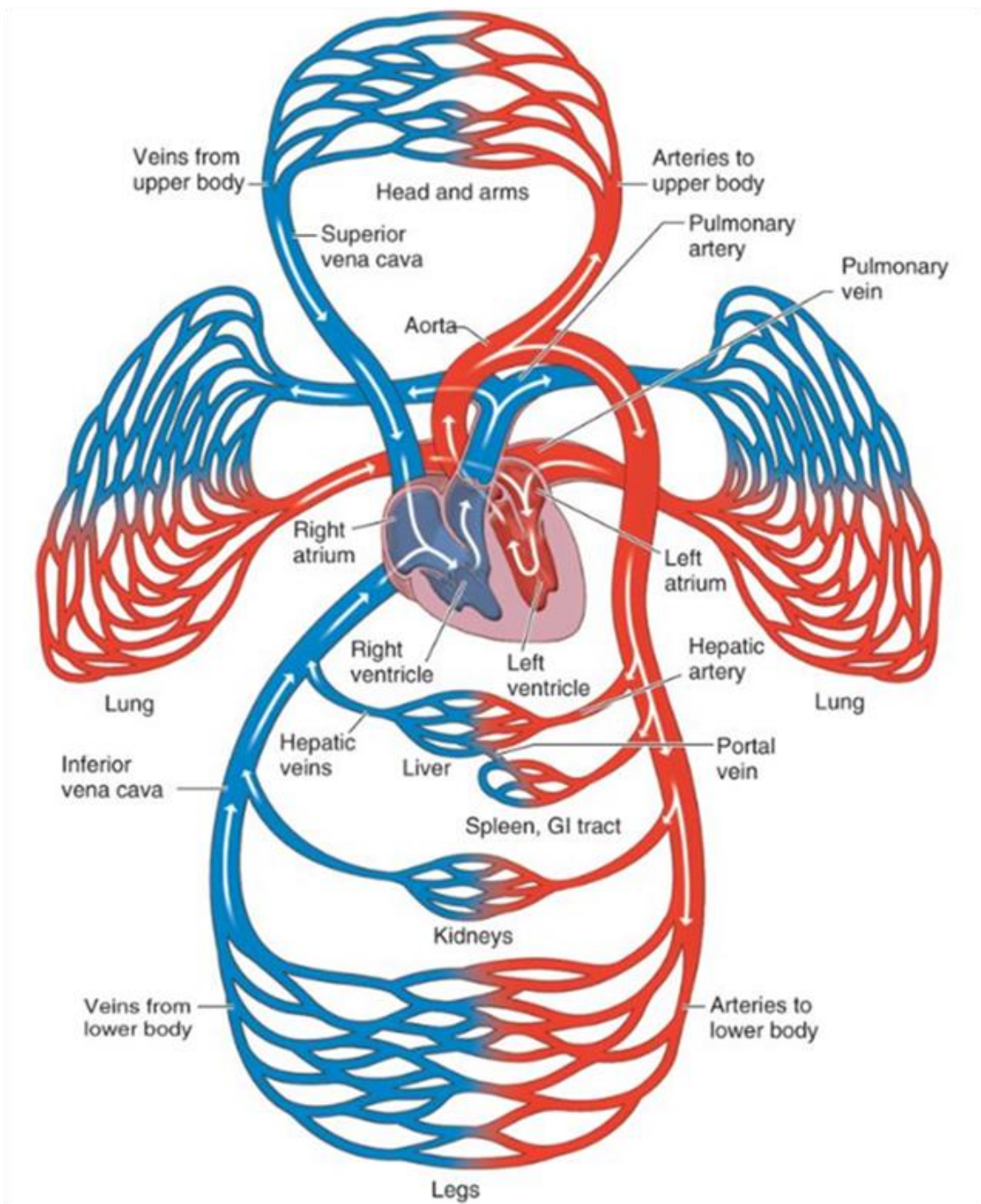
Characteristic	Arteries	Veins
Oxygen	High	Low
Carbon dioxide	Low	High
Walls	Muscular	Thin
Tubes	High pressure	Low pressure
Flow	Pulsating and rapid	Constant and slow
Valves	None	In most veins
Blood direction	Away from heart	Away from body back to heart



Video

Watch this video to learn how the heart works:

- [Structure of Blood Vessels](#) (1min:14sec)
- [Types of Blood Vessels](#) (1min:08sec)
- [Blood Vessel Structure and Function](#) (3min:15sec)
- [Capillaries | Biology | Anatomy](#) (3min:00sec)



Blood

The National Blood Authority (2012) states that blood is a fluid-like substance circulated by the heart through the circulatory or vascular system responsible for transporting oxygen and nutrients to organs and structures around the body. Upon delivering nutrients, the blood then collects waste products and transports these away from tissues.

Aerobic training can cause increases in blood volume and an increase in the amount of oxygen pumped around the body.



- Nutrient transport – oxygen, vitamins, fats, proteins, sugars
- Waste transport – carbon dioxide, urea
- Hormone transport – insulin
- Control of body temperature
- Protect from infection
- Clotting

Blood contains many different components that have been described below.

Component	Function
Plasma	• Fluid portion of the blood (55% of blood volume) • Circulates dissolved nutrients such as macro and micronutrients, and hormones • Removes waste products of carbon dioxide and lactic acid
Red blood cells	• Carry and delivery oxygen to the body tissues via blood flow
Haemoglobin	• Protein within red blood cells delivering oxygen to the body • Haemoglobin molecule is comprised of iron atoms that bind to oxygen • Carries oxygen from the respiratory organs to the rest of the body where it releases the oxygen to burn nutrients and provide energy to power the working muscles
White blood cells	• Cells of the immune system • Defends the body against infectious disease
Platelets	• Are thrombocytes, which are responsible for blood clotting • Attract and bind to each other, forming a plug that causes a clot • Important to stop blood flowing when injured



Video

Watch this video to learn about blood:

- [What is blood](#) (2min:23sec)

Disorders

Some disorders of the circulatory system include:

- Heart disease – coronary artery disease, cardiomyopathy, cardiovascular disease
- Peripheral vascular disease
- Hypertension

SECTION 3 – EXERCISE AND THE CARDIORESPIRATORY SYSTEM

Cardiac output and exercise



Definition

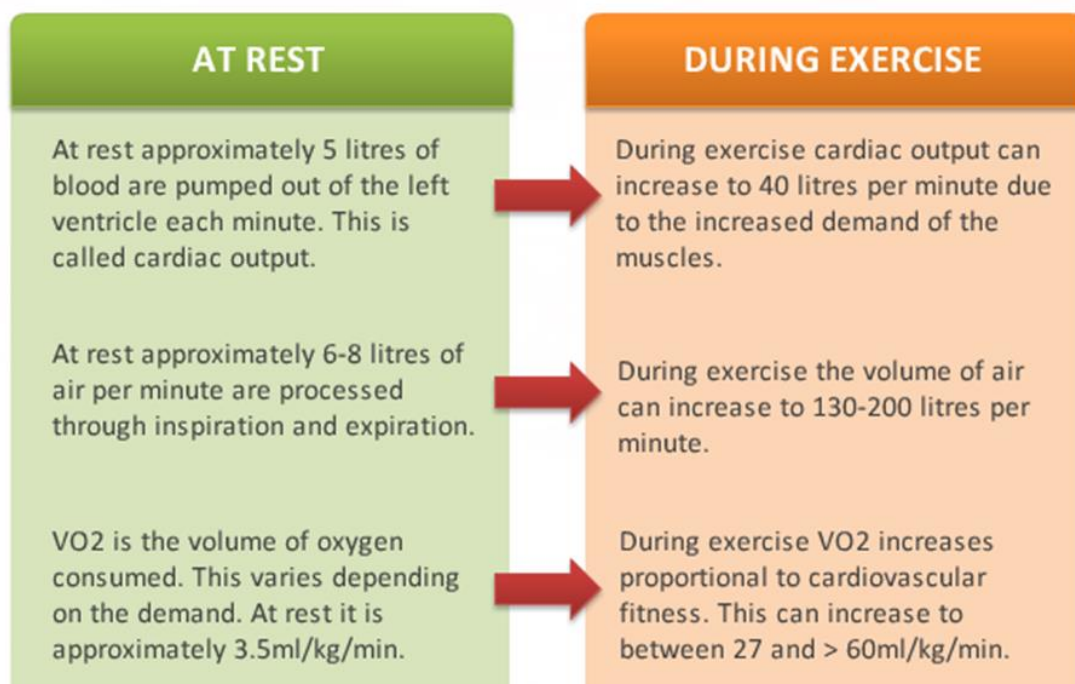
Cardiac output is the amount of blood the heart pumps around the body every minute.

Exercise places many demands on the body and in particular the cardiovascular system. In order for the oxygen demands of the body to be met, the heart must pump an increased amount of blood around the body per minute. This process is described as **cardiac output**.

Cardiac output is made up of two major components:

1. **Heart rate:**
 - The number of times the heart beats per minute
2. **Stroke volume:**
 - The amount of blood pumped by the left ventricle during each beat.

Cardiac Output (L/min) = heart rate (bpm) multiplied by stroke volume (L/min)

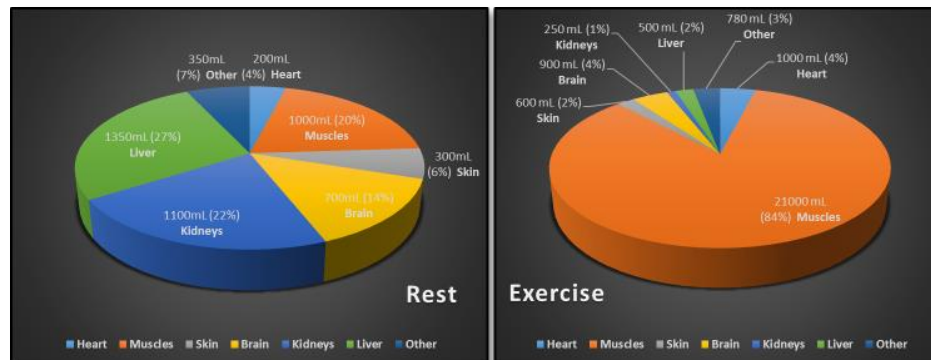


The effects of exercise

During aerobic exercise, cardiac output increases to enable blood to travel around the body quicker, delivering oxygen to working muscles to meet oxygen demands. Heart rate increases when exercise intensity increases, as more oxygen is required for skeletal muscles to work, placing more demands on the heart. After periods of endurance training, the heart can adapt to improve cardiac output. The heart muscle walls thicken which increases the contractility of the heart which results in an increase in stroke volume.

Other immediate cardiovascular responses to exercise include:

- Increased blood flow to the coronary arteries of the heart as it works harder
- Increased blood flow to working skeletal muscles to allow movement
- Decreased blood flow to the kidneys to maintain fluid levels in the body
- Slight increase in brain blood flow
- Decreased blood flow to the digestive system to delay digestion and spare blood and energy for exercise
- Increased blood flow to the skin to assist with cooling off the body
- Increased cardiac output



Long term exercise affects cardiac output by increasing the effectiveness for which blood is pumped around the body. This is due to an increased contractility and volume of the heart itself, meaning the heart can pump more blood with each contraction. This means that stroke volume is larger for a trained person compared to an untrained person and that resting heart rate in a fitter individual is lower in response to a greater stroke volume. The heart is required to beat fewer times per minute as more blood (and oxygen) can be pumped with each beat.

The respiratory system and exercise

Respiratory or lung volumes

The lungs have the capacity to inhale and exhale a certain volume of air. This volume of air can change as a result of factors, such as exercise and fitness level.

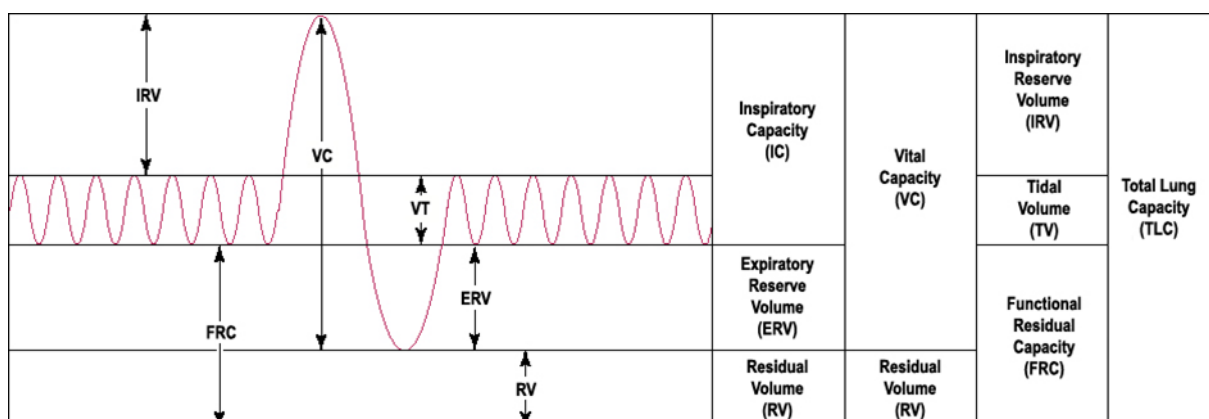
The table below outlines the immediate and long term effects of exercise:

Volume	Definition	Immediate response to exercise	Long term effect of exercise
Tidal volume	Volume of air inspired or expired per breath	Volume increases due to greater oxygen requirements for working muscles, therefore more air is inspired each breath.	Increases as the lungs develop a larger capacity and respiratory muscles increase in strength
Total lung capacity	Volume of air within the lungs after maximal inspiration – the largest amount of air that the lungs can hold	Increases after maximal inspiration. This is the largest volume of air that the lungs can hold	Aerobic exercise causes an increase in lung capacity. More oxygen can be inspired and more carbon dioxide can be expired with each breath. Reduced need for large respiratory rate increase.

Respiratory rate	Rate at which inspiration and expiration occur	Increases during exercise as oxygen demands are increased and more carbon dioxide is being produced and needing to be expired	Rate will decrease due to the heart being able to pump more blood with each contraction, therefore delivering more oxygen with each beat. This occurs due to an increased tidal volume, meaning more oxygen is being inspired with each breath and less breath is needed to meet oxygen requirements.
Heart rate	The rate at which the heart beats measured in beats per minute (BPM)	Increases to pump blood around the body to working muscles faster and deliver required oxygen to muscles that now have an increased oxygen requirement	Decrease due to the heart being able to pump more blood with each contraction therefore delivering more oxygen with each beat and needing to contract less. This is why resting heart rate lowers with improved cardiovascular fitness. It is more efficient and needs to contract less per minute.

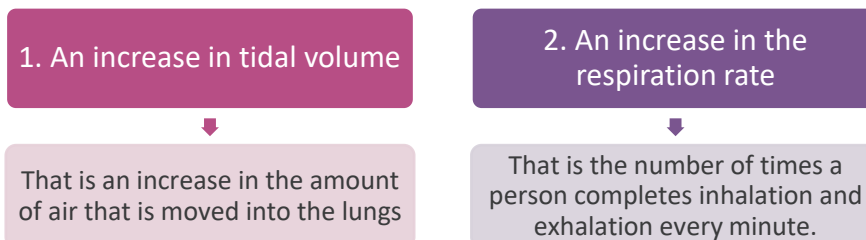
The following figure shows a typical respiratory pattern and the changes in lung volume. Each term in this figure has been explained as follows:

Inspiratory Reserve Volume (IRV)	The maximal volume that can be inhaled from the end-inspiratory level
Functional Residual Capacity (FRC)	The volume in the lungs at the end-expiratory position
Vital Capacity (VC)	The volume of air breathed out after the deepest inhalation.
Tidal Volume (TV)	That volume of air moved into or out of the lungs during quiet breathing
Expiratory Reserve Volume (ERV)	The maximal volume of air that can be exhaled from the end-expiratory position
Residual Volume (RV)	The volume of air remaining in the lungs after a maximal exhalation



Respiratory volumes and relationships to fitness levels and exercise

As we saw previously with cardiovascular function, as exercise commences, the function changes. This is true for the respiratory system. As exercise commences, pulmonary ventilation increases in direct proportion to the intensity of the exercise and the metabolic needs of the body in response to the exercise. There are two main methods by which ventilation patterns change in response to exercise:



If the exercise is intense, breathing rates may increase from a typical resting rate of 15 breaths per minute up to 40 – 50 breaths per minute. With continuous exercise (≥ 1 minute in duration) such as aerobic fitness, longer duration anaerobic fitness, and to a lesser degree muscular endurance training, VO_2 increases linearly with increases in exercise intensity. This is due to an increasing reliance on oxygen to help provide energy as exercise continues.

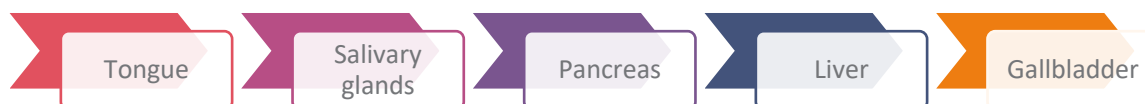
As the intensity of exercise continues to increase, a person reaches a maximum point above which oxygen consumption will not increase any further.

As longer duration exercise commences, an oxygen deficit is created. The size of the deficit largely determines the time that will be spent in recovery to repay the oxygen debt. The respiration rate and depth remain elevated during the recovery period in order to expel the carbon dioxide and return the acid-base balance of the muscles to neutral. The higher the intensity of longer duration training, the bigger the oxygen deficit and the longer respiration rate and depth will stay elevated after the workout has finished.

Module six: The digestive system

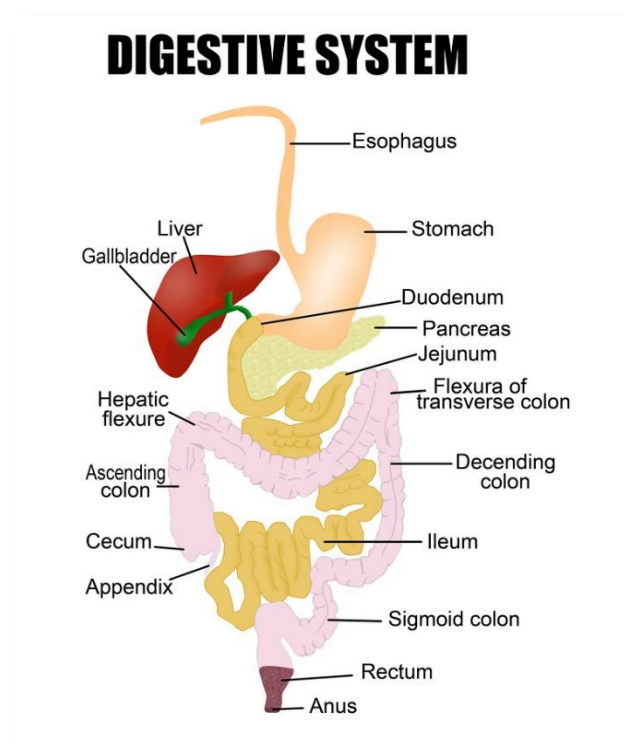
The human digestive system consists of the gastrointestinal tract that extends from mouth to anus. It is roughly nine meters in length.

The digestive system also consists of a range of accessory organs that play a critical role in digestion. These include the following:



In this system, the process of digestion has many stages, the first of which starts in the mouth (oral cavity). Digestion involves the breakdown of food into smaller and smaller components until they can be absorbed and assimilated at the small intestine (major site of absorption of nutrients) and to a lesser extent, in the large intestine (where vitamin K and water is absorbed). The secretion of saliva helps to produce a bolus, which can be swallowed to pass down the oesophagus and into the stomach.

Saliva also contains a catalytic enzyme called amylase, which starts to act on food in the mouth. Another digestive enzyme called lingual lipase is secreted by some of the lingual papillae on the tongue and also from serous glands in the main salivary glands. Digestion is helped by the mastication of food by the teeth and also by the muscular actions of peristalsis and segmentation contractions. Gastric juice in the stomach is essential for the continuation of digestion as is the production of mucus in the stomach.



Peristalsis is the rhythmic contraction of muscles that begins in the oesophagus and continues along the wall of the stomach and the rest of the gastrointestinal tract. This initially results in the production of chime, which when fully broken down in the small intestine, is absorbed across the small intestine. Most of the digestion of food takes place in the small intestine. Water and some minerals are reabsorbed back into the blood in the colon of the large intestine. The waste products of digestion (faeces) are defecated from the anus via the rectum.

The following table summarises the major digestive organs, motility, secretion, digestion, and absorption.

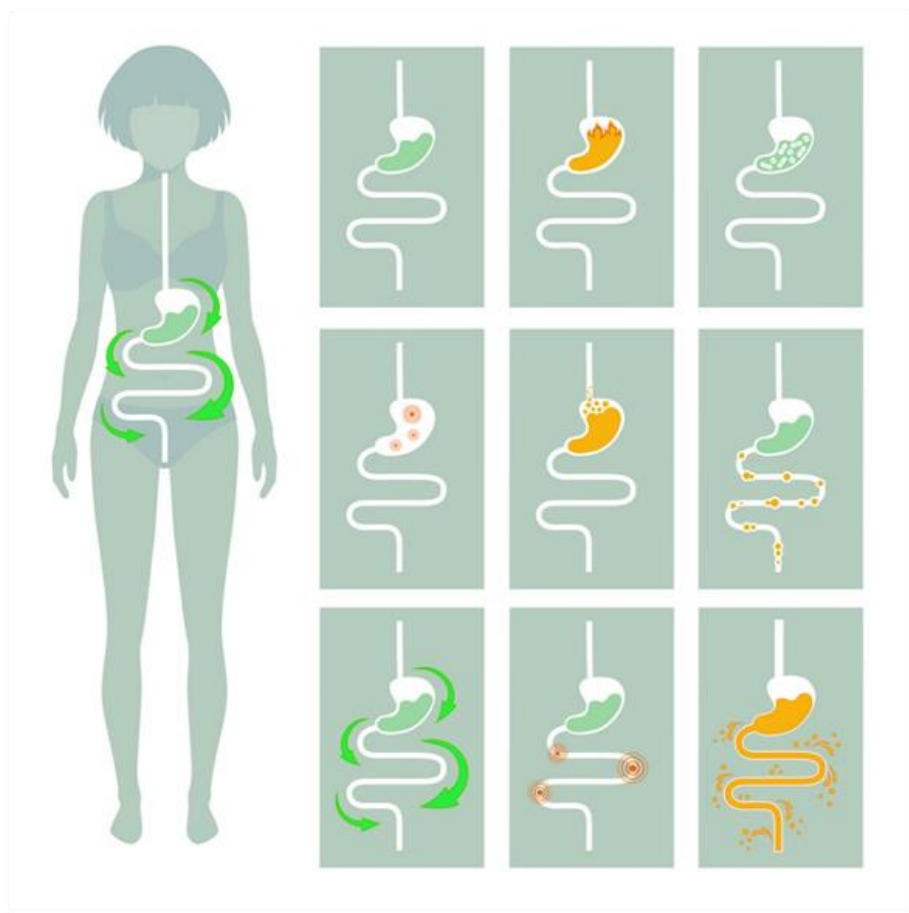
Digestive organ	Motility	Secretion	Digestion	Absorption
Mouth and salivary glands	Chewing	Saliva • Amylase • Mucus • Lysozyme	Carbohydrate digestion begins	No foodstuffs; a few medications – for example, nitroglycerine
Pharynx and oesophagus	Swallowing	Mucus	None	None
Stomach	Receptive relaxation; peristalsis	Gastric juice • HCl • Pepsin • Mucus • Intrinsic factor	Carbohydrate digestion continues in body of stomach; protein digestion begins in antrum of stomach	No foodstuffs; a few lipid-soluble substances, such as alcohol and aspirin
Exocrine pancreas	Not applicable	Pancreatic digestive enzymes • Trypsin, chymotrypsin, carboxypeptidase • Amylase • Lipase • Pancreatic aqueous NaHCO₃ solution	These pancreatic enzymes accomplish digestion in duodenal lumen	Not applicable
Liver	Not applicable	Bile • Bile salts • Alkaline secretion • Bilirubin	Bile does not digest anything, but bile salts facilitate fat digestion and absorption in duodenal lumen	Not applicable
Small intestine	Segmentation; migrating motility complex	Succus entericus • Mucus • Salt <i>(Small intestine enzymes – disaccharides and aminopeptidases – are not secreted but function within the brush border membrane)</i>	In lumen, under influence of pancreatic enzymes and bile, carbohydrate and protein digestion continues and fat digestion is completely accomplished; in brush border, carbohydrate and protein digestion completed	All nutrients, most electrolytes, and water
Large intestine	Haustral contractions, mass movements	Mucus	None	Salt and water, converting contents to faeces

Digestion is the chemical breakdown of structurally complex foods into absorbable units.

Digestion of all food is achieved by enzymatic hydrolysis; this is the breakdown of chemical bonds with water. Humans consume three categories of energy rich food: carbohydrates, proteins and fats.

A brief explanation of the digestion of these macronutrients is explained as follows:

1. Proteins are held together by peptide bonds and composed of smaller fragments called amino acids, which are what the proteins need to be digested into, in order that they can be absorbed by the digestive tract and released into the circulatory system.
2. Carbohydrates are simple sugars or monosaccharides such as glucose, fructose and galactose. Most ingested carbohydrates are in the form of polysaccharides, which consist of chains of interconnected glucose molecules. Through the process of digestion starch (amylose and amylopectin), glycogen (glucose) and disaccharides (sucrose and lactose) are converted into their constituent monosaccharides, principally glucose with smaller amounts of fructose and galactose. These monosaccharides are the absorbable units for carbohydrates.
3. Most dietary fats are in the form of triglycerides. They are neutral fats with three fatty acid molecules attached. Enzymatic digestion of neutral fats splits two of the fatty acid molecules from the triglyceride, leaving a monoglyceride. These one-chain fatty acids are the absorbable units of fat.



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