BodyAid
SOLUTIONS

Level 5 Diploma in Massage Therapy for Sports

Foundation Anatomy for SportsTherapy

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FOCUS AWARDS

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sports therapy
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Unit 1: Anatomy and Physiology and Kinesiology for Exercise and Health

Aim

To provide trainers with comprehensive knowledge of anatomy and physiology in order to better understand what is happening to their client during the demands of exercise and activity. Trainer's will be provided with sound footings to specifically design programmes aimed towards the clients goals with the body systems in mind

Learning Outcomes

Upon successful completion of this unit learners will be able to:

- Describe the heart and circulatory system and its relation to exercise and health
- Explain the musculoskeletal system and its functions whilst identifying the importance of postural and core stability in exercise
- Comprehend the interaction of the nervous system within exercise
- Analyse the energy systems and their relationship with exercise and client goals
- Explain the endocrine system and its relationship with exercise
- Describe the skeletal system and explain its links to activity and exercise

Introduction

The complexities of the body and how each body system works will be explored at a deeper level in this unit. It is important to recognise how they work individually but also the relationships between all systems.

Although all clients will have the same basic anatomy, individual circumstances can vary with age, capabilities, disabilities, gender, genetics and fitness profile. It is important as an exercise professional that the theory of the systems is understood to better understand how specific differences could impact programming of exercise and physical activity.

Unit Contents

Section 1: The Heart and Circulatory System

The heart is a muscular pump, roughly the size of a man's clenched fist, which pushes blood into the tissues. Located behind and to the left of the sternum, it has 4 chambers: 2 atria and 2 ventricles and is predominantly made of cardiac muscle (myocardium).

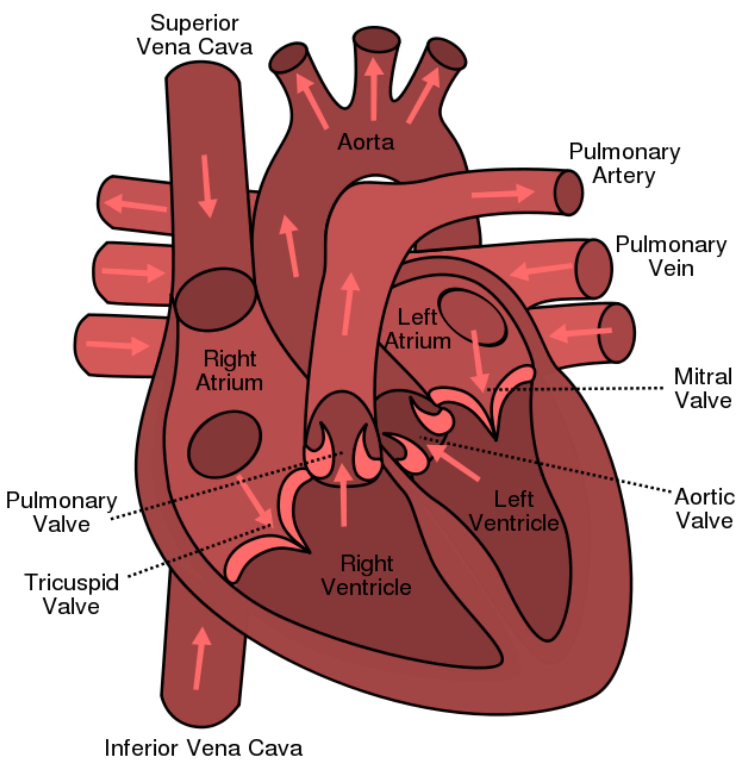
Heart Circulation

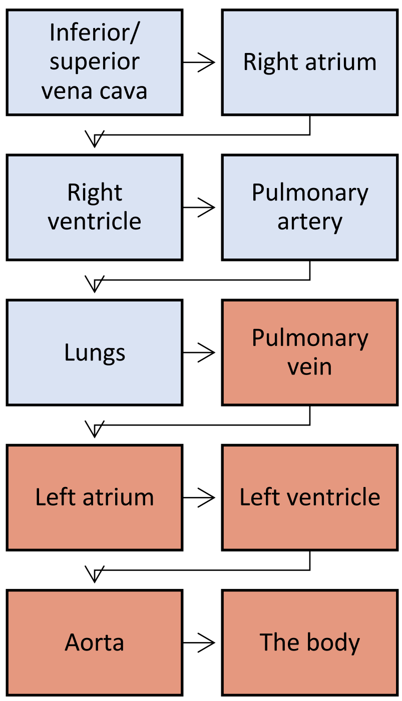
The right hand side of the heart receives blood from the upper and lower body via veins. Blood enters the right atrium through either the inferior or superior vena cava saturated with carbon dioxide (CO_2) (deoxygenated blood) and into the right ventricle through the tricuspid (atrioventricular) valve.

It is ejected by the right ventricle through the semilunar/ pulmonary valve to the lungs via the pulmonary artery. In the pulmonary capillaries, carbon dioxide diffuses into the lungs to be expired. Oxygen(O_2) enters the blood (oxygenated) and travels via the pulmonary vein to the left atrium of the heart, through the bicuspid/mitral (atrioventricular) valve the left ventricle.

The left ventricle then ejects the blood and O_2 via the aortic valve and aorta, to the tissues of the body (system circulation).
Please note arteries carry blood away from the heart and veins always carry blood to the heart (see below for a diagram)

Structure of the Heart





The Valves of the Heart

Unwanted backflow into the chambers is prevented by a number of valves which open and close in response to changes in pressure as the heart contracts and relaxes. They are fundamental to effective circulation as any backflow will compromise the efficiency of each heartbeat.

The main valves are:

- Atrioventricular (AV) valves located between the atria and ventricles and prevent backflow from the ventricles to the atria. As the ventricles contract, pressure rises and forces the valves to snap shut and directing blood through the arteries

- Semilunar (SL) valves located at the base of the arteries leaving the heart. After each contraction there is a relative drop in pressure in the ventricles as they relax. As blood moves back towards the ventricles the SL valves snap shut so blood cannot re-enter

As the valves snap shut they are anchored in place by tendon-like chords known as **chordae tendinea** which stop the valve flaps from being pushed too far into the atria and going 'inside out'.

Control of the Heart - Conductive System

The heart is stimulated to contract by a complex series of integrated systems. The natural pacemaker – the sinoatrial (SA) node, initiates the contraction and can be found in the wall of the right atrium. The myocardium is stimulated to contract about 72 times per minute by the SA node. The stimulation is part of the autonomic nervous system

SA node self excitable – where action potential begins, spreads through the atria.
Contracts in a wave like manner

↓

Flow of action potential to the ventricle controlled via AV node

↓

AV node slows down the AP to give atria enough time to contract
AP then travels down specialised AV node nerve bundles

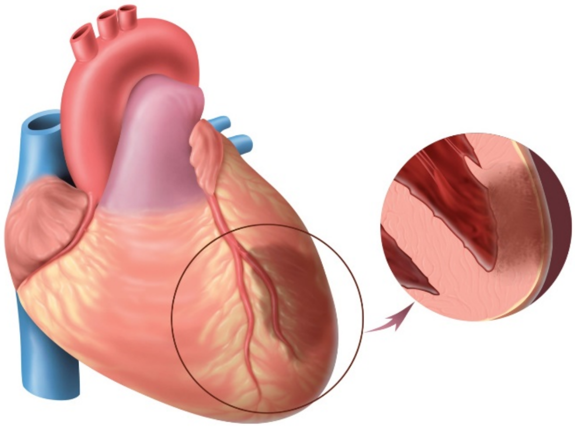
↓

Bundle of his in the centre of the heart (specialised fibres) transmit impulses from atria to ventricles

↓

Bundles split into 2 at the septum and direct the AP can spread outward and upward into ventricles, directing blood up instead of down (Purkinje fibres)

Coronary Circulation



Coronary circulation is the term used to describe circulation of blood to the heart. The heart has its own network of blood vessels to supply it with constant oxygen and nutrients via 2 coronary arteries (left and right coronary arteries). The arteries branch out from the base of the aorta and divide into a crown-like network of blood vessels across the heart wall. Blood is circulated through the superficial and deep tissues of the heart before being drained away by the coronary veins. The right coronary artery supplies blood to the myocardium of the right ventricle, whilst the left coronary artery divides into 2 branches to supply blood to the left ventricle and the posterior of the heart.

Coronary arteries are susceptible to heart disease due to blood clots, fatty plaques or spasms in the smooth muscle in the vessel walls. These complications reduce blood flow and oxygen and nutrients to the heart muscle causing the heart to fail Reduced blood flow is called ischaemia, therefore Myocardial ischaemia is a reduction in blood flow to the heart. It can result in myocardial infarction (heart attack), infarction meaning death of an area of tissue as a result of interrupted blood supply

The effect of Disease Processes on the Blood Vessels

Blood flows freely to reach its target tissue or organ in a healthy blood vessel, however vascular disease narrows the blood vessels, which has a negative impact on their performance. Vascular disease is one of the main causes of death in the developed world and is caused by inflammation in the blood vessels and accumulation of mineral, protein and fat deposits creating a build-up of plaque on vessel walls. If an artery becomes inflamed or damaged, plaque will form to attempt to repair the artery. As the plaque builds up the artery becomes thicker, harder and less elastic – therefore narrower and less able to stretch in response to blood flow. As a result the blood flow (and oxygen) is reduced and can causes target tissue death unless those tissues are supplied by alternative arteries. This build up restricts or completely prevents blood flow to tissue and organs, starving the structures of vital nutrients and oxygen.

Symptoms include reduced ability to exercise, episodes of chest pain and possibly heart attacks. It is also linked to strokes and kidney disease. Narrowed arteries in the brain can also become blocked by clots resulting in a stroke.

SYSTOLIC
In the systolic phase, the heart contracts, blood pressure rises and blood moves out along the vessels.

DIASTOLIC
In the diastolic phase, the heart relaxes, blood pressure falls and blood fills the heart

Blood Pressure and Health Risks

Blood pressure (BP) is a measure of force applied by blood to the walls of the arteries as it flows through them. It is an expression of the arterial blood flow and peripheral resistance the blood encounters as it flows around the body.
Blood pressure = cardiac output x total peripheral resistance
It is measured in mmHg using a sphygmomanometer and is expressed as systolic and diastolic. Optimal BP is below 120/80 mmHg and Hypertension is classed as 140/90 mmHg or higher.

Risks of High Blood Pressure

It is normal for blood pressure to temporarily increase during exertion or when feeling anxious or stressed. Hypertension is the term used to describe blood pressure that is consistently higher than the healthy level when at rest. A high systolic blood pressure (SBP) shows the strain on the blood vessels when the heart is attempting to pump blood out, whilst a high diastolic blood pressure (DBP) shows the blood vessels have little chance to relax between heartbeats. Measuring blood pressure gives an indication of the health of an individual's cardiovascular system and overall health. The term 'white coat hypertension' is sometimes used if you have high blood pressure readings (consistently 140/90mmHg or above) only when you are in a medical setting.

Hypertension

The risk of ischaemic heart disease and cerebrovascular disease are increased with hypertension. Ischaemic heart disease covers a variety of heart conditions including valve disease and heart attack. The term cerebrovascular disease includes acute problems such as haemorrhagic and ischaemic strokes and chronically degenerative conditions like vascular dementia and Alzheimer's disease. Stress is also placed on the small vessels to the retina which can cause blindness as well as the small vessels of the kidneys which can cause renal failure. A combination of genetic and lifestyle factors, such as family history, a lack of exercise, stress, an unhealthy diet, being overweight and smoking, plays a role in the gradual build-up of plaque within the vessel.

There are currently about 12 million people in the UK with hypertension, more than half of those are over the age of 60. Around 5.7 million people have undiagnosed hypertension (UK Blood Pressure Association, 2012). An ischaemic stroke is the most common form of stroke and is usually caused by an obstruction. A haemorrhagic stroke is an intracranial haemorrhage and can be linked to an aneurysm.

Blood Pressure Classifications

Category	Systolic (mmHg)	Diastolic (mmHg)
Low	< 100	< 60
Optima;	< 120	< 80
Normal	< 130	< 85
High normal – Pre-hypertension	130-139	85-89
Stage 1 Hypertension	140-159	90-99
Stage 2 Hypertension	160-179	100-109
Stage 3 Hypertension	>180	>110

Short- term Effects of Exercise on Blood Pressure

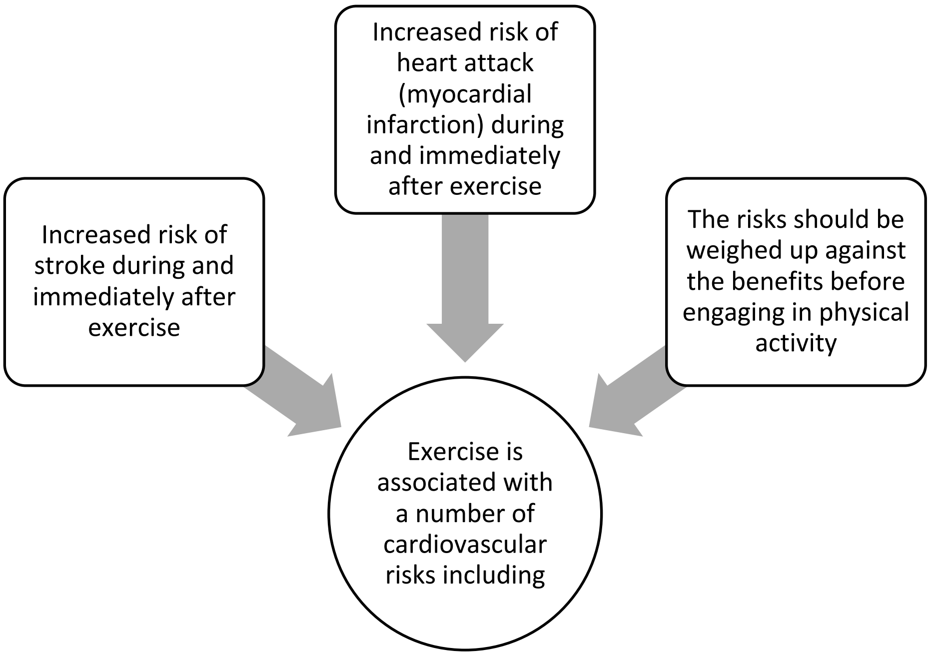
A linear increase in systolic blood pressure (SBP) can be seen with increasing exertion whilst the diastolic (DBP) blood pressure may decrease slightly during exertion due to vasodilation or remain unchanged. Individuals with hypertension may experience a rise in DBP as a result of an impaired vasodilatory response.

Heavy weight training and isometric exercises increase both SBP and DBP so it is important not to hold your breath when performing these exercises to avoid the Valsalva effect. This Valsalva manoeuvre involves holding the breath while straining or a forced exhalation against a closed airway and therefore increases the pressure in the thoracic cavity and prevents venous return. This can increase blood pressure and the risk of a cardiovascular event such as a heart attack or stroke. To avoid this, inhale as you're bringing the resistance back to its resting position and exhale as you're working hardest against the resistance.

Long-term Effects of Exercise on Blood Pressure

Aerobic exercise using large muscle groups in a rhythmical activity helps to reduce blood pressure over time. According to Durstine and Moore (2003) endurance training can cause an average decrease of mmHg in both SBP and DBP in mild and moderate hypertensives. Apart from circuit weight training, chronic strength or resistance training has not been shown to lower resting blood pressure. Resistance training can benefit hypertensives but it is not recommended as a means on its own.

Exercise and Blood Pressure Considerations



Cardiovascular Benefits of Endurance Training

There are both short and long term effects of the cardiovascular system; the short term are physiological responses to physical activity such as an increase in heart rate, stroke volume, blood pressure and cardiac output. This represents the body's attempts to deliver more blood around the system to cope with the demands of physical exertion.

Long term changes are the positive effects can be seen in lasting adaptations

Effects of Exercise

Increased growth of cardiac muscle	Larger stroke volume	Lower HR	Stronger & more elastic arteries
Improved blood cholesterol markers	Increased network density of capillary beds	Increased haemoglobin count in blood	Lower BP in long term
Risks:	Increased BP and used of valsalva manoeuvre/ techniques	Postural hypotension/ increased light headedness	

Resting cardiac output in the heart of a well-trained athlete will be about the same as in a healthy untrained athlete. Although stroke volume is increased, the heart rate is decreased.

Section 2: The Musculoskeletal System and Exercise

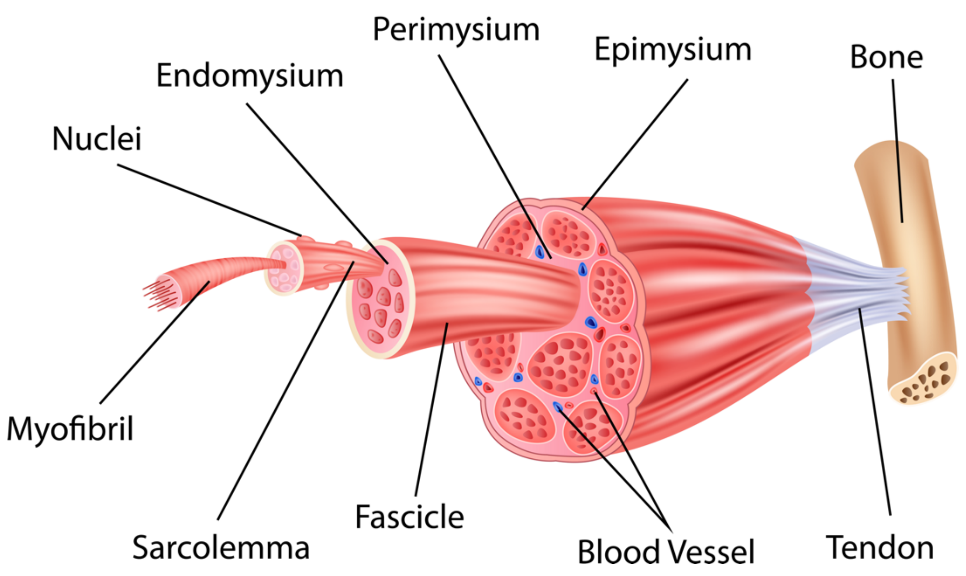
To achieve human movement we are reliant on muscle tissue pulling on bone in order to produce motion at a moveable joint. Movements possible at each joint is dependent on the design of that joint, the origin and insertion point of the muscles and the angle at which the fibres cross the joints.

The Cellular Structure of Skeletal Muscle

Many different systems integrate during movement with the driving force being the muscular system. Basic anatomy of these muscles helps us to understand how these movements occur.
Skeletal muscle is striated tissue and therefore has a striped appearance when looked at under a microscope. This type of tissue is under voluntary control. A number of rod like structures called muscle fibres run parallel along the muscle length and each fibre is constructed from smaller parallel fibres and so on.

Muscles are surrounded and protected by a series of collagen based membranes. The outer layer that covers the whole muscle is called the epimysium (epi meaning upon). In each epimysium there are groups of muscle fibres formed into bundles of fasciculi. A perimysium (peri meaning around) forms an outer sheath around each fascicle. Within each fascicle are bundles of muscle fibres separated from the other by another membrane called the endomysium (endo meaning inside). Myofibrils form the individual muscle fibres and they contain the contractile proteins, myofilaments, which are needed for generating force. The myofibrils, actin and myosin, are arranged in compartments called sarcomeres which are the smallest unit and repeat along the fibre (under a microscope these appear as dark bands and give skeletal muscles their striated appearance).

The connective tissue continues throughout the length of the muscle fibres where it converges to form tendons. Tendons (strong, inelastic, strap structures) attach the muscle to the periosteum that coats the bone. Force production is transferred from the muscles to the skeleton via the tendons



Summary of key points

The whole muscle belly is wrapped in **epimysium** which holds the samller fasciculi

Bundles of fibres, or **fasciculi**, are wrapped in **perimysium**

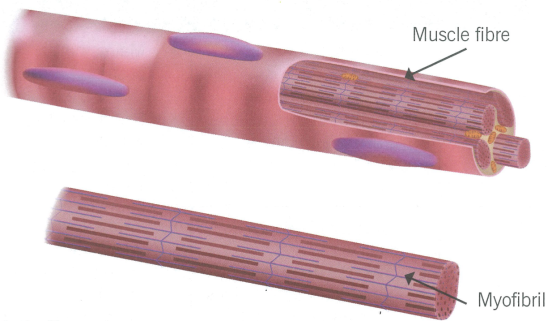
Single muscle fibres which contain the

Inside single muscle fibres are **myofibrils** - the smallest unit

Within myofibrils are **sarcomeres** which contain the **myofilaments** – actin and myosin

Force Generation and the Sliding Filament Theory

For force generation to begin the two contractile proteins (actin and myosin – also referred to thin and thick filaments respectively) must be activated.



The 2 contractile proteins (actin and myosin) begin force generation

They are arranged into compartments in the sarcomere

The sarcomeres run the length of the myofibril

The actin is anchored to the ends of the sarcomere whilst the myosin sits within the middle

The myosin has ‘hook like’ projections referred to as heads

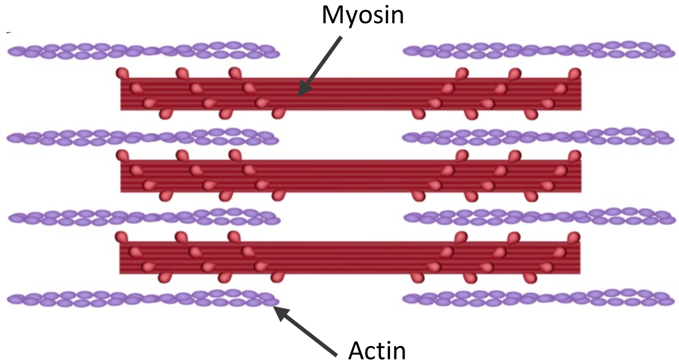
During contraction the myosin heads attach themselves to the actin filaments and rotate, pulling on them

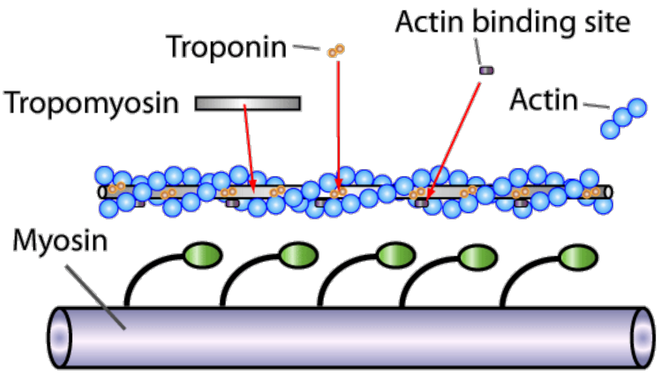
The actin is then drawn inwards, pulling the ends of the sarcomere together

The power to drive the myosin head comes from the ATP

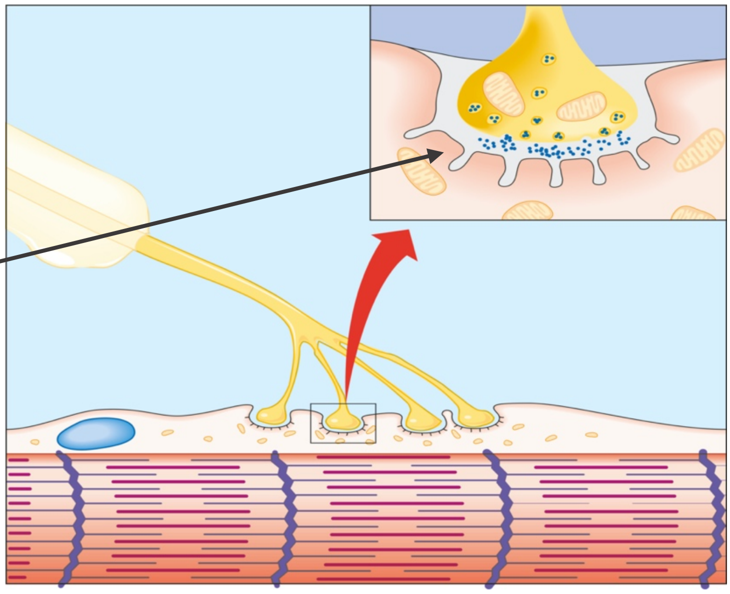
It primes the myosin head ready for binding

When the conditions are right the head will bind with actin





Although primed with ATP, the myosin heads cannot bind to actin without calcium. When relaxed, the active sites on actin are blocked by troponin and tropomyosin.



Surrounding the myofibrils is a network of tubes called the sarcoplasmic reticulum (SR) – calcium reservoirs. An action potential travels along the sarcolemma to produce a nervous system stimulation of the SR causing a release of calcium into the sarcoplasm.

The calcium causes the blocking molecule (troponin) to move away from the myosin binding site. The primed myosin head can then attach to the actin and rotate in the power stroke. ATP then binds to the myosin head to release it from the binding site to re-set

Summary of information

1	Cocking phase	ATP is broken down and energy is released to prime the myosin head into a cocked position
2	Binding phase	Calcium ions are released from the SR and allow the myosin head to attach to the actin binding sites
3	Power stroke	The myosin head rotates and pulls the actin towards the centre of the sarcomere, generating tension/ muscle contraction
4	Re-setting	ATP binds to the myosin head, releasing it from the actin binding site

Effect of Exercise on Fibre Type

Exercise in general has a positive effect on muscle development, but specific activities can influence different muscle fibre types. To recap, the characteristics of the muscle fibres can be seen below.

1
- Type I
- Most aerobic in nature
- Greater blood supply and mitochondria
- Long duration activities with lower intensity

2
- Type IIa
- Intermediate fibres
- All the characteristics of other fast twitch fibres
- Ability to adapt and adopt characteristics of type I depending on the training stimulus

3
- Type IIb
- Very anaerobic in nature
- Reduced blood supply compared to type I
- Significantly lower mitochondria
- Short bursts, high intensity, higher force and power outputs

The table below outlines the effects of different types of exercise on different muscle fibre types

Exercise Type	**Effect**
Aerobic, long slow endurance training	Type I or Type IIa fibre changes: • Improved efficiency and work capacity • Increased number and size of mitochondria • Hypertrophy • Increased aerobic enzyme levels • Increased capillary density No change to Type IIb fibres
Anaerobic, heavy resistance training	Type IIa and IIb fibre changes: • Increase in anaerobic enzyme levels • Increased phosphocreatine stores • Hypertrophy • Increased contractile protein density No change to Type I fibres except hypertrophy

Isotonic (same tone)	muscle actions involving movement i.e. Concentric and eccentric
Concentric	Muscle shortens while generating force i.e. the lifting phase of a bicep curl
Eccentric	Muscle lengthens while generating force i.e. the lowering phase of a bicep curl
Isometric	Muscle stays the same while generating force i.e. holding the weight at the top of the bicep curl
Isokinetic (same speed)	Muscle actions involving movement at a constant speed

Muscle Fatigue, Soreness and Oxygen Debt

Muscle fatigue is a decline in the muscle's ability to produce force – the causes of which can vary:

- Reduced neurotransmitter levels reduce the volume of action potentials reaching muscle fibres
- Perceptions of pain and discomfort decrease performance
- Depletion of glycogen stores can limit ATP synthesis rate
- Insufficient oxygen can change the internal chemistry and directly interrupt the sliding filament mechanism

The cause of fatigue will also be dependent on the mode of exercise. There are many stages to a muscle contraction so causes of muscle fatigue vary

- May be because of an interruption in any of the chains of events between the CNS and muscle fibre
- DOMS- 24-72 hours after exercise
- Cause unsure- muscle damage or inflammation- associated with intense eccentric activity and new exercise

Delayed Onset Muscle Soreness (DOMS)

Delayed onset muscle soreness is very different to the pain or discomfort that may be felt during exercise. It typically occurs 24-72 hours after exercise. The cause is unsure- muscle damage or inflammation- associated with intense eccentric activity and new exercise. Minimising eccentric activity during early stages of training may minimise DOMS. Starting a progressive training programme at a low intensity and gradually introducing overload may be the best approach for a new client.

Muscle		Location	Origin	Insertion	Action
Deltoid		Shoulder	Clavicle, acromion and spine of scapula	Humerus	Anterior: Abduct shoulder Horizontally adduct medially rotate Posterior: Abduct shoulder Horizontally adduct Laterally rotate
Rotator Cuff	Teres minor	Shoulder	Lateral boarder of scapula	Greater tubercle of humerus	Adduct and laterally rotate shoulder
	Subscapularis		Anterior scapula (subscapular fossa of scapula)	Greater tubercle of humerus	Medially rotate and stabilise humerus
	Infraspinatus		(scapula) Infraspinous fossa scapula	Greater tubercle of humerus	Laterally rotate and adduct shoulder
	Subscapularis		Scapula (supraspinatus fossa of scapula)	Greater tubercle of humerus	Adduct and stabilise humerus
Teres major		Shoulder	Inferior angle of scapula	Humerus	Extension, adduction and internal rotation of the shoulder joint
Levator scapula		Upper back and neck	C1-4 vertebrae	Medial boarder of scapula	Elevate scapula unilaterally laterally flex neck Bilaterally extend neck
Tricep brachii		Back of the upper arm	Long head: scapula Medial head: humerus Lateral head: humerus	Ulna	Extend elbow Long head: adduct and extend shoulder
Bicep brachii		Front of the upper arm	Scapula	Tuberosity of radius	Flex elbow Supinate forearm Flex shoulder
Latissimus dorsi			Scapula, spinous processes, ribs, thoracolumbar spine, iliac crest	Humerus	Adduction shoulder Extend shoulder Medially rotate shoulder

Muscle		Location	Origin	Insertion	Action
Trapezius		Upper back	Occipital spinous process C7-T12	Clavicle, spine of scapula and acromion	Bilaterally extend head and neck Unilaterally- lateral flex neck Rotate the head in opposite side Depress and upwardly rotate
Rhomboids	Major	Mid back	Medial boarder of scapula	spinous process T2-T5	Adduct scapula
	Minor		Upper boarder	spinous process C7- T1	Elevate and retract shoulders
Pectorals major		Chest	Clavicle and sternum	Greater tubercle humerus	Medially rotate shoulder Flex and horizontally adduct
Pectoral minor		Chest	3rd, 4th 5th rib	Medial surface of the scapula	Depress the scapula Abduct the scapula
Serratus anterior		Side of the torso	Upper eight or nine ribs	Anterior surface of the medial boarder of the scapula	Abduct shoulder depress the scapula
Erector spinae		Either side of the spine	Sacrum, ilium, ribs and vertebrae	Ribs, vertebrae and base of the skull	Extension and lateral flexion of the spine
Iliocostalis (3 erector spinae muscles)		Either side of the spine	Sacrum, ilium and posterior surfaces of ribs 1-12	Posterior surface of ribs 1-12 and transverse processes of the cervical vertebrae	Lateral flexion and extension of the spine
Longissimus (3 erector spinae muscles)		Either side of the spine	Transverse processes of the lumbar and thoracic vertebrae	Ribs and transverse processes of the thoracic and cervical vertebrae and mastoid process	Lateral flexion and extension of the spine
Spinalis (3 erector spinae muscles)		Either side of the spine	Spinous processes of the upper lumbar and thoracic vertebrae	Spinous processes of the upper thoracic and cervical vertebrae	Lateral flexion and extension of the spine
Multifidus		Either side of the spine	Sacrum and transverse processes of lumbar, thoracic and cervical vertebrae	Spinous processes of 2nd-4th vertebrae above each origin	Extension and rotation of the spine
Quadratus Lumborum		Lower back	Posterior iliac crest	Last rib and transverse processes of 1st -4th lumbar vertebrae	Unilaterally – lateral flex spine Bilaterally- fix ribs during in and exhalation.
Rectus abdominis		Along the centre of the abdomen	Pubis	Cartilage of 5th-7th rib and base of the sternum	Flexion and lateral flexion of the spin and posteriorly tilts the pelvic

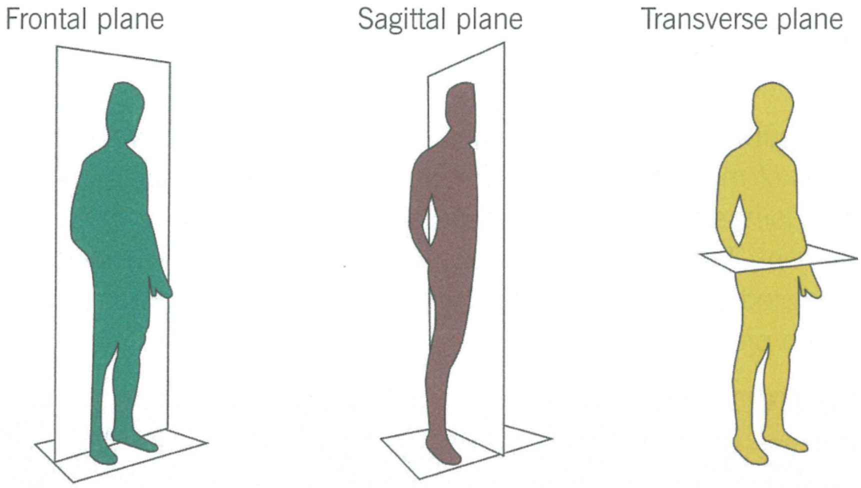
Muscle		Location	Origin	Insertion	Action
Internal obliques		Sides of the abdomen	Iliac crest and thoracolumbar fascia	Lower 3 ribs and the fascial connection to the linea alba	Rotation and lateral flexion of the spine
External obliques		Sides of the abdomen	Outer surface of the 6^{th}-12^{th} ribs	Iliac crest, the pubis and the fascial connection to the linea alba	Compresses and supports the abdominal contents
Diaphragm		Beneath the rib cage	Base of the sternum, inner surface of the lower 6 ribs and the upper 3 lumbar vertebrae	Central tendon of diaphragm	Draws the central diaphragmatic tendon downwards increasing volume of the thorax
Intercostals		Between ribs	Inferior border of the ribs and costal cartilages	Superior border of the rib below	Elevate ribs to aid inspiration and draws down to aid expiration
Hip flexors	Iliacus	Through the pelvis and onto the femur	Iliac fossa	Lesser trochanter	Flexion and external rotation of the hip
	Psoas major		Lumbar transverse processes	Lesser trochanter	Flex hip Unilaterally assist to laterally flex the spine May laterally rotate
Gluteus maximus		Bottom	Scrum, coccyx, iliac crest	IT band and gluteal tuberosity	Extend hip Abduct hip Laterally rotate hip
Abductors	Gluteus medius	Outside of upper thigh	Iliac crest	Greater trochanter	Anterior fibres: Abduct and flex hip Posterior fibres: Extend and laterally rotate the hip
	Gluteus minimus		Ilium	Anterior surface Greater trochanter	Abducts, medially rotates and flexes the hip
	Piriformis	Posterior hip	Anterior of Sacrum	Superior aspect Greater trochanter	Laterally rotates hip

	Tensor facia latae	Outer thigh	Iliac crest and posterior ASIS	Iliotibial tract	Abducts, flexes and medially rotates the hip
Muscle		Location	Origin	Insertion	Action
Adductors	Adductor magnus	Inner thigh	The base of the pubis and ischium	Mid to lower femur	Adduction, internal rotation and extension of the hip
	Adductor longus		Anterior pubis	Mid femur	Adduction and internal rotation of the hip
	Adductor brevis		Anterior pubis	Upper femur	Adduction and internal rotation of the hip
	Pectineus		Anterior, superior pubis	Posterior, upper femur	Adduction and flexion of the hip
	Gracilis		Anterior, inferior pubis	Medial, upper tibia	Adduction and flexion of the hip
Sartorius		Front and inner thigh	Anterior superior iliac spine	Medial, upper tibia	Flexion, abduction & external rotation of the hip Flexion and internal rotation of the knee
Quadriceps	Rectus femoris	Front of thigh	Anterior superior iliac spine	Anterior, upper tibia via the patella tendon	Flexion of the hip and extension of the knee
	Vastus lateralis		Greater trochanter and lateral surface of the femur	Anterior, upper tibia via the patella tendon	Extension of the knee
	Vastus intermedius		Anterior and lateral surface of the femur	Anterior, upper tibia via the patella tendon	Extension of the knee
	Vastus medialis		Medial surface of the femur	Anterior, upper tibia via the patella tendon	Extension of the knee (especially last 20 degrees)
Hamstrings	Biceps femoris	Back of thigh	Ischium and posterior surface of the femur	Head of the fibula	Extension and external rotation of the hip and flexion of the knee
	Semitendinosus		Ischium	Upper, medial surface of the tibia	Extension of hip, flexion of knee and tilts the pelvis posteriorly
	Semimembranosus		Ischium	Upper, medial surface of the tibia	Extension of the hip, flexion of the knee and tilts the pelvis posteriorly
Gastrocnemius		Calf	Posterior, lower femur	Calcaneus	Plantar flex the ankle
Soleus		Calf	Upper, posterior tibia	Calcaneus	Plantarflexion of the ankle
Tibialis anterior		Front of lower leg	Lateral, upper tibia	1st metatarsal and medial tarsal	Dorsiflexion and inversion of the ankle

Anatomical Planes

Planes are imaginary flat surfaces along which movement can occur or that represent anatomical cross-sections. There are three basic planes: frontal (coronal), sagittal and transverse. It is important to point out that human movement occurs simultaneously in multiple planes.

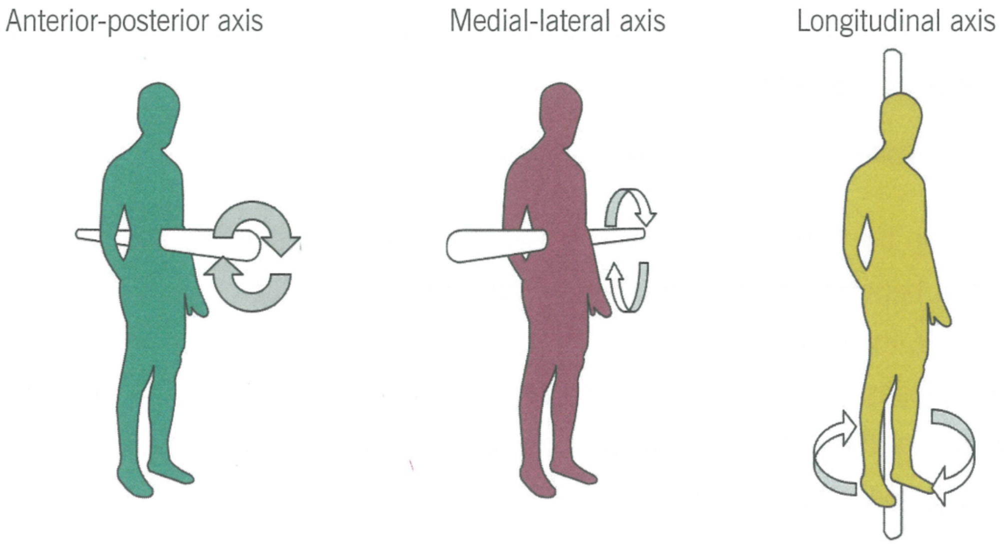
Frontal	•A vertical plane that divides the body into anterior and posterior
Sagittal	•A vertical plane that divides the body into left and right parts
Transverse	•A horizontal cross-section through the body separating the upper body from the lower body



Axes of Movement

An axis is a line that passes through a plane, about which movement (rotation) occurs.

Frontal horizontal axis (medial - lateral)	•Passes through the sagittal plane: rotation would occur in the sagittal plane
Vertical axis (longitudinal)	•Passes through the transverse plane: rotation would occur in the transverse plane
Sagittal horizontal axis (anterior – posterior)	•Passes through the frontal plane: rotation would occur in the frontal plane



The following table provides examples of key joint movements, the planes and axes of movement.

Main Joint Actions	**Dominant Plane of Movement**	**Dominant Axes of Movement**
Flexion Extension Hyper-extension Dorsi-flexion Plantar-flexion	Sagittal plane	Medial-lateral axis
Abduction Adduction Inversion Eversion Lateral-flexion	Frontal plane	Anterior-posterior axis
External rotation Internal rotation Supination Pronation Rotation Horizontal flexion Horizontal extension	Transverse plane	Longitudinal axis

Joint Structure and Movement

Joint types, muscle configurations and sequences of muscle actions are responsible for the range and capability of human movement. It is important to understand the movement available at joints and their limitations to ensure the safety of exercise.

At a basic level it is important to remember the types of joints:

Fibrous:	Immoveable with interlocking bones e.g. the plates in the skull
Cartilaginous:	Slightly moveable bones connected by ligaments e.g. the vertebrae
Synovial:	Freely moveable and the most common type of joint in the human body e.g. hip, knee, ankle, shoulder, elbow

And at a deeper level, the synovial joints:

Gliding Joints:	The mid-carpal and mid-tarsal bones of the wrist and ankle
Pivot Joints:	Between the atlas and axis of the cervical vertebrae
Saddle Joints:	The thumb
Ball and Socket joints:	The hip and shoulder
Hinge Joints:	The elbow and knee
Ellipsoid Joints:	The knuckles between the phalangeal bones of the fingers and toes

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The following table provides an overview of the main synovial joints in the body, the movement available and the planes and axes they move in and rotate about.

Joint	Actions	Plane of Movement	Axis of Movement
Shoulder	Flexion – extension Abduction – adduction Internal – external rotation	Sagittal Frontal Transverse	Medial-lateral Anterior-posterior Longitudinal
Elbow	Flexion – extension	Sagittal	Medial-lateral
Spine	Flexion – extension Lateral flexion Rotation	Sagittal Frontal Transverse	Medial-lateral Anterior-posterior Longitudinal
Hip	Flexion – extension Abduction – adduction Internal – external rotation	Sagittal Frontal Transverse	Medial-lateral Anterior-posterior Longitudinal
Knee	Flexion – extension	Sagittal	Medial-lateral
Ankle	Plantarflexion – dorsiflexion	Sagittal	Medial-lateral

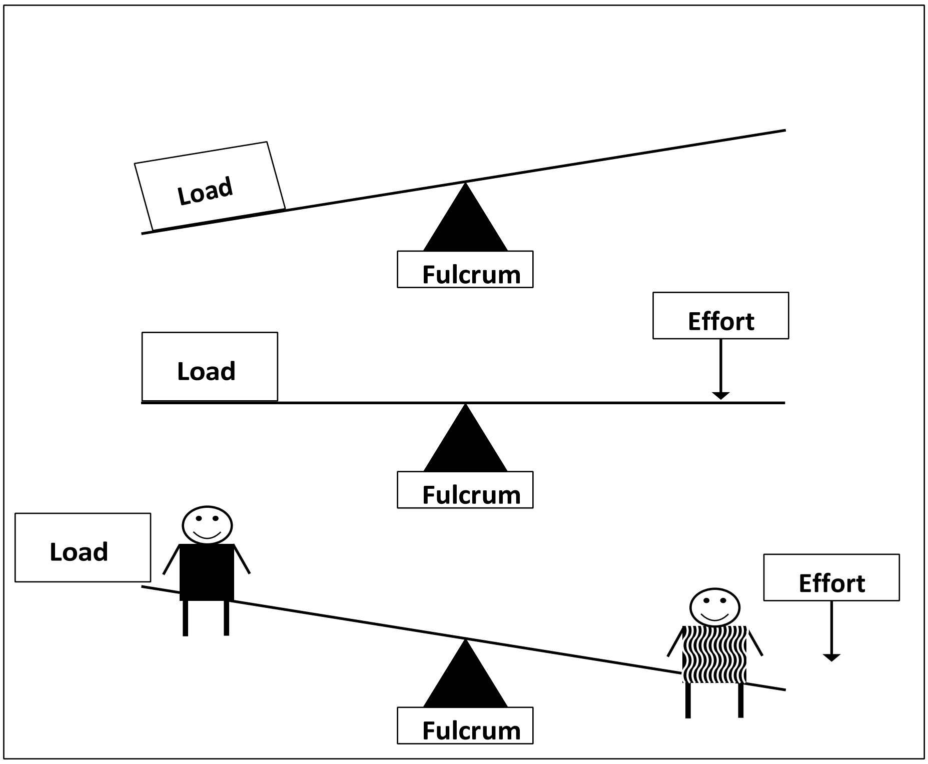
The Lever System

By understanding movement we are able to make better judgments regarding choice of exercises and their execution.

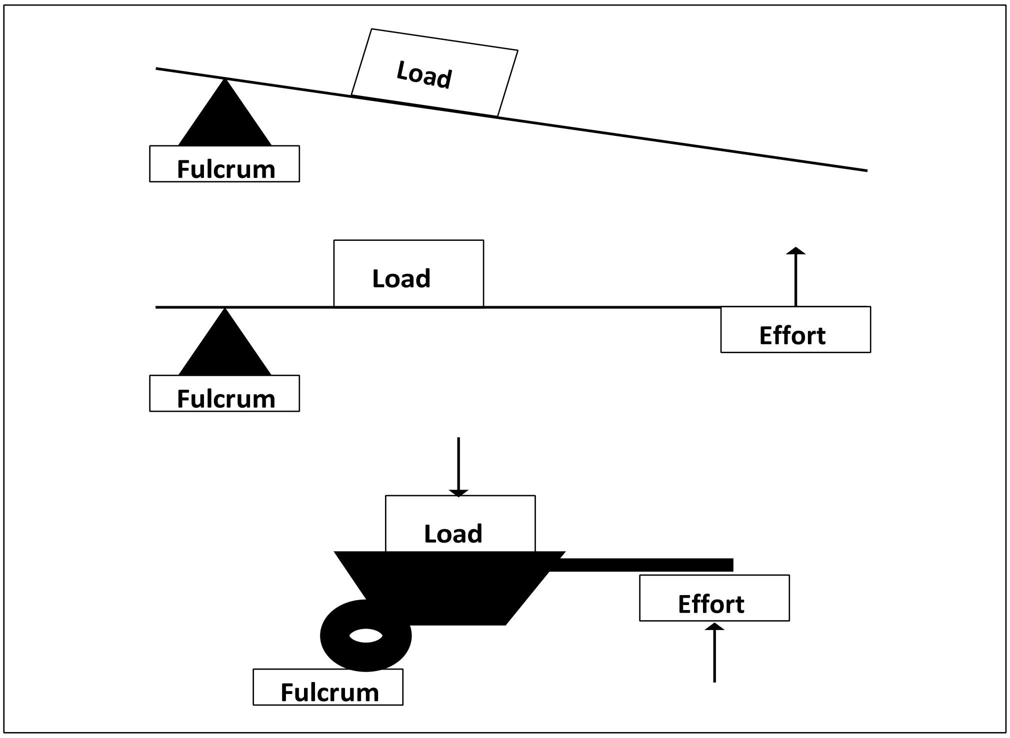
Humans move or pick up objects via a basic system of levers. A lever is a simple machine consisting of a rigid rod that moves or pivots around a fixed point (fulcrum). If we vary the position of the fulcrum, the load or the effort; different combinations of speed, range of movement and force can be generated.

Levers take on three basic forms.

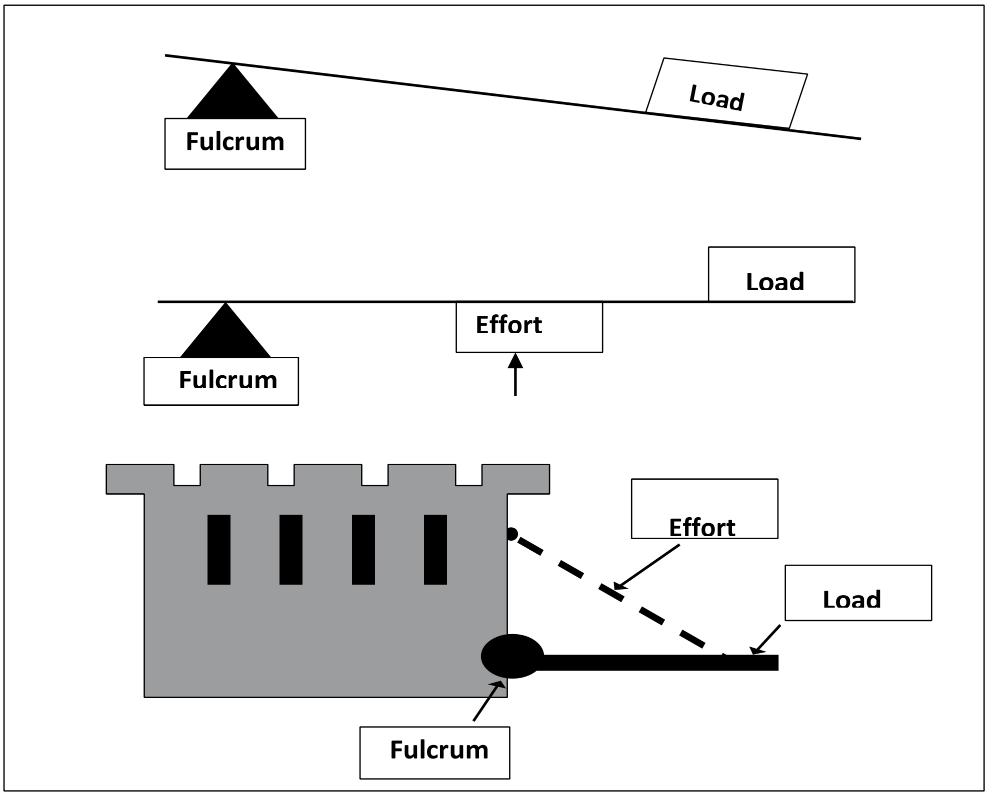
1st class levers: the best example of this kind of lever is a seesaw. The fulcrum is between the effort and the load. Moving the fulcrum closer to, or further away from the load; speed, range of movement and force generated will vary. Although simple, this form of lever is not common in the body. Examples include the triceps extending the forearm; gastrocnemius and soleus plantar flexing the foot when it is off the ground.



2nd class levers: the best example of this type of lever is a wheelbarrow. The fulcrum and the effort are at opposite ends with load placed in between. This arrangement produces plenty of force, but like 1st class levers there are relatively few examples in the body.



3rd class levers: the most common form of lever in the body. The fulcrum and the load are at opposite ends with the effort placed in between. This is similar to a drawer bridge and generally produces less force than the other forms of lever but provides a much greater range of movement and speed.



The Shoulder Joint

Formed by the articulation of the scapula and humerus (shallow ball and socket joint), the shoulder joint allows a wide range of movement including flexion, extension, abduction, adduction, internal and external rotation and circumduction. The majority of movement at this joint is provided by the pectoralis major, latissimus dorsi and deltoids. The shoulder joint may often be referred to as the glenohumeral joint as the head of the humerus articulates with the glenoid cavity (fossa)


Pectoralis Major


Deltoid


Latissimus dorsi

Deep Musculature of the Shoulder

Underneath the joint is a more subtle arrangement of musculature. Each originates on the scapula and inserts on the upper humerus and plays a key role in stabilising the shoulder joint and controlling movement. They are often referred to as the rotator cuff. Having stability, integrity and coordinated function reduces the potential risk of injury to these muscles and at this joint. The subscapularis is the largest and strongest rotator cuff muscle, essential in overhead sports.

Teres Minor	Runs laterally from the scapula to the humerus to aid with adduction and external rotation
Supraspinatus	Runs superiorly from the scapula to the top of the humerus to aid shoulder abduction
Infraspinatus	Runs laterally from the scapula (higher than the teres minor) to the humerus to aid horizontal extension, external rotation and adduction
Subscapularis	Runs from the underneath of the scapular to the front of the humerus to aid internal rotation and adduction


Teres Minor – Abduction and lateral rotation


Supraspinatus – Shoulder abduction

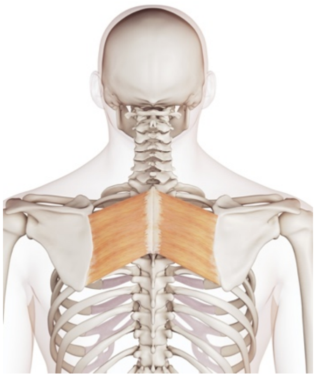

Infraspinatus – Horizontal extension, lateral rotation and abduction


Subscapularis – Internal rotation and adduction

The Shoulder Girdle

The shoulder girdle is comprised of the scapula and the clavicle. They move in coordination with the shoulder joint to allow complex movements in the upper limbs.

Posterior Muscles of the Shoulder Girdle



Rhomboid Major

Rhomboid Minor

Levator Scapula

Trapezius

These muscles allow for various combinations of elevation (shrugging the shoulders), retraction (shoulders back, chest out) and depression (shoulders dropped) to occur

Anterior Muscles of the Shoulder Girdle

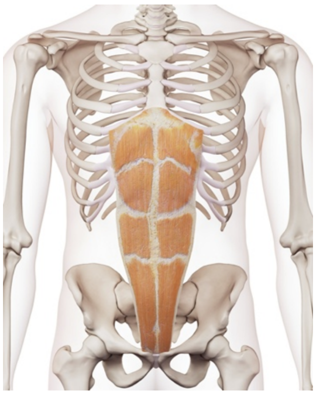
Serratus Anterior

Pectoralis Minor

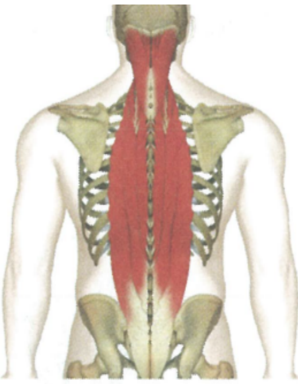
The pectoralis minor and serratus anterior originate at the costal bones and insert on the anterior surfaces of the scapula. The anterior-inferior alignment allows them to both to protract and depress the shoulder girdle. When used with the appropriate shoulder joint action they can assist in pushing movements such as press ups.

The Vertebral Column

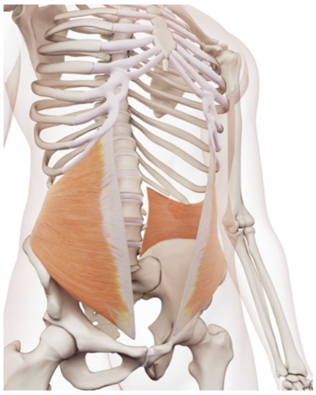
A series of irregular vertebral bones linked by cartilaginous, slightly moveable joints, separated by intervertebral discs. The muscles below control spinal movement causing flexion, extension and rotation. Working unilaterally they pull the spine into lateral flexion



Rectus Abdominis



Erector Spinae



Internal Obliques

External Obliques

Two important muscles of the posterior are the multifidus and quadratus lumborum.

Multifidus	Runs from the sacrum to the cervical spine. It links small sections of the vertebrae together. It aids the control of flexion and rotation of the vertebral column. Considered a key element of the core musculature
Quadratus Lumborum	Runs from the iliac crest to the lumbar vertebrae and lower ribs. It aids to laterally flex and extend the spine. It also assists in laterally tilting the pelvis

The Hip Joint

A ball and socket joint, formed by the articulation of the acetabulum of the pelvis with the head of the femur. Subjected to the forces from the strong muscles of the leg and hip, it allows us to walk, run and jump.

Designed to be a stable and weight bearing joint, musculature either flexes (iliacus, psoas, rectus femoris) or extends (gluteus maximus and hamstrings), abducts (piriformis and tensor fascia latae; gluteus medius or minimus) or adducts (adductor longus, brevis, or magnus; pectineus and gracilis).

The hip joint opts for stability over mobility, whilst the opposite is true of the shoulder joint, therefore (despite being the same 'type' of joint) the shoulder is more prone to dislocation than the hip.

The Knee Joint

A synovial hinge joint that joins the thigh bone (femur) to the shin bone (tibia), the knee is one of the most complex joints which plays an essential role in supporting the body's weight.

During normal activity the knee can tolerate considerable force and stress, however it often lacks the necessary support and is more susceptible to damage and injury from rotational forces.

The primary movements at the knee are flexion and extension which is associated with muscles found on the anterior or posterior of the hip and femur.
Whilst in a flexed position a small amount of internal rotation is possible.

The Quadriceps


Vastus intermedius


Vastus lateralis


Vastus medialis


Rectus femoris

Although the 4 quadricep muscles originate from different places they all insert onto the tibia via the patella tendon.
The rectus femoris is the only muscle to pass both the hip and knee joint so therefore enables hip flexion and knee extension.

The Hamstrings

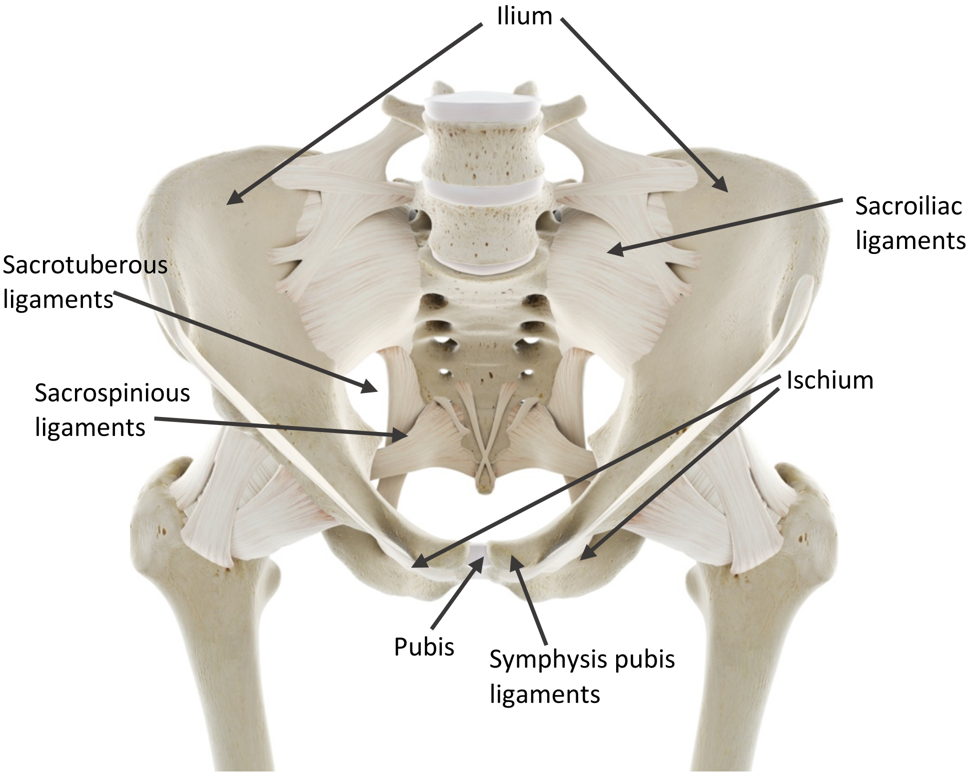

Biceps femoris


Semimembranosus


Semitendinosus

The three muscles of the posterior leg all cross the knee and the hip. They are responsible for knee flexion and hip extension. The biceps femoris has 2 heads – one long and one short. The short head only cross the knee so cause knee flexion but have no part in hip extension.

The Pelvic Girdle



Most of the main musculature for the hip and knee originates in the pelvic girdle. The pelvis forms a strong, bone ring that sits in between the base of the vertebral column and the head of the femur. The 'pelvic girdle' is commonly referred to as a collective name for the 6 bones that form the pelvis and structures that connect it to the hip and sacrum. Normally, it is a symmetrical structure of 2 halves which are joined at the pubis and sacrum.

Each half has 3 separate bones:

- The top flat half is called the ilium
- The front middle section is the pubis
- The bottom section is called the ischium

The left and right pubic bones are united by a cartilaginous joint known as the pubis symphysis

Pelvic Ligaments

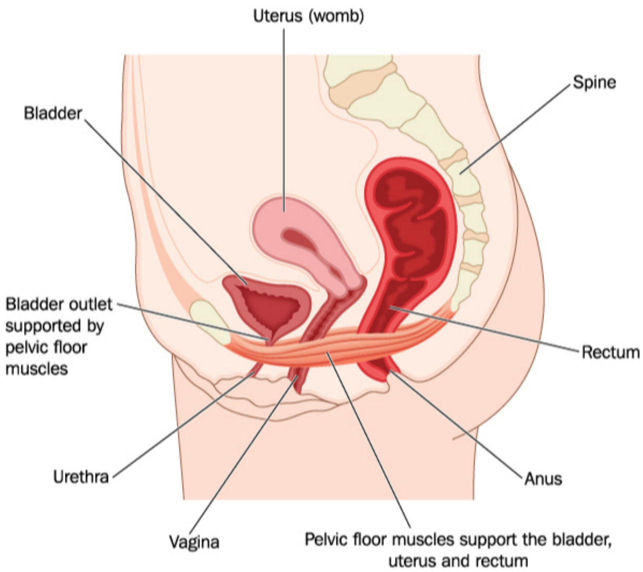
Ligaments connect the pelvic girdle and provide passive strength and rigidity

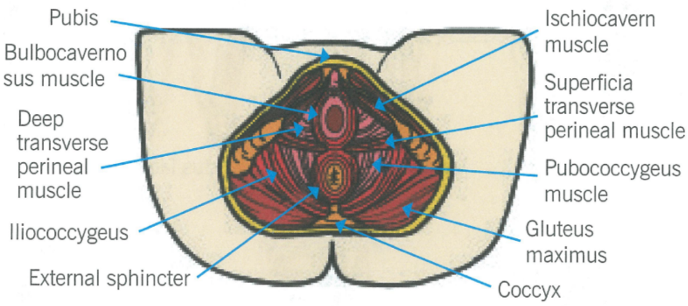
Sacroiliac ligaments	pass in front of and behind each sacroiliac joint
Symphysis pubis ligaments	are used to bridge spaces in the walls of the pelvis
Sacro-tuberous ligaments	extend from the sides of the sacrum to the ilium crossing the sciatic notches
Sacrospinous ligaments	pass from the sides of the sacrum to the ischial spines, extending across the greater sciatic notch

Pelvic Muscles

There are 35 different muscles in the pelvis with various functions. They support the internal organs, control lumbar spine movement, stabilise the pelvic position and generate gross physiological movement. The primary muscles are:

- Iliopsoas
- Adductor complex
- Hamstrings
- Gluteal muscles
- Rectus femoris
- Tensor fascia latae
- Pelvic floor muscles
- Abdominals and obliques
- Quadratus Lumborum
- Piriformis





Section 3: Postural and Core Stability

One of the most upward trending concepts in health and fitness is training the core (the trunk of the body). Contrary to common belief, the core contains more than just the abdominals and the lower back muscles. This section will focus on the muscles and ligaments that help to stabilise the spine and support core movement.

Core stability can be defined as " the ability of your trunk to support the effort and forces from your arms and legs, so that muscles can joints can perform in their safest, strongest and most effective positions" (Elphinstone and Pook, 1998)

Stabilising Ligaments

Ligaments provide some passive support (weaker than muscles) and prevent unwanted movement of the spine. There are 4 main ligaments that run the length of the spine:

Anterior Longitudinal Ligament	Posterior Longitudinal Ligament	Interspinous Ligaments	Intertransverse Ligaments
•Connects each vertebral body together •Runs anteriorly along the front of the spine •Prevents excess extension of the spin	•Runs along the back of the spine underneath the spinous processes •Connected to the vertebral bodies of each segment •Prevents excess flexion of the spine	•Connect the spinous processes to the one immediately above or below •Work with the posterior longitudinal ligament to prevent excess flexion of the spine	•Connect each transverse process to the one immediately above or below •Run on both the left and right side of the spine •Prevent excess lateral flexion

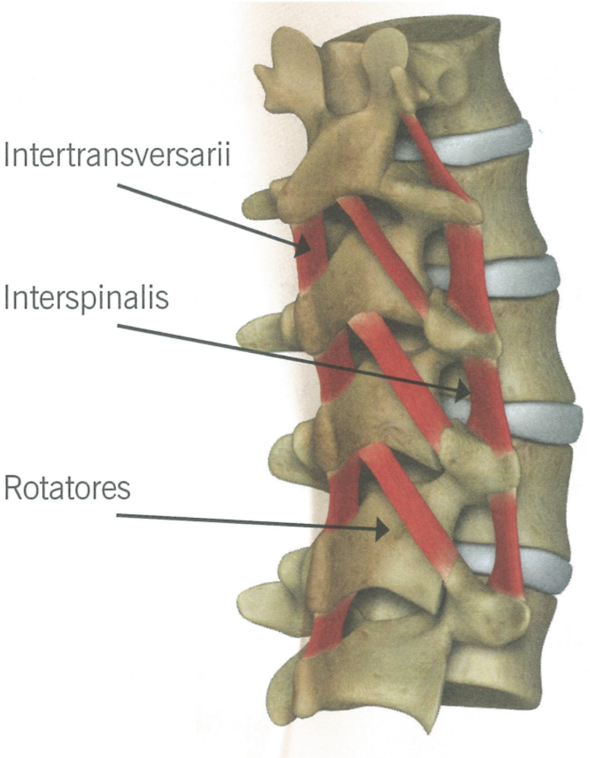
The Muscles of the Spine

Without the supporting musculature the human spine is unstable. Muscles can be grouped into 3 distinct layers – deep, middle and outer; and the coordination of these muscles determines the level of safe and effective core function

The Deep Muscles of the Spine (Position Sense Muscles)

Movements of the spine and extremities are categorised into 2 groups: Physiological and Accessory. Gross physiological movements are responsible for large motions and functional tasks, whilst accessory movements occur within a joint.
To control accessory movements small, deeper muscles immediately next to the spine maintain vertebral segment alignment and are referred to as position sense muscles.
Position sense muscles provide feedback to the central nervous system about small movements and variations in spinal position

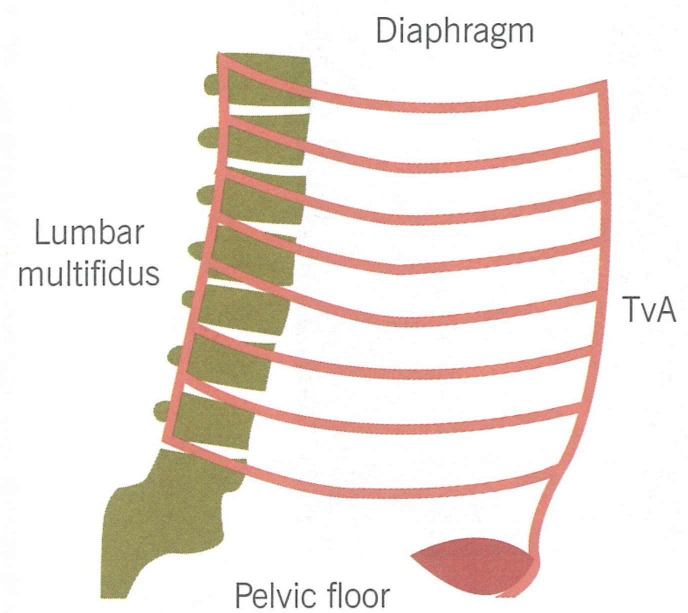
The Deep Muscles of the Spine



Intertransversarii	Attach between the transverse processes of the spine Help to bring about lateral flexion and control smaller movements between the vertebrae
Interspinalis	Attach between the spinous processes of the spine Help to bring about extension of the spinal sections whilst controlling smaller movements between the vertebrae
Rotatores	Attach from the spinous process of one vertebrae to the transverse process of the vertebrae immediately below Help to bring about rotation between spinal sections and control the smaller movements between the vertebrae

The Middle Muscle Layer (Inner Unit)

These muscles help to provide stability and create intra-abdominal pressure to stabilise the spine during movement. It includes the transversus abdominis (TVA), lumbar multifidus, diaphragm and pelvic floor. The muscles contract together to form a cylinder to stabilise the spine so the arms and legs can function optimally. Research has shown that before movement of the extremities the inner unit is activated. Faulty inner unit recruitment is likely to result in lower back pain



Transversus Abdominis	Multifidus	Diaphragm	Pelvic Floor
•Wraps around the body attaching to the lower ribs and pelvis •Draws the waist in and compresses the abdominal contents •Increases intra-abdominal pressure to stabilise the spine	•A series of smaller muscles that connects the spinous processes of the spine to the transverse processes 2 or 3 vertebrae below •Help to provide rotation and extension of the spine and hold the lumbar segments in an extended position	•Primary muscle that initiates breathing •Contracts downwards and helps create intra-abdominal pressure to help stabilise the spine along with all of the other muscles in the group	•Made up of several small muscles •Acts as a hammock at the base of the body to hold the organs •Contracts at the same time as the diaphragm and other core muscles to create intra-abdominal pressure and stabilise the spine

The Outer Muscle Layer (Outer Unit)

The muscles are more responsible for the large movements. They stabilise the spine by creating tension across the trunk for external support
The muscle include:

- Rectus abdominis
- External obliques
- Erector spinae
- Latissimus dorsi
- The gluteals
- The adductors

These muscle slings which criss cross the body and contribute to maintaining an optimal working relationship between joints.

Integrated Core Function

Good core function is the ability of the trunk to support and transfer the forces of the arms and legs in the safest, strongest and most effective way. All the trunk muscles must work together for effective core movement and stability. If the core muscles do not contract in the right order (deep to outer layers) or the deeper muscles lack strength, there can be an over-reliance on global muscles closer to the surface. This can cause muscle spasms and is a common cause of back pain

Postural Dysfunction and its Effect on Movement Efficiency

Postural deviations cause core muscular dysfunction around the core. This affects an individual's ability to hold good form and a neutral spine during exercise and activity.
Posture can be affected by:

- Employment (desk jobs can affect the length tension relationships of muscles)
- Bodyweight (e.g. being overweight)
- Height
- Lifestyle
- Activity habits
- Degenerative disease/ previous injury

Neutral Spine

Holding a neutral spine is a common term to help avoid back injuries reducing stress on the supporting structures and standing in a natural position that has all 3 curves of the spine cervical thoracic and lumbar in good alignment.

Kyphosis

Those who are in a seated position for most of the day tend to adopt the following posture:

- Thoracic kyphosis with lengthened middle trapezius and rhomboids
- Protracted shoulders and shortened pectorals
- Extended cervical spine and shortened upper trapezius
- Posteriorly tilted pelvis and lumbar flexion

Individuals with postural dysfunctions tend to show limited thoracic rotation and extension – restricting the movement of the arms above the head

Lordosis and Hyperlordosis

Abdominal obesity shifts the centre of gravity forwards which leads to an increased chance of postural deviations such as an excessive lordotic posture. As a result loading patterns become faulty and increase the strain on the spine and surrounding joint structures. Those with hyperlordosis (excessive lumbar lordosis) often have a reduced range of lumbar flexion and restricted hip mobility which increases the risk of disc protrusion or herniation and sciatica.

Scoliosis

Is a sideways lateral curve in the spine and can affect people of any age however most common during teenage years. Core stability and corrective exercises can be incorporated into an exercise programmes to improve posture. Often it is to strengthen overstretched muscles that are causing tightness in another area.

Flatback Posture

The lumbar lordosis is lost and the centre of gravity shifts posteriorly. There is reduced range of lumbar extension and restricted hip mobility and therefore increased risk of lower back pain and injury due to stress placed on structures that are not designed to load bear.

Performing Core Exercises

Core exercises perform an important part of training programmes and technique should be monitored very carefully with core stabilisation exercises. Not all core exercises will be suitable for all clients as exercises can carry a risk of creating injury or aggravating an existing spinal condition. If a client has an existing spinal condition or postural problem that is beyond the scope of the exercise professional it would be appropriate to refer them to someone suitably qualified.

Types of Stretching

A stretching programme can help correct core dysfunction and other postural deviations. It is important to stretch the right areas but also to select the right type of stretch for the right purpose
There are 3 major types:

- Static
- Dynamic
- PNF

Static Stretching

Can be used for maintenance and development of muscle flexibility

Static Maintenance Stretching

- The muscle is taken to the end of its normal range and held without bouncing for 15-30 seconds
- Used to maintain the normal length of the muscle
- Can be both passive and active
- Passive – the position is held by a partner or piece of apparatus. They are good for developmental stretching but can cause pain
- Active – no assistance to stretch the muscle. Uses reciprocal inhibition to stretch the antagonists. It increases active flexibility and strengthens the active muscle. They are difficult to hold for longer than 10 seconds

Developmental Stretching

- Usually involves 3 stages of progressive stretch where the limb is moved slightly further each time
- Must be careful not to push beyond the muscle end range
- Used in flexibility training to develop the length of the fibres and increasing range of movement

Dynamic Stretching

Dynamic stretching involves movement and tends to be used in a warmup based around the exercises about to follow. Movements should be performed under control, progress from mid to end range and start slowly, avoid unnecessary explosive movements that could strain the tissues before they are ready.. Increasing the speed will promote blood flow and the elasticity of the tissues, but if movements are not controlled there is a risk of tearing tissues. Dynamic stretching helps to reduce the risk of injury by warming the muscle tissue and mobilising the joints.

Proprioceptive Neuromuscular Facilitation (PNF)

PNF takes advantage of the neuromuscular feedback loops in muscle tissue and is based on the contract-relax principle – a contraction of a muscle causes the relaxation of the muscle after (inverse stretch reflex). A muscle group is passively stretched and then isometrically contracted (7-15 seconds) against resistance in the stretched position. After 2-3 seconds the muscle is then passively stretched further increasing the range of motion. PNF stretching usually requires the help of a partner to provide the resistance and then the passive stretch after. It can be done without assistance but isn't usually as effective. PNF should only be applied to warm muscles and by an experienced practitioner.

When to Stretch

Although usually advised after a warmup, the client could stretch at any time that is appropriate to them throughout the day. Stretching should form an integral part of the warmup and cool down.
Static stretching should generally be avoided in the warmup as according to evidence it can:

- Do little to prepare the muscles for dynamic activity and could be detrimental to performance as it can decrease power output (Kokkonen et al., 1998)
- Predispose the occurrence of injury rather than decrease it (Martin, 2003; Rowland, 2003)

One exception to static warm up stretches is in a corrective context (i.e. relaxing shortened pectoral muscles when training the back).

Dynamic stretching is better prescribed for the warmup and should be performed after a pulse raising activity. In the post training, cool down section, static stretching is advised and could be in the form of static maintenance, developmental or PNF stretching.

Section 4: The Nervous System and its Relation to Exercise

The nervous system regulates and controls body activities.
This section will cover:

- The specific roles of the central and peripheral nervous systems
- Impulses
- Neurons and motor units
- Neuromuscular adaptations
- The benefits of improved neuromuscular coordination and efficiency

The Role of the Nervous System

Sending, receiving and processing nerve impulses throughout the body is the responisbility of the nervous system. It controls and communicates and ultimately dictates movement.
It is a communication network that at its simplest level can be broken down into 3 basic elements: ‘sensation’, ‘analysis’ and ‘response’.

Sensation

Gathering information from the environment

The array of sensors spread throughout the body provide information on the internal and external environment

Analysis

Deciphering the information received

The nervous systems receives vast amounts of information which it must analyse and interpret to be able to decide on the appropriate response

Many of these decisions are automated with no voluntary control

Response

Initiating a desired reaction

The appropriate response must be intitiated

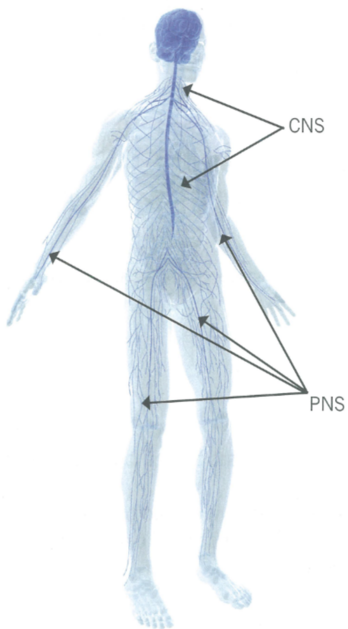
The nervous system is made up of network or neurons and coordinates with other body systems to achieve necessary functions and outcomes. The most important connection of systems to a fitness professional is arguable that of the nervous system and muscular system – it is referred to as the neuromuscular system.

Messages are sent and received from around the body via neurons, allowing the body to adapt to situations in the environment.
The human body has millions of neurons which connect to the spinal cord and the brain, where we are able to process the impulses and make the appropriate and necessary reaction/response.

Components of the Nervous System

There are 2 major divisions of the nervous system (the central nervous system (CNS) and the peripheral nervous system (PNS)).

The brain and spinal cord make up the central nervous system, whilst all other neural elements form the peripheral nervous system.



The Central Nervous System

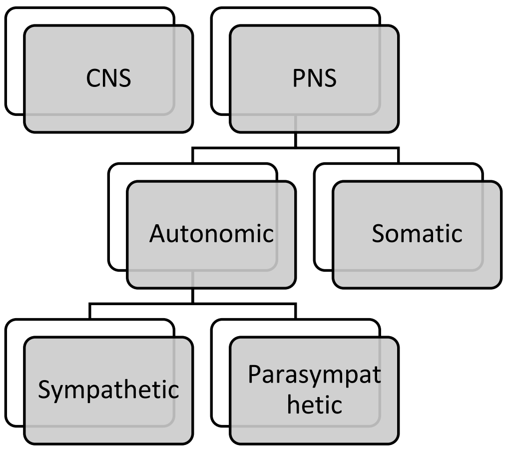
The cerebellum (lower part of the brain) is responsible for controlling the group action of muscles and is the hub of the CNS. The spinal cord communicates between the brain and the PNS (below the head) by integrating incoming information and producing responses via the reflex mechanism.

The Peripheral Nervous System

All of the nerves (bundles of neurons) outside of the spinal cord form the PNS. Peripheral nerves connected to the spinal cord are divided into sensory and motor neurons. Sensory neurons (nerve cells) feed into the spinal cord and, connecting with sensory receptors throughout the body to relay information to the CNS. Motor neurons (nerve cells) exit the spinal cord and send out impulses from the CNS to organs, muscles and glands causing them to contract/secrete. The PNS is further split into the somatic and autonomic systems. The somatic are nerves which serve the outer areas of the body and skeletal muscle. They are responsible for voluntary movement and conscious interaction. The autonomic system supplies neural input to the involuntary body systems such as the heart, and is responsible for the unconscious regulation of homeostasis

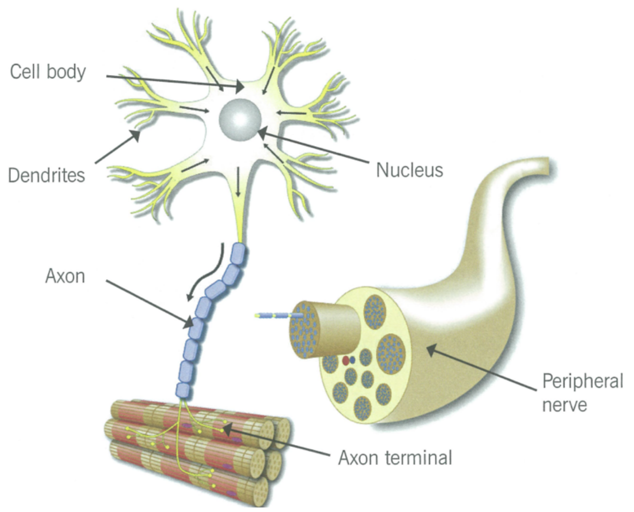
The Autonomic Nervous System

The autonomic system is further split into the sympathetic and parasympathetic systems (fight and flight). In terms of exercise, this system will either speed up (sympathetic) or slow down (parasympathetic) internal processes and levels of activation. In preparation for activity our sympathetic system is working whilst during rest and recovery our parasympathetic nervous system is at work



The Structure and Function of a Neuron

A neuron or nerve works like a cable or wire. It allows signals or impulses to travel from one part of the body to another. The distance may be short or relatively long. Different neurons have the same fundamental anatomical features.



Key Anatomical Features:

- Cell body
- Axon
- Dendrites

Cell Body (Soma)	•Contains all of the necessary components of a cell such as a cell body, endoplasmic reticulum and ribosomes, and mitochondria •Regulates cell activity •If the cell body dies the neuron dies
Axon	•A long cable-like projection that transmits the action potential and carries the electrochemical message along the length of the cell •Axons within the peripheral sensory and motor neurons are covered in a myelin sheath which acts as a thin insulating layer •The myelin sheath helps to speed up the action potential as it travels along the axon •At the end of the axon is the axon terminal which is the interface between the neuron and other cells
Dendrites	•These carry incoming action potentials •Small branch-like projections which make connections to other cells to allow communication with them or the perceived environment •Can be found on one or both ends of a cell •Sense the stimulus

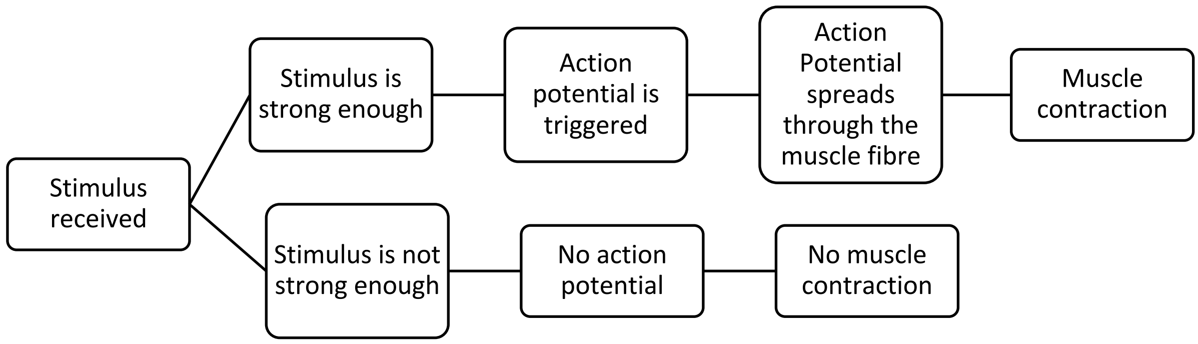
Transmission of a Nervous Impulse

Action Potentials, Axon Terminals and Neurotransmitters

The term action potential refers to a wave of electrical activity that passes along electrically excitable cells. It is created when sodium and potassium move into or out of the cells along the outer membrane. At the end of the axon terminals are swellings/ ‘synaptic end bulbs’ which contain small sacs of the neurotransmitter acetylcholine (ACh). When the action potential reaches the end of the axon terminals the Ach is released into the gap at the end (synaptic cleft/gap). The ACh then diffuses across the cleft to the muscle membrane where is binds with specialised receptors. This then triggers a muscle action potential and stimulates the muscle to contract.

The Motor Unit and Motor Unit Recruitment

The neuromuscular system is where the muscular system and nervous system interact – where our nerves communicate with our muscles. Physical abilities such as strength, power and endurance, balance, reactivity and coordination are all controlled by how well these two systems communicate. The nervous system relates to our muscular system via motor units in the process below.



A motor unit cannot vary the amount of force they generate. They either contract maximally or not at all – the 'all or none' law

The number of muscle fibres in a motor unit varies depending on the purpose of the muscle. A motor unit in the rectus femoris will have a large number of fibres as it is required to generate a big force. This means an action potential can generate more power. A motor unit found in the rectus of the eye will have a small number of fibres as it generates very small forces to control the fine movements. Motor units can be stimulated in isolation or with another depending on the muscle action. Stimulating units at the same time will achieve a short, sharp, strong contraction. An alternating sequence over a longer period of time achieves a less intense, longer contraction. Adjusting the number of motor units recruited, along with the frequency of their discharge can control the force. Recruiting more motor unit and increasing the frequency of discharge creates more tension.

Motor units are recruited in order of size. Coordinating motor unit activity is key to optimising force generation and improving exercise performance		
The smallest motor units contain few type I fibres and generate small forces for fine movements	Intermediate motor units contain large numbers of type I or type IIa fibres and are recruited along side the small motor units when a moderate force is needed	Large motor units contain large numbers of type IIb fibres and are only recruited with small and intermediate units to overcome heavy loads or create explosive movements

Muscle Proprioceptors

Proprioceptors are sensors in the muscle and connective tissue of the limbs. Their role is to provide feedback on joint angle, muscle length and muscle tension which is then integrated to give us information about the position of the limbs. Once we have this information we can respond accordingly, such as recruiting more motor units or using a different force.

Stretch Reflex and Autogenic Inhibition

Different types of proprioceptors provide different sensory information. Muscle spindles detect changes in muscle length, whilst Golgi tendon organs (GTO) detect changes in muscle tension.

Muscle Spindles

Located deep in the muscle fibre, muscle spindles are wrapped tightly around like a coiled spring. They sense changes in muscle length and the rate it occurs to cause muscular contraction. The stretch reflex is a protective mechanism for preventing muscle tears caused by overstretching, therefore when the muscle changes length the coils are pulled apart or pushed together. When the muscle is rapidly lengthened the change in the muscle spindle stimulates neural firing and an action potential is sent to the spinal cord. The signal is then transmitted to the motor neuron which relays an action potential to the muscle. The muscle then contracts rapidly and shortens back up to prevent damage – 'the stretch reflex' Muscle spindles are activated proportionally to the speed of the stretch. During a static stretch the muscle spindles will be firing and contract against the stretch. Holding the stretch should desensitise the spindle to relax the muscle.

Golgi Tendon Organs

Located in the tendon, GTOs are inelastic so cannot detect change in length. When a muscle contracts it pulls on the tendon creating tension which the GTO can measure. When activated it sends a signal to the spine which has an inhibitory effect on the muscle. The relaxation response caused by the GTO firing is called autogenic inhibition or the inverse stretch reflex. This is exploited during PNF stretching where the muscle is contracted against resistance to stimulate the GTO and relax the muscle. The muscle is then susceptible to stretching and can be lengthened further.

Muscle Spindle and GTO interaction in Movement

As movements are carried out the muscle continually changes length and the spindle is constantly activated. This provides the CNS with valuable information about muscle length and where body parts are. The muscle spindles also cause the contraction that helps movements being performed. After muscular contraction the GTO responds and inhibits muscular contraction to allow the opposite movement to be performed. Muscle spindles and GTO work like on/off switches for muscle activity. During explosive plyometric exercises the rapid lengthening of the muscle activates the muscle spindle, this causes a reflex contraction and causes a more explosive contraction. If this sort of training is carried out more frequently the firing thresholds of the muscle spindle are lowered and motor units are more synchronised leading to more powerful and explosive movements.

Reciprocal Inhibition

The reflex inhibition of the antagonist muscle when the agonist contracts. All body movements are coordinated with muscles working together and to control the movement patterns effectively, muscles must be stimulated in various patterns and sequences. The antagonist must be relaxed for the agonist to contract – therefore the motor units in the antagonist must be inhibited. This process is called reciprocal inhibition and is a necessary part of everyday movement. This reflex operates to ensure smooth, coordinated and explosive movements without resistance from the opposing muscle.

Neuromuscular Adaptations to Training

Most types of training effect the nervous system. If the nervous system is developed, the muscular system will follow and overall performance will improve and improvements in speed, acceleration, coordination, strength, endurance, and other aspects of fitness can be seen. Early improvements will be seen in the CNS (especially with resistance training) where smoother and more accurate movement patterns will lead to a greater performance. Regular structured exercise will result in improvements in neural control and coordination of muscular force generation and performance. Improvements include improved reaction times, greater force production, improved timing of movement, enhanced stability and balance, better exercise technique

Section 5: The Endocrine System and its Relation to Health and Exercise

Hormones play a vitally important role in the body. This section will aim to cover how a hormone functions, the major endocrine glands and their location and the key hormones in health and exercise.

The Endocrine System

The endocrine system helps maintain homeostasis along with the nervous system. It uses hormones (chemical messengers) produced by glands and secreted into the bloodstream. Hormones are chemical messengers that help control and manage the body's internal environment. They could be seen as the 'key' to a specific 'lock' on the binding site of a target cell. Different hormones have different chemical shapes which determine the effect it will have so the binding action 'unlocks' the cell and causes the desired response.

How Hormones Work

Endocrine function can be summarised as:

↓

Endocrine gland receives stimulus

↓

Gland releases chemical hormone

↓

Hormone travels in bloodstream

↓

Hormone receieved by target cell receptors

↓

Cell stimulated to cause desired response

↓

Feedback to the originating gland

The process starts when an endocrine gland receives a stimulus that requires a response. A specialised chemical (hormone) is then released into the bloodstream to look for its specific target cell. Each type of hormone is attracted to specific receptors in target cells which can only be triggered by the right hormone (like a lock and key). Once the hormone reaches the target cell it docks at the receptor site and initiates the desired response. When the hormone response has the desired effect a feedback loop between the target tissue and the endocrine gland will reduce or stop the hormone production.

Major Endocrine Glands

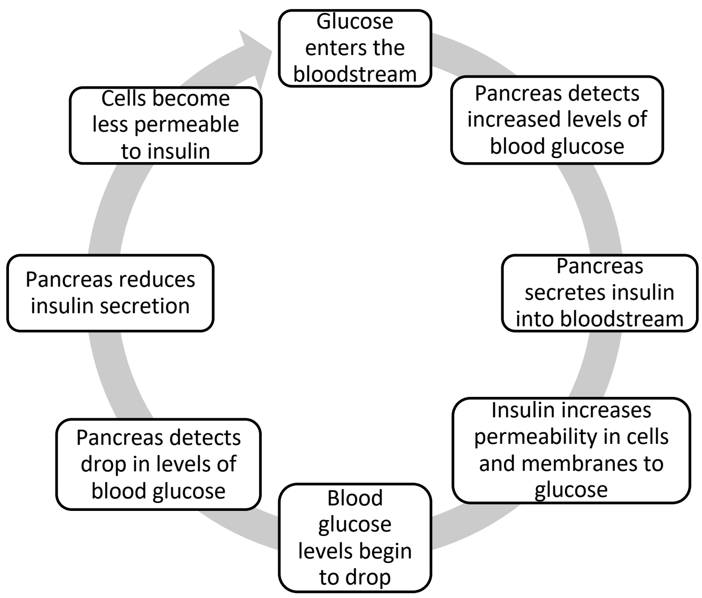
The endocrine system and its functions are governed by specialised glands that are scattered throughout the body. They produce the hormones that maintain the delicate internal balance.

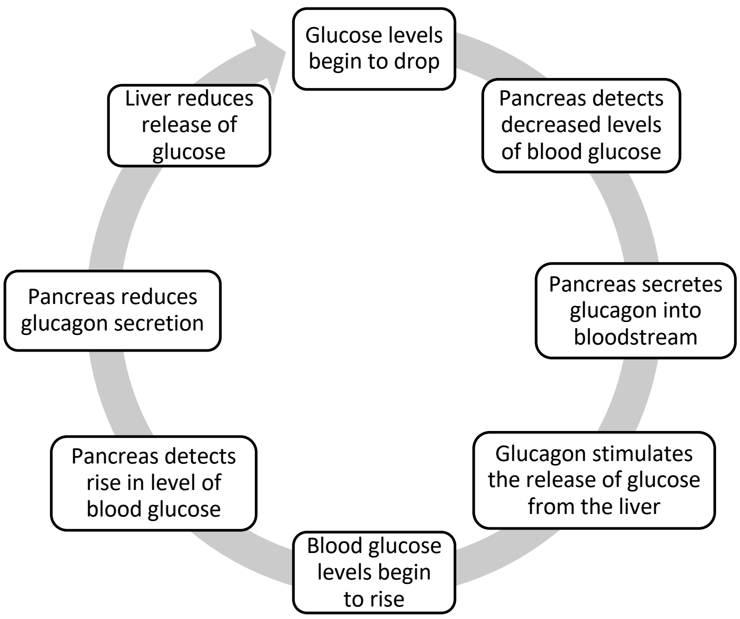
Pituitary gland	•Considered the master gland as most endocrine outputs originate from here
Thyroid gland	•Considered the master regulator of metabolism
Adrenal glands	•Named after their location on top of the renals (kidneys) and help to control/ manage the stress response
Pancreas	•Sits below the stomach and helps to control carbohydrate metabolism
Ovaries	•Located in the female lower abdomen either side of the uterus – responsible for numerous functions of female sexuality
Testes	•Located in the scrotum and are responsible for numerous functions of the male sexuality

The Functions of Hormones

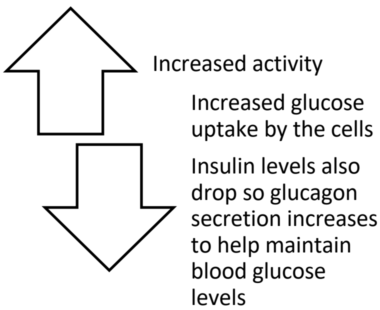
Insulin and Glucagon

The pancreas is responsible for producing 2 counterbalancing hormones – insulin and glucagon, which regulate glucose levels. When a carbohydrate is consumed and digested it is broken down into glucose where it is absorbed by the bloodstream. When blood glucose rises the pancreas knows to secrete insulin, which travels to target tissues and signals for cellular channels to open to allow glucose to be moved from the blood into the cell where it can be used. Blood glucose then returns to normal levels. (See diagram on the right)





After a long period without food or with prolonged activity, glucose levels may drop below optimal. This time the pancreas secretes glucagon which stimulates the liver to break down glycogen which helps to restore blood glucose to a more acceptable level. (See diagram on the left). The effect of exercise can be seen in the diagram below:



Testosterone and Oestrogen

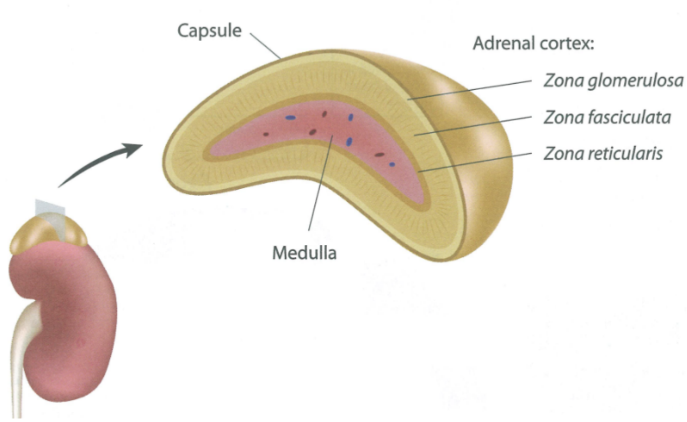
The sexual glands in both males and females release hormones that cause physical changes during puberty and health during adulthood. They control key functions associated with growth, repair and storage in the body. In females the ovaries release oestrogen and in males the testes release testosterone. Testosterone (males and females) helps to stimulate the growth of muscle tissue. Males produce up to 10 x more than females and is responsible for facial and body hair growth and greater muscle mass. Oestrogen helps to influence the storage of fat around the hips, buttocks and thighs. Women of a reproductive age have higher levels than men which are responsible for breast development and regulating the menstrual cycle.

Catecholamines and Corticosteroids

On top of the kidneys are small glands called adrenals which are divided into an inner and outer layer

- Inner layer (adrenal medulla) produces catecholamines
- Outer layer (adrenal cortex) produces corticosteroids

They are well located on top of the kidneys as they have a direct link to the major blood vessels of the body – meaning the hormones can be circulated and have an effect very quickly.



The most well-known catecholamine is adrenaline. Adrenaline and nor-adrenaline are released from the adrenal medulla when a 'fight or flight' response is needed. They are the hormones of action and cause an increased heart rate, blood flow and breathing and alertness levels in order to rapidly prepare the body for action.

Cortisol is the main corticosteroid released from the adrenal cortex which helps to provide reserves for dealing with stress. Cortisol, often referred to as the 'stress hormone', is catabolic and breaks down carbohydrates and fats to provide energy for the body during stressful periods. In long-term chronic stress, the excess cortisol can lead to a deterioration in health due to an imbalance in the endocrine system. Aldosterone is another corticosteroid released from the adrenal cortex which helps to regulate and balance, sodium and potassium in the bloodstream – maintain the water balance in the blood.

Growth Hormone and Thyroid Hormones

Growth hormone (GH) is directly released by the pituitary gland and is an anabolic hormone that promotes growth – particularly bone growth during puberty and protein synthesis in muscle tissue. It helps to break down and release fat tissue from storage sites around the body for oxidation.
Thyroid hormones are released from the thyroid gland in the upper chest – although secretions from the pituitary gland stimulate the release from the thyroid gland. Thyroid hormones are responsible for human metabolism and help regulate the use of oxygen in cellular energy production, the maintenance of body temperature and overall metabolic rate.

Both hormones influence how the body works to maintain good health so it is vital they are kept at the correct levels. Low thyroid function can lead to low metabolism, fatigue, depression, sensitivity to cold and weight gain.

Section 6: Energy Systems and their Relation to Exercise

Energy is needed for the body to function, grow and repair damaged tissue.
This section will cover:

- The chemical compounds that energy is derived from
- The way those chemical compounds are converted into energy
- A focus on the different energy system requirements of exercise

Adenosine Triphosphate: Energy Currency

Our bodies need energy for movement, to produce force against objects, generate heat and to grow and repair. This energy comes from adenosine triphosphate (ATP), of which carbohydrates, fats and proteins play a key role in the complex process of production. Fat and Carbohydrates are the preferred fuel sources, but protein can be used certain circumstances if carbohydrate stores are depleted.

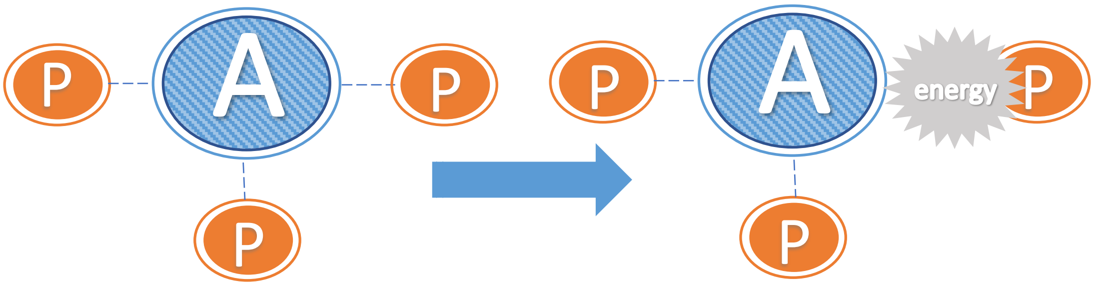
Structure of ATP

ATP provides the energy to drive the sliding filament theory. An energy rich compound it is composed of 1 adenosine molecule and 3 phosphates.
Energy is stored in the high energy bonds that join the 3 phosphate molecules to the larger adenosine molecule. When 1 of the high energy bonds is broken by the enzyme ATPase energy is released leaving an adenosine molecule bound to 2 phosphates and 1 free phosphate.
This reaction occurs during muscular contraction and is controlled by the enzyme myosin ATPase. The ATP stored in the myosin head is broken to ADP (adenosine diphosphate). Release of the ADP causes the myosin head to 'nod' and slide over the actin where it binds with another ATP molecule and detaches from the active site. This continues to happen while there is ATP available, nervous stimulation present and no interference from fatiguing factors

The Energy Systems

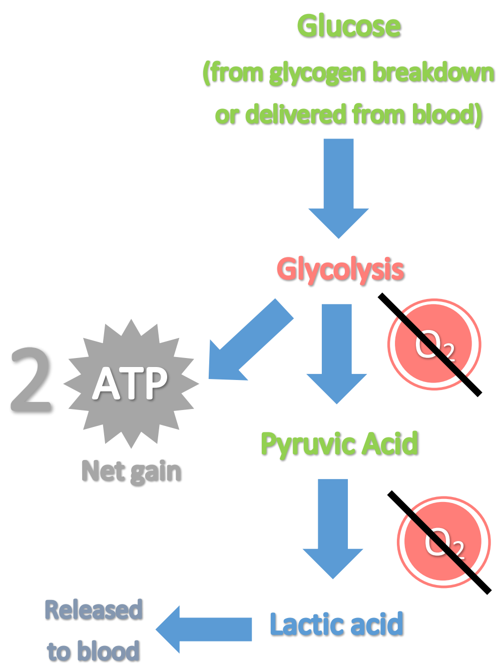
The Creatine Phosphate System – Immediate Energy

High intensity, short duration activities e.g. Explosive jumping, 100m sprint, javelin throw or maximal lift are supplied by intramuscular (within the muscle) stores of ATP and creatine phosphate (CP). ATP stores are limited and may only last for the first few seconds of exercise. Once depleted they can be regenerated almost immediately by the breakdown of CP. It has a high energy bond which, when broken down, releases enough to yield and ATP molecule. CP formed naturally and stored in the muscles (120g in a healthy adult) but stores are also limited so only lasts about 10 seconds, however they can be restored after 5 minutes of rest. Stores are replenished by the liver and kidneys breaking down amino acids or taking on dietary creatine - the process does not use oxygen or have immediate demands for carbohydrates or fat.



The Lactate System

This system is generally associated with the burning feeling during high intensity activities and bridges the gap between the CP and aerobic systems. It allows rapid ATP production at a rate greater than the aerobic system and takes 20 minutes – 2hours to recover.



Higher intensity activity that lasts 60-180 seconds e.g. 400m running and 100m swimming, bursts of speed in team sports, 75-85% HR max are fuelled by the system which provides energy by the incomplete breakdown of carbohydrates. The glucose is broken down into pyruvate which follows 1 of 2 paths.

If there is sufficient oxygen the pyruvate will enter the aerobic system but if there is insufficient oxygen the pyruvate is converted to lactic acid. This process yields 3 ATP per glucose molecule and does not use oxygen (anaerobic). When the lactate system is used blood lactate level increases to a threshold level, anything above this level is known as onset blood lactate accumulation (OBLA) which can cause a decline in performance.

Traditional theories denote lactate at the cause of the 'burning sensations' and 'fatigue' during high-intensity activities. Interestingly, research by Robergs et al. (2004) casts doubt on this and suggests that the cause is caused by a concurrent build-up of hydrogen ions associated with lactate, causing the pH level to drop and inducing acidosis.

Acidosis inactivates various enzymes that are involved during energy production and therefore can interfere with muscles' contractile ability (McArdle et al. 2001). This then poses that question of whether lactate production causes an increase in hydrogen ions or whether it simply occurs in tandem.

When ATP is broken down into ADP hydrogen ions are released, normally they are absorbed in the aerobic energy systems however during high intensity activities the breakdown is occurring at a massive rate so the build-up of hydrogen ions is unavoidable. Pyruvate is used to maintain the pH and buffer hydrogen ions by binding with them, forming lactate. It is proposed therefore that the production of lactate is a result of the body attempting to prevent acidosis rather than the cause of it.

Aerobic (Oxygen) System

This system produces ATP from the complete breakdown of carbohydrates and fats in the presence of oxygen during low to moderate intensity exercise (up to 75% HRmax) e.g. Sleeping, light aerobic activities. It produces carbon dioxide, water and heat as by products, lactic acid does not accumulate due to the presence of oxygen. There is no limit on the amount of ATP that can be produced, however there is a limit on the rate of production. Recovery time is dictated by how long it takes to eat, drink and replenish fuel stores. Fat is said to burn in a carbohydrate flame which means it cannot be broken down without carbohydrate present, relative proportions of fat and carbohydrates burnt will depend on nutritional status and exercise intensity. At low intensities fat provides the fuel, but as energy demand increases as ATP is needed quicker Carbohydrates contribute.

Energy Systems and Training Adaptations

Aerobic Training Adaptations

The main limit on exercise is the ability to take in, transport and utilise oxygen

Pulmonary Changes

- Improvements in the efficiency of the respiratory muscles
- Increased maximal breathing rate and tidal volume
- Use less oxygen and produce fewer waste products
- Increase oxygen availability to working muscles

Cardiovascular changes

- Significant hypertrophy and coronary blood flow (greater capacity for work)
- Increased stroke volume, lower resting heart rate and greater cardiac output at maximal heart rates
- Increased blood plasma volume and greater blood flow to working tissues
- Changes in control of blood distribution, increased arterial diameter and capillary density

Muscular Changes

- Improved blood supply gives a greater ability to extract and utilise oxygen from the blood
- Increased size and number of mitochondria meaning greater ATP production
- Significant increase in the volume of aerobic enzymes which increases the muscles ability to metabolise carbohydrates and fat
- Maximised aerobic potential muscle fibres
- A trained individual will have a greater proportion of slow twitch muscle fibres

Training and the Lactate System

Changes in this system are related to changes in the cardiorespiratory system. Muscles that receive and utilise more oxygen produce less lactic acid at given intensities. Regular anaerobic training improves the tolerance to lactic acid build up – targeted interval training at higher intensities tend to improve the body’s ability to tolerate the build-up of lactic acid (lactate tolerance) and/or the ability to remove it more quickly, leading to a delay or prevention of the accumulation.

Training and the CP System

Activities emphasizing the CP system (heavy weightlifting and sprinting) increase muscle mass and fast twitch muscle fibres. It can also increase the muscular stores of anaerobic fuel sources (ATP, creatine phosphate and glycogen) and improve the activation of the muscle by the nervous system

Interaction of the Energy Systems

All 3 systems provide the body with energy simultaneously, but the proportion of their contribution changes depending on the demands of the exercise. As the demands of the exercise change so does the relative contributions of the energy systems.

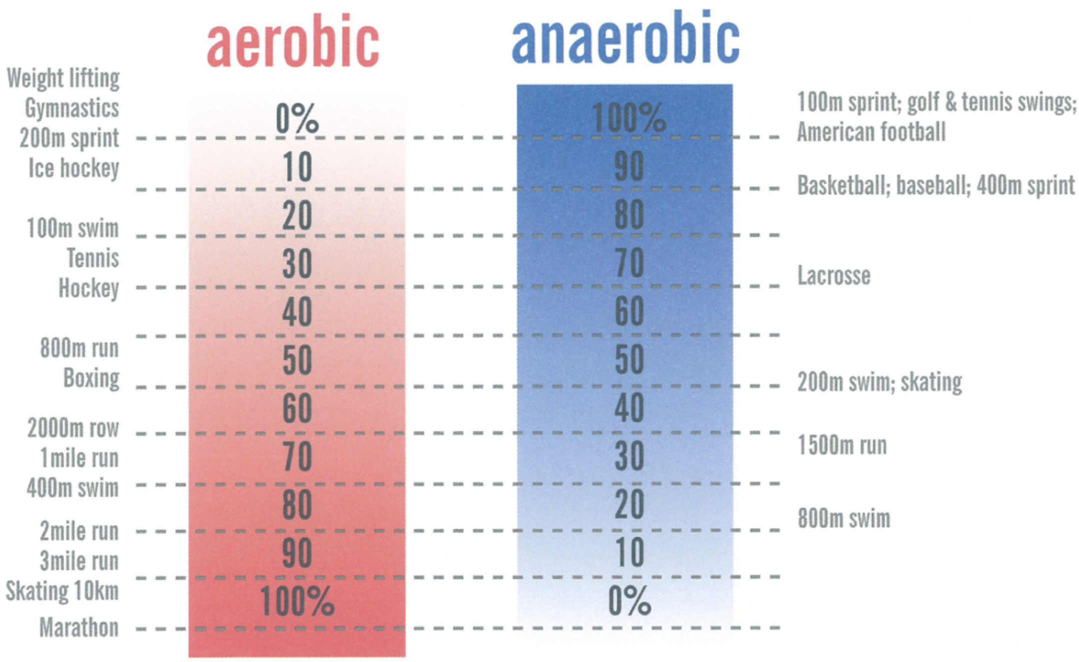
Muscle cell burns off the ATP they already have in 3 seconds

ATP-PCr system kicks in for 8-10 seconds

If exercise continues longer, lactic acid energy system kicks in for 60-90 seconds

If exercise continues the aerobic energy system take over

CP system	Lactate system	Aerobic system
Anaerobic	Anaerobic	Aerobic
Very rapid	Rapid	Slow
Chemical energy	Glycogen	Glycogen and fat
Very limited ATP	Limited ATP	Unlimited ATP
No fatiguing waste products (creatine is recycled)	Lactic acid Fatiguing by-product (lactic acid)	No fatiguing waste products (carbon dioxide and water)
Short duration (0-10 seconds)	1-3 minutes of intense activity	Long duration
Very high intensity (95-100% max effort)	High intensity (75-85% max effort)	Low to moderate intensity (up to 75% max effort)
Quick recovery (30 seconds-5 minutes)	20 minutes-2 hours (breakdown of lactic acid)	Time to eat and drink (to replenish fuel stores)
Type 2b	Type 2a and 2b	Type 1 and 2a



Section 7: The Structure and Function of the Skeleton

The skeletal system provides us with a framework and structure with which to move, protect and support the internal systems.

Structure of the Skeleton

The skeletal system is classified into two main structures:

Bone	Hard dense calcified tissue that forms the skeleton. There are 206 bones in an adult body connected by a series of joints.
Cartilage	A resilient, dense, fibrous rubber like connective tissue. There are three types in the body each with different roles. Hyaline, Elastic, Fibrocartilage.

Types of Cartilage

The three types of cartilage found in the human body are:

Hyaline Cartilage	Found at the end of long bones that meet to form synovial joints.
Elastic Cartilage	Has the ability to change and regain shape in response to tension, pressure and compression. It is present in the outer ear, Eustachian tube and epiglottis.
Fibrocartilage	The thickest and strongest of the different types of cartilage and acts as a shock absorber at cartilaginous joints.

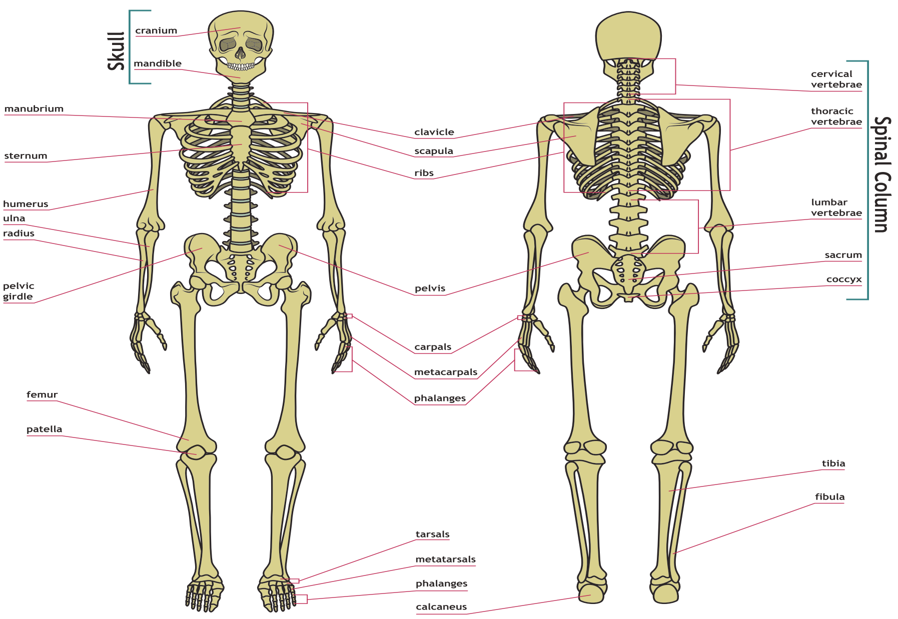
The Skeleton is made up of two main sections:

Axial Skeleton:

- Bones that form the main frame or axis.
- Spine, Ribs, Skull.

Appendicular Skeleton:

- Bone that attaches to the main frame.
- Upper and lower limbs. Shoulder and pelvic girdles.



Classification of Bones

Bones are classified according to their shape.

Classification	Description	Examples
Long Bones	• Greater in length than in width. • Consist of main shaft (Diaphysis) and two epiphysis (ends). • Act as levers during movement. • Contain mainly compact bone.	Humerus, femur, fibula, tibia, ulna, radius, metacarpals, metatarsals and phalanges.
Short Bones	• Shaped roughly like a cube. • Mostly cancellous bone. • Located in the hands and feet.	Carpals and tarsals.
Flat Bones	• Layer of cancellous bone between two layers of compact bone. • Provide protection and large areas for muscle attachment.	Scapula, Cranial, Costals, Sternum, Ilium.
Irregular Bones	• Vary in shape and structure.	Vertebrae and Calcaneus (heel bone).
Sesamoid	• Embedded in tendons where friction and tension occur. • Offer leverage and protection.	Patella, hands, feet.

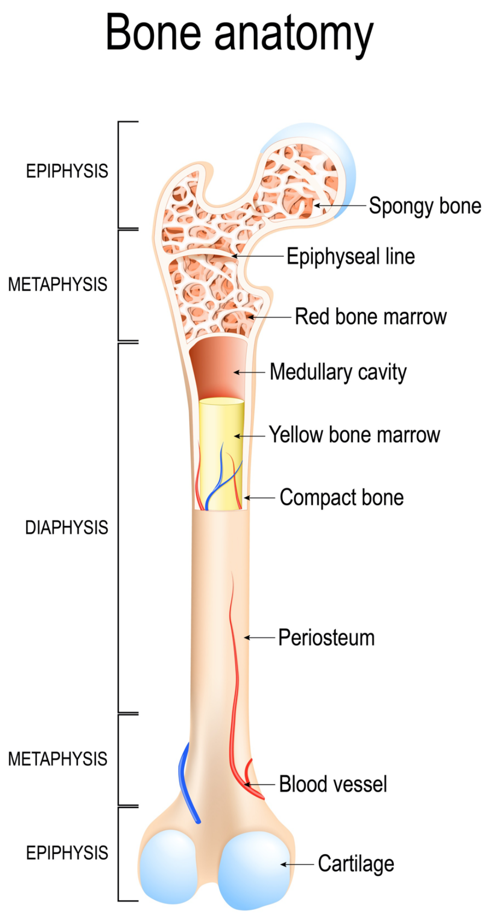
Functions of Skeletal System

Shape	The Skeletal System gives the body its shape.
Protection	The skeletal System protects vital internal organs.
Attachment	Muscles, Ligaments and Tendons have attachments to create stability and movement.
Movement	Muscles pull on bones to create movement.
Production	Some bones produce white and red blood cells.
Storage	Bones store minerals such as calcium and phosphorus supporting growth.

Ossification

Ossification is the process in which bones of the skeleton are formed. There are three processes involved in ossification which are:

Osteoblasts	Are the bone builders and form new bone.
Osteoclasts	Are the cells that remove old bone by making and secreting digestive enzymes that break up and dissolve old bone tissue.
Osteocytes	Are formed from old osteoblasts that have remained present and are involved in bone remodelling.



Epiphysis: The rounded end of the long bone containing spongy bone.

Diaphysis: The tubular shaft that runs between the proximal and distal ends of the bone.

Epiphyseal Line / Plate: Growth plates that allow for increase in length until adult hood.

Hyaline Cartilage: Covers both ends of the bone attached to other bones through a joint.

Periosteum: A tough fibrous sheath that covers the whole of the bone.

Compact bone: Solid bone that assists bones in withstanding pressure placed upon it through weight bearing exercises.

Spongy bone: Spongey bone tissue containing red bone marrow.

Medullary Cavity: Hollow tube that runs down the centre of the bone.

Yellow bone marrow: Storage of fat.

Red bone marrow: Production of blood cells.

Effects of Exercise on the Skeletal System

- Increased bone density.
- Increased levels of synovial fluid.
- Increased strength of ligaments.
- Increased range of motion.
- Decreased risk of bone disease.

Factors Effecting Bone Growth

Bone health and development is influenced by a number of external factors and dictated by a person's lifestyle.

Nutrition is an important factor of bone health and growth. A diet of calcium rich foods vegetables and adequate protein intake are all important to the bone growth and avoiding issues in later life.

Physical activity provides immediate and long term effects. Improvements are made to bone density, strength and stability including the structures surrounding them. Reduces risk of disease later in life. Sunlight is important to bone health and produces vitamin D which plays a role in absorption of calcium.

Ligaments and Tendons

Ligaments are a tough white band of connective tissue that are able to withstand a large amounts of tension and attach bone to bone. Ligaments prevent excessive movement and maintain alignment to ensure smooth movement patterns.

Tendons are one of the strongest tissues in the body that attach muscle to bone transmitting a mechanical force produced by the muscle they are attached to muscle fibres at one end and part of the bone at the other end.

Joints

The point at which two or more bones meet is called a joint or articulation. There are three types of joint classifications that have different roles in the body Fibrous, Cartilaginous, Synovial.

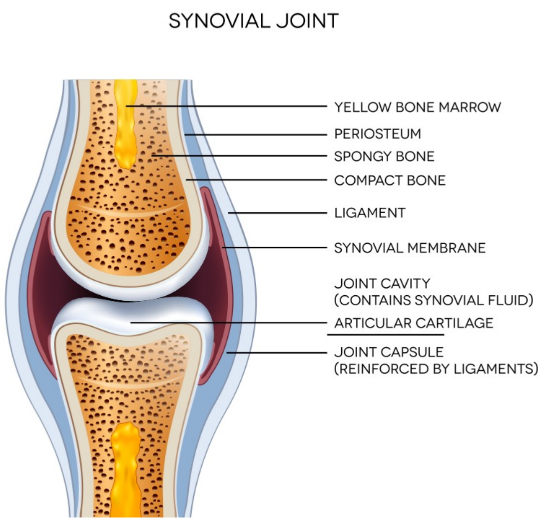
Joint Name	Range of Movement	Examples
Synovial	Freely Moveable	Shoulders, Hips, Knees
Cartilaginous	Slightly Moveable	Vertebrae
Fibrous	Fixed and Immovable	The Skull

Injuries

Injuries to bone, muscle, ligaments, tendons, cartilage all heal at different rates due to their different characteristics.

Blood supply is one of the major factors in healing injuries. Bone and muscles heal relatively quickly due to a good blood supply. Ligaments, tendons and cartilage have poor blood supply which limits their chances of recovery and often require surgery procedures to fix them.

Synovial Joints



Synovial joints are the most common joint. They are freely moveable, provide a wide range of large movements dependant on the type of synovial joint listed below. The synovial joint is the site in which articulating surfaces of bones have contact with each other. The joint is surrounded by an articular capsule filled with synovial fluid allowing for smooth movements between the adjacent bones. The articulating surfaces of the bones are covered by a thin layer of articular cartilage. Ligaments support the joint by holding the bones together and resisting excess or abnormal joint motions.

Type of Joint	Range of motion	Example
Ball and Socket	Flexion, extension, abduction and adduction, circumduction, and medial and lateral rotation.	Hip or Shoulder
Hinge	Flexion, extension.	Knee or Elbow
Pivot	Rotation around an axis.	Neck
Saddle	Flexion, extension, adduction, abduction.	Thumb
Gliding	Two bones glide past each other.	Shoulder Girdle
Ellipsoid	flexion, extension, adduction, abduction, and circumduction.	Knuckles

Joint Movements

A series of terminology used to describe movements listed below:

Terminology	
Flexion	Angle of a joint decreases
Extension	Angle of a joint increases
Rotation	A bone rotating around its axis
Abduction	Movement away from the midline of the body
Adduction	Movement towards the midline of the body
Horizontal Flexion	Arm outstretched moves towards midline of the body
Horizontal Extension	Arm outstretched moves away from midline of the body
Lateral Flexion	Bending to the side from a standing position
Circumduction	Circular motion
Elevation	Lifting the shoulder girdle towards the ears
Depression	Lowering the shoulder girdle away from the ears
Protraction	Rounding of the shoulders through forward movement of the shoulder girdle
Retraction	Squeezing the shoulder blades together pushing the chest outwards
Pronation	Palm of the hand facing downwards
Supination	Palm of the hand facing upwards
Dorsiflexion	Lifting toes towards shin
Plantarflexion	Planting the toes on the floor with heel elevated
Inversion	Turning the foot inwards
Eversion	Turning the foot outwards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