ORIGYM

Level 2 Certificate In Fitness Instructing Online

MODULE 3:
MUSCLE ANATOMY AND ENERGY SYSTEMS

CONTENTS

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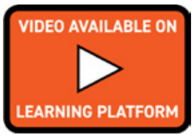
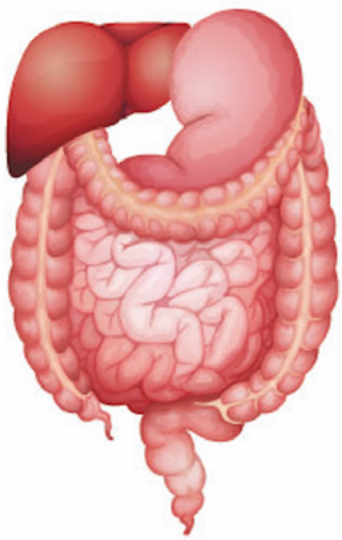


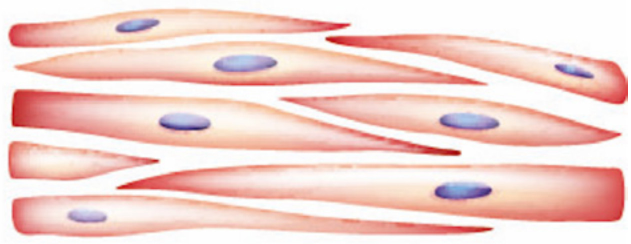
The Muscular System

MODULE 3:
MUSCLE ANATOMY AND ENERGY SYSTEMS

Types Of Muscle Tissue

Muscles have the ability to contract, producing movement in the body or maintaining the position of parts of the body. There are three types of muscle tissue:

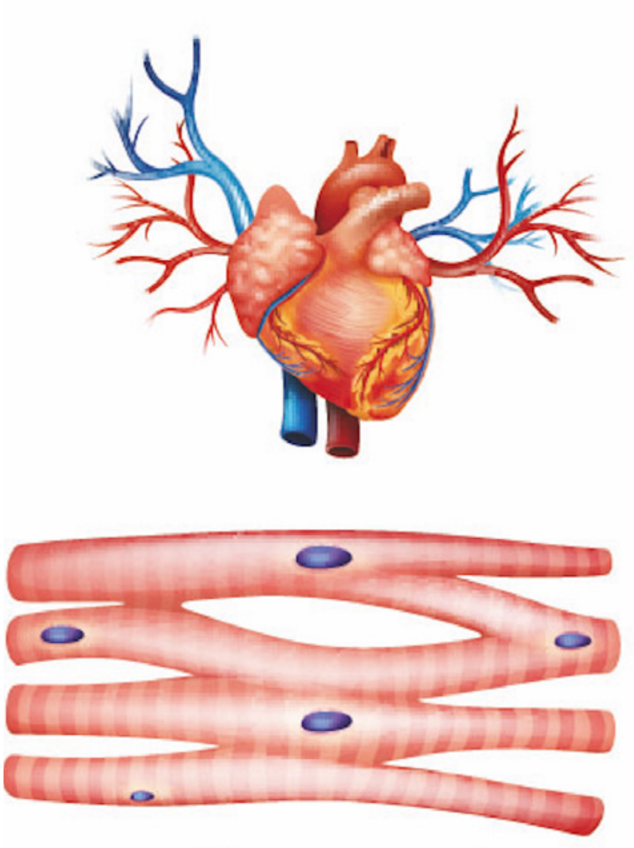




SMOOTH MUSCLE

- The most diverse type of muscle in the body.
- Found in internal organs e.g. digestive and circulatory systems.
- Involuntary as it is controlled by the autonomous nervous system.

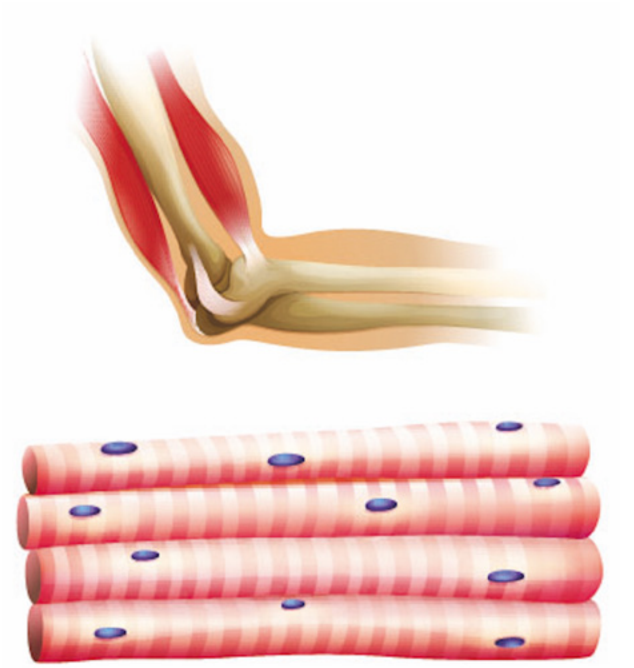
Gastrointestinal Tract
Respiratory Tract
Blood Vessels
Urinary Organs
Reproductive Organs



CARDIAC MUSCLE

- Also known as Myocardium.
- Found in the heart.
- Involuntary as it is controlled by the sinoatrial nod.

Myocardium
Coronary Circulation
Conduction System

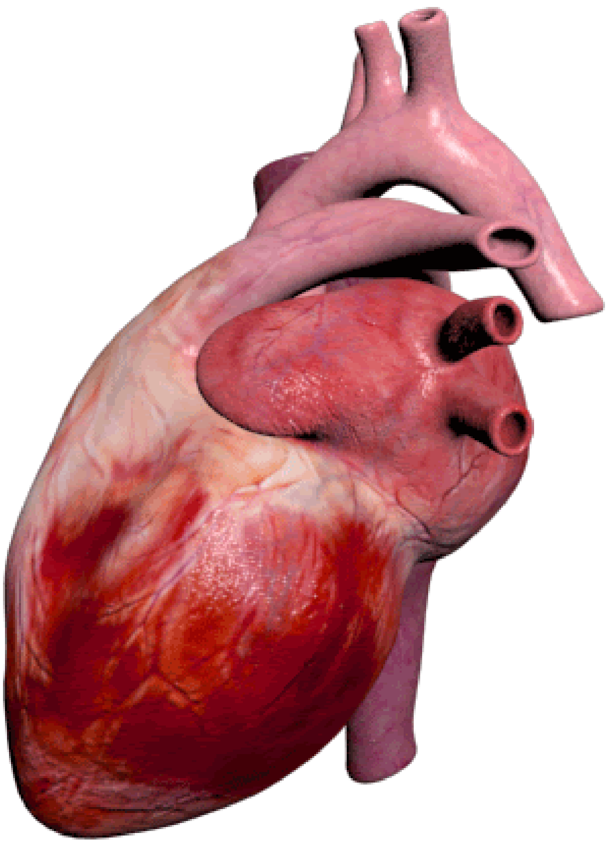


SKELETAL MUSCLE

- Represents the majority of muscle in the body.
- Attaches to bone across joints via tendons.
- Produces movements within the body.
- Determines posture by stabilising body position.
- Transports and stores substances within the body.
- Generates heat,
- Voluntary as it is controlled by the somatic nervous system.

Head/Neck
Shoulder Girdle
Thorax/Abdomen
Pelvis/Hip
Upper Limbs
Lower Limbs

Functions of the Muscular System

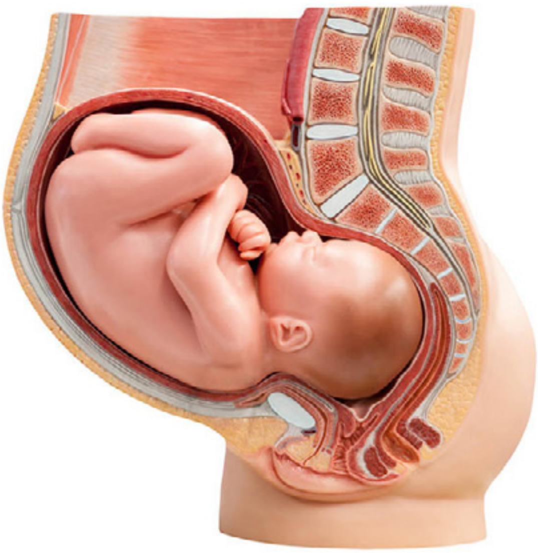


Mobility

Your skeletal muscles are responsible for the movements you make. Skeletal muscles are attached to your bones and partly controlled by the Central Nervous System. You use your skeletal muscles whenever you move. Fast-twitch skeletal muscles cause short bursts of speed and strength. Slow-twitch muscles function better for longer movements.

Circulation

The involuntary cardiac and smooth muscles help your heartbeat and blood flow through your body by producing electrical impulses. The cardiac muscle (myocardium) is found in the walls of the heart. It's controlled by the autonomic nervous system responsible for most bodily functions. The myocardium also has one central nucleus like a smooth muscle. Your blood vessels are made up of smooth muscles and also controlled by the autonomic nervous system.



Respiration

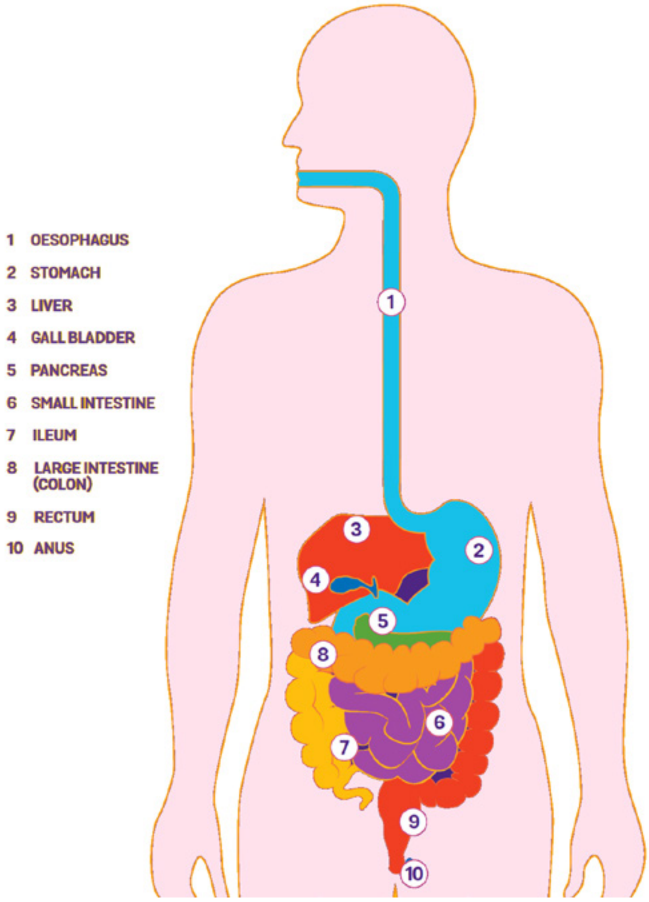
Your diaphragm is the main muscle at work during breathing. Heavier breathing, like what you experience during exercise, may require accessory muscles to help the diaphragm. These can include the abdominal, neck, and back muscles.

Childbirth

Smooth muscles are found in the uterus. During pregnancy, these muscles grow and stretch as the baby grows. When a woman goes into labour, the smooth muscles of the uterus contract and relax to help push the baby through the vagina.

Urination

Smooth and skeletal muscles make up the urinary system. The urinary system includes the: **Kidneys, Bladder, Ureters, Urethra, Penis or Vagina and Prostate**. All the muscles in your urinary system work together so you can urinate. The dome of your bladder is made of smooth muscles. You can release urine when those muscles tighten. When they relax, you can hold in your urine.



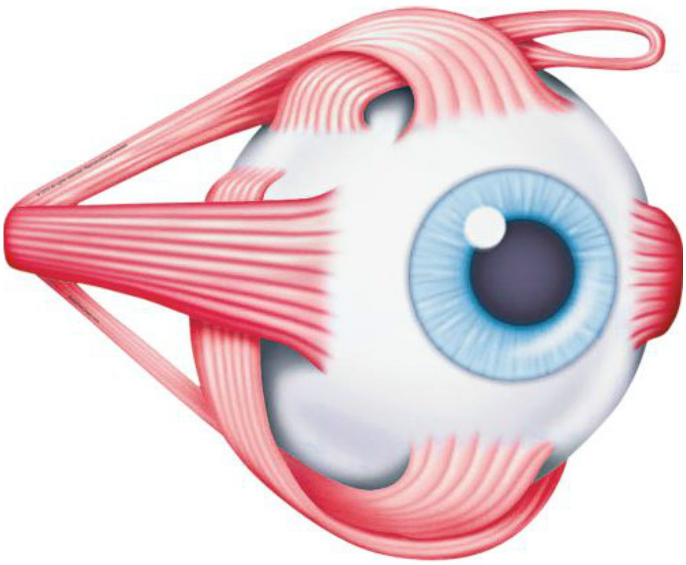
Digestion

Digestion is controlled by smooth muscles found in your gastrointestinal tract. This comprises the: **Mouth, Oesophagus, Stomach, Small and large intestines, Rectum and Anus**. The digestive system also includes the liver, pancreas and gallbladder. The smooth muscles contract and relax as food passes through your body during digestion. These muscles also help push food out of your body through defecation, or vomiting when you're sick.

Stability

The skeletal muscles in your core help protect your spine and help with stability. Your core muscle group includes the abdominal, back, and pelvic muscles. This group is also known as the trunk. The stronger the core, the better you can stabilise your body. The muscles in your legs also help steady you.

Posture



Your skeletal muscles also control posture. Flexibility and strength are keys to maintaining proper posture. Stiff neck muscles, weak back muscles, or tight hip muscles can throw off your alignment. Poor posture can affect parts of your body and lead to joint pain and weaker muscles. These parts include the: **Shoulders, Spine, Hips and Knees.**

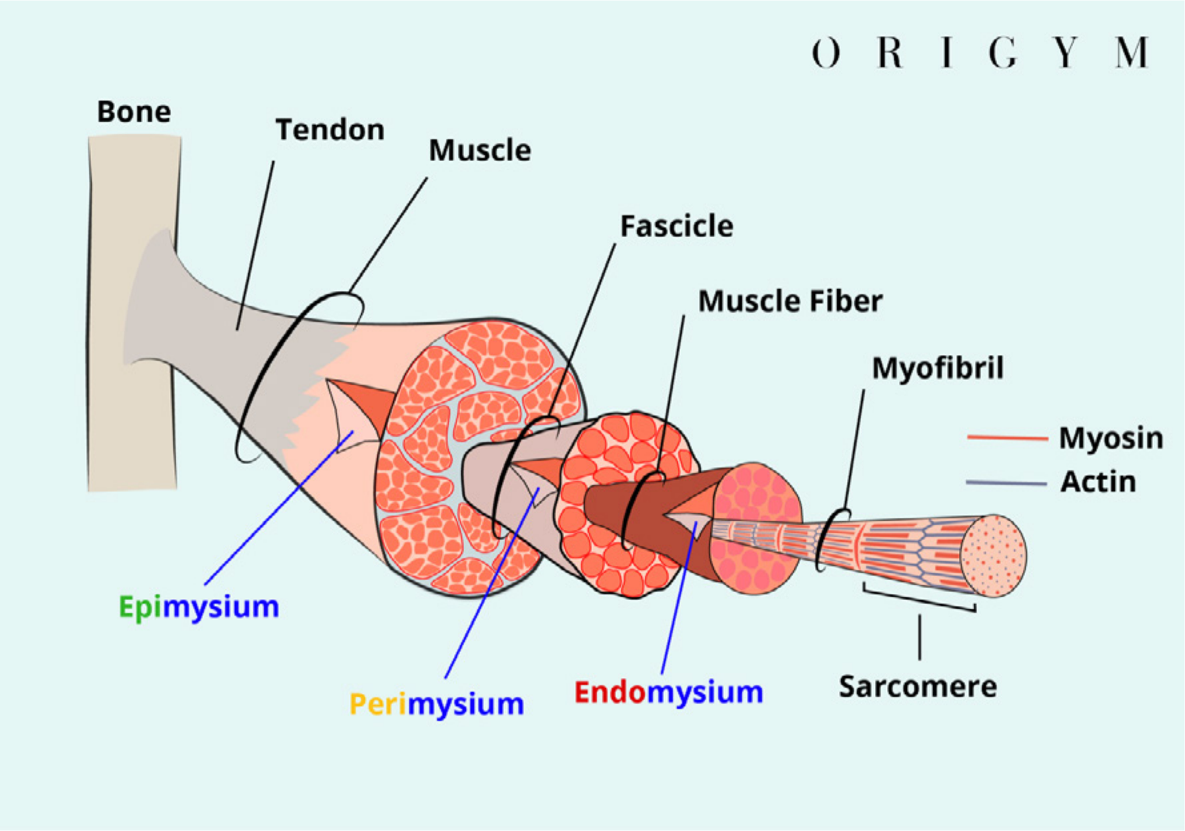
Vision

Your eye sockets are made up of six skeletal muscles that help you move your eyes. And the internal muscles of your eyes are made up of smooth muscles. All these muscles work together to help you see. If you damage these muscles, you may impair your vision.

Properties of Skeletal Muscle

THERE ARE FOUR MAIN PROPERTIES OF MUSCLE TISSUE:

- **Elasticity:** Returns to the original length after a stretch.
- **Contractility:** Develops tension in order to perform a contraction.
- **Electrical excitability:** Can respond to a stimulus.
- **Extensibility:** Ability to be stretched or to increase in length.



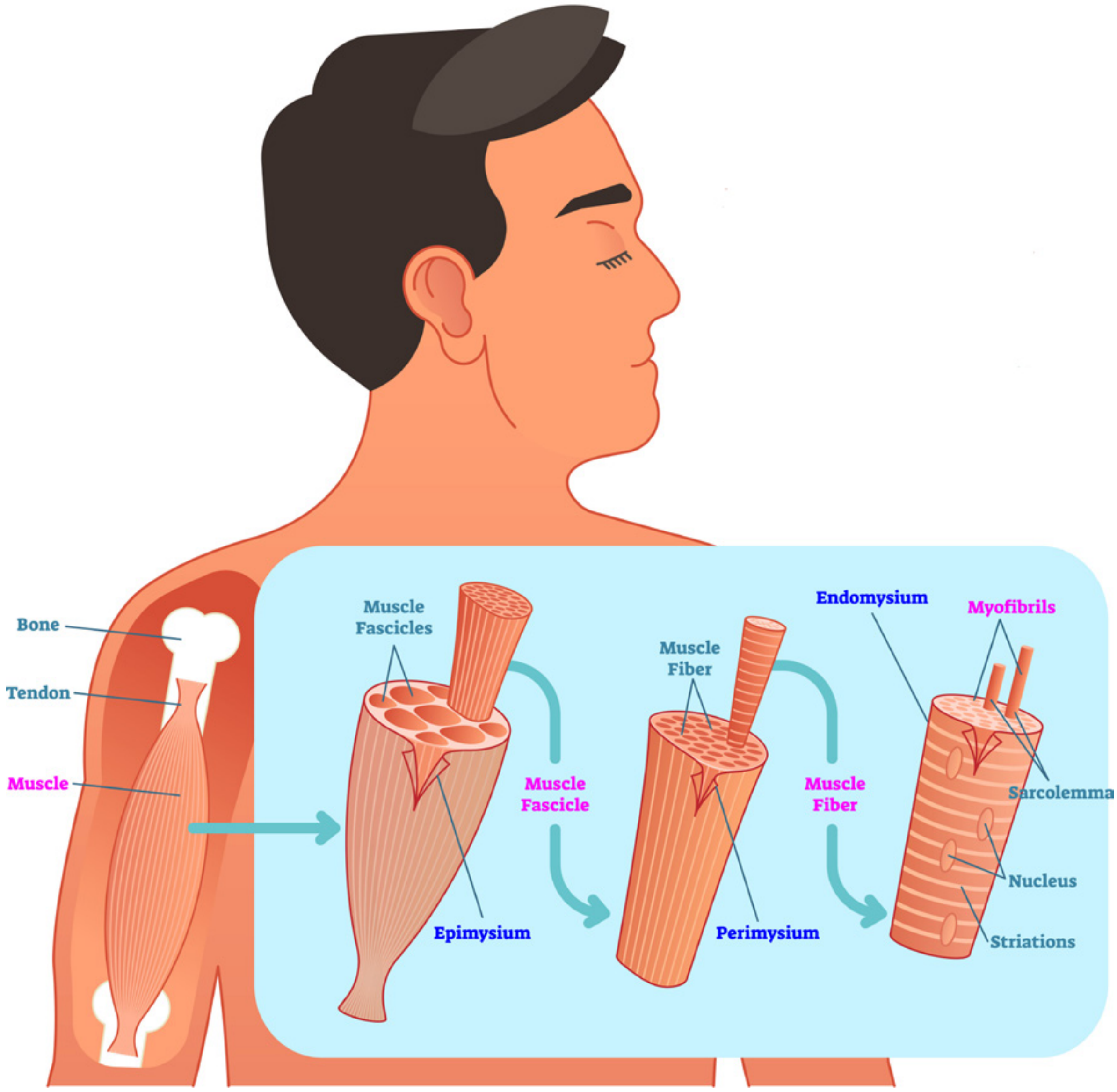
Skeletal Muscle Anatomy

here are no exact figures to determine the number of muscles in the human body, although they make up approximately 40% of body weight. They comprise of 70% water, 23% protein and 7% minerals.

Myofilaments are the rigid protein filaments (actin and myosin) within myofibrils and are responsible for the creation of tension during contraction. Many myofibrils are grouped together to form a muscle fibre which is surrounded by endomysium. The number of muscle fibres varies according to the location and function of each muscle. The greater the demands of the muscle, the more fibres will be required. Each group of fibres is held together by perimysium to form a fascicle which means ‘cluster’ or ‘bundle’.

Finally, the many fasciculi are covered by a fascia of epimysium to form the muscle. Connective tissue is continuous throughout the length of a muscle and these layers come together to form tendons. The tendons attach to the periosteum sheath which surrounds the bone.

Connective Tissue



(Area) = (INSIDE THE AREA) = (Around the area)

1. Muscle = GROUP OF FASICLES = Epimysium
2. Muscle Fascicle = GROUP OF MUSCLE FIBRES = Perimysium
3. Muscle Fibre = GROUP OF MYOFIBRILS = Endomysium
4. Myofibril = GROUPS OF ACTIN AND MYOSIN in a chain = Sarcolemma

NB: Sarcolemma is not connective tissue however it is continuous around myofibrils

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Muscle Contraction Overview

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The Sliding Filament Theory

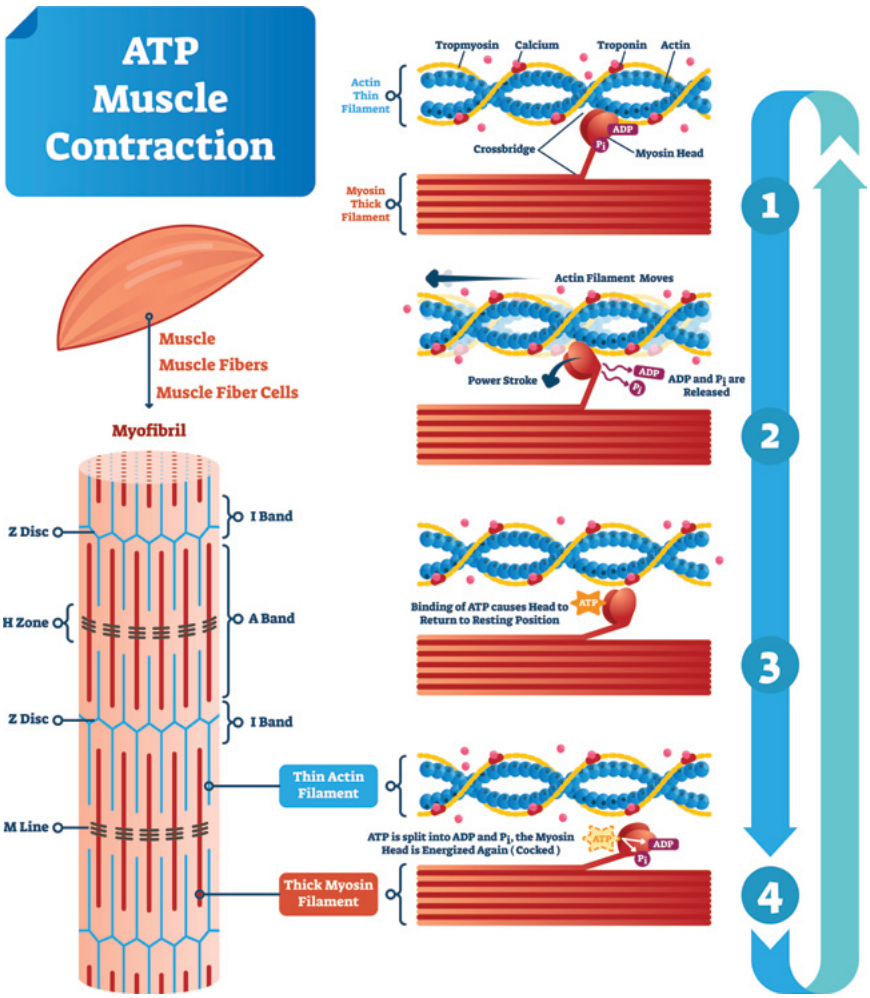
The ability of skeletal muscle to contract is dependent on the movement of **protein myofilaments**:

Actin - Thin protein strand

Myosin - Thick protein strand

These rigid protein strands do not actually contract or decrease in size, but simply slide over each other to reduce the size of the space they occupy which is called a sarcomere, (this underlying principle of muscle movement was popularised as The Sliding Filament Theory in 1954).

There are many myofilaments in each sarcomere. The heads of the myosin, known as cross-bridges attach to a binding site and pull on the actin, causing them to slide inwards causing an overlap in the centre of the sarcomere. This is known as the contraction phase or 'power stroke'. The myosin cross-bridges then detach from the actin in the 'recovery stroke'. At this point, the myosin is free to attach to the next binding site and repeat the process.



Force Generation

You must look at the fine structure of a muscle fibre to understand how a muscle generates force. Beneath the endomysium, there are even smaller rows of fibres: myofibrils. It is within these myofibrils that the structures which are responsible for force production are located; Myosin and Actin.

Myosin And Actin & The Sliding Filament Mechanism

Responsible for force generation are two contractile proteins called myosin and actin, often referred to as thick and thin filaments respectively. These are arranged in a series of partitions called sarcomeres that run the length of the myofibril. Sprouting from the myosin filament is a series of 'hook-like' bulges referred to as myosin heads. During the "stroke phase" and indeed a muscular contraction, these heads attach themselves to the actin filament and rotate.

The result of this is that the thinner actin filaments are drawn inwards drawing the ends of the sarcomeres together. This process is referred to as the sliding filament mechanism.

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In Summary:

The Phases of the Sliding Filament Theory

- Binding - the myosin head attaches to the binding site.
- Power stroke/contraction phase - the myosin head pulls on the actin filament and moves inwards (ADP & Pi Released).
- Recovery - the myosin head detaches from actin and is free to bind with another site.
- Cocking - the myosin head re-energised by ATP splits into ADP and Pi (inorganic phosphate)

Myosin And ATP

The power to drive the myosin head is provided by adenosine triphosphate (ATP). The ATP molecule primes the myosin for activity by binding with the head. When the conditions are right, the myosin head will bind with the actin and rotate.

Actin And Calcium

Although the ATP has primed the myosin the binding to actin would not be successful without the presence of calcium. During muscular relaxation, the myosin-binding sites on the actin are blocked by a combination of other molecules (troponin and tropomyosin). These must be cleared before myosin can be attached.

Surrounding the myofibrils is a network of tubes called the sarcoplasmic reticulum (SR) that act as calcium reservoirs. The release of calcium is through stimulation of the sarcoplasmic reticulum from an action potential. This causes calcium to be flushed into the fluid surrounding the myosin and actin, the sarcoplasm. The calcium causes the molecule that is blocking the myosin binding site to move away, allowing the now 'primed' myosin head to bind with the actin and rotate.

Without the influx of calcium into the muscle fibre, the sliding filament mechanism could not take place. Therefore the question arises as to what triggers the sarcoplasmic reticulum to flood the myofibril with calcium. To understand this process, it is necessary to take a look at the point at which nervous impulses reach the muscle.

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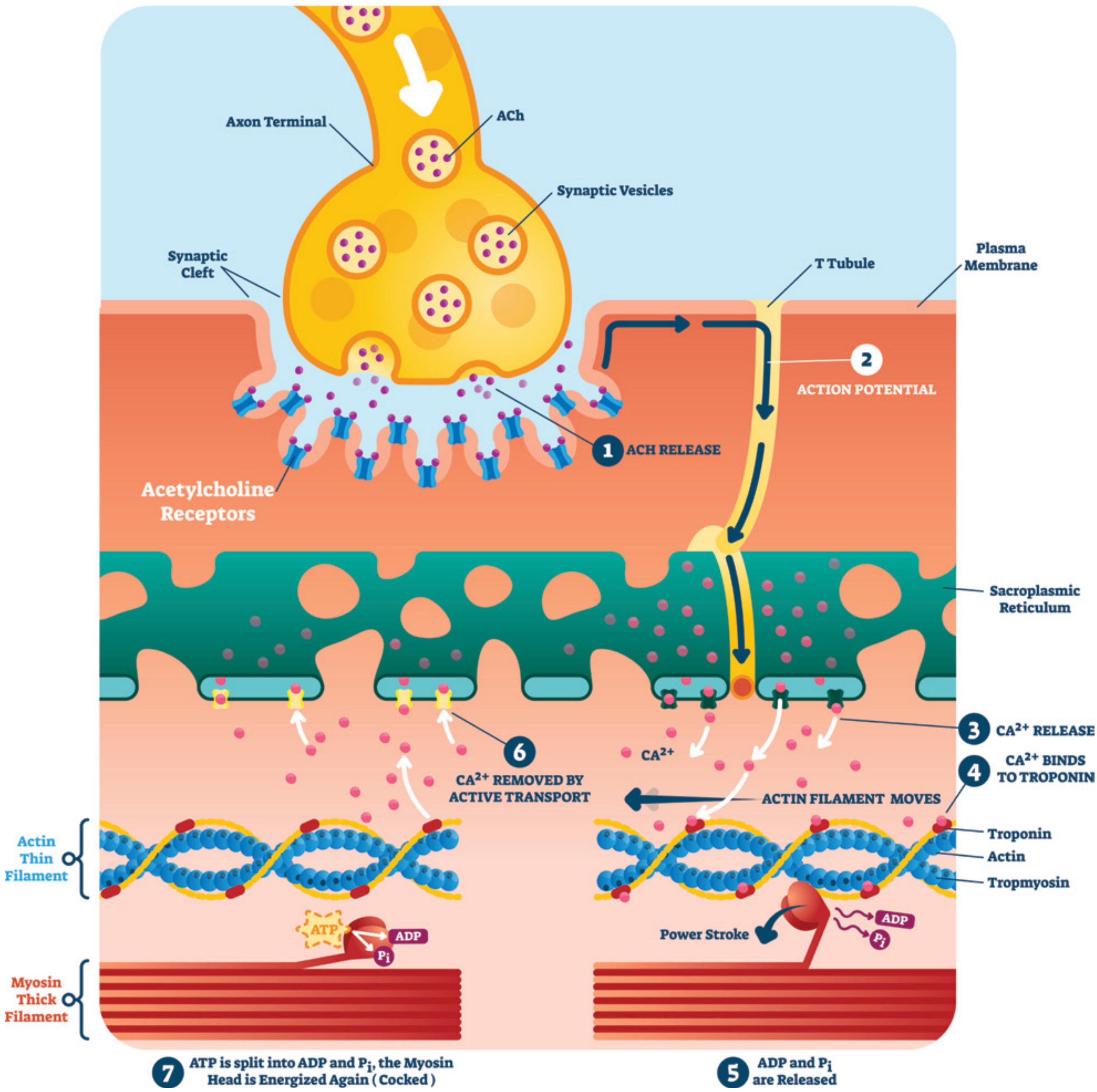
Action Potentials

The stimulus for the release of calcium is the spread of electrical activity (the action potential) along the length of the muscles. During rest, muscle membranes are negatively charged interiorly and a positively charged exteriorly. The difference between the two serves as a form of potential energy, rather like that stored in a battery (Tortora & Grabowski, 1996). This is achieved through a combination of selective permeability of the cell membrane and the presence of sodium pumps. The pumps actively remove positively charged sodium ions from the cell.

The arrival of an action potential at the neuromuscular junction (where the nerve meets the muscle) causes the release of a neurotransmitter; acetylcholine. Acetylcholine causes sodium to rush through the muscle membrane. This results in a reversal of electrical activity (depolarisation), which if large enough, will cascade along the muscle fibre as an action potential, there by triggering a release of calcium and beginning the sliding filament mechanism.



Initiation of a Muscle Action

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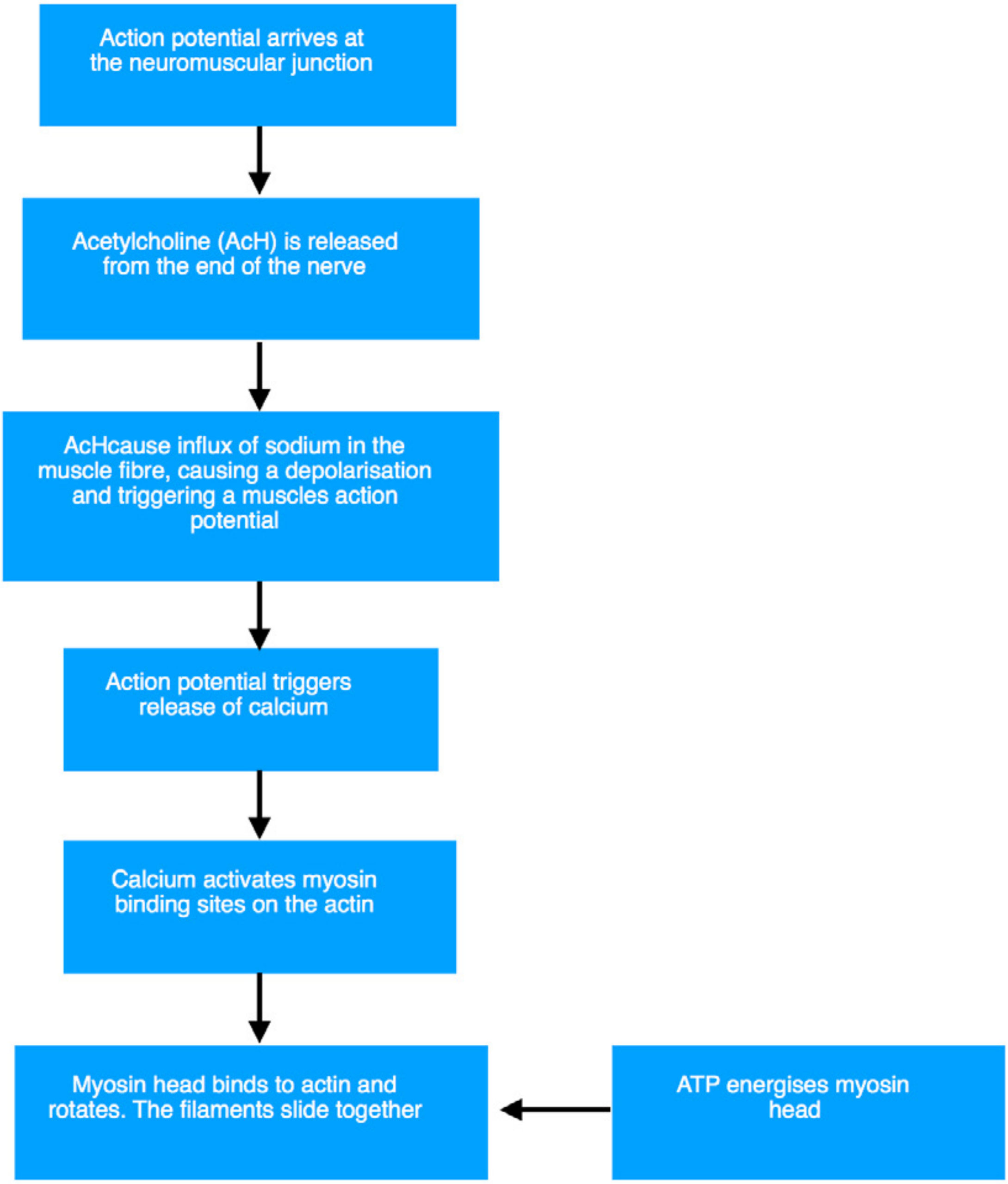
Summary - Initiation of a Muscle Action



Control Of Muscular Activity

The fundamentals of muscular contraction exploration gives a better understanding of how muscles generate force. However, questions still remain regarding the mechanisms of how muscular activity is controlled. The following section takes a closer look at the muscular control systems.

Motor units and the 'all or nothing' law

Muscles are divided up into motor units; a single motor unit consists of one motor neuron (nerve) and the muscle fibres it innervates. As was discussed earlier if the stimulus is strong enough to trigger an action potential then it will spread through the whole length of the muscle fibre. More specifically it will spread through all the muscle fibres supplied by a single nerve. Conversely, there will be no action potential and no muscle contraction if the stimulus is not strong enough.

Motor units cannot, therefore, vary the amount of force they generate, they either contract maximally or not at all – hence the 'all or nothing' law.

CONTROL OF MUSCULAR FORCE IS ACHIEVED THROUGH A COMBINATION OF:

- **Adjusting the number of motor units recruited (i.e. the greater the number the greater the force)**
- **Increasing the frequency of their discharge.**

It is worth noting that co-ordinating motor unit activity is fundamental to optimising force generation and therefore, improving exercise performance (McArdle et al., 2001).

Muscle Proprioceptors

The muscles have two small neural sensors that help to provide feedback and respond to changes within the muscle itself:

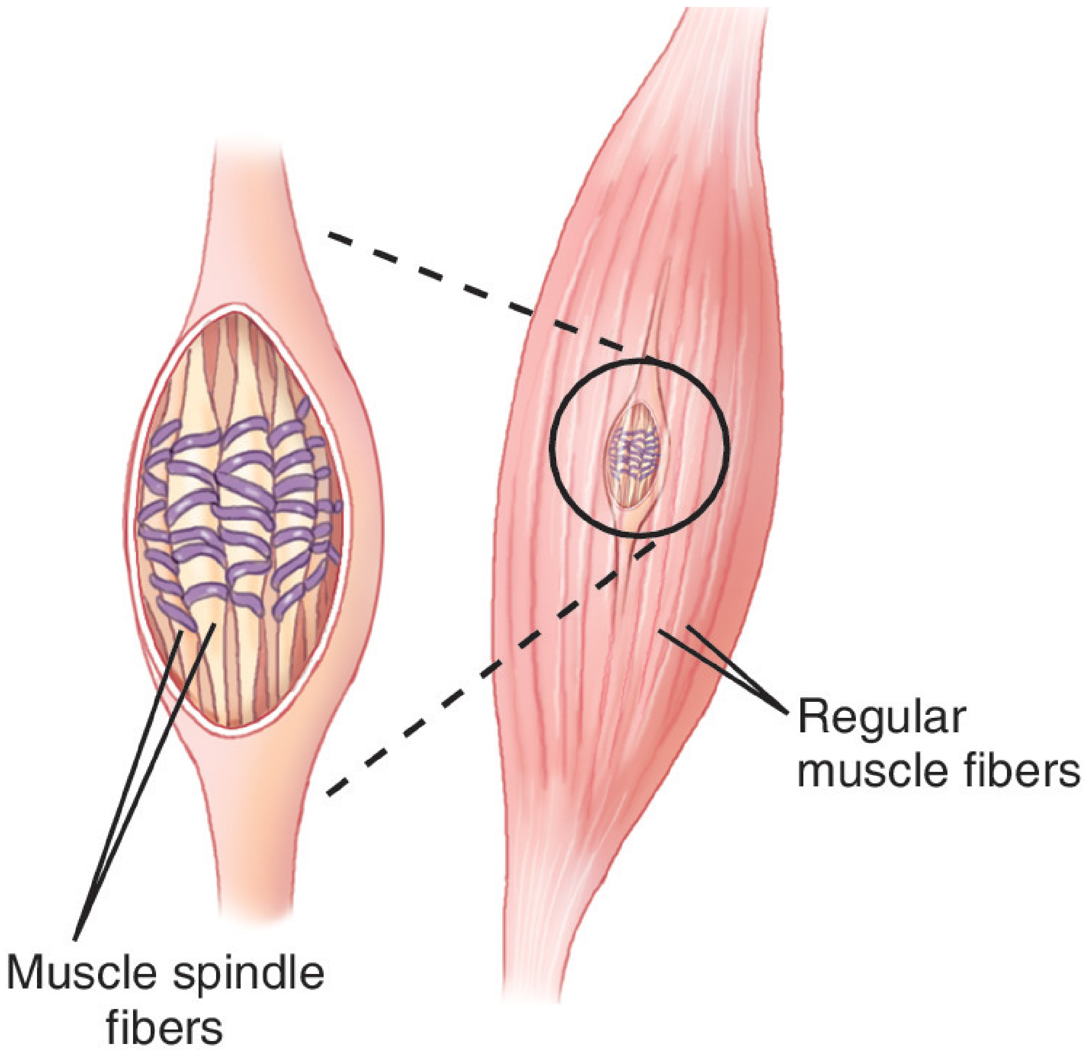
- Muscle spindles
- Golgi Tendon Organs (GTO)

MUSCLE SPINDLES

Muscle spindles are located deep within the muscle fibres. The spindle is a small sensory unit wrapped tightly around the individual muscle fibres like a coiled spring. When the muscle changes length, depending on whether the muscle is lengthening or shortening the 'coils' of the muscle spindle are either pulled apart (lengthening) or pushed together (shortening).

This change in muscular length and a resulting change in the muscle spindle stimulates neural firing to the central nervous system at the spinal level. The resulting outcome of a lengthened muscle and muscle spindle is a stimulus to contract that same muscle. The degree of contraction that occurs will depend on the degree of change in muscle length and the rate at which the change in length occurs. As a general rule the greater the range of motion and the faster the muscle lengthens the greater the resulting contraction will be.

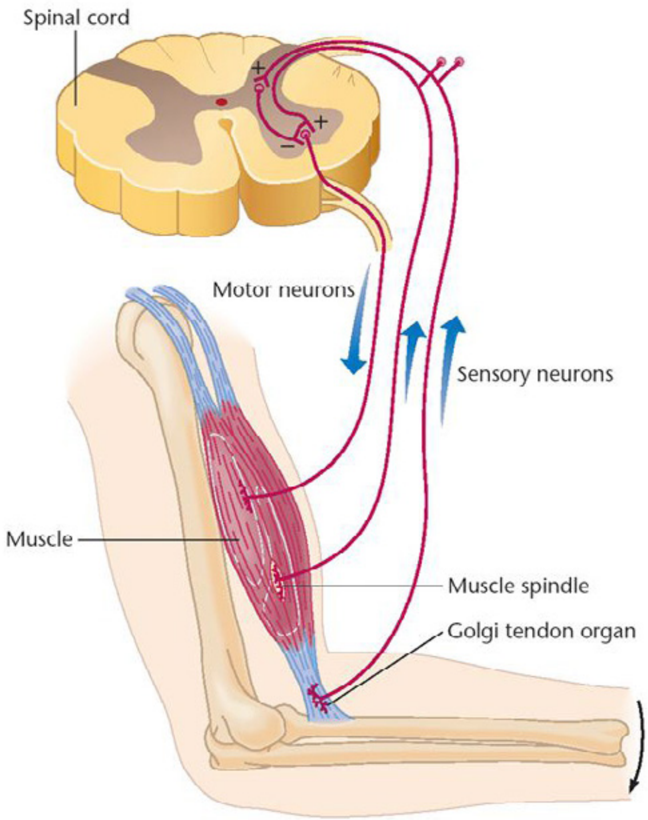
This process is often referred to as the stretch reflex.

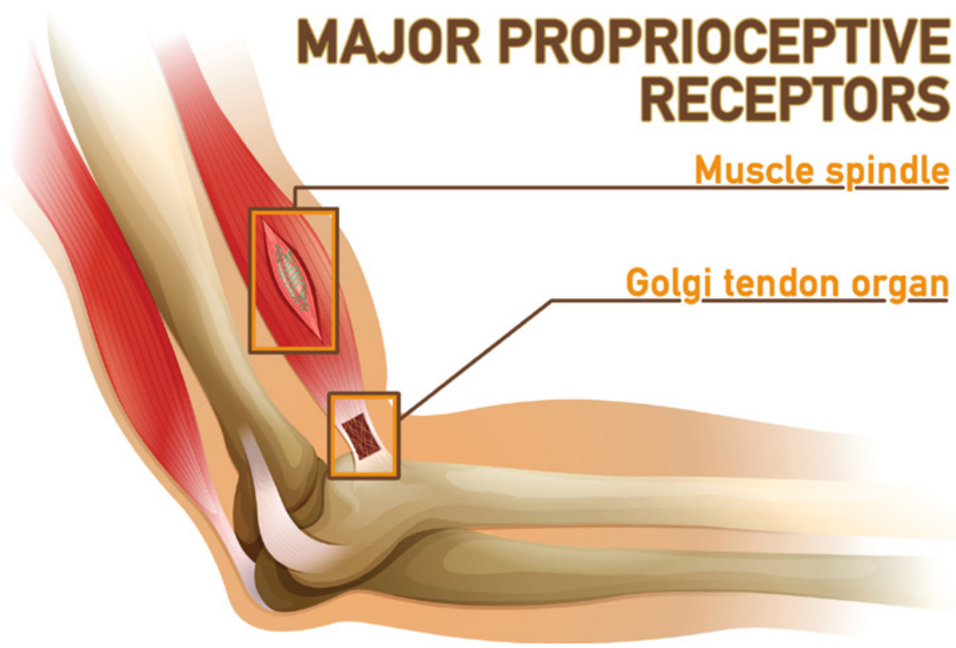


The Golgi Tendon Organ (GTO)

The Golgi Tendon Organ (GTO) has an influence on the muscle but is actually located in the tendon and is such its namesake. The tendon is inelastic and so the GTO cannot detect changes in muscle length. However, when a muscle contracts it pulls on the tendon that is attached to the bone creating tension within the tendon. The GTO is ideally located to measure the amount of tension created by a muscle. When the GTO is activated a signal is sent to the spine which brings about an inhibiting effect on the same muscle.

This relaxation response, a result of GTO firing, is called the inverse stretch reflex.





The muscle spindles will be continually activated during human movement as the muscles will be changing lengths in conjunction with the movements being carried out. This is providing a constant stream of valuable information to the CNS about muscle length and where body parts are in space. The spindles also bring about the muscular contraction that assists with the movements being performed. The GTO responds just after the muscular contraction has engaged by inhibiting the muscular contraction to allow the opposite action to be performed. GTOs and muscle spindles can be thought of as the on and off switches for muscle activity during exercise and movement.

The Stretch Reflex

The stretch reflex is the contraction of a muscle that occurs in response to its stretch. It is not controlled by higher functioning centre i.e. the brain, and is a monosynaptic response that is transmitted to the spinal cord. Exercise and training have been shown to increase the neural side of the muscular response with improvements in the stretch reflex and the net response from the inverse stretch reflex. Training methods such as plyometrics, have been designed particularly to develop the stretch-shortening cycle with effective results. Not only does the muscle learn to develop more force through this type of training, but timing and co-ordination of movement at speed also improves as the muscle spindles in supporting muscle tissue are also trained to respond better.

Reciprocal Inhibition

Reciprocal inhibition (RI) is a neuromuscular reflex that inhibits opposing muscles during movement. For example, if you contract your elbow flexors (biceps) then your elbow extensors (triceps) are inhibited. Consider this, when a muscle is causing its primary actions to occur the opposing muscles need to be switched off (relaxed) to allow that movement to take place. RI is a necessary part of normal movement. However, it can also play a part in creating muscular imbalance. A very tight muscle group will send a continuous RI signal to the opposing muscle which can lead to them becoming inhibited in their function.

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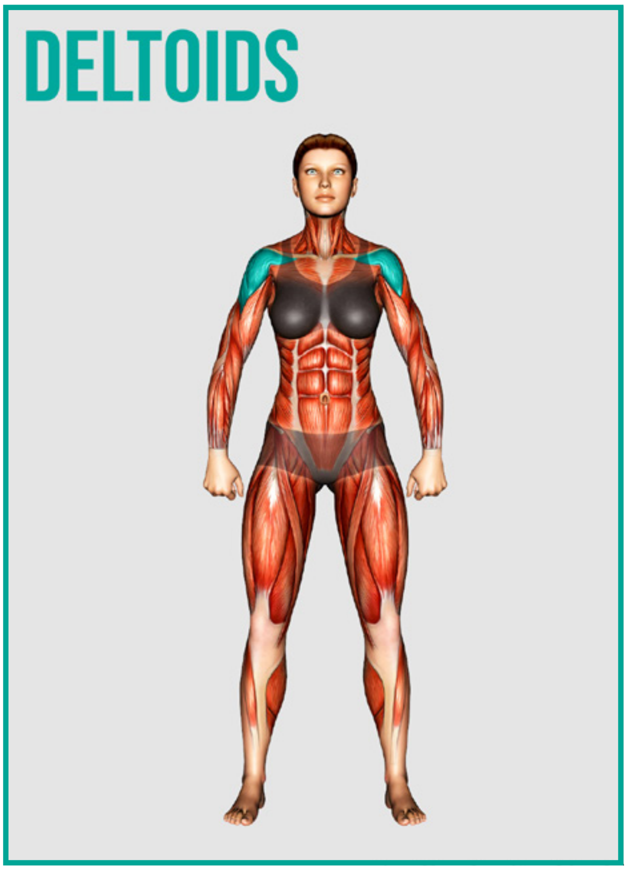
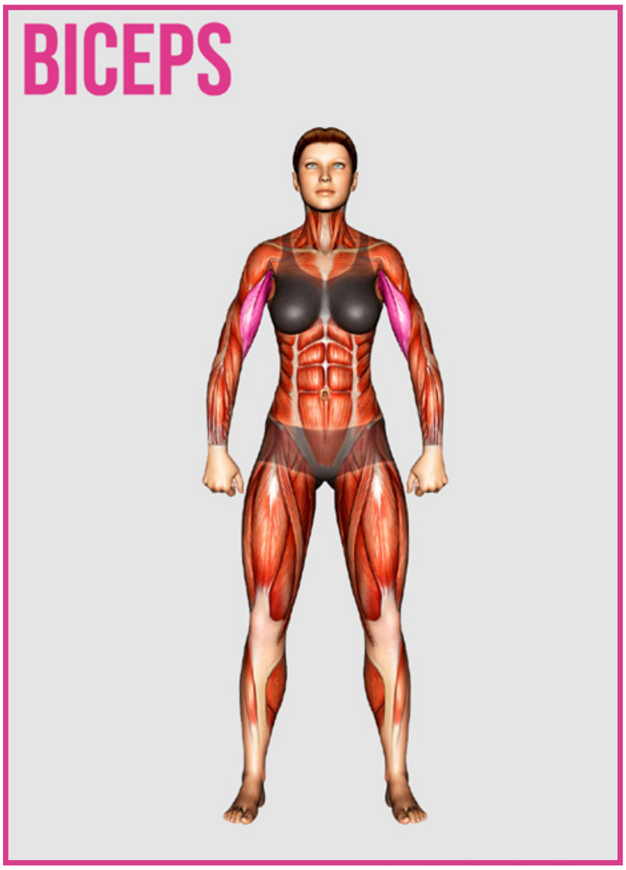
Muscles and Muscle Actions

MODULE 3:
MUSCLE ANATOMY AND ENERGY SYSTEMS

Upper Body Muscles





TRICEPS

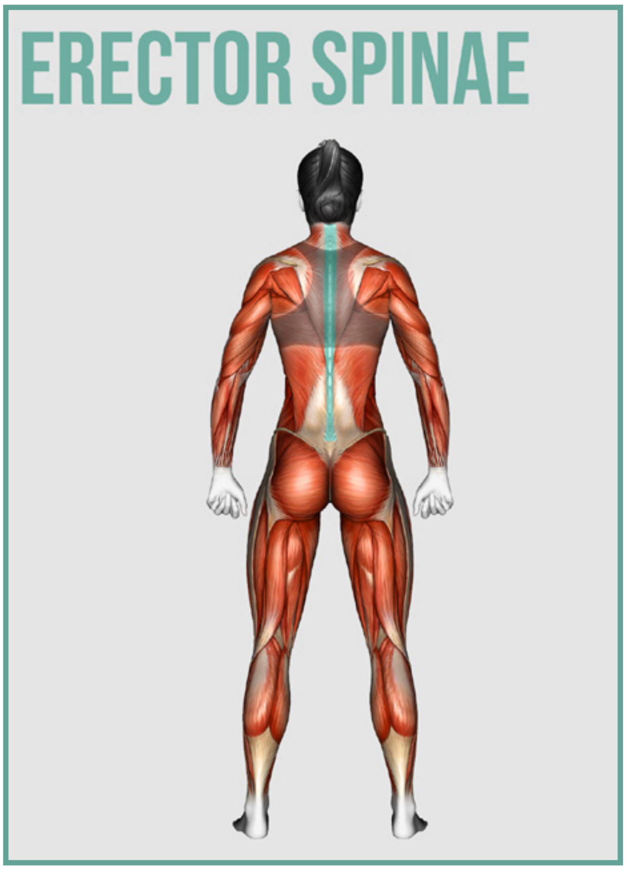
PECTORALS

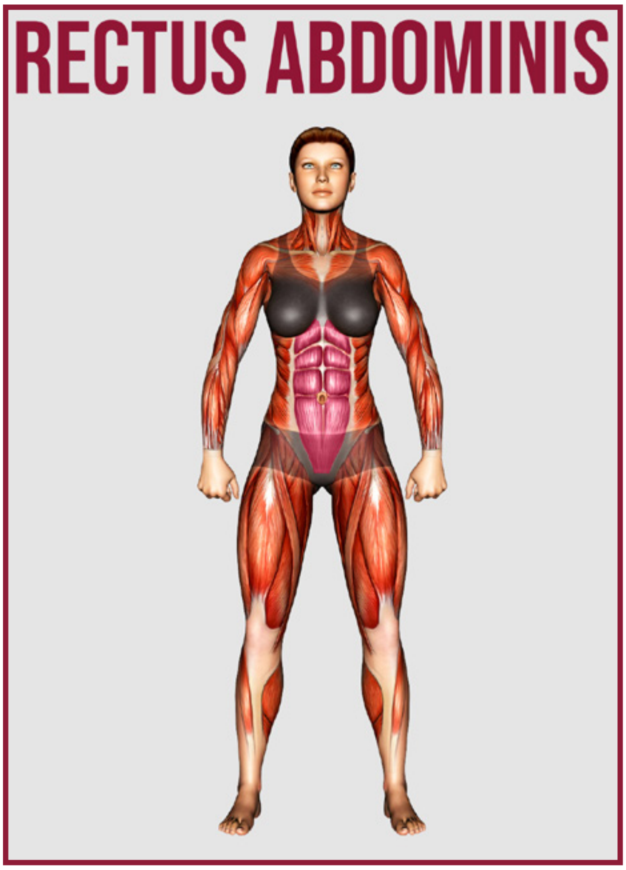
LATISSIMUS DORSI

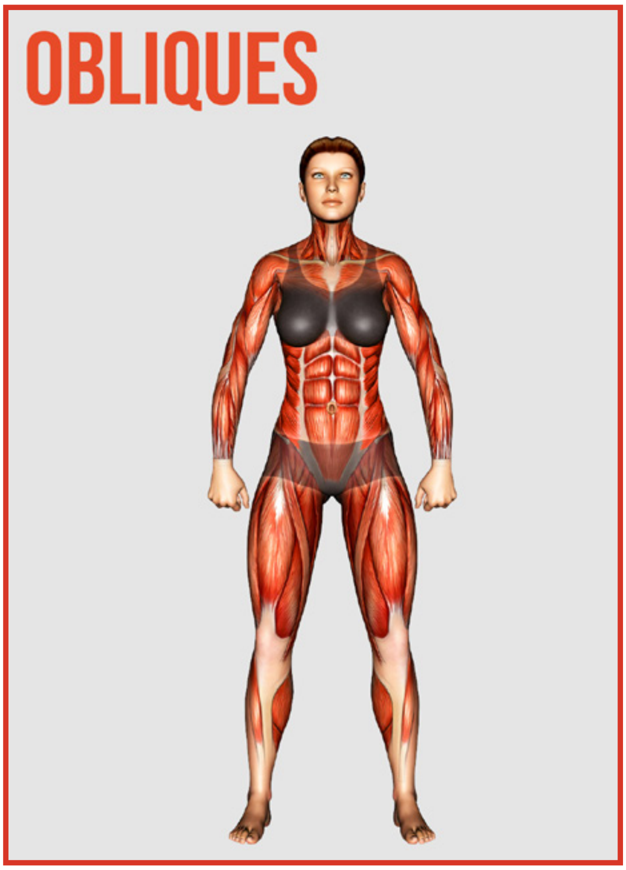
RHOMBOIDS

TRAPEZIUS

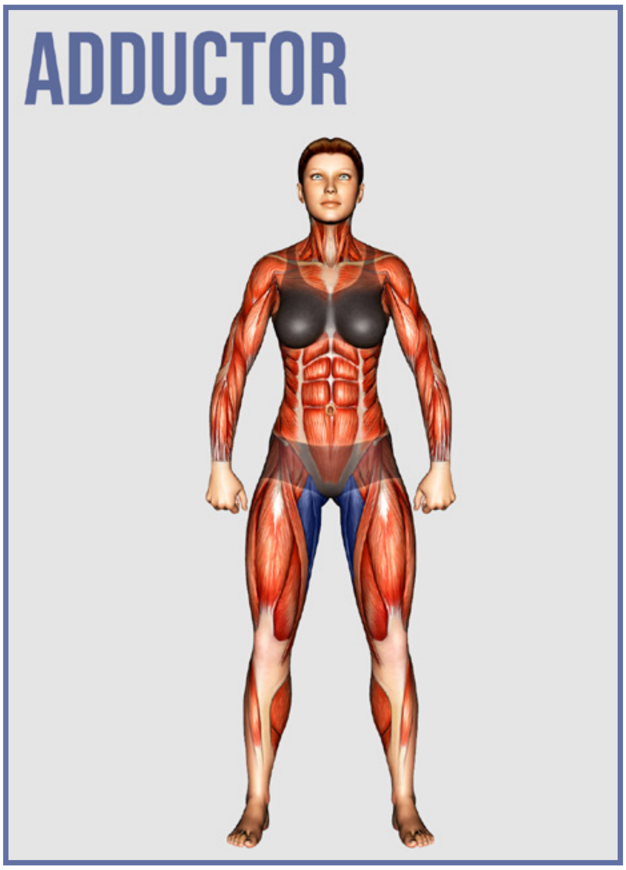
Core Muscles

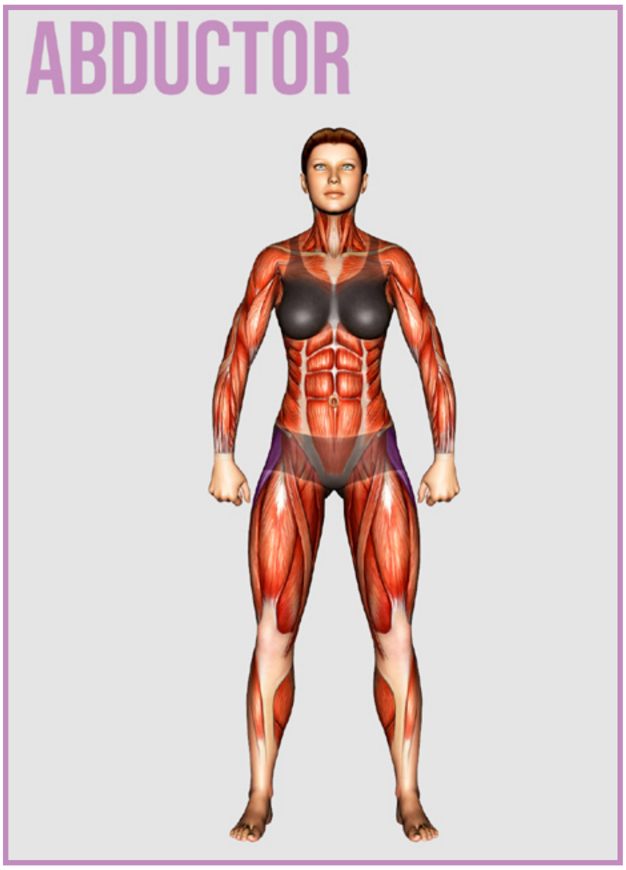


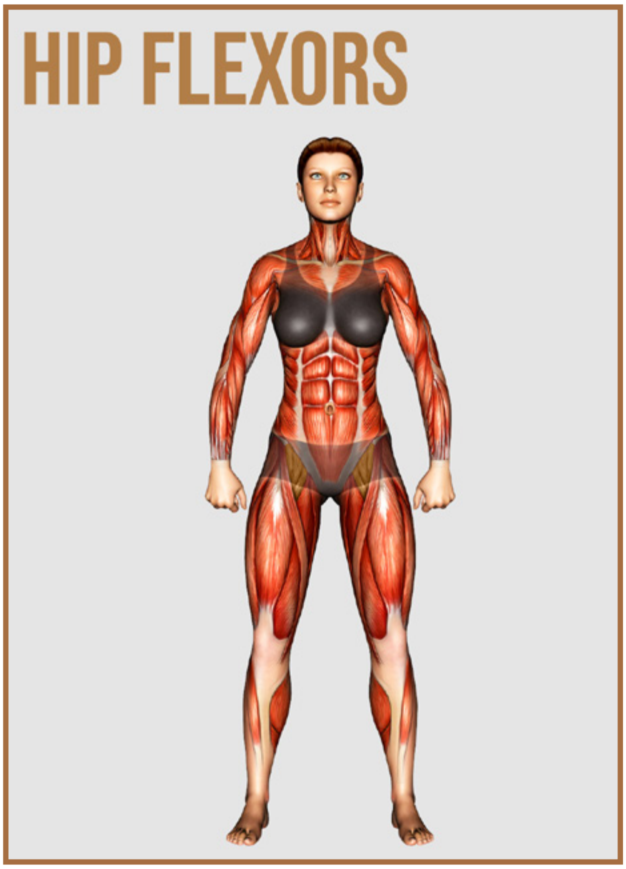


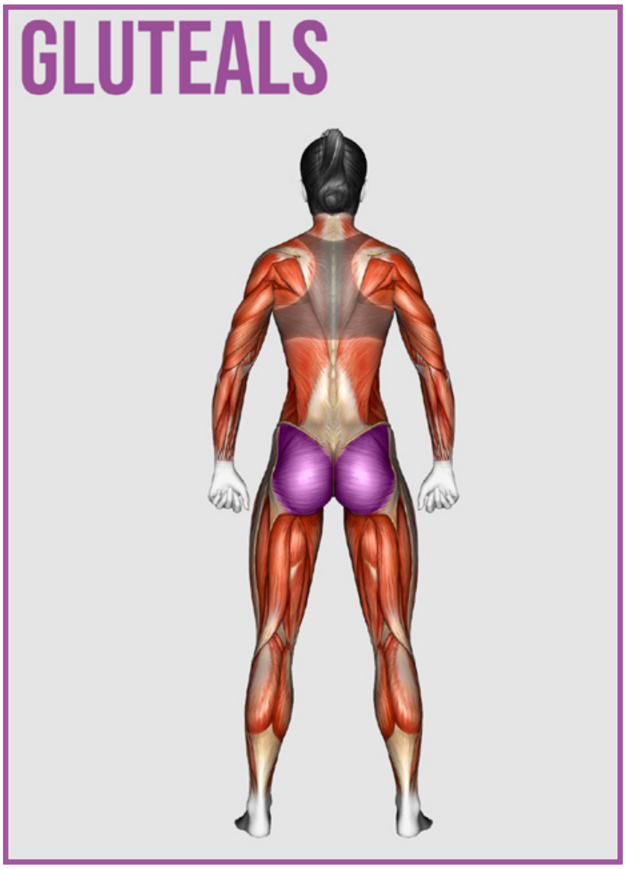


Lower Body Muscles







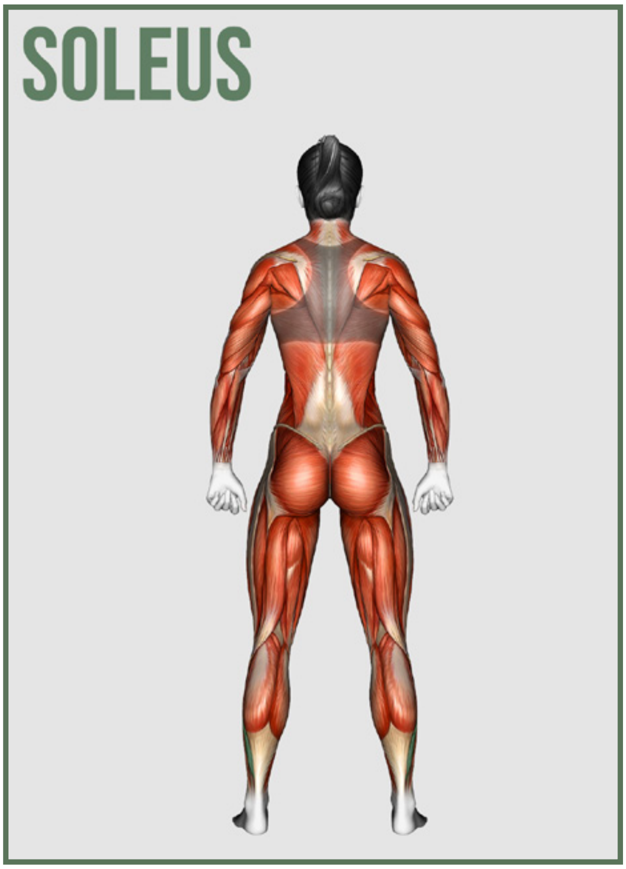


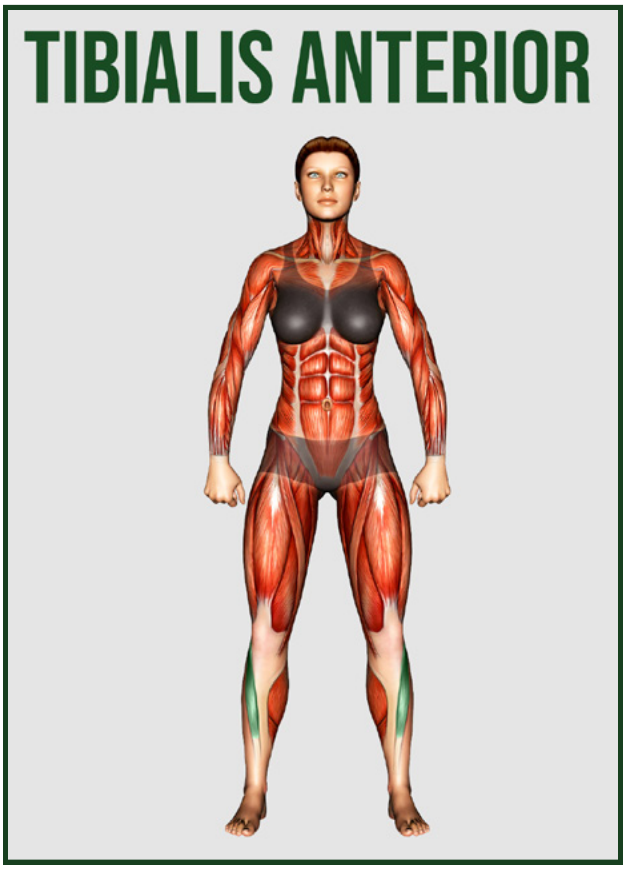
HAMSTRINGS

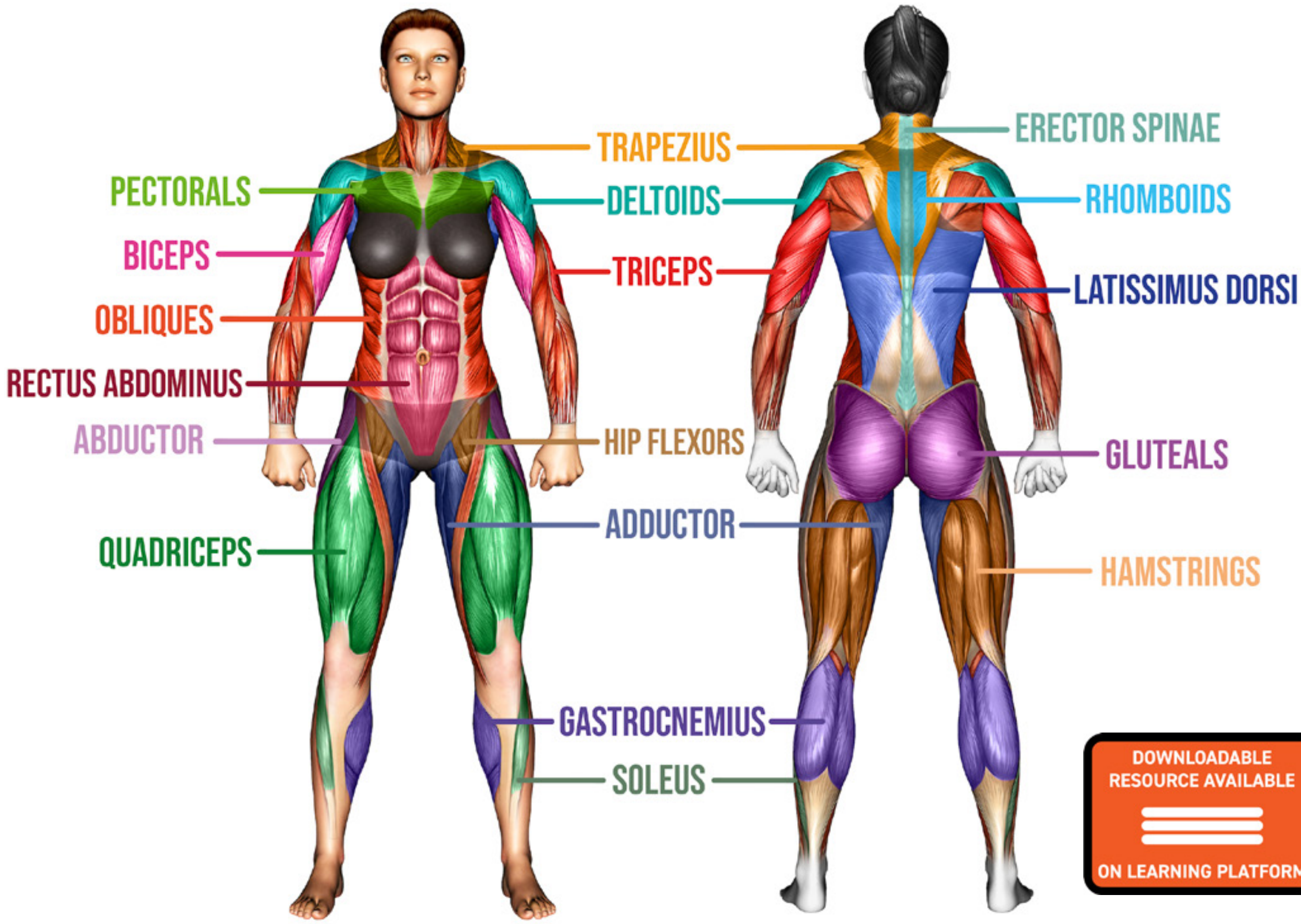
SARTORIUS

QUADRICEPS

GASTROCNEMIUS







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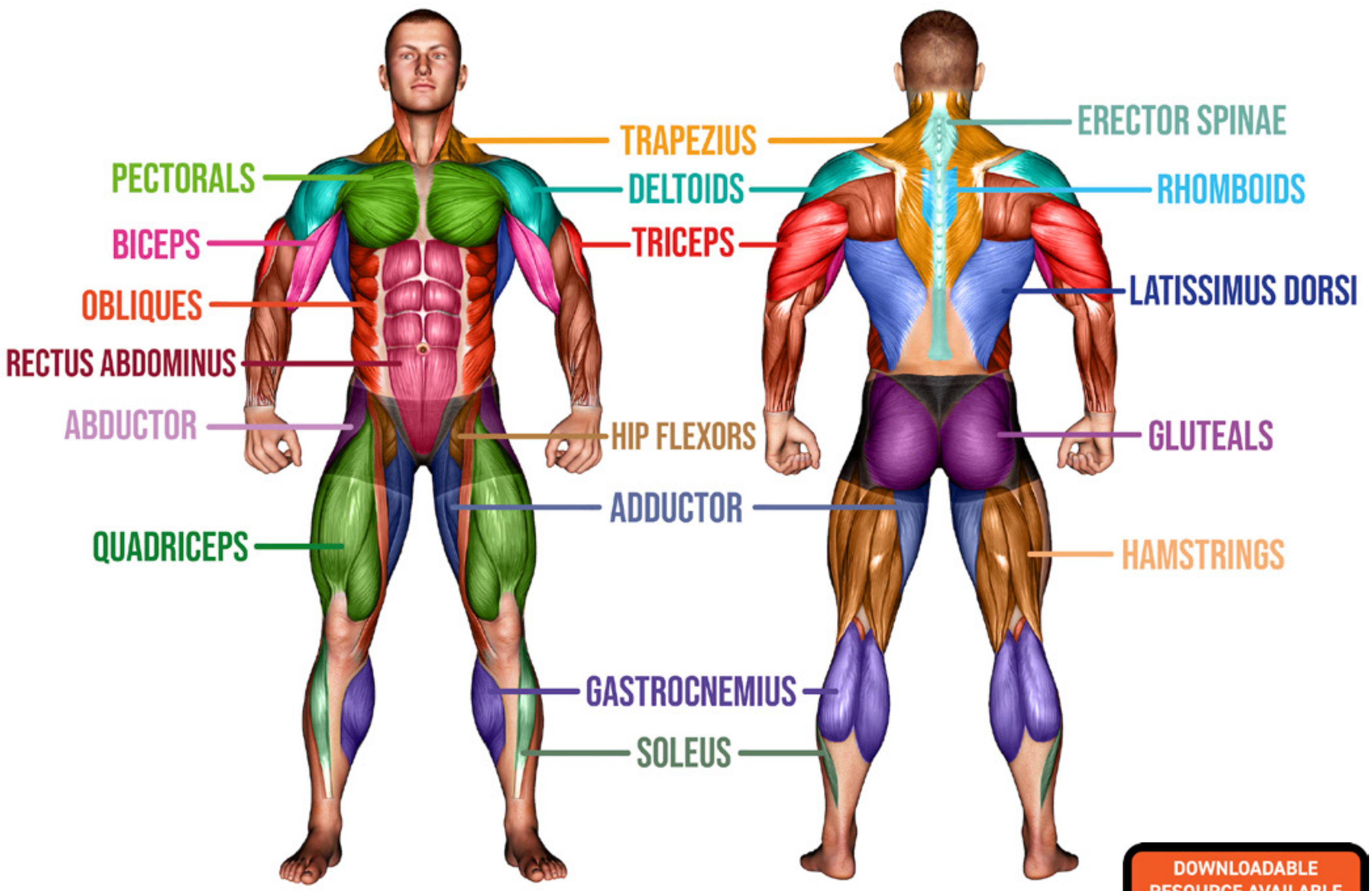

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Muscle Anatomy and Voice Over

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Muscle Contraction Types

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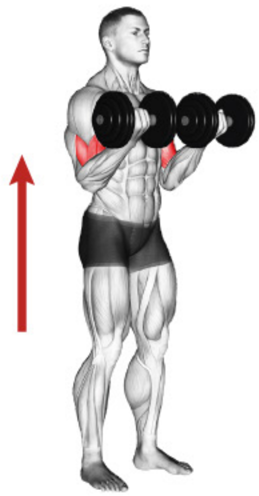
CONTRACTION TYPES:

Eccentric: Muscle lengthens under contraction.

Concentric: Muscle shortens under contraction.

Isometric: Muscle stays the same length under contraction.

BICEP CURL CONCENTRIC:



Bicep Curl Concentric Contraction = Muscle shortens under tension

- Bicep concentrically contracts/shortens

BICEP CURL ECCENTRIC:

Bicep Curl Eccentric Contraction = Muscle lengthens under tension

- Bicep eccentrically contracts/lengthens

BICEP CURL ISOMETRIC:

Bicep Curl Isometric hold = The muscle length stays the same under tension

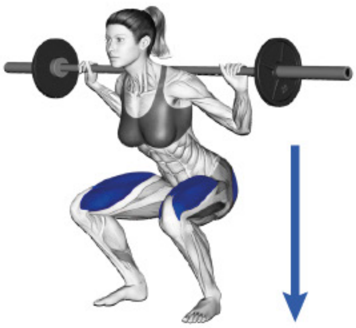
- Biceps isometrically contracting

SQUAT CONCENTRIC:

Squat Concentric Contraction = Muscle shortens under tension

- Gluteals concentrically contract/shorten
- Quadriceps concentrically contract/shorten

SQUAT ECCENTRIC:



Squat Eccentric Contraction = Muscle lengthens under tension

- Gluteals eccentrically contract/lengthen
- Quadriceps eccentrically contract/lengthen

SQUAT ISOMETRIC:

Squat Isometric hold = The muscle length stays the same under tension

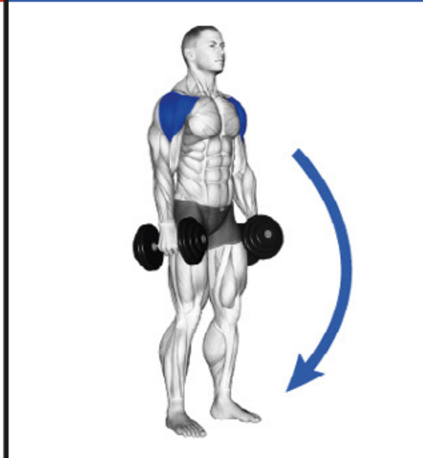
- Gluteals isometrically contracting
- Quadriceps isometrically contracting

LATERAL RAISE CONCENTRIC:

Lateral Raise Concentric Contraction = Muscle shortens under tension

- Deltoids concentrically contract/shorten

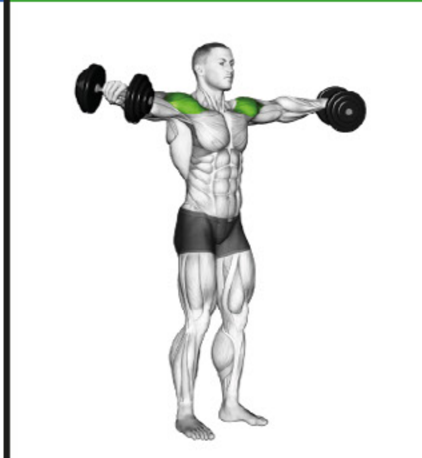
LATERAL RAISE ECCENTRIC:



Lateral Raise Eccentric Contraction - Muscle lengthens under tension

- Deltoids eccentrically contract/lengthen

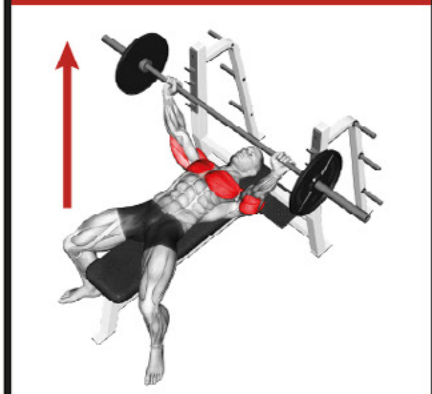
LATERAL RAISE ISOMETRIC:



Lateral Raise Isometric hold - The muscle length stays the same under tension

- Deltoids isometrically contracting

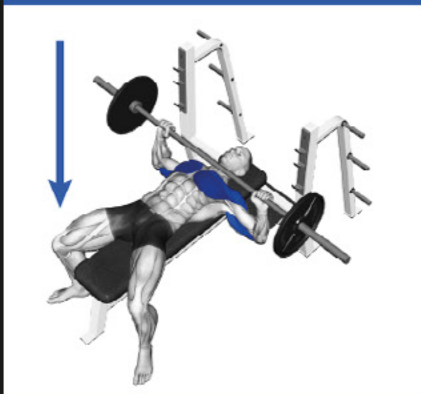
BARBELL BENCH PRESS CONCENTRIC:



Bench Press Concentric Contraction = Muscle shortens under tension

- Anterior Deltoid concentrically contract/shorten
- Pectorals concentrically contract/shorten
- Triceps concentrically contract/shorten

BARBELL BENCH PRESS ECCENTRIC:



Bench Press Eccentric Contraction = Muscle shortens under tension

- Anterior Deltoid eccentrically contract/lengthen
- Pectorals eccentrically contract/lengthen
- Triceps eccentrically contract/lengthen

BARBELL BENCH PRESS ISOMETRIC:

Bench Press Isometric hold = The muscle length stays the same under tension

- Anterior Deltoid isometrically contracting
-Pectorals isometrically contracting
-Triceps isometrically contracting

LYING HAMSTRING CURL CONCENTRIC:

Hamstring Curl Concentric Contraction = Muscle shortens under tension

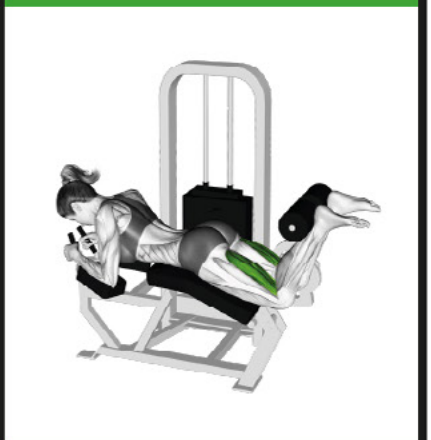
- Hamstrings concentrically contract/shorten

LYING HAMSTRING CURL ECCENTRIC:

Hamstring Curl Eccentric Contraction = Muscle lengthens under tension

- Hamstrings eccentrically contract/lengthen

LYING HAMSTRING CURL ISOMETRIC:



Hamstring Curl Isometric hold = The muscle length stays the same under tension

- Hamstrings isometrically contracting

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ON LEARNING PLATFORM

MUSCLE ROLES KEY:

Agonist/Prime mover = Muscle directly responsible for the desired movement.
Antagonist = Muscle that causes the opposite action to the agonist.
Synergist = Muscle that assists the prime mover.
Fixator = Muscle that stabilises the origin of the prime mover.

BICEP CURL MUSCLE ACTIONS:

ANTAGONIST:
- Triceps

AGONIST:
- Biceps

FIXATORS:
- Deltoids

LATERAL RAISE MUSCLE ACTIONS:

ANTAGONIST:
- Latissimus Dorsi

AGONIST:
- Deltoids

SYNERGIST:
- Serratus Anterior
- Trapezius

FIXATORS:
- Pectorals

SQUAT MUSCLE ACTIONS:

ANTAGONIST:
- Hamstrings

AGONIST:
- Quadriceps

SYNERGIST:
- Gluteals
- Soleus
- Adductors

FIXATORS:
- Hip Flexors

LYING LEG CURL MUSCLE ACTIONS:

ANTAGONIST:

- Quadriceps

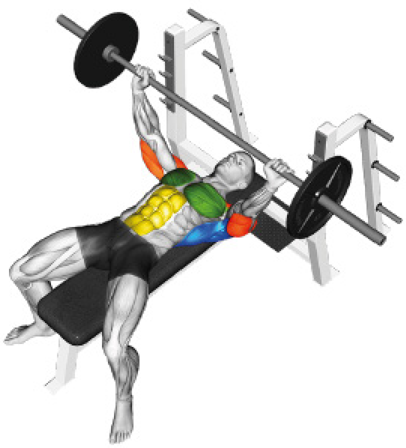
AGONIST:

- Hamstrings

FIXATORS:

- Gluteals

BARBELL BENCH PRESS MUSCLE ACTIONS:



ANTAGONIST:

- Latissimus Dorsi

AGONIST:

- Pectorals

SYNERGIST:

- Deltoids
- Triceps

FIXATORS:

- Rectus Abdominus

After this section you will find a muscle booklet download available on the Learning Platform

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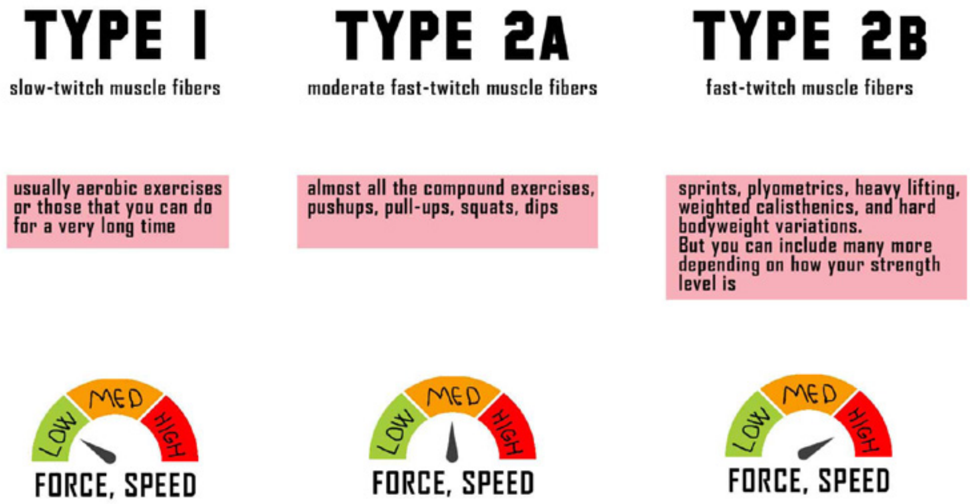
ON LEARNING PLATFORM

Muscle Fibre Types

MODULE 3:
MUSCLE ANATOMY AND ENERGY SYSTEMS

Types Of Muscle Fibre



There are several categories of muscle fibre types however there are three main distinct types of skeletal muscle fibres. The fibres are categorised depending on the functions that they perform. Distinct fibre types have been classified according to these following characteristics:

Classification	Structure	Function	Activities
Type 1: Slow twitch (slow oxidative)	• Red coloured • Smallest diameter • Large myoglobin content • Many mitochondria • Many capillaries	• Increased aerobic delivery • Produce less force • Resistant to fatigue • Slow contractions	• Maintenance of posture • Endurance based activity
Type 2A: Fast twitch A (fast oxidative)	• Red/pink colour • Larger diameter • Large myoglobin content • Many mitochondria • Many capillaries	• Requires aerobic delivery • Produce more force • Less resistant to fatigue • Fast contractions	• Walking • Running • Sprinting
Type 2B: Fast twitch B (fast glycolytic)	• White/pale • Largest diameter • Small myoglobin content • Fewer mitochondria • Fewer capillaries	• Anaerobic delivery • Produce most force • Least resistant to fatigue • Fastest contractions	• Throwing • Jumping • Weight lifting

Muscle Fibre Type Considerations

Muscles contain a mixture of muscle fibre types. The activities performed will determine the proportion of each fibre type contained within. Muscles which are used to support the body will contain more type 1 fibres, such as the muscles that support the back and the head.

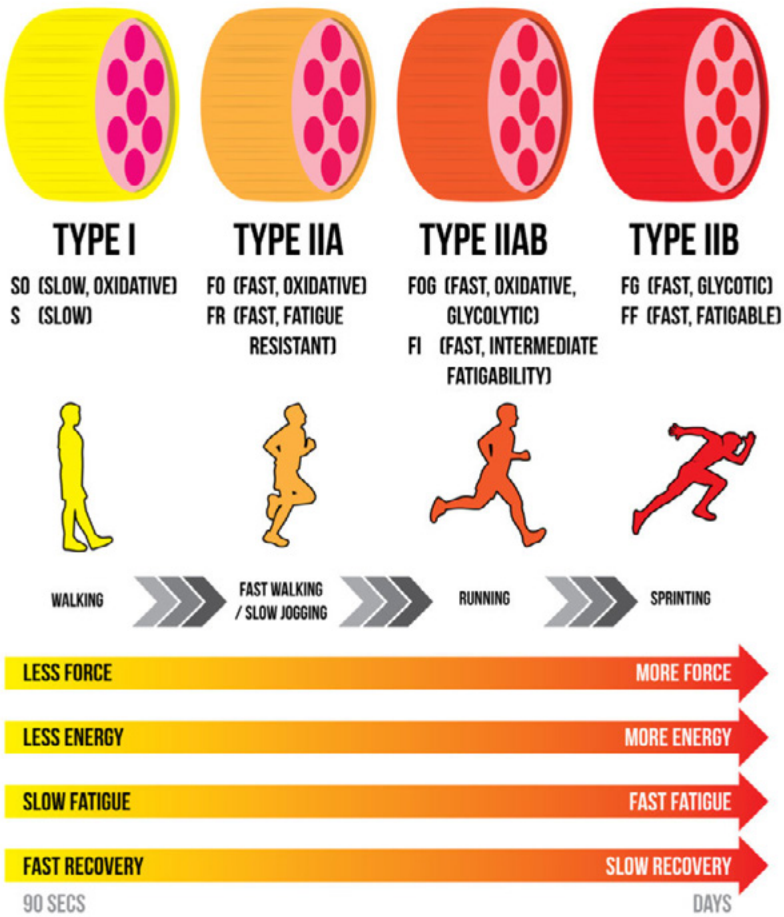
In contrast, the muscles responsible for the force generated by the arms and shoulders will contain more type 2 fibres. The muscles of the legs have a more even distribution of both fibre types as they must generate movement and support the structure of the body parts above.

Each person will have different fibre type combinations and no two persons are the same. The athletic ability of each individual will depend on these fibre combinations, which explains the fact that some people excel at endurance activities and others at power disciplines.

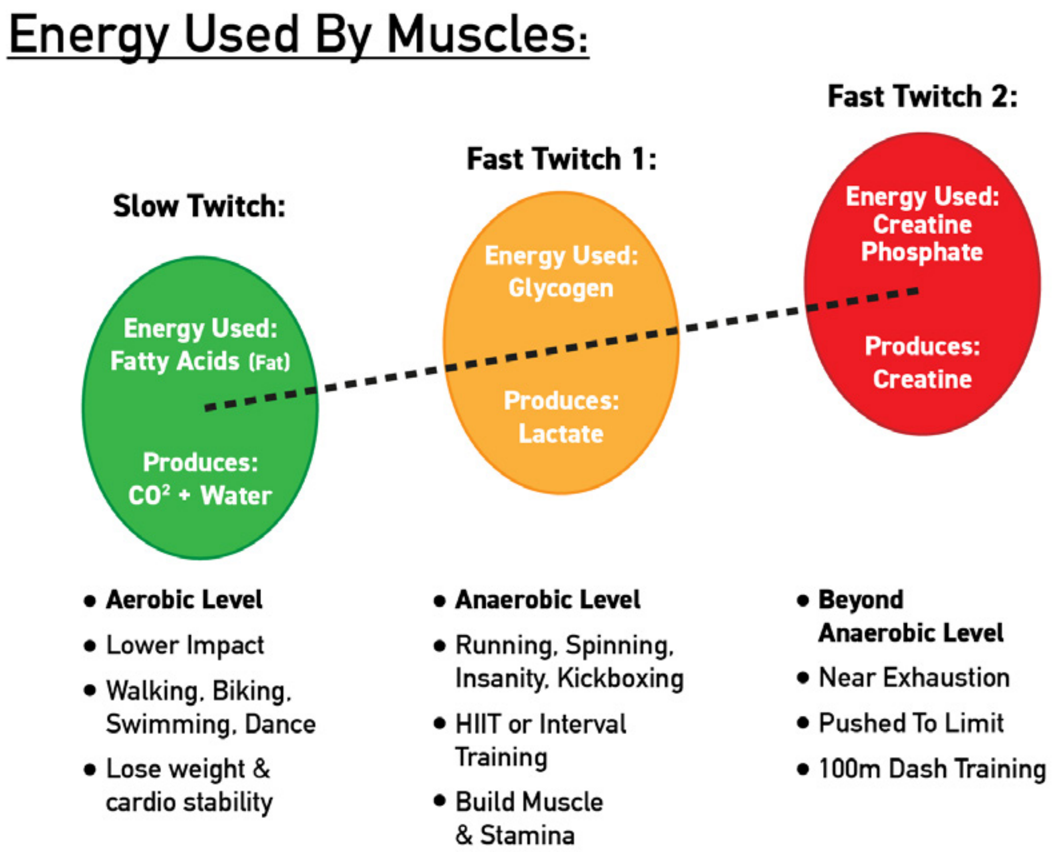
Appropriate training can develop the size and capacity of both muscle fibre types.

It is possible to transform one fibre type to another with an appropriate shift in training. An increase in aerobic exercise will result in a gradual change from type 2B fibres into type 1 fibres. The opposite will occur with an increase in resistance training.

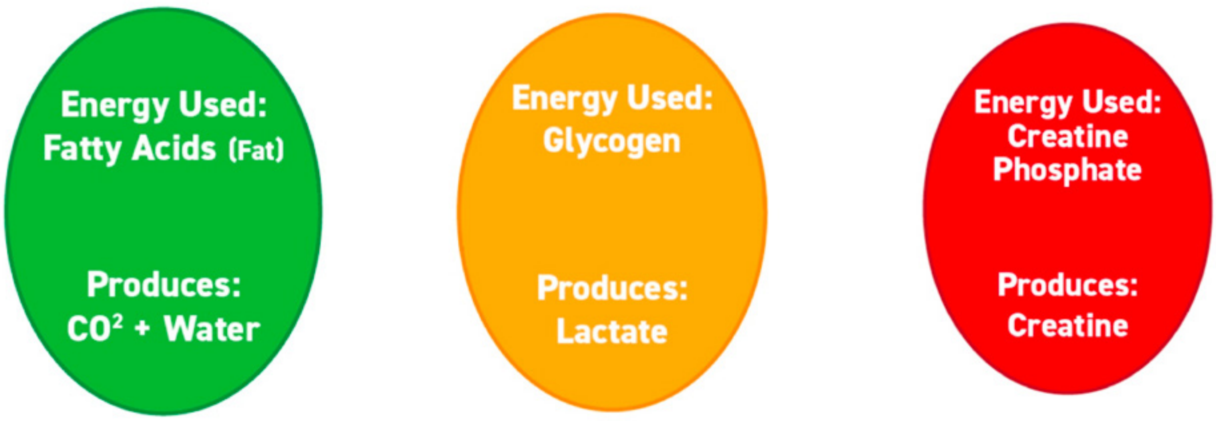
The image below shows an additional variation in muscle fibres:



Energy Consumption



The Interchangeable Names for Muscle Fibres



Type I Muscle Fibres

- Type 1
- Slow Twitch

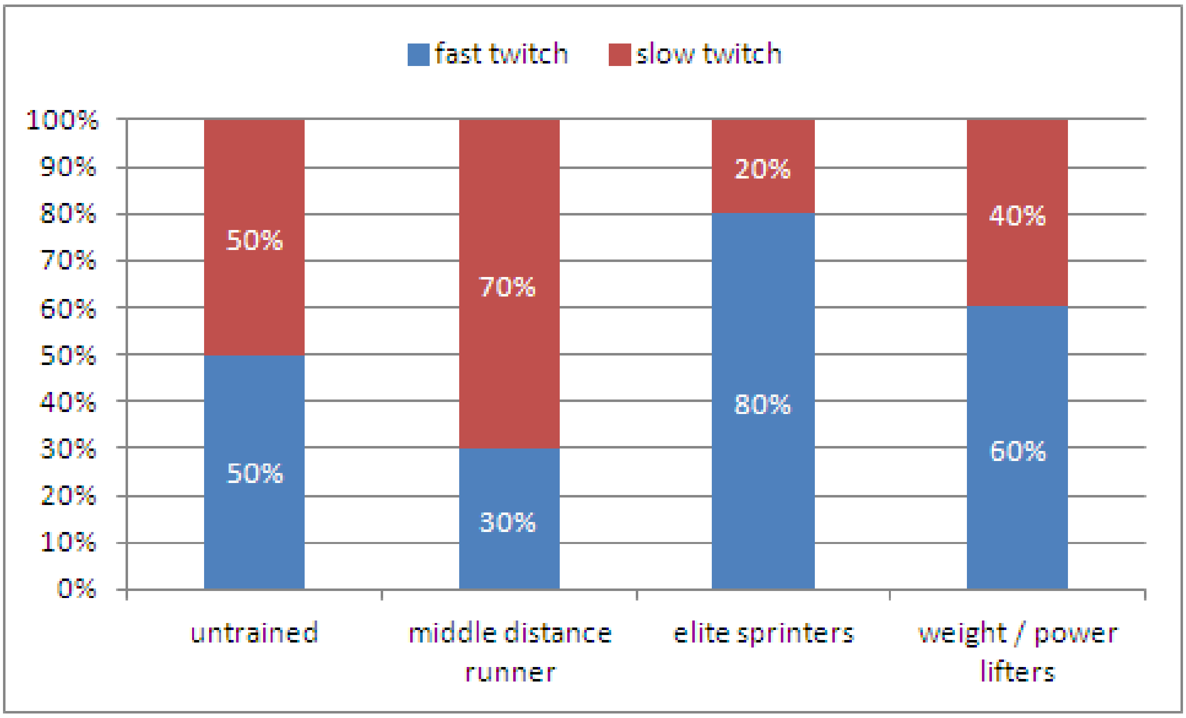
Type IIA Muscle Fibres

- Type 2A
- Fast Twitch 1
- Moderate-Fast Twitch
- Intermediate

Type IIB Muscle Fibres

- Type 2B
- Fast Twitch 2
- Fast Twitch

Effects Of Exercise On Muscle Tissue Type



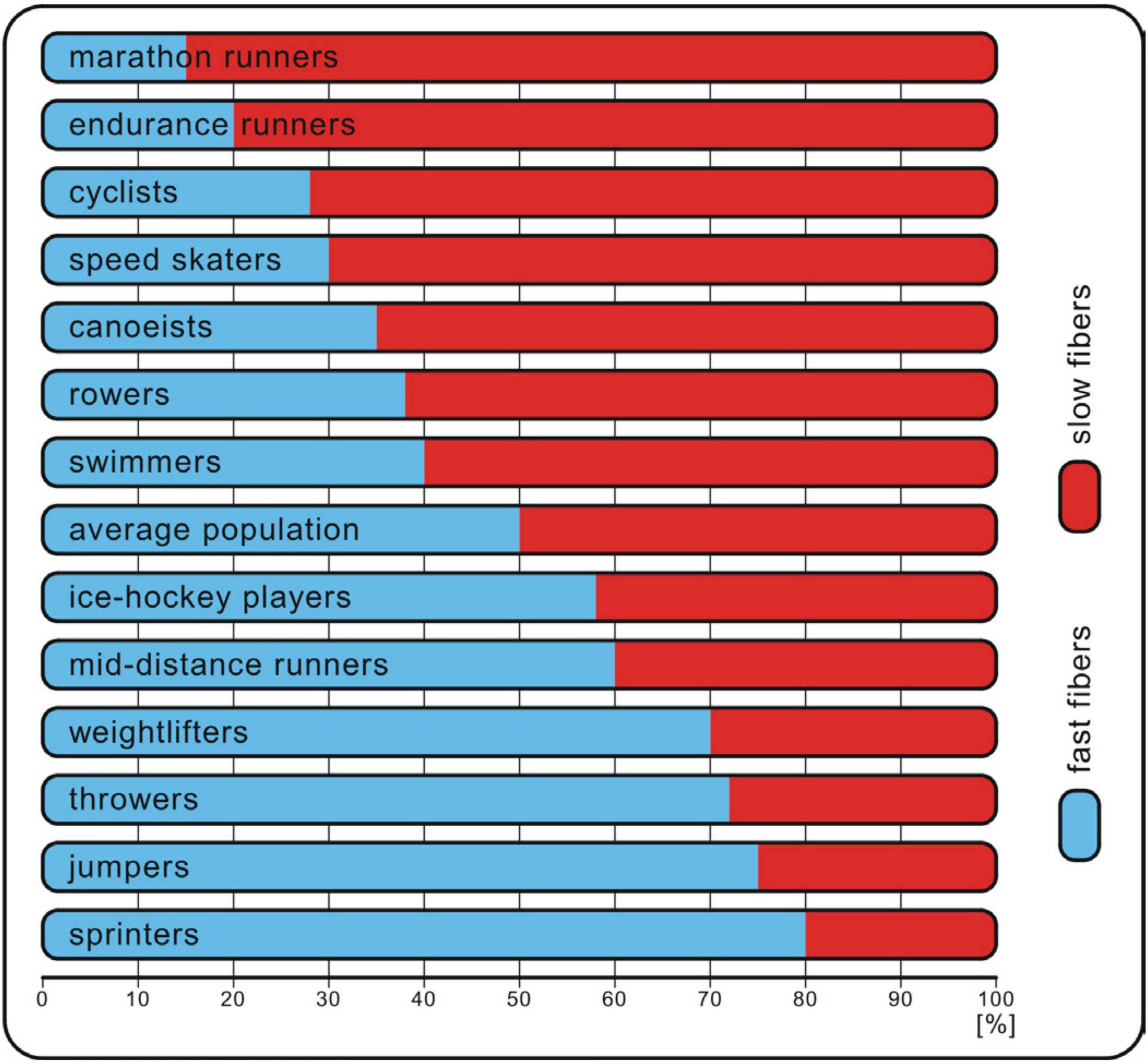
Whilst it is acknowledged that exercise, in general, will have a positive impact on muscle tissue development, certain types of activity have been shown to influence different muscle fibre types. Simply put muscles have three categories of muscle tissue, Type 1 or slow-twitch, Type 2a and Type 2b or fast-twitch. Science is continuing to expand this area of knowledge and other types of muscle tissue have been determined based on function and response.

The most aerobic in nature are the Type 1 (slow-twitch) muscle fibres, which have a greater blood supply and more mitochondria and as a result respond well to aerobic, low to moderate-intensity training.

The opposing fibre type, which is very anaerobic in nature with a reduced blood supply and fewer mitochondria is Type 2b (fast-twitch) muscle fibres. Type 2b fibres respond well to high-intensity exercise with a higher force and power outputs.

The Type 2a (intermediate twitch) fibres have all the characteristics that one would find in other fast-twitch fibre types, but with the added ability to adapt a little more and take on some of the properties of the Type 1 fibre. Type 2a fibres will respond to varying levels of exercise intensity in the direction of the stimulus applied.

Muscle Fibre Types in Sport



Energy Systems

MODULE 3: MUSCLE ANATOMY AND ENERGY SYSTEMS

Introduction

The human body is, at its most basic level, a machine and like any machine, it needs a supply of energy work. As a car needs petrol or a light bulb needs electricity, your body needs a substance called Adenosine Triphosphate which is known as ATP for short.

ATP is the universal fuel for everything that happens in your body; from lifting weights to running to reading to sleeping – ATP is what powers your body.

ATP is made up of one adenosine molecule and three phosphate molecules. These molecules are held together by high energy bonds which, when broken, release energy for us to use. The result of this reaction is ADP (adenosine diphosphate) + energy +one lone molecule of phosphate.

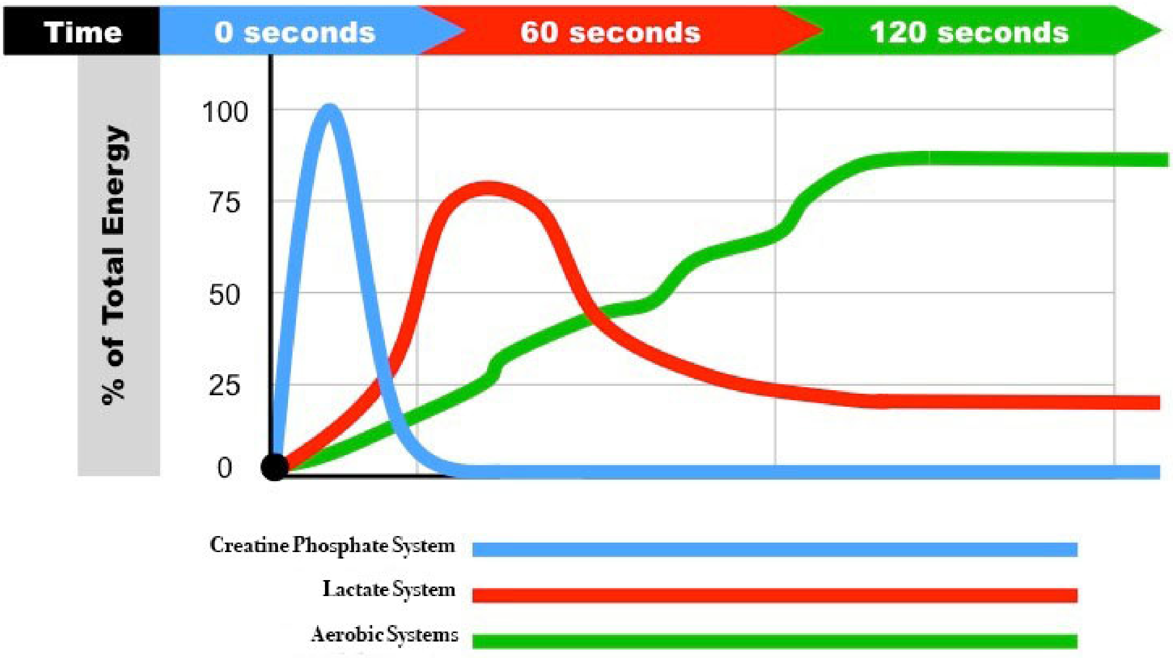
We only have a very limited supply of ATP stored in our bodies; about enough for 1-2 seconds of activity, however, humans convert food into ATP to ensure that we always have plenty of energy. In addition to food, ATP can be manufactured from fat stored around your body and the carbohydrate reserves in your muscles and liver called glycogen.

Food + O_2 + digestion = energy (ATP) + muscular contractions + CO_2 + H_2O + heat

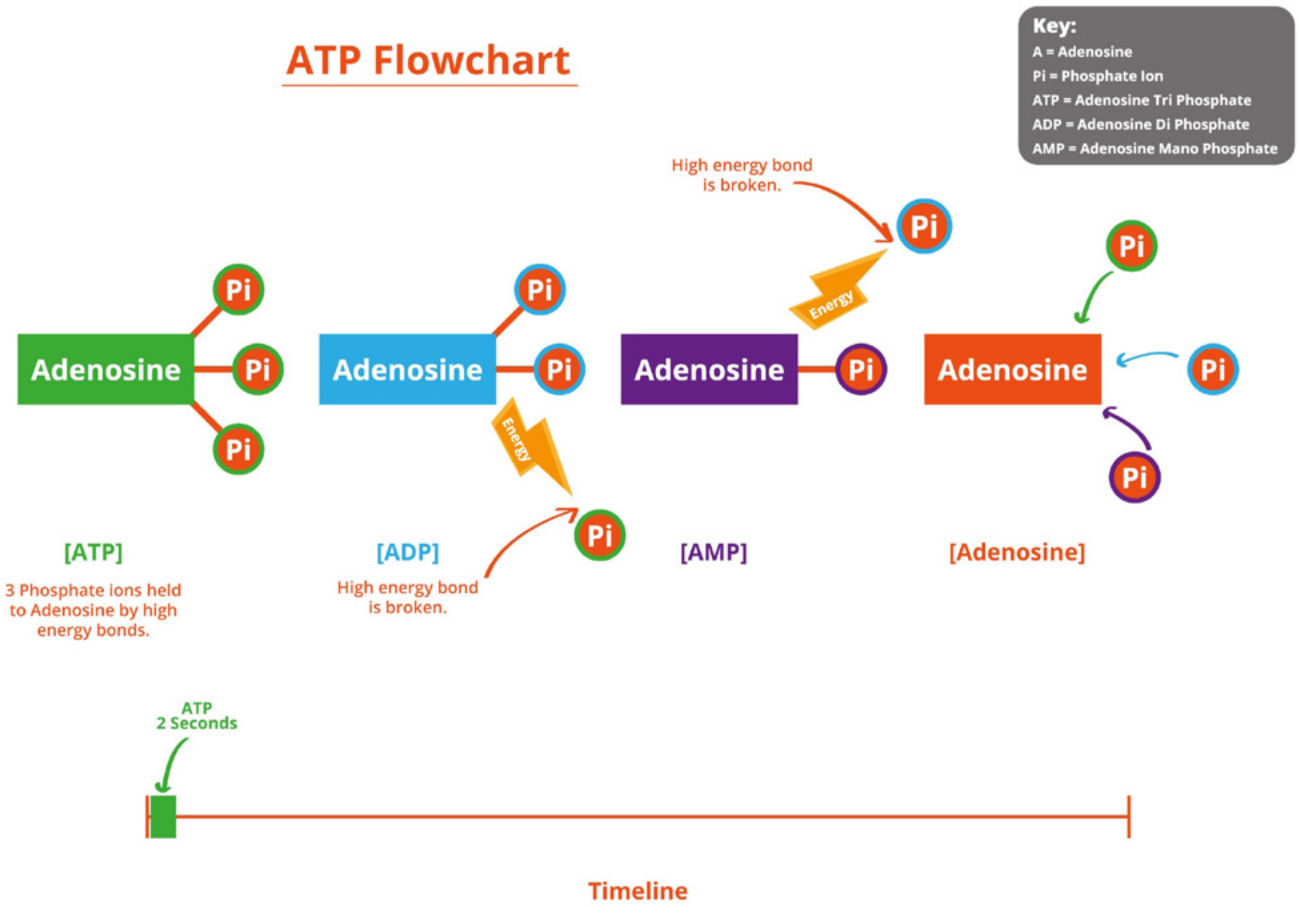
Humans use three primary systems for creating ATP or regenerating ADP back into ATP for use by the body. There are two anaerobic energy systems that operate without oxygen and one that requires an abundance of oxygen.

The Three Energy Systems

1. **Creatine phosphate system:** also known as the CP system, the phosphocreatine system or the anaerobic lactate system
2. **Lactate system:** also known as the lactic acid system or the anaerobic glycolysis system
3. **Aerobic system:** also known as the oxidative system



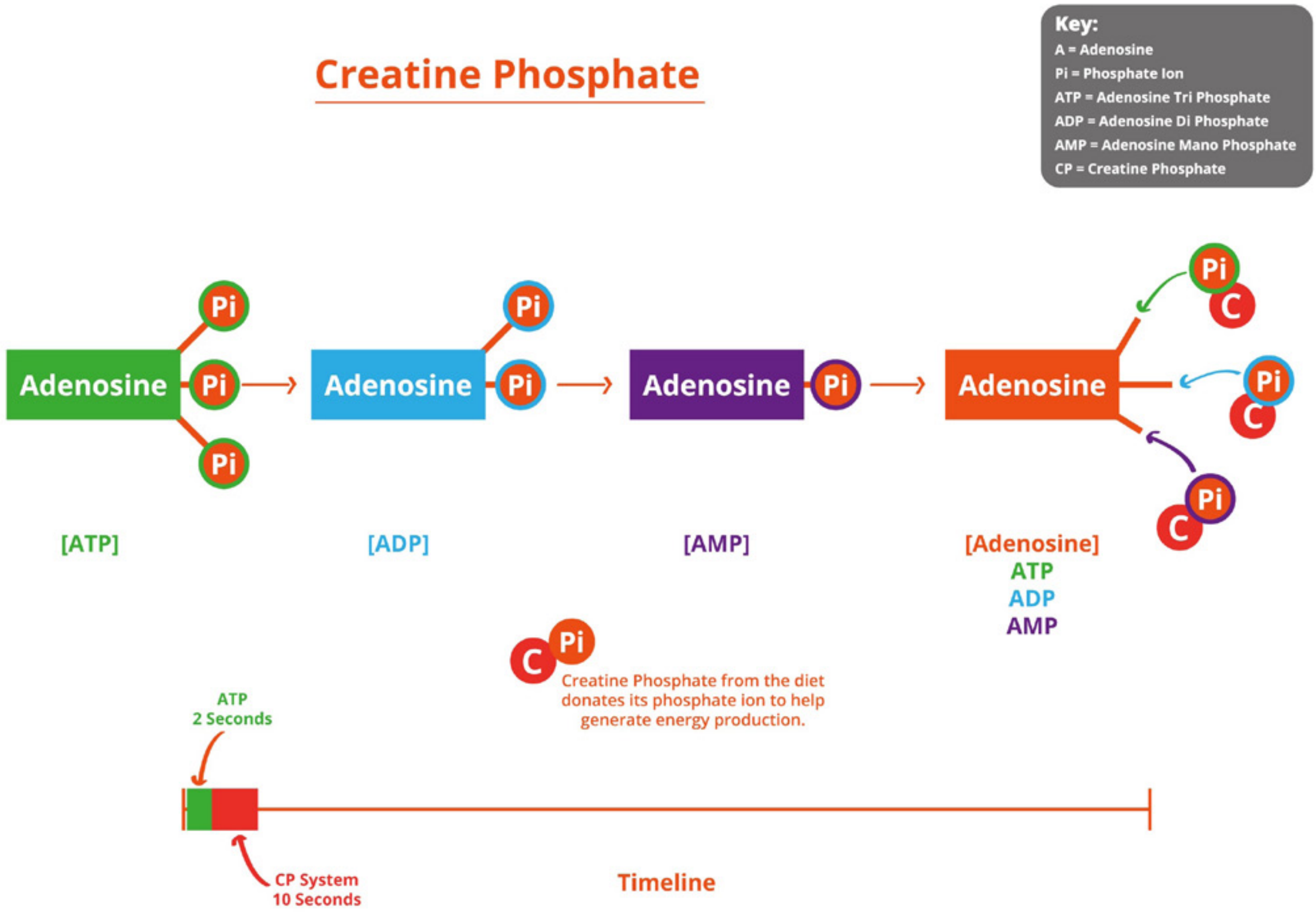
The breakdown of ATP to release energy



Creatine Phosphate Training Adaptations

There is little doubt that activities emphasising the CP system, such as heavy weight lifting and sprinting have a significant training effect; namely increased muscle mass and a pre-domination of fast-twitch muscle fibres (Jones and Round, 1991) As well as a significant increase in muscular stores of anaerobic fuel sources i.e. ATP, creatine phosphate and glycogen.

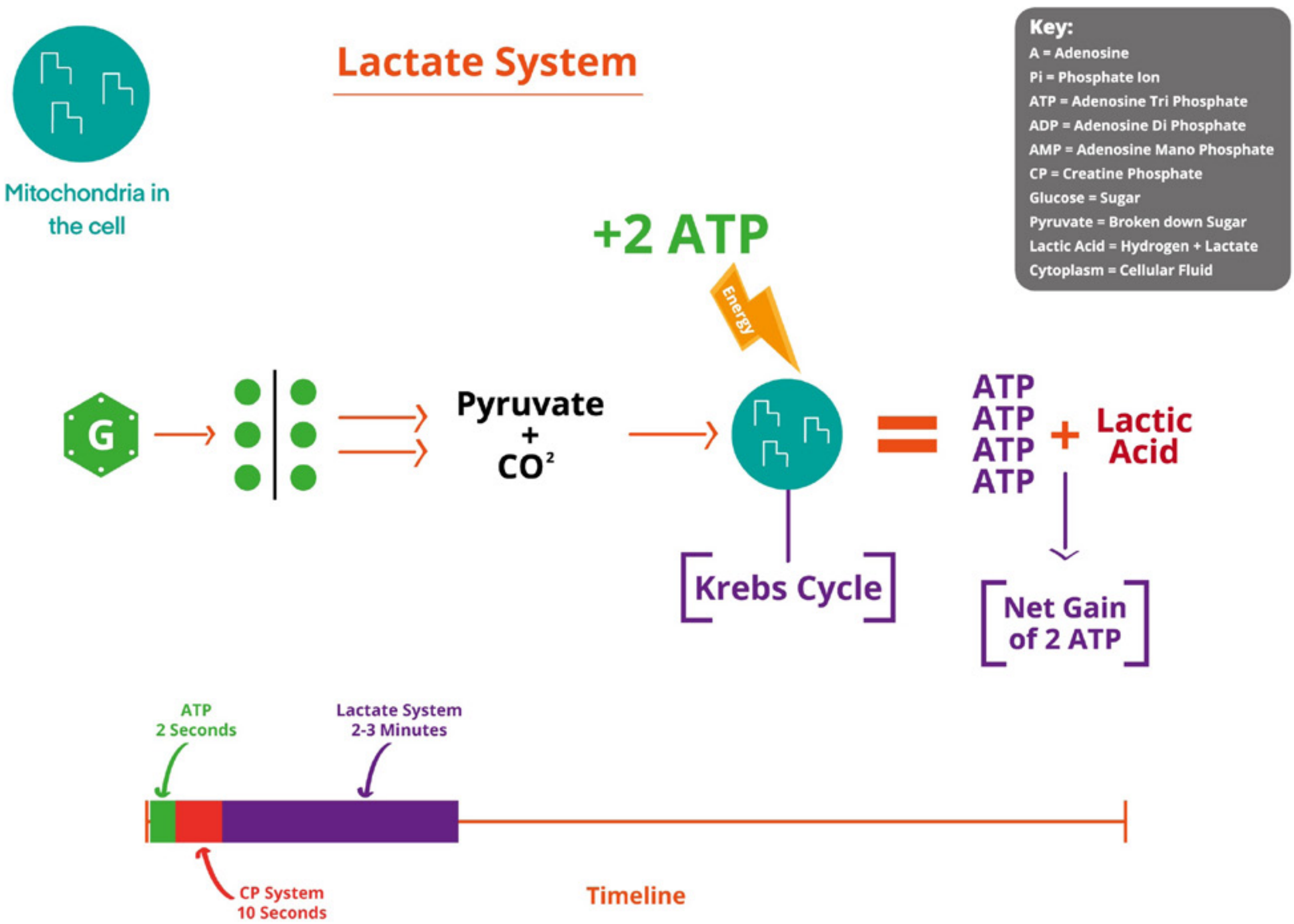
Debate continues, however, as to whether this form of training improves the ability of enzymes within these muscles to generate greater amounts of ATP. To date, there is little research to support this idea. In summary, the principle adaptations associated with training the PC system would appear to be increased muscle size (fast-twitch) and improved activation of the muscle by the nervous system.



Training and the Lactate System

Changes in this system are related to improvements in the cardio-respiratory system and are difficult to describe. Muscles that receive and utilise more oxygen, for example, are going to produce less lactic acid at any given exercise intensity.

It would also appear that regular anaerobic training improves tolerance to the build-up of fatiguing waste products. As of yet, however, researchers can only speculate as to whether this is due to physiological adaptations or is simply the result of motivational changes.



Aerobic System
(Oxidative System)

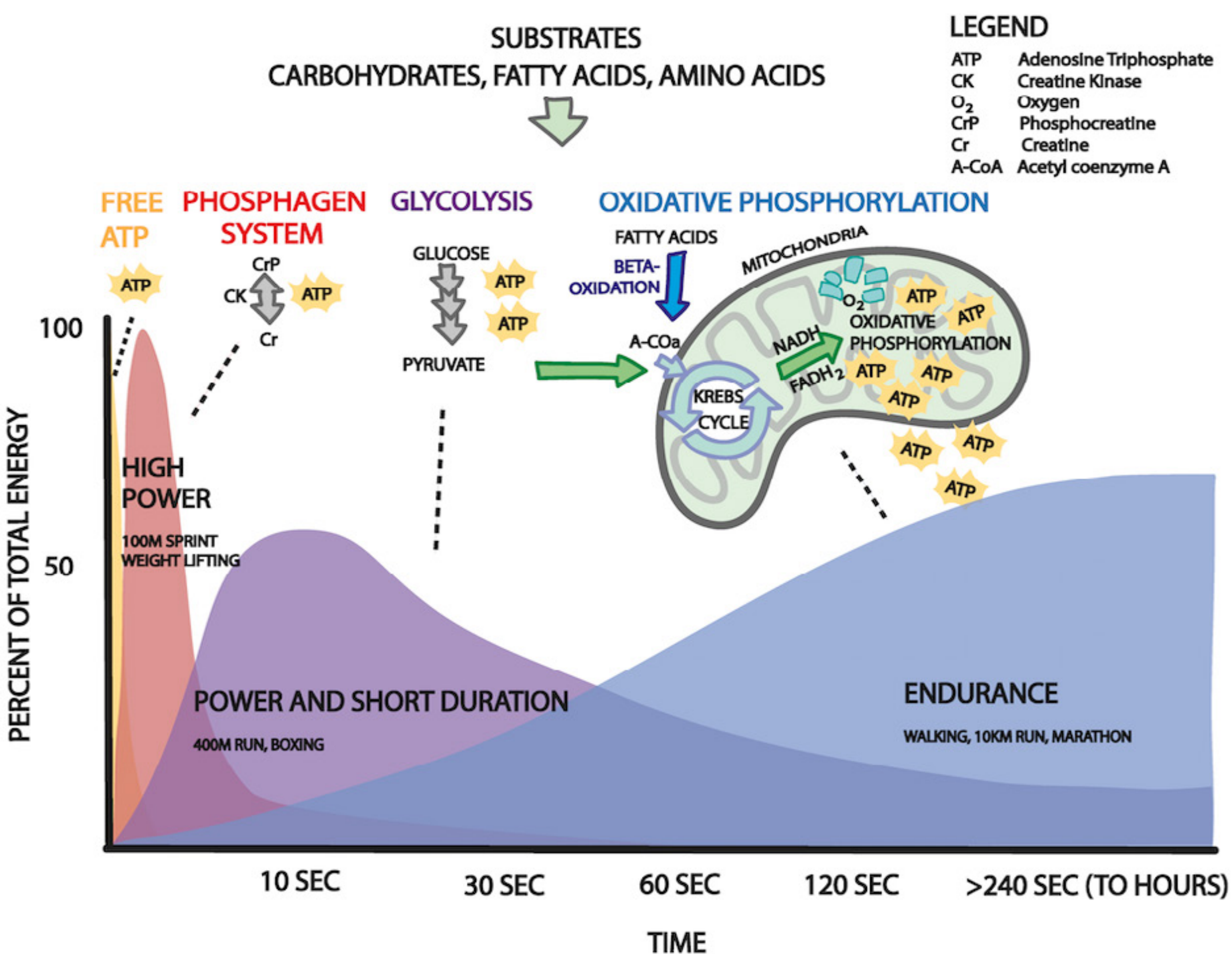
Meaning “with oxygen”, the aerobic or oxidative system produces ATP from the complete breakdown of carbohydrate and fat. The lower the intensity, the more fat is used and the higher the intensity, the more carbohydrate is used. Because both fat and carbohydrate are “burnt” to produce ATP, it is often said that fat burns in the flame of carbohydrate. The aerobic system can only provide meaningful amounts of ATP when oxygen is abundant i.e. at low to moderate levels of intensity such as while at rest or while walking or jogging.

- **Carbon dioxide**
- **Water**
- **Heat**

Different fuel sources produce different amounts of energy. The complete breakdown of one carbohydrate-derived glucose molecule yields 262 kcal (a thousandth of a calorie) while the complete breakdown of one fat-derived molecule of fatty acid will yield 3360 kcals.

However, and despite fat providing much more energy per molecule, carbohydrate is the preferred source of ATP in the body because it is released much more quickly.

All ATP, irrespective of which of the three energy systems is responsible, is produced in cells called mitochondria. Aerobic energy production occurs in the organelles of the mitochondria while anaerobic energy production occurs in the cytoplasm surrounding the mitochondria. Mitochondria are best thought of as cellular power stations and the larger or greater the number of mitochondria present, the higher the potential for energy production.



Oxygen Uptake

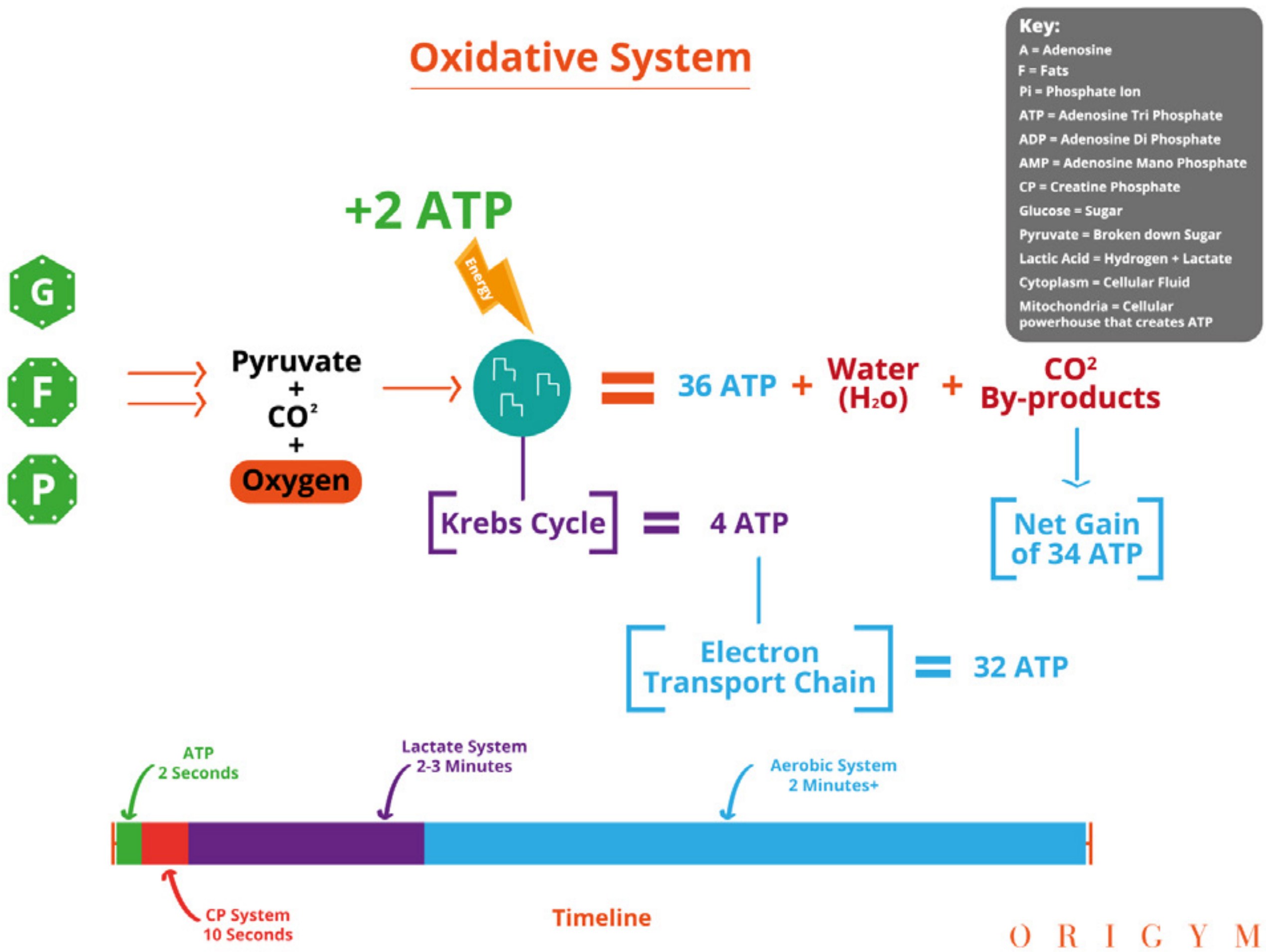
During aerobic activity and during the recovery from anaerobic activity, the cells of the body require oxygen. The aerobic system is essentially the "go-to" energy system as once the anaerobic activity has stopped, the aerobic system is always the system to which your body returns. The use of oxygen by the cells is called oxygen (or O2) uptake or consumption.

At rest, oxygen consumption is approximately 3.5 millilitres per kilogram of body weight per minute (ml/kg/min). This value is also known as one metabolic equivalent or one MET for short. As activity intensity increases, so do does oxygen uptake which is mirrored by an increase in heart and breathing rate.

The maximum amount of oxygen that a person can take in, transport and utilise during exercise is called the VO2 max and is a commonly assessed measure used to identify an exerciser's fitness level as well as predict their performance. The greater the potential for oxygen uptake, the higher the VO2 max, the higher the fitness level of the test subject would be.

However, the person with the highest VO2 max score may not necessarily be the winner of an event or race as things like strategy, lactic acid tolerance, mental toughness, recovery, nutritional status and motivational state all play a part in physical performance.

The physiology of the Aerobic (Oxidative) System

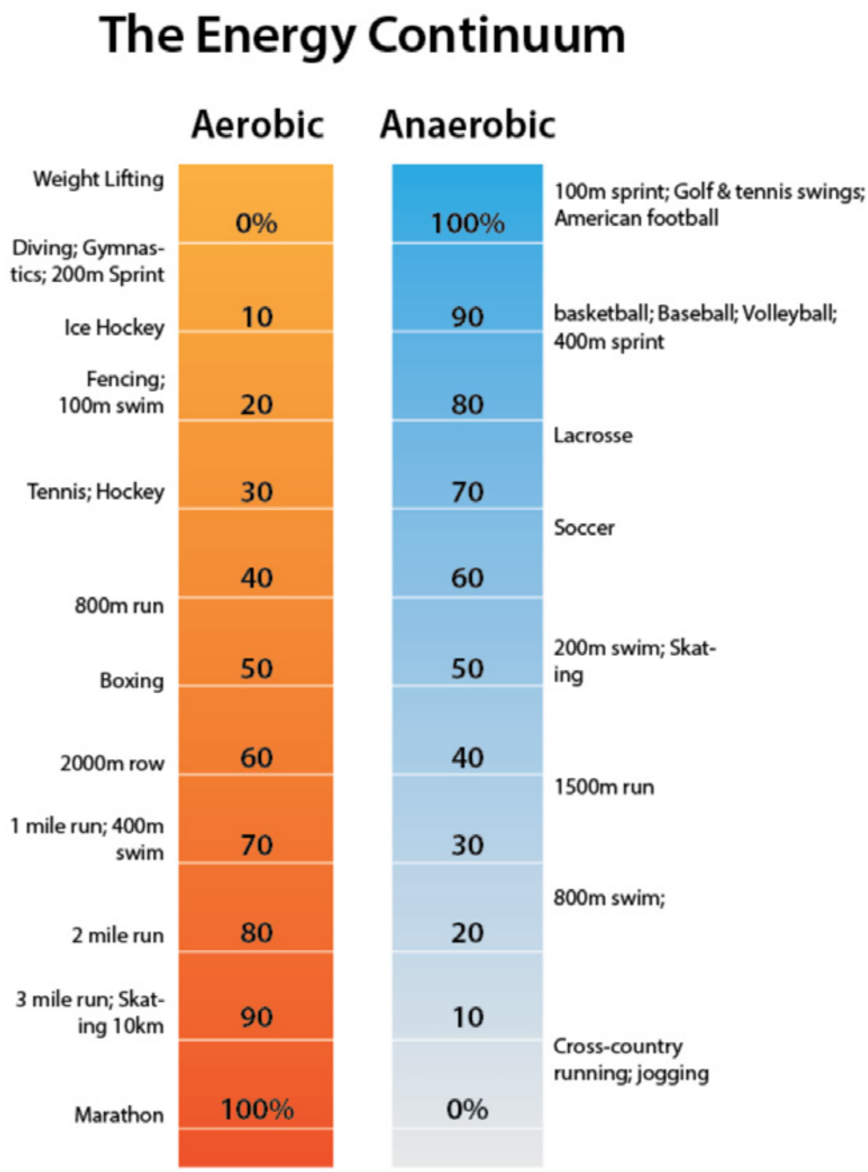


Interaction Between Energy Systems

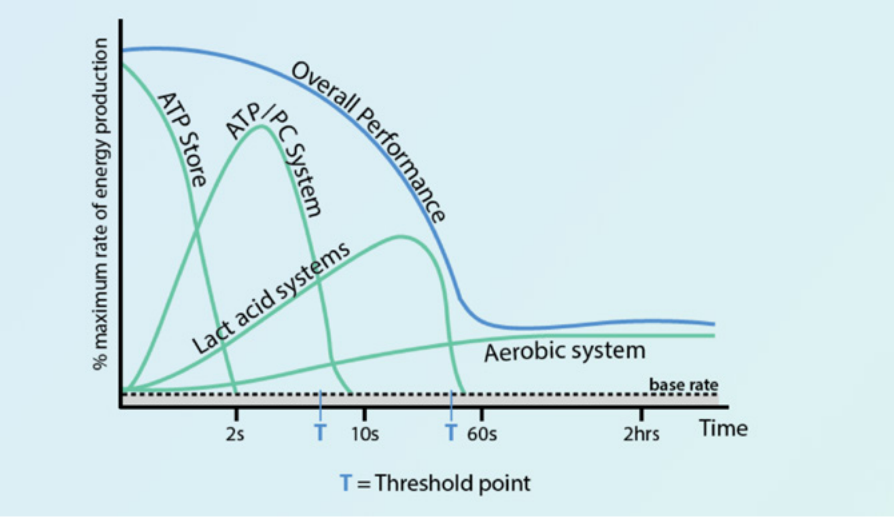
Although the energy systems are presented separately here, it is important to underline that there is considerable overlap between them. In fact, at any one time, all three systems could be providing the body with energy. However, the relative contribution of each is determined by the intensity of the activity.

The Energy Continuum

While it should be remembered that at no point do we use one of the three energy systems in isolation, it is possible to identify which system is most dominant in any given activity. This is useful when designing sports-specific exercise programs for athletes.



Energy System	Fuel	By-Product	Lasts
ATP	N/A	N/A	Up to 3 Seconds
CP System	Creatine Phosphate	N/A	Up to 10 Seconds
Lactate System	Carbohydrates (glycogen/glucose)	Lactic Acid	Up to 3 Minutes
Aerobic (Oxidative) System	Carbohydrates (glycogen/glucose) Fat Protein	Carbon Dioxide Water	From 3 Minutes



In Summary

- The energy systems work together to replenish ATP.
- The 3 energy systems are the Creatine Phosphate, Lactate and Aerobic.
- The energy systems all work together at the same time to keep replenishing ATP. At no point, will only one energy system will be used, but there is often a predominant system.
- The predominant energy system used during exercise will depend on the intensity and duration of the activity and the individual's levels of fitness.
- ATP-PC system is predominantly used during maximum intensity activities lasting no longer than 10 seconds.
- Anaerobic Glycolysis system is predominantly used for high-intensity activities lasting approximately 1 minute.
- The aerobic system is predominantly used during medium to low-intensity activity.
- The predominant energy system being used at rest is the aerobic system.
- The predominant energy system used during exercise will depend on the intensity and duration of the activity and the individual's levels of fitness.
- ATP-PC system is predominantly used during maximum intensity activities lasting no longer than 10 seconds.
- Anaerobic Glycolysis system is predominantly used for high intensity activities lasting approximately 1 minute.
- The aerobic system is predominantly used during medium to low intensity activity.
- The predominant energy system being used at rest is the aerobic system.

Energy Systems and Training Adaptations

Provided the right training stimulus is used, the energy systems show a variety of differing adaptations which ultimately equate to improvements in exercise performance. Many of these adaptations are not fully understood, even today, so for the purpose of simplicity only the principle ones will be discussed below.

Aerobic Training Adaptations

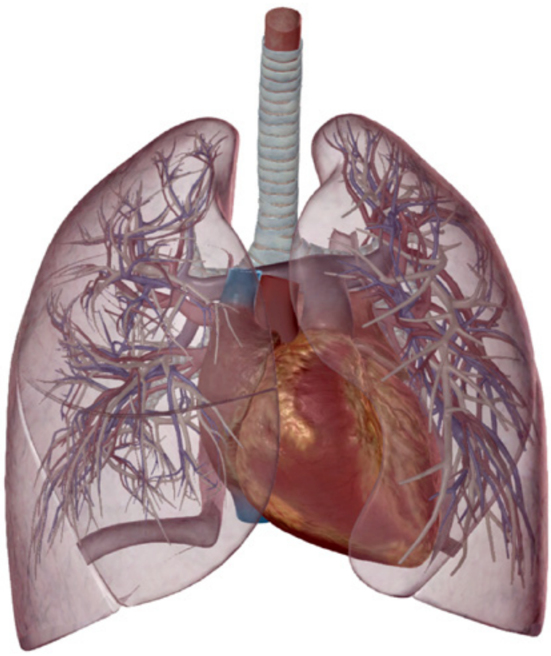
It was discussed earlier that the main limit on aerobic energy production is the ability to take in, transport and utilise oxygen (these will be referred to as pulmonary, cardiovascular and muscular changes respectively).

Aerobic training has been shown to enhance all three of these areas:

PULMONARY CHANGES

Evidence suggests that the principle adaptations associated with the pulmonary system are improvements in the efficiency of the respiratory muscles. This is indicated by an increase in maximal breathing rate and tidal volume (breathing quicker and deeper at maximal intensities).

It is also suggested that more efficient respiratory muscles are likely to use less oxygen, produce fewer waste products and thus potentially increase oxygen availability to other working muscles (McArdle et al, 2001).

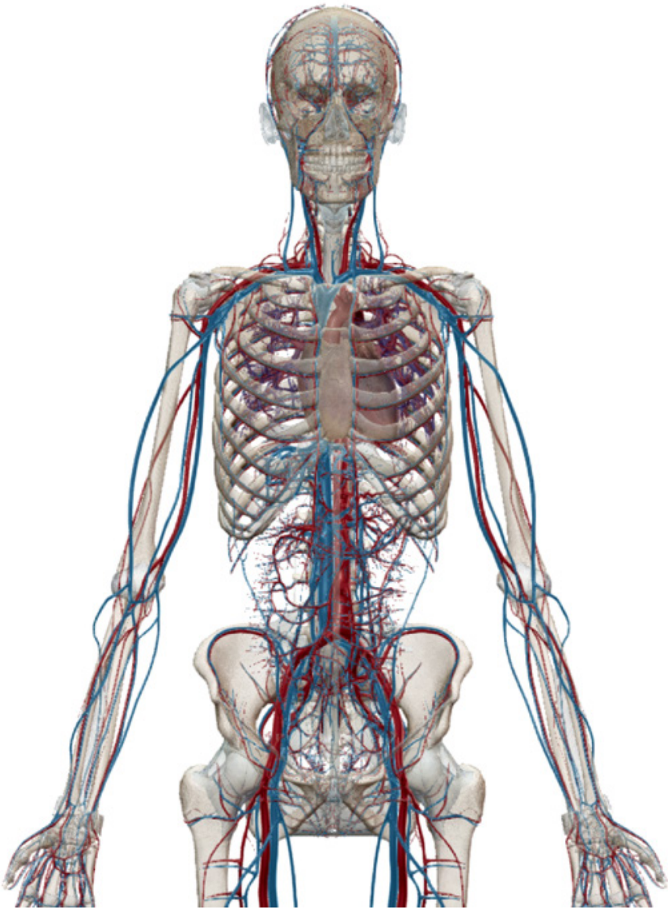


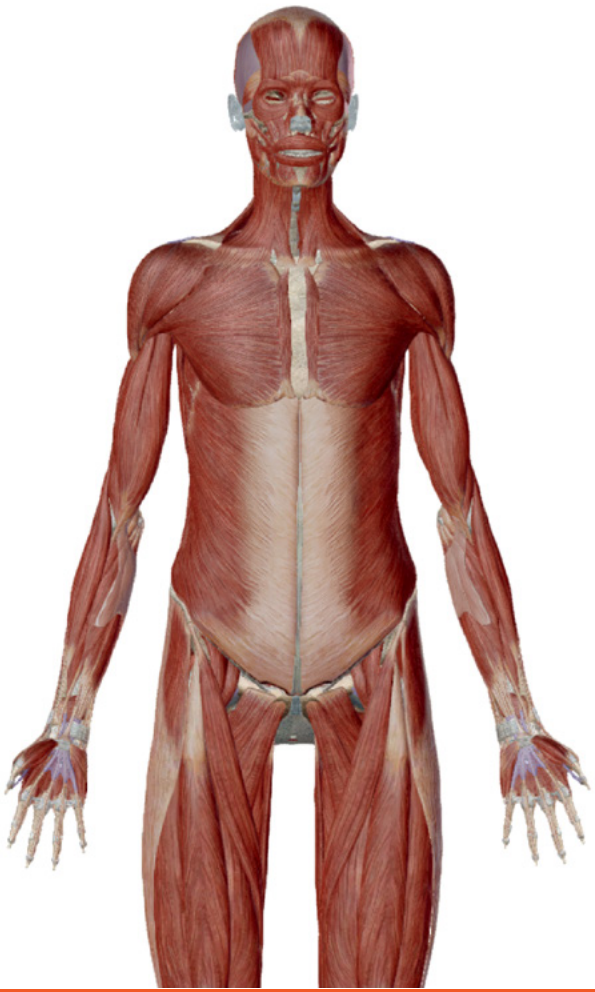
CARDIOVASCULAR CHANGES

There are a number of training adaptations associated with the cardiovascular system. Firstly, the heart of a trained individual shows significant hypertrophy and improvements in coronary blood flow, thus allowing a greater capacity for work.

The most significant coronary adaptation appears to be an increased stroke volume. This is indicated by a lower resting heart rate and a greater cardiac output at maximal heart rates. These improvements are complimented by an increase in blood plasma volume which may also contribute to the increased stroke volume, and oxygen transport (McArdle et al, 2001).

The larger cardiac output of the heart facilitates a greater flow of blood to the working tissues. However, changes in the control of blood distribution, increased arterial diameter and capillary density also serve to maximise blood flow to the muscles.





MUSCULAR CHANGES

Improved blood supply to the active muscles is matched by a greater ability of these muscles to extract and utilise oxygen from the blood. In this respect, one of the key adaptations within the muscles is an increase in size and number of mitochondria. Mitochondria are the structures within the muscle cells, where aerobic ATP production takes place, thus bigger and more numerous mitochondria mean greater ATP production.

Furthermore, within the mitochondria, there are significant increases in the volume of aerobic enzymes, which increases the muscles ability to metabolise (breakdown) fat and carbohydrate.