PHYSIOLOGY OF EXERCISE

Master of Physical Education (M.P.Ed.)
Course Material for Students circulation

Edited by

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MCC103 - PHYSIOLOGY OF EXERCISE

Unit I

Skeletal Muscles and Exercise Macro and Microstructure of the Skeletal Muscle, Chemical Composition. Sliding Filament theory of Muscular Contraction. Types of Muscle Fibre. Muscle Tone, Chemistry of Muscular Contraction Heat Production in the Muscle, Effect of exercises and training on the muscular system.

Unit II

Cardiovascular System and Exercise Heart Valves and Direction of the Blood Flow Conduction System of the Heart Blood Supply to the Heart Cardiac Cycle Stroke Volume Cardiac Output Heart Rate Factors Affecting Heart Rate Cardiac Hypertrophy Effect of exercises and training on the Cardiovascular system.

Unit III

Respiratory System and Exercise Mechanics of Breathing Respiratory Muscles, Minute Ventilation at Rest and During Exercise. Diffusion of Gases Exchange of Gases in the Lungs ~Exchange of Gases in the Tissues Control of Ventilation and the Anaerobic Threshold. Oxygen Debt Lung Volumes and Capacities Effect of exercises and training on the respiratory system.

Unit IV

Metabolism and Energy Transfer Metabolism ATP PC or Phosphagen System Anaerobic Metabolism Aerobic Metabolism Aerobic and Anaerobic Systems during Rest and Exercise. Short Duration High Intensity Exercises High Intensity Exercise Lasting Several Minutes Long Duration Exercises.

Unit V

Climatic conditions and sports performance and ergogenic aids Variation in Temperature and Humidity Thermoregulation Sports performance in hot climate. Cool Climate, high altitude. Influence of: Amphetamine, Anabolic steroids, Androstenedione, Beta Blocker, Choline, Creatine, Human growth hormone on sports performance. Narcotic, Stimulants: Caffeine, Ephedrine, Stimulants, and sports performance.

REFERENCE BOOKS:

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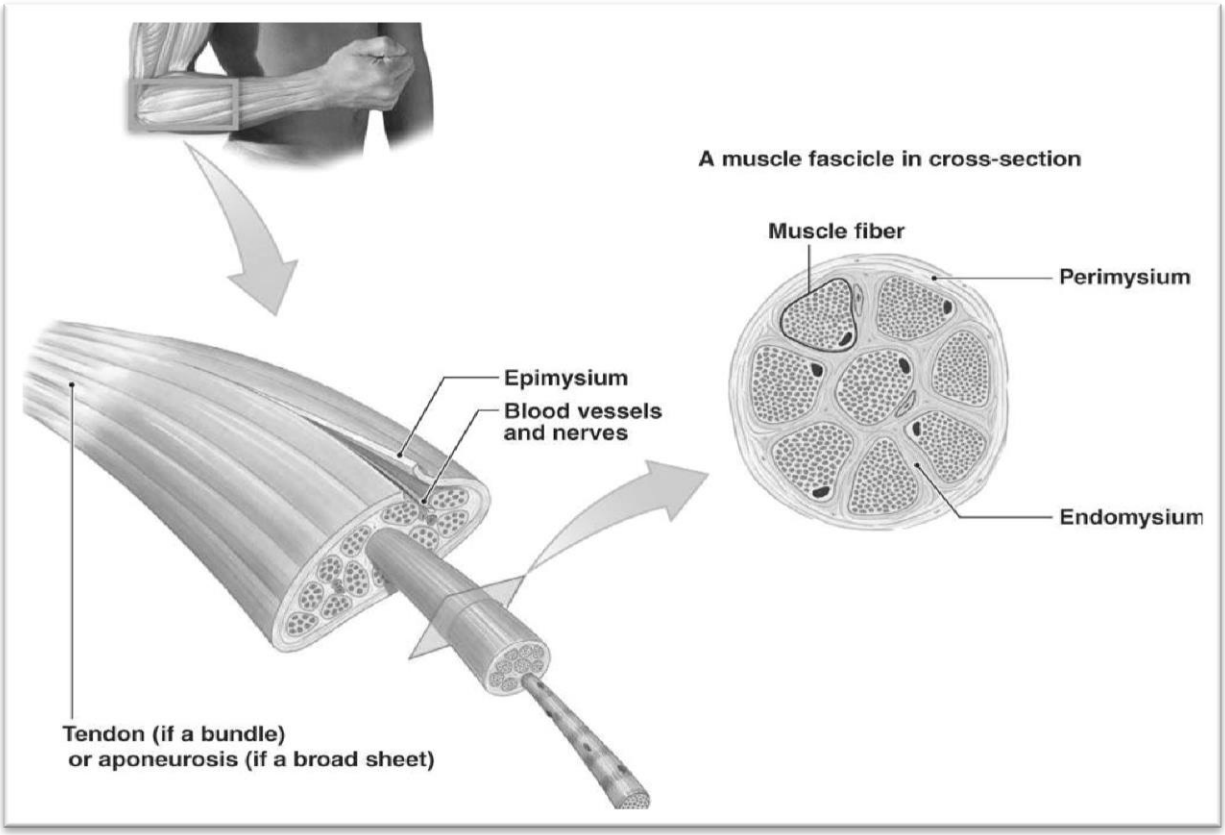
UNIT I - SPORTS PHYSIOLOGY

SKELETON MUSCLES

- Gross Anatomy: Muscle is divided into groups of muscle Fibers called **fascicles**; muscle Fibers, in turn, are divided into contractile units called **myofibrils** containing the contractile proteins actin and myosin.
- Muscle uses high amounts of energy (ATP) and gives off large amounts of waste,therefore it is necessary to be highly vascularized to remove excessive waste.
- Connective tissue covers each subdivision of muscle:
  - **Epimysium** - covers the entire muscle
  - **Perimysium** - covers each fascicle
  - **Endomysium** - covers each muscle Fiber

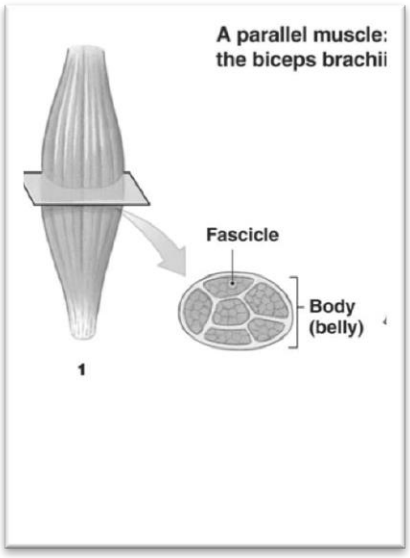


- Muscle also contains nerve Fibers and blood vessels between the connective tissue septa (divisions) into the endomysium
- Muscle spans joints and attach to bones at two points: the movable bone (**insertion**)toward the less movable (**origin**
- Muscle may be classified according to attachment and fascicle arrangement:

Types of muscle attachments: direct and indirect

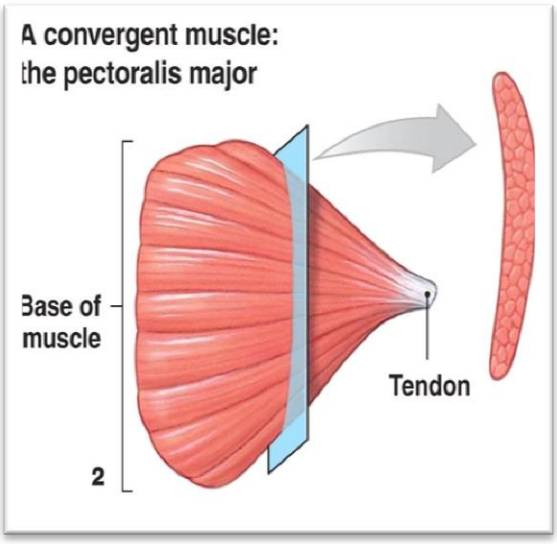
- Direct (**tendon**) - epimysium of muscle fused to periosteum of bone or perichondrium of cartilage.

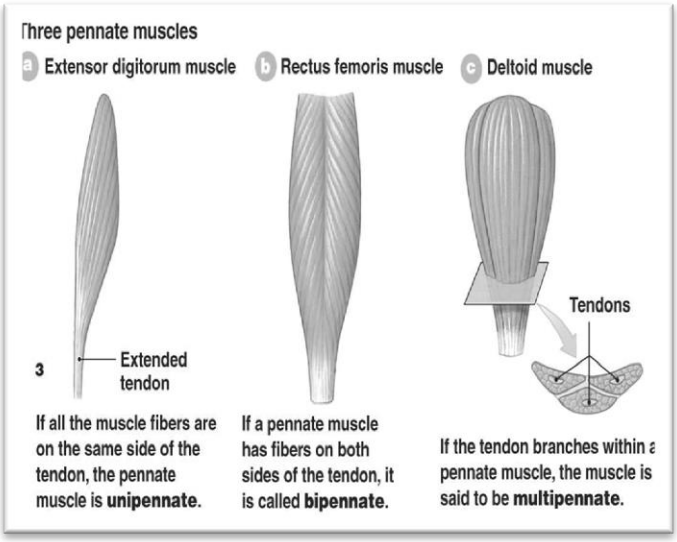
- Indirect (**aponeurosis**) - muscle fascia extends beyond the muscle to boneor another muscle.
- **Parallel** - long axis of fascicle runs with longitudinal axis of muscle ex:stylohyoid muscle



Types of fascicle arrangement:

1. **Pennate** - fascicle branch form central tendon diagonally **Unipennate** - extensormuscles **Bipennate** - rectus femoris **Multipennate** – deltoid
2. **Convergent** - fascicle converge toward a single tendon ex: pectoralis major
3. **Circular** - fascicle are arranged in concentric rings ex: orbicularis orris and oculi





- **Microanatomy**

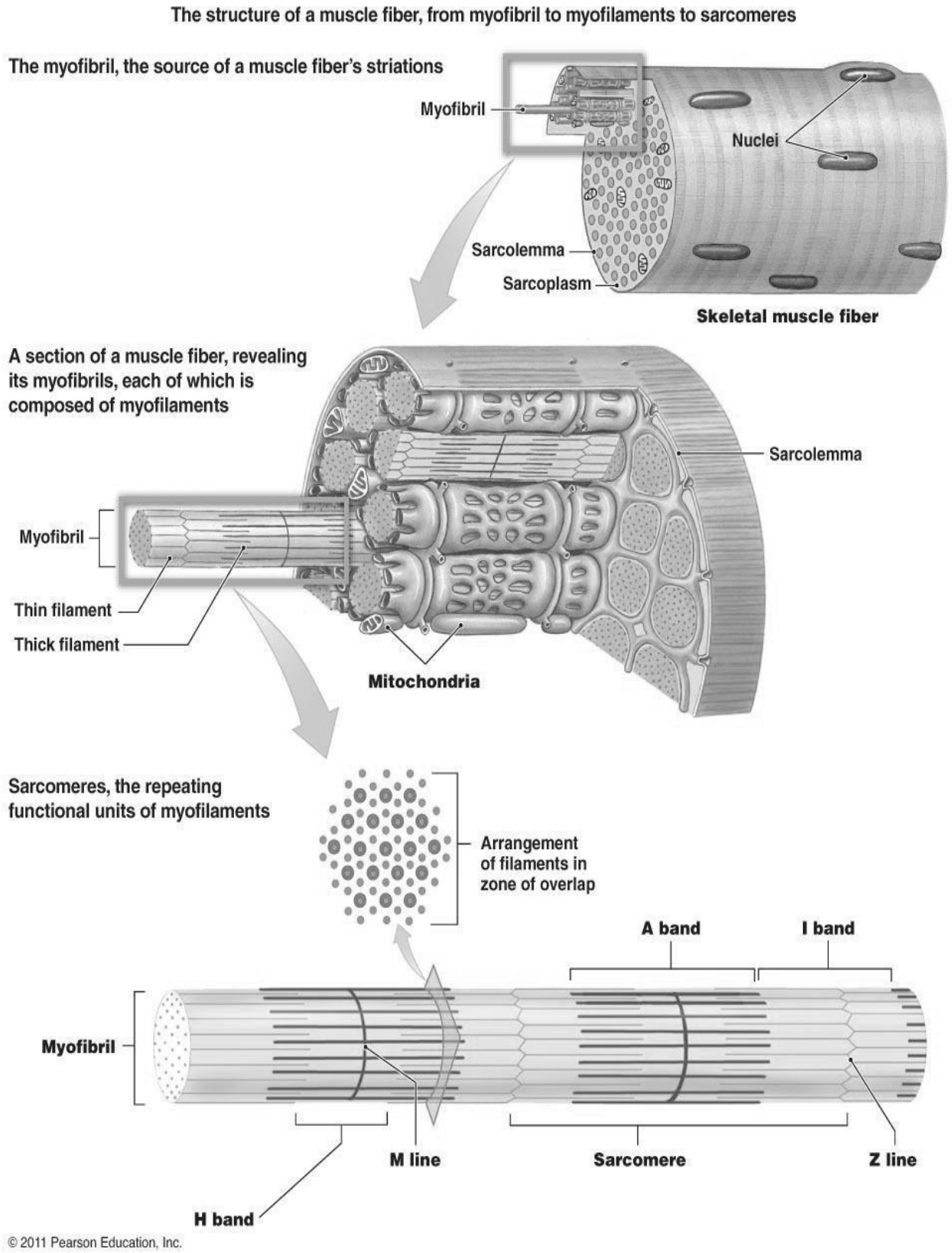
Myoblasts fuse together to form a **syncytium** (union of cells)

Each muscle cell is called a muscle Fiber because of its elongated shape

Muscle cell components:

- **Sarcolemma** - plasma membrane
- **Sarcoplasm** - cytoplasm (contains glycogen and myoglobin and higher concentration of mitochondria)
- **Sarcoplasmic reticulum** - smooth ER forming interconnecting tubulessurrounding myofibrils
- **Transverse (T) tubules** - tubules running between sarcoplasmic reticulum and penetrating deeply into cell; aids in conducting "stimulus" into cell
- **Terminal cisternae** - terminal portions of sarcoplasmic reticulum adjacent totransverse tubules
- **Triads** - sarcoplasmic reticulum, T tubules, terminal cisternae

- Muscle Fibers are composed of the myofibrils which are subdivided into contractile unitscalled **sarcomeres.** Each sarcomere is composed of light and dark bands (striations) as a result of alternating the composition of actin (thin filaments) and myosin (thick filaments)

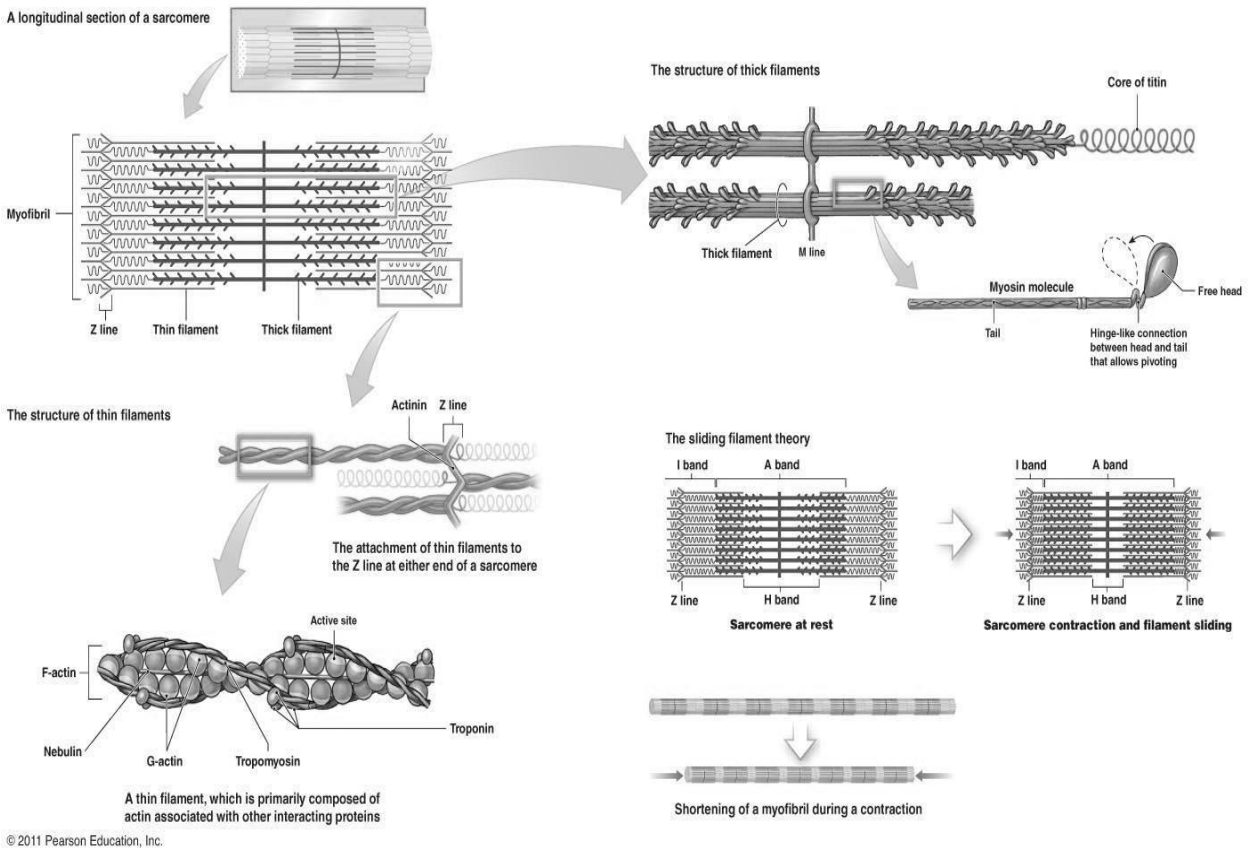


- The dark bands, called **A bands**, result from the proteins' ability to polarize light(anisotropic) and light bands, called **I bands**, result from the proteins' inability topolarize light (isotropic).
- Thick filaments extend the entire length of the A band and thin filaments extendacross the I band and partly into the A band.

Sarcomere Structure

Adjacent thick filaments are connected by myosin protein which forms the **Mline**.

Thin filaments are connected to each other in an alternating or zig-zagging structure called the **Z line**. Each A band has a light strip in its midsection called the **H zone**



Ultrastructure of myofibril myofilaments:

- **Thick filaments** - **Myosin** protein with heads (cross bridges) and tail; heads interact with special active sites on thin filaments (heads contain ATPases thatenzymatically split ATP)
- **Thin filaments** - **Actin** protein made up of many protein subunits called globular actin (**G actin**); each G actin has an active site that binds myosin heads during contraction; G actin units are polymerized into a **F actin**; two F actins make up the thin filament (actin); surrounding the F actin is two regulatory proteins called **tropomyosin** and **troponin**; tropomyosin spirals around and stiffens the F actin; troponin contains three subunits, TNi (binds actin), TNt (binds tropomyosin), and TNc (binds calcium).

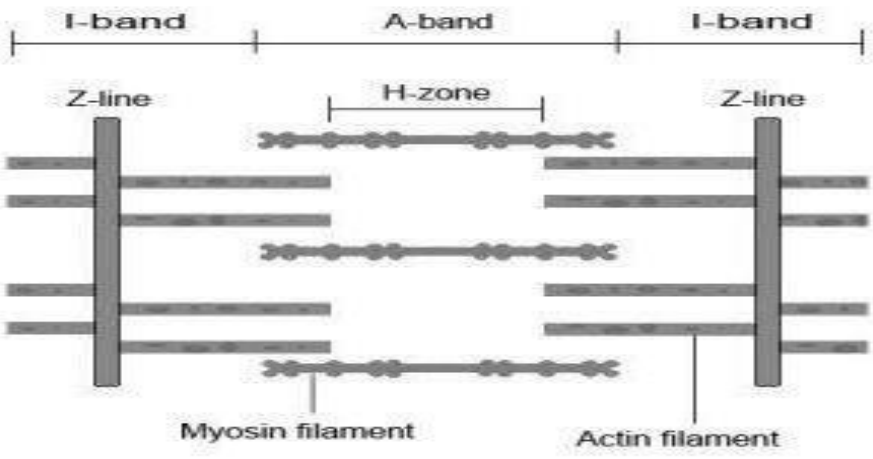
Chemical composition of skeletal muscle: Contains 75% water and 20% protein, with remaining 5% comprising inorganic and high energy phosphates, urea, lactate, calcium, magnesium and phosphorous, enzymes and pigments. Sodium potassium and chloride ions and amino acids, fats and carbohydrates.

Contraction of a Skeletal Muscle Fiber: During the process of contraction, sarcomeres shorten and the distance between Z lines isreduced

Steps in contraction:

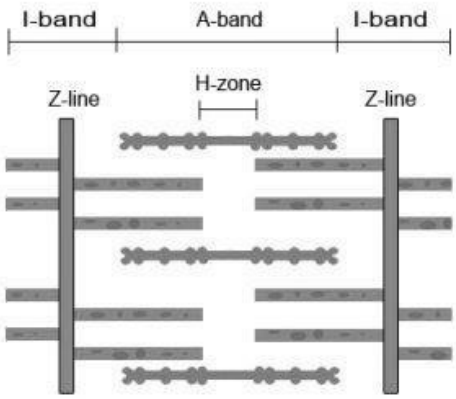
- Attachment of myosin cross bridges is inhibited by troponin which covers the active sites on G actin. The binding of calcium ions to troponin causes troponin tochange shape and move so that the active sites on actin are not covered (thus allowing myosin heads to bind to active sites). Calcium ion concentration is regulated by the extent of "stimulus" sent via nerve impulses.
- Once binding sites are exposed.... Myosin head with high-energy configuration attaches to the actin
- The myosin head pivots and bend as it pulls on the actin filament, sliding it towards the midline
- As new ATP attaches to the myosin head with a low-energy configuration, themyosin head detaches from the actin
- ATP is split and the bond energy is transferred to the myosin head to move it uptowards the actin to start the process again
- Muscle contraction may occur as a result of recruitment. The various motor neurons to a whole muscle fire asynchronously. While some motor units are active others are inactive. This pattern of activity prevents muscle fatigue and produces smooth movements.
- Sliding filament theory of muscular contraction

Stretched Muscle: A stretched muscle where the I - bands and the H - zone is elongated due to reduced overlapping of the myosin and actin filaments. There would be reduced muscle strength because few cross bridges can form between theactin and myosin.



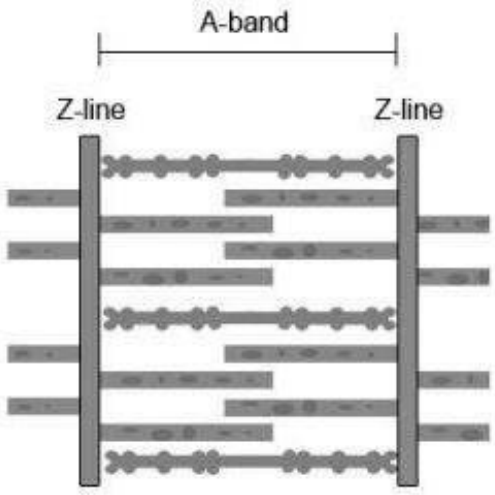
Partially Contracted Muscle

The diagram above shows a partially contracted muscle where there is more overlapping of the myosin and actin with lots of potential for cross bridges to form. The I - bands and H - zone are shortened.

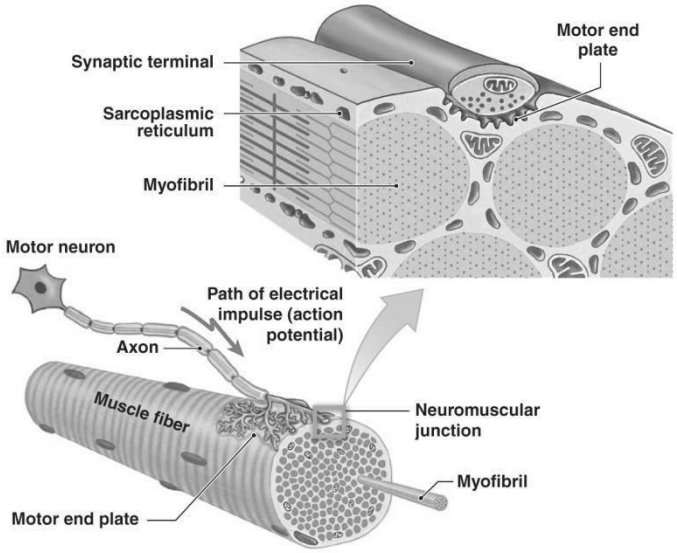


Fully Contracted Muscle

The diagram above shows a fully contracted muscle with lots of overlap between the actin and myosin. Because the thin actin filaments have overlapped there is a reduced potential for cross bridges to form again. Therefore there will be low force productionfrom the muscle.



Neuromuscular Junction and **Nerve Stimulus** Motor neuron's cellular extensions (axonterminals) form a branching neuromuscular junction with a single muscle Fiber (usually at centre of Fiber). When the nerve impulse reaches the end of the axon, calcium channels open in axon membrane, causing vesicles to fuse with axon membrane releasing the neurotransmitter **Acetylcholine** (ACh) into synaptic cleft by exocytosis. Acetylcholine diffuses across the cleft and attaches to receptors the sarcolemma, leading to an **action potential**.



The structural relationship between a skeletal muscle fiber and its lone neuromuscular junction

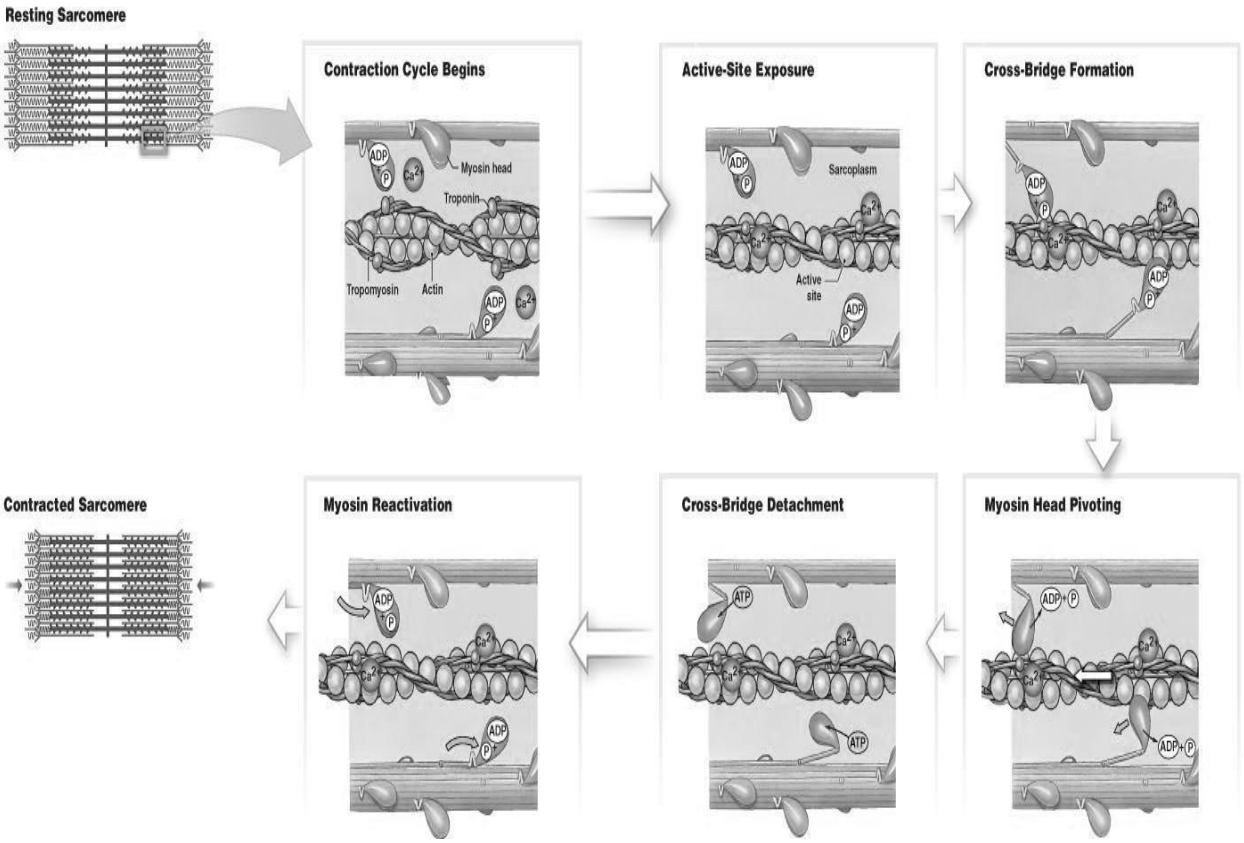
Generation of an Action Potential (sequence of electrical changes in the sarcolemma). The resting sarcolemma is **polarized** (difference in ionic charge across the membrane, slightly negative inside). ACh attaches to receptors on the sarcolemma, causing **depolarization** -- ion gates to open and changing sarcolemma permeability locally. Depolarization then propagates to adjacent portions of the membrane changing permeability in successive and unidirectional waves. Immediately after depolarization, ion gates close (**repolarization**) thereby completing the depolarization wave. During repolarization, muscle fibers are in a **refractory period** when they are insensitive to further stimulation until repolarization is complete. Action potentials are considered an **allor none response** because once initiated, they are unstoppable.

Regulation of factors involved in action potentials

- Acetylcholine destruction - an enzyme, **acetylcholinesterase**, is located in the sarcolemma and destroys/degrades acetylcholine to close the ion gate (repolarization).
- Removal of neurotransmitter form synaptic cleft
- Diffusion out of cleft
- Enzymatic degradation (acetylcholinesterase)
- Uptake into cells
- Calcium ion concentration regulation - **calsequestrin** and **calmodulin** - proteins that can bind calcium and return to the sarcoplasmic reticulum
- **Excitation-Contraction Coupling** Action potential travels along axon until axon terminal; here ACh is released causing depolarization of the motor end plate; action potential propagates along sarcolemma down T tubules.
- Action potential triggers Ca^{++} release from terminal cisternae of sarcoplasmic reticulum

(calcium ion gates open).

- Calcium ions bind to troponin causing troponin to change shape and expose actin activesites.
- Contraction occurs
- Calcium levels decrease (due to change in permeability) and tropomyosin blockage isrestored.

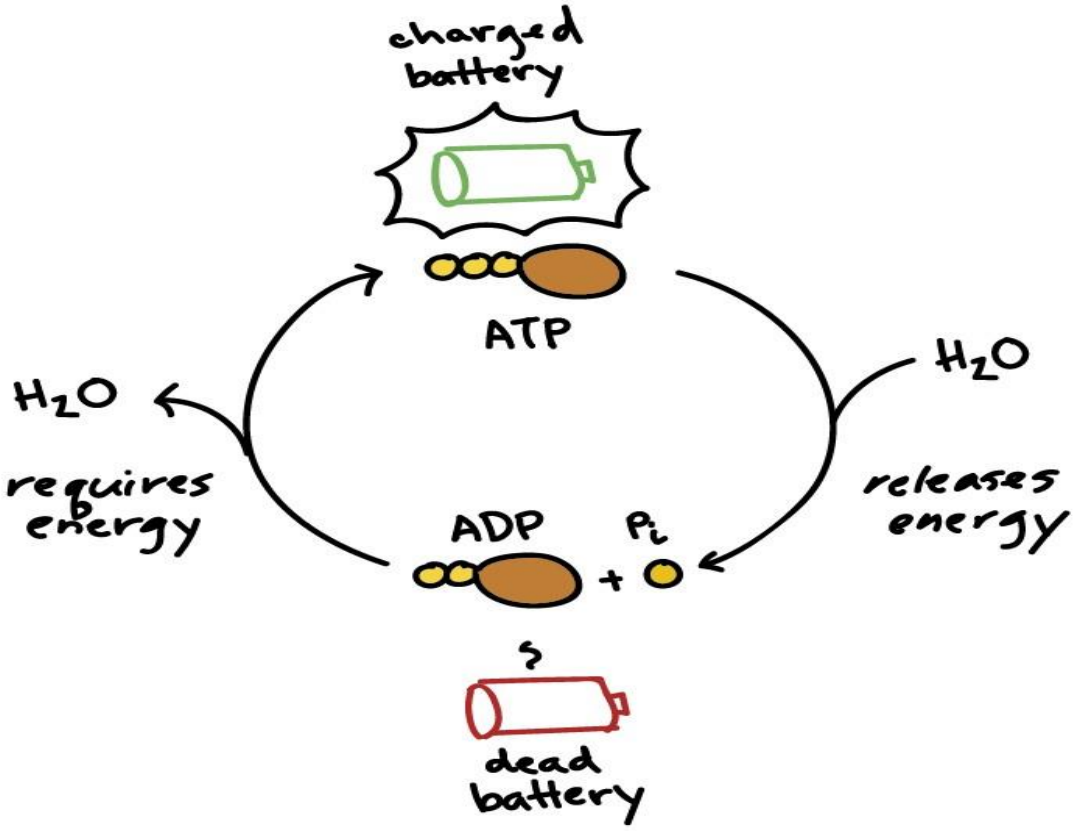


Skeletal Muscle Fibers: The 3 types of skeletal muscle fibers: **Red / Slow (Type I fibres, 'slow** twitch fibres')**Red / Fast (**Type II a **fibres, 'fast oxidative fibres') White / Fast (**Type II b **fibres,** 'Fast **glycolytic** fibres')

	Type I fibers	Type II a fibers	Type II b fibers
Contraction time	Slow	Moderately Fast	Very fast
Size of motor neuron	Small	Medium	Very large
Resistance to fatigue	High	Fairly high	Low
Activity Used for	Aerobic	Long-term anaerobic	Short-term anaerobic
Maximum duration of use	Hours	<30 minutes	<1 minute
Power produced	Low	Medium	Very high
Mitochondrial density	High	High	Low
Capillary density	High	Intermediate	Low
Oxidative capacity	High	High	Low
Glycolytic capacity	Low	High	High
Major storage fuel	Triglycerides	Creatine phosphate, glycogen	Creatine phosphate, glycoge

Muscle Tone: Muscle tone (residual muscle tension **or** tonus**) is the continuous and passive partial contraction of the** muscles**, or the muscle's resistance to passive stretch during** resting state.[1] **It helps maintain posture**

Chemistry of muscular contraction: The contraction **of skeletal** muscles **is an energy-requiring process. In order to perform the mechanical work of** contraction**, actin and myosin utilize the** chemical **energy of themolecule adenosine triphosphate (ATP).**



Heat production in the muscle: Muscle **contractions** produce heat **and as much as 70% of body** heat **is** produced **by energy** produced **in** muscle **tissue. Blood is an essential element in temperature control during exercise, taking** heat **from the body core and working** muscles **and redirecting itto the skin when the body is overheating.**

Maintenance heat source

- Slow liberation of heat via resting muscle
- Unrelated to contraction, “background heat”
- Initial Heat Liberated during contraction
- Byproduct of chemistry of contractile process
    - Activation heat, A: related to excitation-contraction coupling
    - Shortening heat, as: related to shortening of muscle

  - Tension-time heat, f(P, t): related to cross-bridge turnover during time when muscle is maintaining tension
- Recover heat – heat generated at end of contraction
  - Largely aerobic
  - Related primarily to oxidation of lactate
  - Liberated during relaxation (if muscle can relax without bearing load)
  - Degradation of potential energy of lifted load into heat (i.e. no longer bearing load)

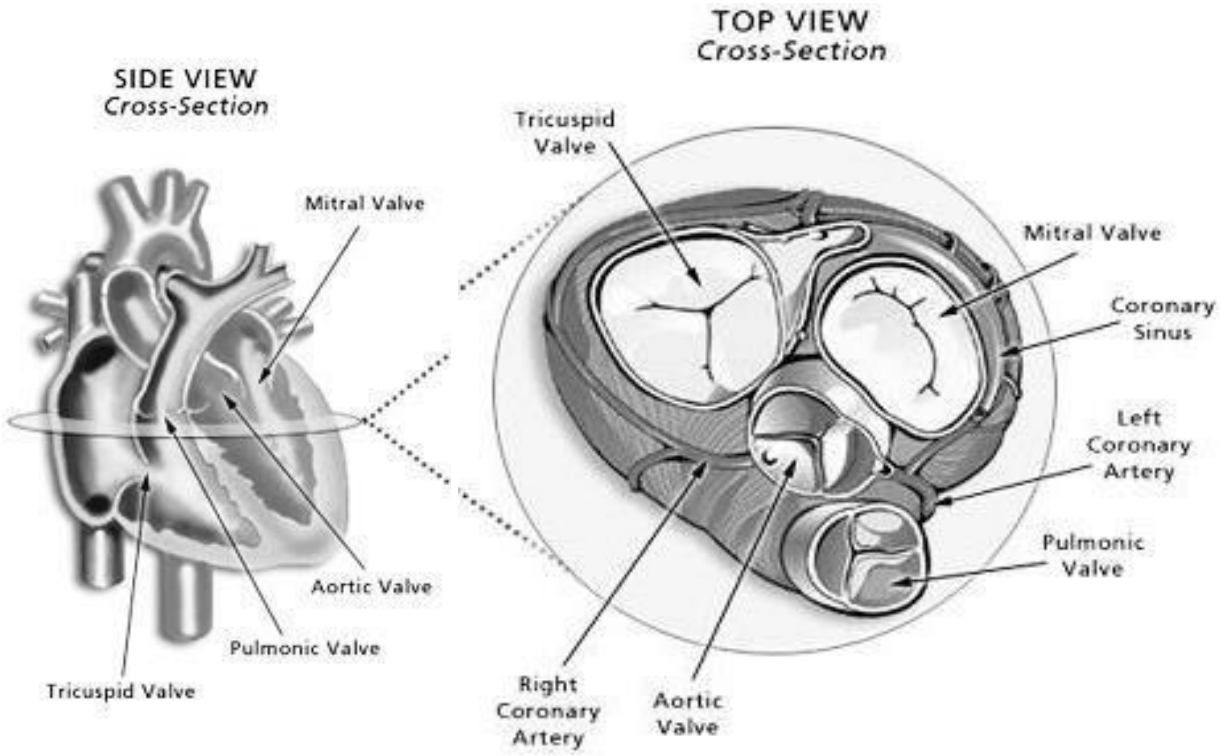
Unit II - CARDIOVASCULAR SYSTEM

Heart valves and blood flow:

The heart has 4 valves:

- The mitral valve and tricuspid valve, which control blood flow from the atria to theventricles.
- The aortic valve and pulmonary valve, which control blood flow out of the ventricles
- The atria are the receiving chambers of the heart, receiving blood flowing back to the heart.
- The ventricles are the chambers of the heart that pump the blood out of the heart.

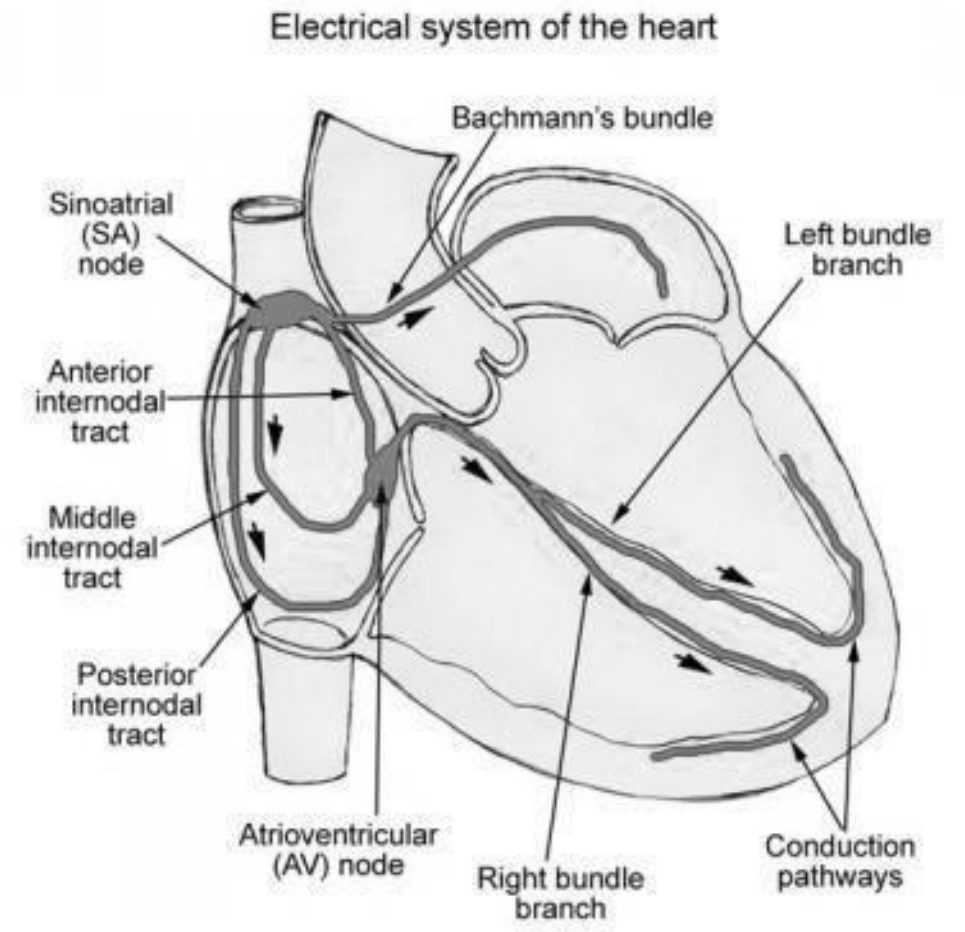
The valves of the heart are located within the chambers of the heart and are critical to theproper flow of blood through the heart. All of the valves, when functioning normally, act as one-way valves, allowing blood toflow either from one chamber to another, or allowing blood to flow out of the heart, in only one direction. The valves control the flow of blood through the heart by opening and closing during thecontractions of the heart.



Conduction system of the heart:

- The conducting system of the heart consists of cardiac muscle cells and conducting Fibers (not nervous tissue) that are specialized for initiating impulses and conducting them rapidly through the heart (see the image below). They initiate the normal cardiac cycle and coordinate the contractions of cardiac chambers. Both atria contract together, as do the ventricles, but atrial contraction occurs first.

- The conducting system provides the heart its automatic rhythmic beat. For the heart to pump efficiently and the systemic and pulmonary circulations to operate in synchrony, the events in the cardiac cycle must be coordinated



Blood supply to the heart:

The aorta (the main **blood** supplier to the body) branches off into two main coronary **blood** vessels (also called arteries). These coronary arteries branch off into smaller arteries, which **supply** oxygen-rich **blood** to the entire **heart** muscle. The rightcoronary artery **supplies blood** mainly to the right side of the **heart**.

Cardiac cycle:

The **cardiac cycle** refers to the sequence of mechanical and electrical events that repeats with every heartbeat. It includes the phase of relaxation diastole and the phase of contraction systole.

The period of time that begins with contraction of the atria and ends with ventricular relaxation is known as the **cardiac cycle**. The period of contraction that the heart undergoes while it pumps blood into circulation is called **systole**. The period of relaxationthat occurs as the chambers fill with blood is called **diastole**.

Atrial Systole and Diastole

Contraction of the atria follows depolarization, represented by the P wave of the ECG. Asthe atrial muscles contract from the superior portion of the atria toward the atrioventricular septum, pressure rises within the atria and blood is pumped into the ventricles through the open atrioventricular (tricuspid, and mitral or bicuspid) valves. At the start of atrial systole, the ventricles are normally filled with approximately 70–80 percent of their capacity due to inflow during diastole. Atrial contraction, also referred to as the "atrial kick," contributes the remaining 20–30 percent of filling. Atrial systole lastsapproximately 100 Ms and ends prior to ventricular systole, as the atrial muscle returns todiastole.

Ventricular Systole: It follows the depolarization of the ventricles and is represented by the QRS complex in the ECG. It may be conveniently divided into two phases, lasting a total of 270 Ms. At the end of atrial systole and just prior to atrial contraction; the ventricles contain approximately 130 mL blood in a resting adult in a standing position. This volume is known as the end diastolic volume (EDV) or preload.

Ventricular Diastole: Ventricular relaxation, or diastole, follows repolarization of the ventricles and is represented by the T wave of the ECG. It too is divided into two distinct phases and lasts approximately 430 Ms.

Stroke volume: The amount of blood pumped by the left ventricle of the heart in one contraction. The **stroke volume** is not all the blood contained in the left ventricle; normally, only about two-thirds of the blood in the ventricle is expelled with each beat.

Cardiac output: The **cardiac output** is simply the amount of blood pumped by the heart per minute. Necessarily, the **cardiac output** is the product of the heart rate, which is the number of beats per minute, and the stroke volume, which is amount pumped per beat. CO = HR X SV. The **cardiac output** is usually expressed in Liters/minute.

Heart rate is the speed of the heartbeat measured by the number of contractions ofthe heart per minute (bpm). The heart rate can vary according to the body's physical needs, including the need to absorb oxygen and excrete carbon dioxide. Itis usually equal or close to the pulse measured at any peripheral point. Activities that can provoke change include physical exercise, sleep, anxiety, stress, illness, and ingestion of drugs.

Factors affecting heart rate:

- Fitness Level

- Biological Variability
- Acute Fatigue & Cardiovascular Drift
- Emotional State
- Music
- Chronic Fatigue/Overtraining:
- Sex
- Environment
- Site of Muscular Activity
- Body Position
- Air temperature
- Body size
- Medication use:

Cardiac hypertrophy

- Cardiac hypertrophy is a thickening of the heart muscle (myocardium)
- Cardiac hypertrophy - the heart increases in size and volume. The wall of the left ventricle getsthicker which can increase the force of contraction.
- Stroke volume - at rest stoke volume has been shown to be significantly higher after an aerobic training programme. The heart can therefore pump more blood per minute, increasing cardiac output during maximal levels of exercise. Blood flow increases because of an increasein size and number of blood vessels. This allows for a more efficient delivery of oxygen and nutrients.

Effect of exercise on cardiovascular system:

- Cardiac output – during exercise cardiac output increases as a result of the increase in heart rate and stroke volume. Stroke volume doses do not increase significantly beyond lower intensity work rates so the increase in cardiac output at higher level is achieved through increases in heart rate. As stroke volume increases as result of training this will give a subsequent increase in the cardiac output.
- Resting heart rate – these decreases after aerobic endurance training as a result of the increased resting stroke volume the heart does not have to beat as fast at rest.
- Capillarisation - long term exercise can lead to the development of the capillary network to a part of the body. Aerobic exercise can increase the number of capillaries. As a result of this blood flow to the muscle will increase which will give a more efficient delivery ofoxygen and nutrients.
- Increase in blood volume – blood volume represents the amount of blood circulating in the body and varies from person to person and can increase as a result of training.

Capillarisation is the cause of the increase.

- Resting blood pressure – exercise increases blood pressure during the activity but it returns to normal afterwards. The quicker it does this the more aerobically fit you are likely to be. Research suggests that regular exercise can decrease resting blood pressure however this is only in hypertensive people.
- Decreased recovery time - heart rate recovery is a measure of how much your rate falls during the first minute after exercise. The fitter you are the quicker the heart rate will return to normal.

Unit III - RESPIRATORY SYSTEM

MECHANICS OF BREATHING:

- The mechanics of breathing follow Boyle's Law which states that pressure and volume have an inverse relationship.
- The process of inhalation occurs due to an increase in the lung volume (diaphragm contraction and chest wall expansion) which results in a decrease in lung pressure in comparison to the atmosphere; thus, air rushes in the airway.
- The process of exhalation occurs due to elastic recoil of the lung tissue which causes a decrease in volume, resulting in increased pressure in comparison to the atmosphere; thus, air rushes out of the airway.
- There is no contraction of muscles during exhalation; it is considered a passive process.
- The lung is protected by layers of tissue referred to as the visceral pleura and parietal pleura; the intrapleural space contains a small amount of fluid that protects the tissue by reducing friction.
- Parietal pleura the portion of the protective tissue that lines the inner surface of the chest wall and covers the diaphragm visceral pleura the portion of protective tissue that is attached directly to the lungs
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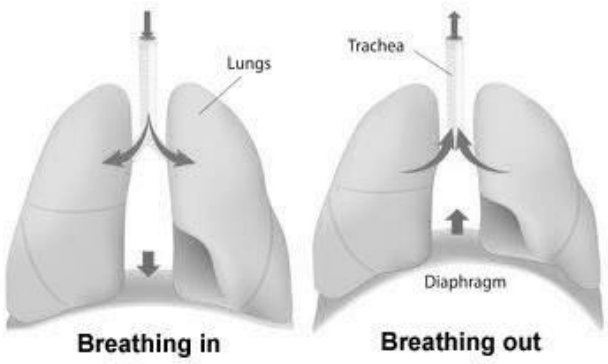
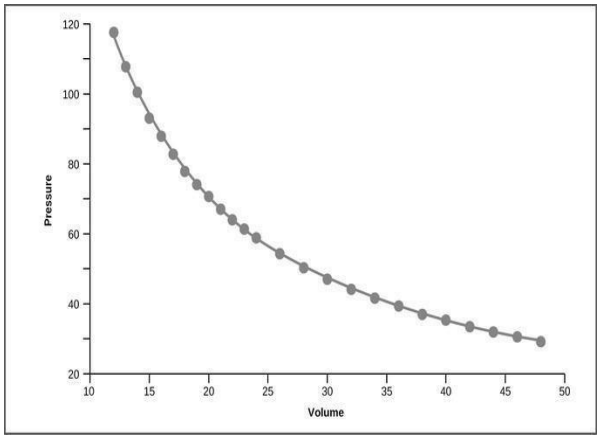
    - Parietal pleura: The portion of the protective tissue that lines the inner surface of the chest wall and coversthe diaphragm.
    - Visceral pleura: the portion of protective tissue that is attached directly to the lungs



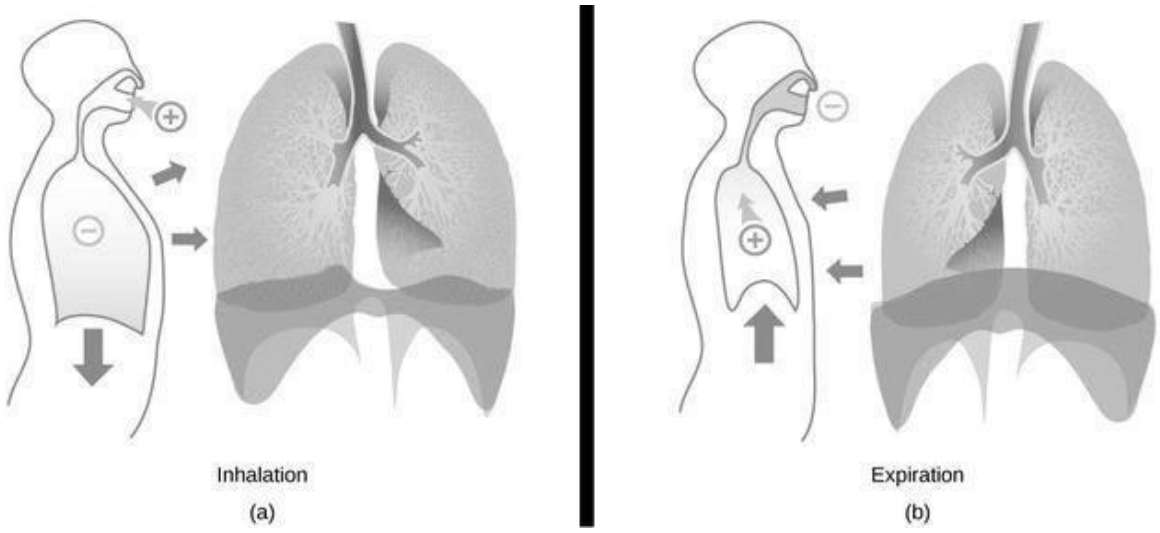


Mechanics of Breathing

- **Boyle's Law** describes the relationship between the pressure (P) and the volume (V) of a gas. The law states that if the volume increases, then the pressure must decrease (or vice versa). This relationship is often written algebraically as PV = constant, or $P_1V_1 = P_2V_2$. Both equations state that the product of the pressure and volume remains the same. (Boyle's Law applies only when the temperature does not change.)
- Breathing occurs when the contraction or relaxation of muscles around the lungs changes the total volume of air within the air passages (bronchi, bronchioles) inside the lungs. When the volume of the lung's changes, the pressure of the air in the lungs changes in accordance with Boyle's Law. If the pressure is greater in the lungs than outside the lungs, then air rushes out. If the opposite occurs, then air rushes in. Here is a summary of the process:
- Inspiration occurs when the inspiratory muscles—that is, the diaphragm and the external intercostal muscles—contract. Contraction of the diaphragm (the skeletal muscle below the lungs) causes an increase in the size of the thoracic cavity, while contraction of the external intercostal muscles elevates the ribs and sternum. Thus, both muscles cause the lungs to expand, increasing the volume of their internal air passages. In response, the air pressure inside the lungs decreases below that of air outside the body. Because gases move from regions of high pressure to low pressure, air rushes into the lungs.
- Expiration occurs when the diaphragm and external intercostal muscles relax. In response, the elastic Fibres in lung tissue cause the lungs to recoil to their original volume. The pressure of the air inside the lungs then increases above the air pressure outside the body, and air rushes out. During high rates of ventilation, expiration is facilitated by contraction of the expiratory muscles (the intercostal muscles and the abdominal muscles).
- Lung compliance is a measure of the ability of the lungs and thoracic cavity to expand. Due to the elasticity of lung tissue and the low surface tension of the moisture in the lungs (from the surfactant), the lungs normally have high compliance.

Respiratory muscles:

- When you breathe in, or inhale, your diaphragm contracts (tightens) and moves downward. This increases the space in your chest cavity, into which your lungs expand.The intercostal muscles between your ribs also help enlarge the chest cavity. They contract to pull your rib cage both upward and outward when you inhale.
- These press the **abdominal organs** cranially (upward) into the **diaphragm**, reducing the volume of the **thoracic cavity**. The **internal intercostal muscles** have fibres that are angled obliquely downward and backward from rib to rib. These muscles can therefore assist in lowering the **rib cage**, adding force to exhalation.
- **Breathing** is usually automatic, **controlled** subconsciously by the respiratory centre at the base of the brain. Sensory organs in the brain and in the aorta and carotid arteries monitor the blood and sense oxygen and carbon dioxide levels.



Minute ventilation:

Respiratory **minute** volume (or **minute ventilation** or **minute** volume) is the volume of gas inhaled (inhaled **minute** volume) or exhaled (exhaled **minute** volume) from a person's lungs per **minute**. It is an important parameter in respiratory medicine due to its relationship with blood carbon dioxide levels.

For Example: The minute ventilation is the amount of air a person breath in a minute. The minute ventilation is calculated by the multiplication of the tidal volume and the respiratory rate. **What is minute ventilation?** The normal tidal volume of a person is around 8- 10ml per kg of weight. That is for a 70 kg person the tidal volume would be 700 ml. The tidal volume is actually the amount of air a person takes during each breath at rest. The normal respiratory rate is about 14- 18 breaths per

minute. Hence, Minute ventilation =Tidal Volume X Respiratory rate.

So **what is minute ventilation** of a 70kg person. Minute ventilation for a 70 kg person would be 700 X 15 which would be approximately 10500ml. A person requires a minimum of 6 to 8 litres of minute volume for the proper oxygenation of the tissues and the removal of carbon dioxide from the lungs. The minute volume increases at times of stress and exercise. This increase compensates for the increase in the demand of oxygen and the increased production of Carbon dioxide. This minimum volume of air required to be breathed every minute is also called as the minute volume.

Ventilation at rest and during exercise:

During exercise, the increase in ventilation which occurs to meet the increasing oxygen demands (called "hyperpnea") is not fully explained by the control of the peripheral or central chemoreceptors alone. There are non-chemical controls of ventilation that are required to provide input to the respiratory centre to increase ventilation, especially during the initiation of exercise when ventilation needs to increase quickly.

These "non-chemical controls" of ventilation include:

1. the **motor cortex (cortical control):** feed-forward mechanism to increase ventilation at the onset of exercise.
2. **active muscles and joint receptors:** active muscles and joints provide feedback to the respiratory centre to increase ventilation (muscle metaboreflex) in order to meet the higher oxygen demands and to remove carbon dioxide
3. **core body temperature:** higher body temperature stimulates increased ventilation
4. **stretch receptors in the lungs tissue and bronchioles:** when these receptors are stretched, they send a signal to the medulla to stop inhalation and start exhalation. This ensures that the lungs will never exceed their maximal physical capacity.

A) **At Rest**

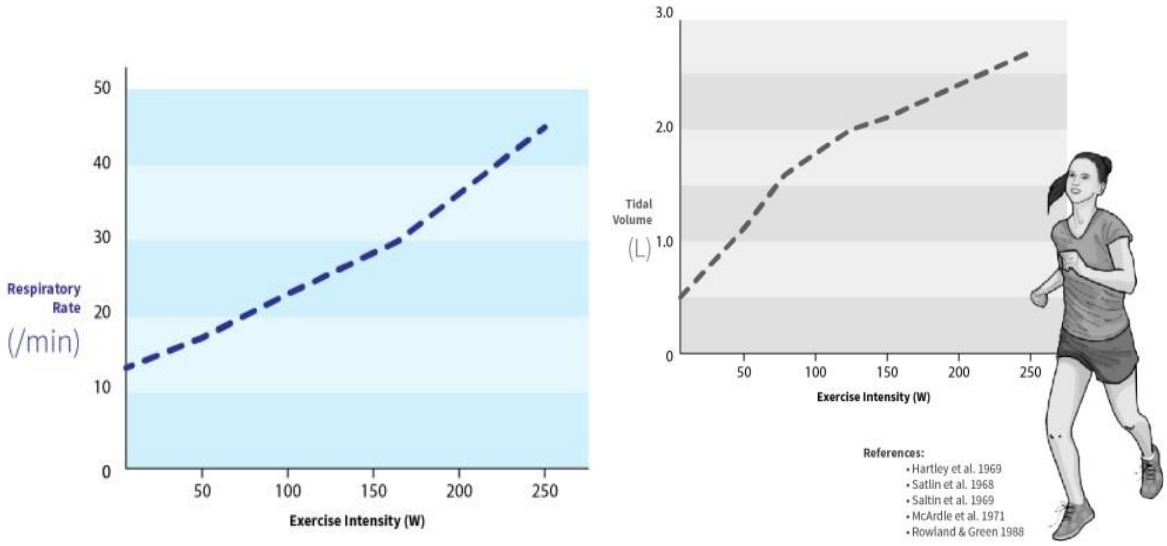
The normal respiratory cycle of a healthy individual at rest is constant and predictable. The rate and depth of breathing is considered "automatic" with no conscious input required from the individual. This results in a predictable number of breaths per minute with a similar amount of time between breaths.

Minute Ventilation is determined by the following equation: where **VT** is the tidal volume per breath and **fB** is the frequency of breaths per minute. Generally, a healthy individual should have a minute volume of 6 L/min at rest. This number, of course, depends on size, age, and health status on an

individual.

B) **With acute exercise**

In any sort of physical exertion, light or strenuous, the body must compensate for the increased oxygen demand. To get more oxygen into the body during exercise, various sensors within the body will tell the central controller in the brain to increase minute ventilation, this means taking more breaths per minute as well as larger volumes of air per breath. Minute ventilation can increase to over 100 L/min with heavy exercise! Thisconcept is illustrated by Figure



The sensors for the arterial blood gas regulator are situated in the aortic and carotid bodies, which are primarily sensitive to the partial pressure of oxygen (PO2) in the arterial blood, and the anterior and lateral surfaces of the medulla oblongata in the brainstem which measures the PCO2 and pH of the cerebrospinal fluid and consequently the arterial blood. Information from these sensors is conveyed along nerves to the respiratory centers in the brain stem. The respiratory centers are located in the medulla oblongata and the pons in the brainstem.

1. Inspiratory center - reticular formation, medulla oblongata
2. Expiratory center - reticular formation, medulla oblongata
3. Pneumotaxic center - various nuclei of the pons
4. Apneustic center - nucleus of the pons

From the respiratory centers the skeletal muscles of ventilation, in particular the diaphragm, are alternately activated to cause air to move in and out of the lungs.

Unit IV - METABOLISM AND ENERGY TRANSFER

METABOLISM:

The chemical processes that occur within a living organism in order to maintain life. Metabolism is a term that is used to describe all chemical reactions involved in maintaining the living state of the cells and the organism. Metabolism can be conveniently divided into two categories:

- Catabolism - the breakdown of molecules to obtain energy
- Anabolism - the synthesis of all compounds needed by the cells

Metabolism is closely linked to nutrition and the availability of nutrients. Bioenergetics is a term which describes the biochemical or metabolic pathways by which the cell ultimately obtains energy. Energy formation is one of the vital components of metabolism.

Carbohydrates in metabolism: Foods supply carbohydrates in three forms: starch, sugar, and cellulose (Fiber). Starches and sugars form major and essential sources of energy for humans. Fibers contribute to bulk in diet. Body tissues depend on glucose for all activities. Carbohydrates and sugars yield glucoseby digestion or metabolism.

The overall reaction for the combustion of glucose is written as:

$$C_6H_{12}O_6 + 6O_2 \text{ --> } 6CO_2 + 6H_2O + \text{energy}$$

Most people consume around half of their diet as carbohydrates. This comes from rice, wheat, bread, potatoes, pasta, macaroni etc.

Proteins in metabolism:

Proteins are the main tissue builders in the body. They are part of every cell in the body. Proteins help in cell structure, functions, haemoglobin formation to carry oxygen, enzymes to carry out vital reactions and a myriad of other functions in the body. Proteins are also vital in supplying nitrogen for DNA and RNA genetic material and energy production. Proteins are necessary for nutrition because they contain amino acids. Among the 20 or more amino acids, the human body is unable to synthesize 8 and these are **called essential** amino acids.

The essential amino acids include:

- Lysine
- Tryptophan
- Methionine
- Leucine
- Isoleucine

- Phenylalanine
- Valine
- Threonine

Foods with the best quality protein are eggs, milk, soybeans, meats, vegetables, andgrains.

Fat in metabolism:

Fats are concentrated sources of energy. They produce twice as much as energy either carbohydrates or protein on a weight basis.

The functions of fats include:

- helping to form the cellular structure.
- forming a protective cushion and insulation around vital organs.
- helping absorb fat soluble vitamins,
- providing a reserve storage for energy
- Essential fatty acids include unsaturated fatty acids like linoleic, linolenic, and arachidonic acids. These need to be taken in diet. Saturated fats, along with cholesterol, have been implicated in arteriosclerosis and heart disease.

Minerals and vitamins in metabolism:

The minerals in foods do not contribute directly to energy needs but are important as body regulators and play a role in metabolic pathways of the body. More than 50 elements are found in the human body. About 25 elements have been found to be essential since a deficiency produces specific deficiency symptoms.

Important minerals include:

- Phosphorus
- Iron
- Sodium
- Potassium
- chloride ions
- copper
- cobalt
- manganese
- zinc
- magnesium
- fluorine
- iodine

Vitamins are essential organic compounds that the human body cannot synthesize by itself and must therefore, be present in the diet. Vitamins particularly important in metabolism include:

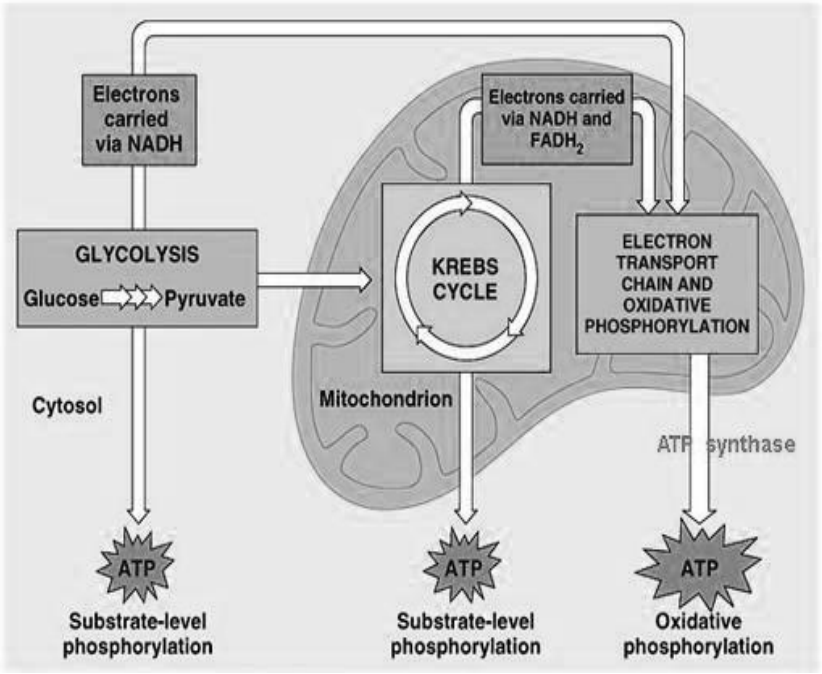
- Vitamin A
- B2 (riboflavin)
- Niacin or nicotinic acid
- Pantothenic Acid etc.

ATP-PC ($C_{10}H_{16}N_5O_{13}P_3$):

Adenosine Triphosphate. Adenosine triphosphate (ATP) is considered by biologists to be the energy currency of life. It is the high-energy molecule that stores the energy we need to do just about everything we do.

ATP (adenosine triphosphate) is required in all living cells as a continual supply of energy, to be **used** in processes, which keep the organism alive such as muscle contraction. **ATP** is made up of three main components, the base (adenine), a phosphatechain (made of three phosphate groups) and a ribose sugar backbone.

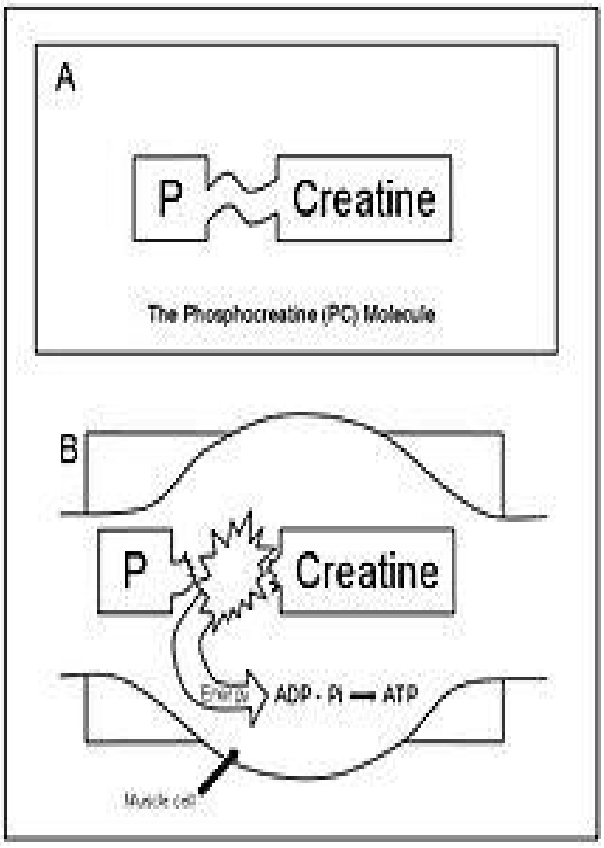
Phosphocreatine, also known as **creatine phosphate** (**CP**) or **PCr** (**Pcr**), is a phosphorylated creatine molecule that serves as a rapidly mobilizable reserve of high-energy phosphates in skeletal muscle and the brain. Non phosphorylated creatine is formed from parts of three amino acids: arginine (Arg), glycine (Gly), and methionine (Met).



PHOSPHAGEN SYSTEM:

As the fastest way to resynthesize ATP, the phosphagen system is the predominant energy system used for all-out exercise lasting up to about 10 seconds. However, since there is a limited amount of stored CP and ATP in skeletal muscles, fatigue occurs rapidly.

- Phosphocreatine, which is stored in muscle cells, contains a high energy bond.
- When creatine phosphate is broken down during muscular contraction, a large amount of energy is released. The energy released is coupled with the energy requirement to resynthesize ATP



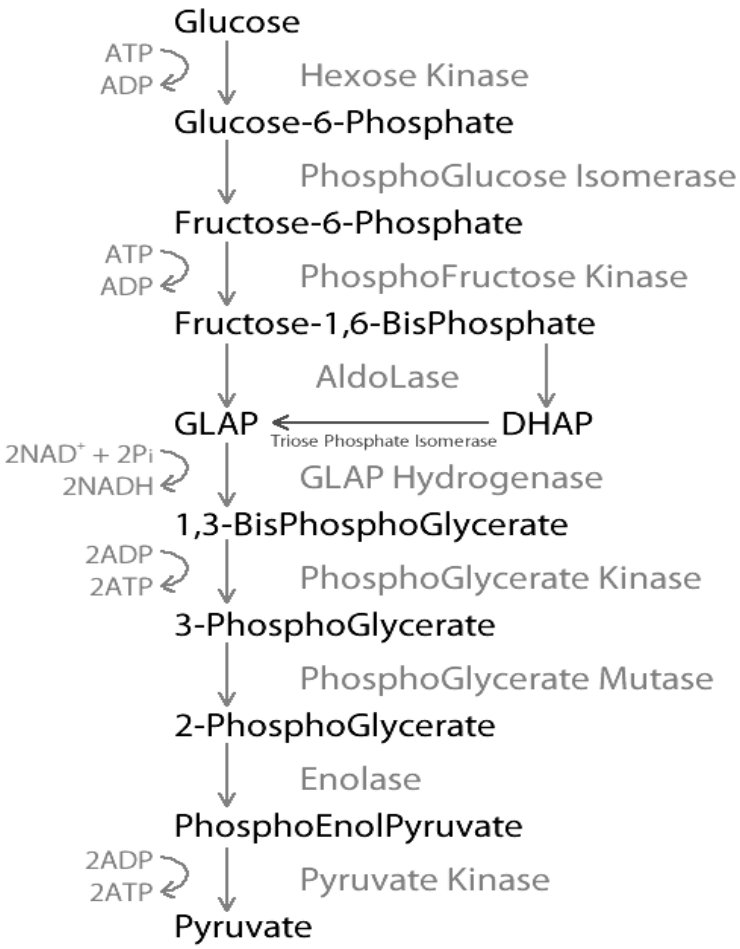
ANAEROBIC METABOLISM: The anaerobic glycolysis (lactic acid) system is dominant from about 10–30 seconds during a maximal effort. It replenishes very quickly over this period and produces 2 ATP molecules per glucose molecule, or about 5% of glucose's energy potential (38 ATP molecules).

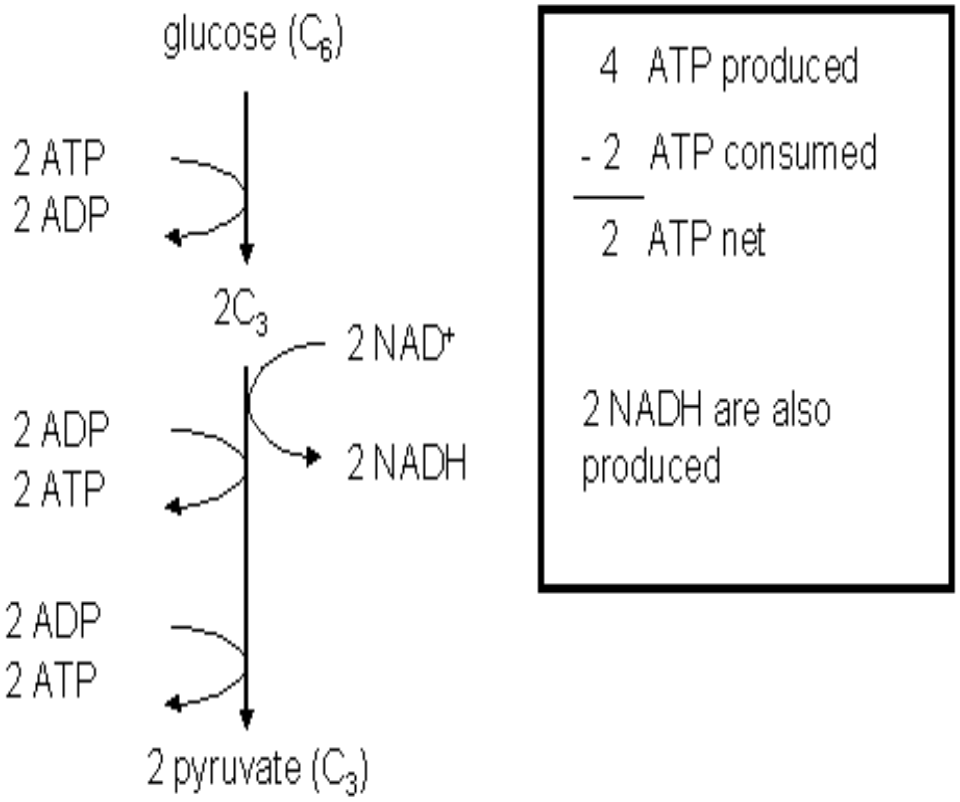
Step 1: Hexokinase. In the first step of glycolysis, the glucose ring is phosphorylated. ...

Step 2: Phosphoglucose Isomerase. The second step of glycolysis involves the conversion of glucose-6-phosphate to fructose-6-phosphate (F6P). ...

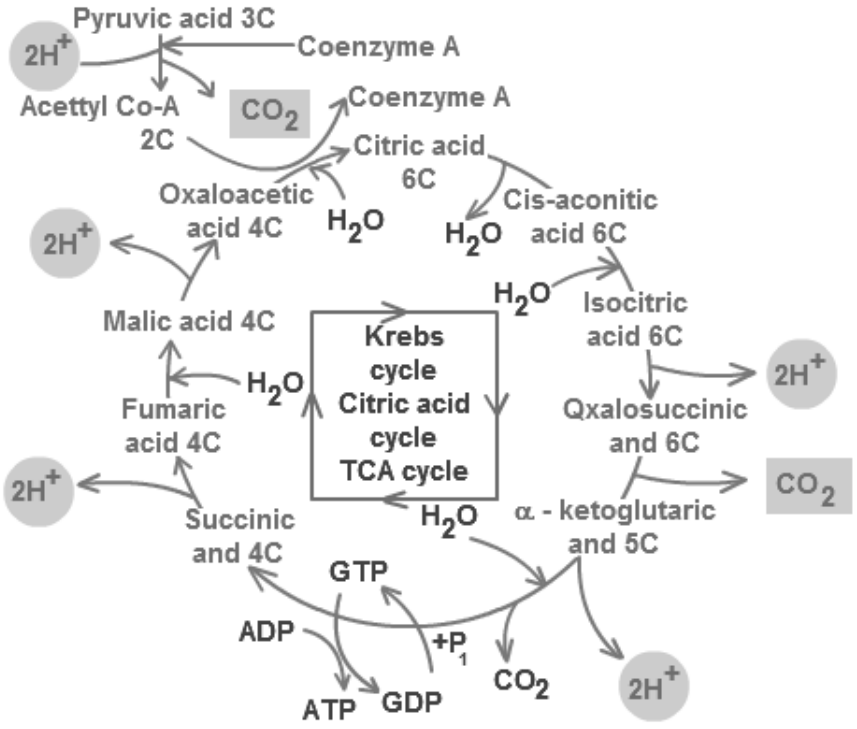
Step 3: Phosphofructokinase.

Reactions and Enzymes of Glycolysis:

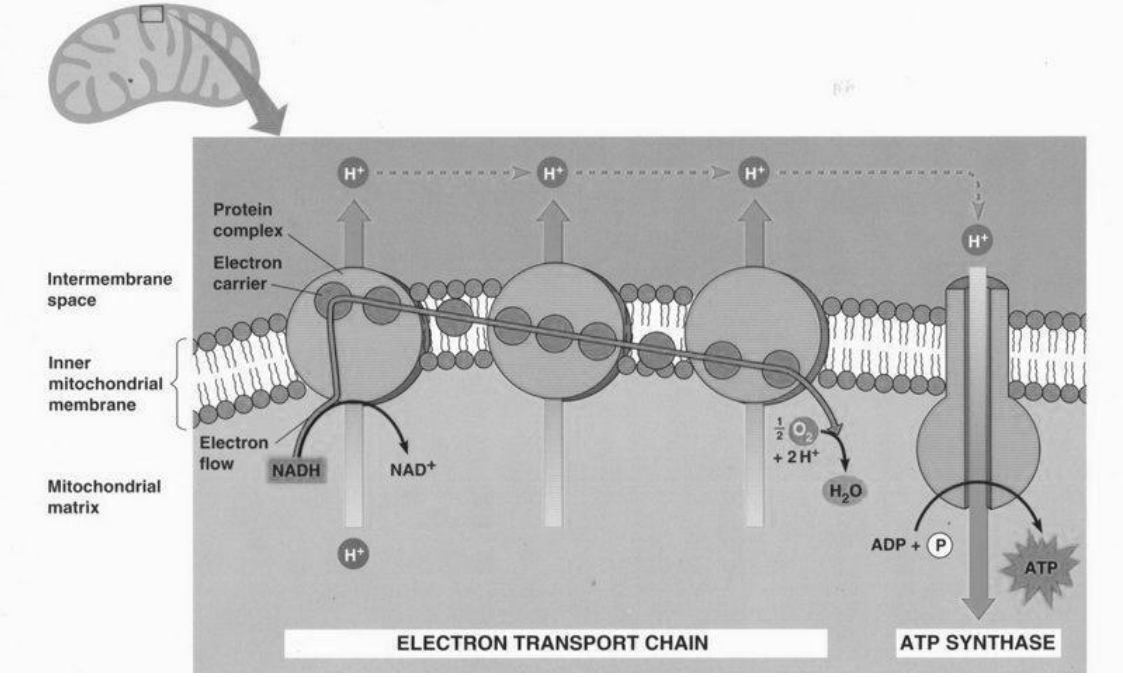


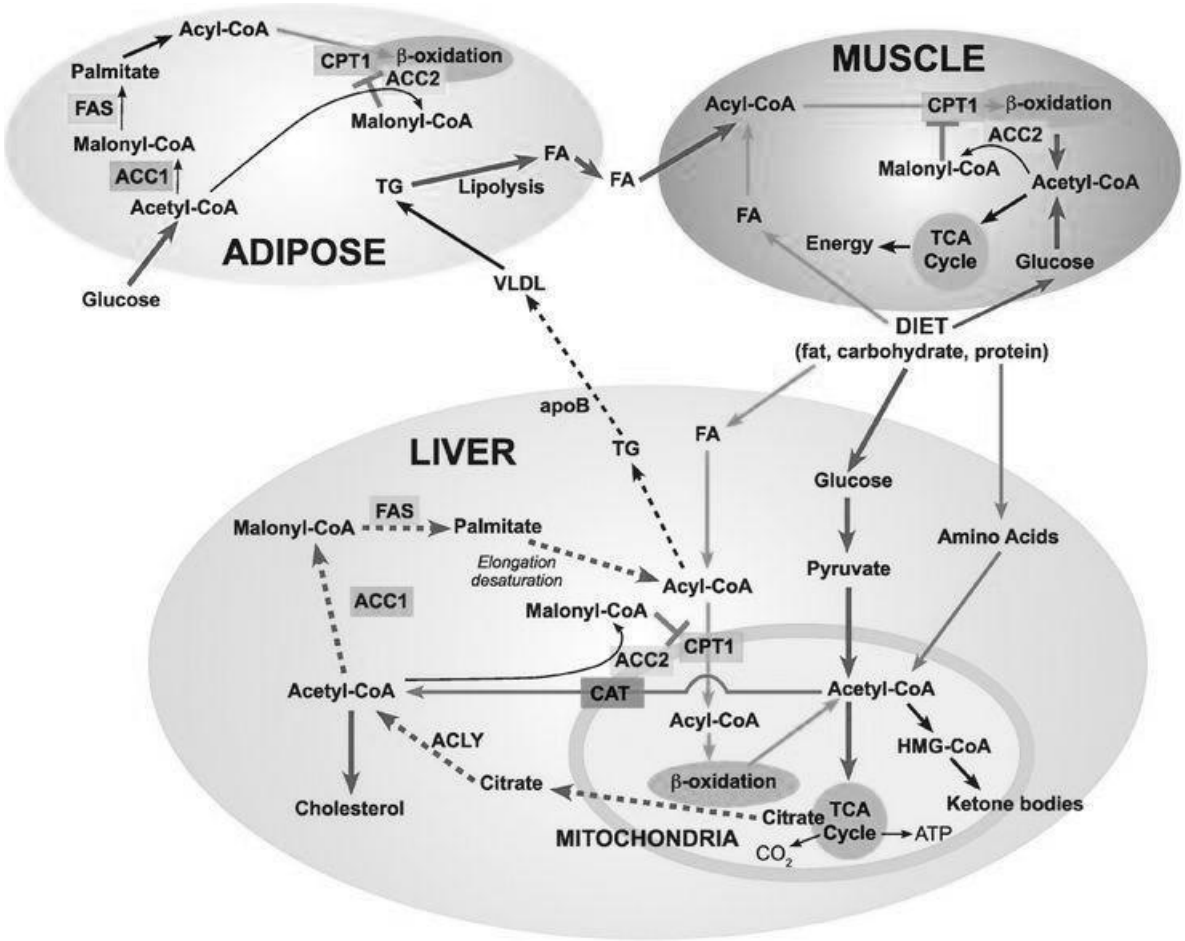

glucose (C_6)
2 ATP
2 ADP
$2C_3$
2 NAD^+
2 NADH
2 ADP
2 ATP
2 ADP
2 ATP
2 pyruvate (C_3)
4 ATP produced
- 2 ATP consumed
2 ATP net
2 NADH are also produced

AEROBIC


Pyruvic acid 3C
$2H^+$
Coenzyme A
Acettyl Co-A
2C
CO_2
Coenzyme A
Citric acid
6C
Oxaloacetic
acid 4C
H_2O
H_2O
Cis-aconitic
acid 6C
$2H^+$
H_2O
Isocitric
acid 6C
Malic acid 4C
Krebs
cycle
Citric acid
cycle
TCA cycle
$2H^+$
H_2O
Fumaric
acid 4C
Qxalosuccinic
and 6C
$2H^+$
CO_2
Succinic
and 4C
H_2O
α - ketoglutaric
and 5C
GTP
ADP
+P_1
CO_2
$2H^+$
ATP
GDP

METABOLISM:


Protein complex
Electron carrier
Intermembrane space
Inner mitochondrial membrane
Electron flow
Mitochondrial matrix
NADH
NAD+
H+
½ O2 + 2H+
H2O
ADP + P
ATP
ELECTRON TRANSPORT CHAIN
ATP SYNTHASE


ADIPOSE
Acyl-CoA
Palmitate
FAS
Malonyl-CoA
ACC1
Acetyl-CoA
CPT1
β-oxidation
ACC2
Malonyl-CoA
TG
Lipolysis
FA
Glucose
VLDL
MUSCLE
Acyl-CoA
CPT1
β-oxidation
ACC2
Malonyl-CoA
Acetyl-CoA
FA
Energy
TCA Cycle
Glucose
DIET
(fat, carbohydrate, protein)
apoB
LIVER
TG
FA
Glucose
Amino Acids
Malonyl-CoA
FAS
Palmitate
Elongation desaturation
Pyruvate
ACC1
Acyl-CoA
Malonyl-CoA
ACC2
CPT1
Acetyl-CoA
CAT
Acetyl-CoA
Acyl-CoA
HMG-CoA
ACLY
Citrate
β-oxidation
Ketone bodies
Cholesterol
Citrate
TCA Cycle
ATP
MITOCHONDRIA
CO2

Stages of Metabolism

Catabolic reactions:

Stage 1: Digestion and hydrolysis

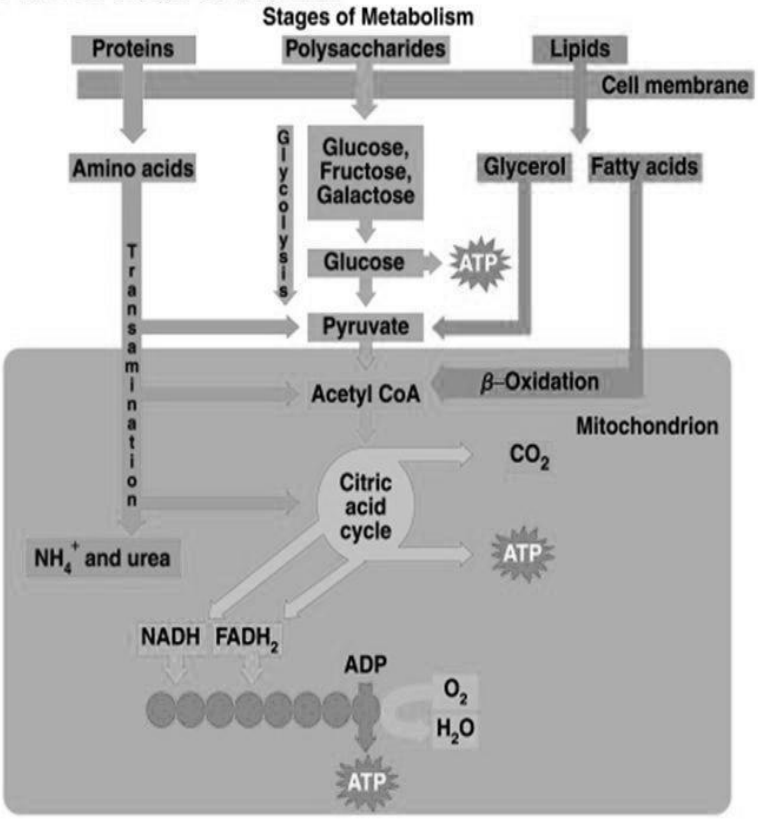
break down large molecules to smaller ones that enter the bloodstream.

Stage 2: Degradation

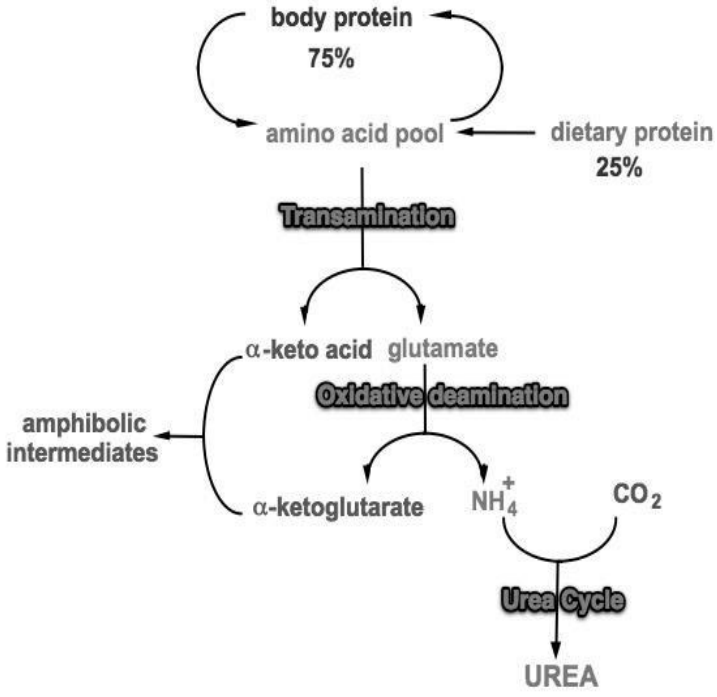
Further breaking and some oxidation of molecules to 2 & 3-carbon compounds.

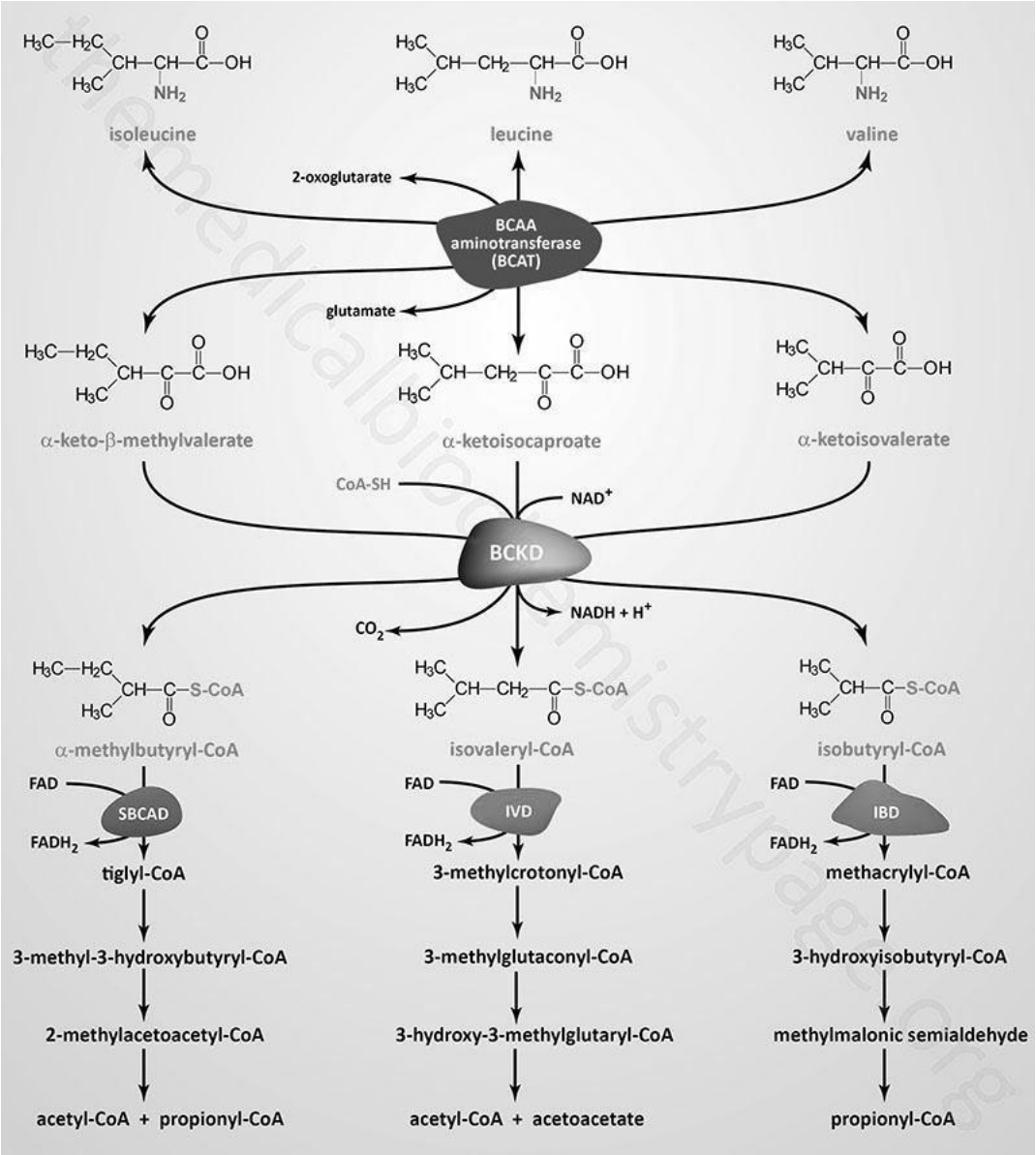
Stage 3: Oxidation

of small molecules to CO_2 & H_2O in the citric acid cycle and electron transport provides energy for ATP synthesis.



PROTEIN METABOLISM:




isoleucine
leucine
valine
2-oxoglutarate
BCAA aminotransferase (BCAT)
glutamate
α-keto-β-methylvalerate
α-ketoisocaproate
α-ketoisovalerate
CoA-SH
NAD+
BCKD
CO2
NADH + H+
α-methylbutyryl-CoA
isovaleryl-CoA
isobutyryl-CoA
FAD
SBCAD
FADH2
IVD
IBD
tiglyl-CoA
3-methylcrotonyl-CoA
methacrylyl-CoA
3-methyl-3-hydroxybutyryl-CoA
3-methylglutaconyl-CoA
3-hydroxyisobutyryl-CoA
2-methylacetoacetyl-CoA
3-hydroxy-3-methylglutaryl-CoA
methylmalonic semialdehyde
acetyl-CoA + propionyl-CoA
acetyl-CoA + acetoacetate
propionyl-CoA

Unit V - CLIMATIC CONDITION AND ERGOGENIC AIDS

Variation in temperature and humidity:

- In the troposphere, the source of heat is the surface of the Earth as well as particles inthe **air** which absorb heat and energy from the Sun and release it back into the **atmosphere**. The ozone layer absorbs radiation from the Sun, helping to increase the **temperature** in the upper portion of the stratosphere.
- The troposphere is hotter near the Earth's surface because heat from the Earth warms thisair. As the **altitude** increases the number of air molecules decreases, thus the average of their kinetic energy decreases. The results is a decrease in air **temperature** with an **increase** of **altitude.**
- Water vapor is the gaseous state of water and is invisible to the humaneye. **Humidity** indicates the likelihood of precipitation, dew, or fog. Higher **humidity** reduces the effectiveness of sweating in cooling the body by reducingthe rate of evaporation of moisture from the skin.
- When you consider that people generally are most **comfortable** when the relative **humidity** is approximately 40 percent, you can see how dry indoor air can take a toll onyour family. Low **humidity** causes static electricity, dry skin, lips and hair, scratchy throats and noses, and itching and chapping

Thermoregulation:

- Thermoregulation is a process that allows your body to maintain its core internal temperature. All **thermoregulation** mechanisms are designed to return your body tohomeostasis
- The hypothalamus works with other parts of the **body's temperature-regulating** system,such as the skin, sweat glands and blood vessels — the vents, condensers and heat ducts of your **body's** heating and cooling system. The middle layer of the skin, or dermis, stores most of the **body's** water.
- The hypothalamus is the processing centre in the brain that controls **body temperature**.It **does** this by triggering changes to effectors, such as sweat glands and muscles controlling **body** hair. Heat stroke can happen when the **body** becomes too hot; and hypothermia when the **body** becomes too cold.
- Homeostasis: the ability to keep a system at a constant condition. Hormone: a chemical message released in the **body** by cells and glands that affects other cells in an organism. **Hypothalamus**: a part of the brain that controls things like thirst, hunger, **bodytemperature**, and the release of many hormones.

Sports performance in hot and cool climate and high altitude:

In hot:

- Eccrine sweat glands under the skin secrete sweat (a fluid containing mostly water with some dissolved ions), which travels up the sweat duct, through the sweat pore and ontothe surface of the skin. This causes heat loss via evaporative cooling; however, a lot of essential water is lost.
- The hairs on the skin lie flat, preventing heat from being trapped by the layer of still air between the hairs. This is caused by tiny muscles under the surface of the skin called arrector pili muscles relaxing so that their attached hair follicles are not erect. These flat hairs increase the flow of air next to the skin increasing heat loss by convection. When environmental temperature is above core body temperature, sweating is the only physiological way for humans to lose heat.
- Arteriolar vasodilation occurs. The smooth muscle walls of the arterioles relax allowing increased blood flow through the artery. This redirects blood into the superficial capillaries in the skin increasing heat loss by convection and conduction.

In hot and humid:

In general, humans appear physiologically well adapted to hot dry conditions. However, effective thermoregulation is reduced in hot, humid environments such as the Red Sea and Persian Gulf (where moderately hot summer temperatures are accompanied by unusually high vapor pressures), tropical environments, and deep mines where the atmosphere can be water saturated. In hot-humid conditions, clothing can impede efficient evaporation. In such environments, it helps to wear light clothing such as cotton,which is pervious to sweat but impervious to radiant heat from the sun. This minimizes the gaining of radiant heat, while allowing as much evaporation to occur as the environment will allow. Clothing such as plastic fabrics that are impermeable to sweat and thus do notfacilitate heat loss through evaporation can actually contribute to heat stress

In cold:

- Sweat production is decreased. The minute muscles under the surface of the skin called arrector pili muscles (attached toan individual hair follicle) contract (piloerection), lifting the hair follicle upright. This makes the hairs stand on end, which acts as an insulating layer, trapping heat. This is what also causes goose bumps since humans do not have very much hair and the contracted muscles can easily be seen.
- Arterioles carrying blood to superficial capillaries under the surface of the skin can shrink (constrict), thereby rerouting blood away from the skin and towards the warmer core of the body. This prevents blood from losing heat to the surroundings and also prevents the core temperature dropping further. This process is called vasoconstriction. It is impossible to prevent all heat loss from the blood, only to reduce it. In extremely cold conditions, excessive vasoconstriction leads to numbness and pale skin. Frostbite occurs only when

water within the cells begins to freeze. This destroys the cell causing damage.

- Muscles can also receive messages from the thermoregulatory center of the brain (the hypothalamus) to cause shivering. This increases heat production as respiration is an exothermic reaction in muscle cells. Shivering is more effective than exercise at producing heat because the animal (includes humans) remains still. This means that less heat is lost to the environment through convection. There are two types of shivering: low-intensity and high-intensity. During low-intensity shivering, animals shiver constantly at a low level for months during cold conditions. During high-intensity shivering, animals shiver violently for a relatively short time. Both processes consume energy, however.
- High-intensity shivering uses glucose as a fuel source and low-intensity tends to use fats. This is a primary reason why animals store up food in the winter.
- In addition to heat production by shivering, mitochondria can metabolize brown fat and produce heat energy via the thermogenic protein, in turn increasing the temperature of all cells in the body. Brown fat is specialized for this purpose and is abundant in new-borns and animals that hibernate.

In high altitude:

- About brain - Traveling to 6,000 or higher feet above sea level can cause altitude sickness, also known as acute mountain sickness, in the first two or three days. The reduced oxygen in the air and, therefore, in your blood may cause the blood vessels in the brain to dilate, which causes brain swelling and sometimes headaches, according to the Institute for Altitude Medicine. In theory, pressure on the brain is also what causes dizziness, tiredness, nausea, chills, irritability, and the other possible effects of high altitude that can negatively impact your athletic performance.
- About cardio - VO2 max is a measurement of the maximum amount of oxygen your body can absorb and use in one minute. Physically fit people have higher VO2 max than less fit people, which allows them to perform cardio sports faster and longer. At 5,000 feet above sea level, your VO2 max should be close to what it is at sea level. Going up from there, your VO2 max drops 3 percent with each 1,000 feet of higher altitude. Acclimatization -- allowing your body time to adjust to a higher altitude -- will help, but you will not be able to perform cardio exercise at the same pace that you could at lower altitudes. The Institute for Altitude Medicine recommends 10 to 20 days of acclimatization for athletes before performing cardio exercise. If you are performing aerobic sports at an elevation of 12,000 feet or more, you should also first acclimatize at a lower part-way-up elevation before you exercise at the top.
- During acclimatization, the hormone erythropoietin or EPO is released and causes your bone marrow to produce more red blood cells. This increases the ability of your blood to

carry oxygen to your body tissues, but the process takes several weeks. The end effect of increased EPO is improved sports performance for endurance athletes. Anaerobic athletes who perform sports like weightlifting and sprinting might not need weeks of acclimatization but can still suffer from some of the longer-lasting effects of high altitude.

The longer-term changes are

- A decrease in maximum cardiac output a decreased maximum heart rate
- An increased number of red blood cells
- Excretion of base via the kidneys to restore acid-base balance. (Unfortunately, the netresult is that you have less tolerance for lactic acid.)
- A chemical change within red blood cells that makes them more efficient at unloading oxygen to the tissues.
- An increase in the number of mitochondria and oxidative enzymes.

PRACTICAL IMPLICATIONS FOR ATHLETES

- *Diet - A high carbohydrate, low salt* diet allows for better adaptation and less risk of "mountain sickness". Some people experience significant decline in appetite and the resulting loss of muscle mass may hinder performance. *Iron* is used to make haemoglobin and the demand for making more red blood cells may require iron supplementation -- especially in women and vegetarians. Mega doses of vitamins are not helpful and are potentially dangerous.
- *Fluids-Because Mountain* air is cool and dry you can lose a lot of water so be sure to maintain adequate hydration.
- *Alcohol* - It is best to avoid alcohol consumption during the acclimatization period since it appears to increase the risk of "mountain sickness".

Ergogenic aids:

A performance enhancer, or **ergogenic aid**, is anything that gives you a mental or physical edge while exercising or competing. This can range from caffeine and sports drinks to illegal substances. There are a variety of both safe and harmful **ergogenic aids.**

Influence of Amphetamine:

- When the nerve cells within the brain and the spinal cord are activated by amphetamines, there is an increase in mental alertness and the ability for the user to stay awake, focused and to concentrate. This is why amphetamines are sometimes used in the treatment of ADD or ADHD (attention deficit hyperactivity disorder (ADHD) is one of the most common childhood disorders.), to help those with these behavioural disorders to focus and it's also why amphetamine containing drugs are used in the treatment of sleep disorders such as

narcolepsy to help the user stay awake.

- Amphetamines have many adverse effects on the brain, the central nervous system and the user's body. When amphetamines are used, the neurotransmitters dopamine and norepinephrine are released from nerve endings within the brain and the ability for the neurotransmitters to reuptake is inhibited. This causes an influx of the neurotransmitters at the nerve endings or synapses of the brain which can lead to various problems and side-effects.

Medical Uses of Amphetamines

- **ADHD** (attention deficit hyperactivity disorder)
- **Narcolepsy** (a neurological condition resulting in disturbed night-time sleep and periods of excessive daytime sleepiness)
- **Chronic fatigue syndrome** (a poorly understood condition characterised by muscle and joint pain, cognitive difficulty, and chronic mental and physical exhaustion)

Effects on Performance

Amphetamines have been used by drug cheating athletes to resist fatigue and increase alertness, although use appears to have diminished due to publicity over its negative side- effects. There is also evidence that Amphetamines are capable of increasing speed, power, endurance, and concentration.

Side-Effects of Amphetamines

The main adverse effect of Amphetamine use is the associated addiction. Athletes can become dependent on the drug, resulting in long-term use and a higher risk of more severe side-effects.

Even short-term use can produce the following side-effects:

- **Cerebral haemorrhage** (rupture of a blood vessel in the brain)
- **Confusion, paranoia & delirium, Hypertension** (high blood pressure), **Angina** (chest pain resulting from a lack of blood to the heart), **Vomiting, Abdominal. I pain, Irritability & restlessness, Insomnia, Dizziness, Tremors**

Influence of Anabolic steroids: Some athletes take a form of steroids — known as anabolic-androgen steroids or just anabolic steroids — to increase their muscle mass and strength. The main anabolic steroid hormone produced by your body is testosterone. ... Androgenic effects are responsible for male traits, such as facial hair and a deeper voice. Anabolic steroids have been manufactured to enhance the anabolic properties (tissue building) of the androgens and minimize the androgenic (sex-linked) properties.

Uses of Anabolic Steroids

- Anabolic Steroids have been used previously as a hormone replacement to treat: Hypogonadism (defect of function of the testes or ovaries)
- Klinefelter's syndrome (Sometimes known as XXY syndrome, where a male has an additional X chromosome. This results in reduced fertility)
- Delayed puberty
- Some forms of anemia (AAS's have a stimulatory effect on bone marrow which may increase red blood cell production)
- Angioneurotic edema (swelling in the deep layers of the skin, often due to the body mistakenly initiating an allergic reaction)
- COPD (Chronic Obstructive Pulmonary Disease)HIV
- Muscular dystrophy
- Severe cases of osteoporosisEffects on Performance
- Steroids are most commonly used by athletes involved in power sports, for example weightlifting, throwing and sprinting events. Field sports such as American Football and Rugby also demonstrate a high incidence of use, as does body building. The perceived benefits of AAS use include:
    - Increased muscle bulk
    - Increased muscle strength
    - Faster muscle recovery
    - Reduced muscle catabolism (breakdown of muscle) following intense exercise which aids muscle recovery and development (not proven as yet)

Side-Effects of Anabolic Steroids

Side-effects from the use of steroids are extremely common and can be quite significant.Most side-effects are reversible once the athlete stops usage although serious long-term side-effects and even death have occurred as a direct result of steroid use.

- Decreased sperm production and sex drive
- Increased aggression, irritability and mood swings
- Liver disorders
- Acne
- Baldness (alopecia)
- Hypertension (high blood pressure)
- Raised cholesterol
- Gynecomastia (development of over-sized mammary glands in males)
- Menstrual irregularities (in women)

- Hirsutism (excessive hair growth occurring in females which follows the pattern ofmale hair growth, i.e., facial)
    - Deepening of the voice
    - Reduced immunity
    - Possible development of tumours (wilm's tumour, prostate carcinoma and leukaemia have been reported, although a connection is not proven)

Influence of Androstenedione:

- Some body builders report anecdotally that they notice increased strength on the daysthey work out when they use it.
- Men who use muscle-building supplements containing creatine or androstenedione may have a higher risk of getting testicular cancer
- Androstenedione can have androgenic side effects that include acne, (Acne, also knownas acne vulgaris, is a long-term skin disease that occurs when hair follicles are clogged with dead skin cells and oil from the skin) scalp hair loss, facial hair growth in women, aggressiveness, and irritability. Chronic use can also raise levels of oestrogen, something that could lead to enlarged breasts and an increased risk of certain types of cancer.
- Influence of Beta blocker: These drugs can have a range of effects (some of which have not been proven). Known as beta blockers or beta antagonists they work by blocking the body's receptors for adrenalin. Beta blockers have been used by athletes in sports where a steady hand and eye is needed such as snooker, archery, darts and rifle shooting.
- Beta-blockers are a class of medications prescribed to block the effects of adrenaline; a hormone produced by the adrenal glands. They help the heart work more efficiently, thereby reducing blood pressure, heart rate, muscle tremors and even anxiety. As well, beta-blockers have a relaxing effect on muscle function, gaining the drug class a popular reputation as an illegal, performance-enhancement drug for athletes who benefit from the adrenaline-blocking effects of the medication.
- Propranolol is a beta-blocker that interferes with the reaction of nerve impulses inside the body, especially in the heart. As a result, propranolol causes the heart to beat slower, decreases blood pressure and calms the symptoms of anxiety. Some athletes use propranolol specifically for its anxiety-reducing effects, resulting in steadier hands, an even heart rate and the increased ability to focus
- Side effects of beta blocker,
- Beta-blockers can have dangerous effects when taken without a physician's advice. Some beta-blockers can cause severe blood sugar changes and heart failure in some people. Symptoms of heart failure include chest pain, difficulty breathing, weight gain and extreme fatigue. Seek immediate medical treatment for any of these symptoms. Beta- blockers can

also interfere with the ability to perform strenuous physical activities and can cause symptoms of nausea and weakness when the heart cannot compensate for the body's demands. This is the reason beta-blockers are not used by athletes involved in strenuous sports but are instead used by athletes who require steady hands, increased focus and a relaxed state of mind to perform at the utmost level.

- Influence of Choline:
- It's a vitamin-like compound (in fact, some nutritionists have contended that it is a vitamin) which is an essential part of the human diet. Without it, no cell in the human body could function normally.
- And without an adequate supply of it, runners cannot possibly reach their potential in the marathon, according to some exercise scientists. That contention is based on the fact that choline is used by nerve cells to manufacture a closely related chemical called acetylcholine. Acetylcholine allows nerve cells to communicate with each other; if there were no acetylcholine in your brain, you wouldn't remember who you were, let alone find your way to the starting lines of your races.

Supplements were associated with several positives:

1. Choline takers were less fatigued before practices.
2. Choline takers reported that they felt more vigour as practices began.
3. They also felt more vigorous at the ends of practices.

On the negative side, two Holy Cross shooters complained of diarrhoea while on choline (that's a common side effect), and another was forced to warn his teammates of flatulence (another common occurrence). All in all, though, daily intakes of choline seemed to increase vigour and suppress fatigue in these college athletes.

Influence of Creatine:

Creatine was thought by some to improve strength, increase lean muscle mass, and help the muscles recover more quickly during exercise. This muscular boost may help athletes achieve bursts of speed and energy, especially during short bouts of high- intensity activities such as weightlifting or sprinting.

Creatine is a nitrogenous organic acid produced in the liver; it helps supply energy to cells throughout the body - particularly muscle cells. The compound is formed of three amino acids: L-arginine, glycine, and L-methionine and makes up about 1 percent of the total volume of human blood. Creatine is a natural substance that turns into creatine phosphate in the body. Creatine phosphate helps make a substance called adenosine triphosphate (ATP). ATP provides the energy for muscle contractions. The body produces some of the creatine it uses.

The most popular supplement among athletes is probably creatine monohydrate. Creatine is a naturally occurring compound produced by your body that helps your muscles release energy. Research has shown that the most rapid way to increase muscle creatine stores is to follow the loading method, by taking 0.3 grams/kg/day of creatine monohydrate for 5 to 7 days (e.g., 5 grams taken four times perday). Studies show that this rate can increase muscle creatine.

There is some concern that it could harm the kidney, liver, or heart function. However, aconnection between high doses and these negative effects has not been proven. Creatine can also cause stomach pain, nausea, diarrhea, and muscle cramping. Creatine causes muscles to draw water from the rest of your body.

Human growth hormone on sports performance: Human Growth hormone (hGH) is also sometimes known as somatotrophic hormone or somatotrophin. It is produced by the pituitary gland and is essential for normal growth and development. hGH is anabolic, meaning it accelerates protein synthesis and also aids the metabolism (breaking down) of fat stores.

- Increased Muscle Strength
- Better Fracture Healing
- Enhanced Weight Loss
- Stronger Bones
- Reduced Cardiovascular Disease Risk
- Decreased Obesity
- Better Mood and Cognitive Function
- Better Sleep

Medical Uses of Human Growth Hormone

The uses of HGH are limited in a medical setting:

- Dwarfism **and replacement therapy in growth-deficient children**
- Turner's syndrome **(a chromosomal condition where the second X sex chromosome in females is either absent or deformed. This causes growth and development problems)**
- Renal insufficiency **(kidney failure)**
- HIV **(to treat muscle wasting)**

Effects on Performance

Athletes involved in powerful, strength demanding sports and events (weightlifting, body building, American football etc) are most likely to use hGH due to its perceivedanabolic effect:

- Increased muscle mass
- Decreased fat stores
- Accelerated muscle recovery

- Many small studies, however, have shown no increases in muscle size or strength following injection with hGH. A common practice among bodybuilders and weight-lifters is to combine hGH and anabolic steroids, with recent research demonstrating beneficial effects.

The side-effects of hGH are vast and some serious:

- Gigantism in younger athletes (or pituitary gigantism or gigantism. Refers to abnormally excessive growth in height, considerably above average)
- Acromegaly in adult athletes (a condition where the pituitary gland produces too much hGH, resulting in the growth and swelling of body parts, typically hands, feet, nose but can progress to brow and jaw protrusion and swelling of internal organs)
- Hypothyroidism (low production of the thyroid hormone which disrupts metabolic rate and protein production)
- Cardiomyopathy (disease of the cardiac muscle, increasing the risk of arrhythmia and sudden cardiac death)
- Cardiac failure
- Hypercholesterolemia (presence of high levels of cholesterol in the blood)
- Ischemic heart disease (a lack of blood to the heart often due to coronary artery disease)
- Myopathies (neuromuscular diseases affecting the function of muscle Fibers)
- Arthritis
- Diabetes
- Impotence
- Osteoporosis
- Menstrual irregularities in women
- CJB (Creutzfeldt-Jakob disease or mad cow disease. This is only possible when the hGHis maintained from cadavers (corpses) rather than synthetic production)

Influence of Narcotics:

- The use of pain killers is frequent in sports, especially among athletes engaged in violent sports. Additionally, narcotic analgesic may reduce anxiety, possibly enhancingperformance in sport events in which excessive anxiety could affect fine motor control adversely, such as pistol shooting and archery.
- Narcotics are derived from the opium poppy and include the commonly known painkillers morphine, diamorphine, and pethidine.

Medical Uses of Narcotics: Narcotics are used in medicine to reduce moderate to severe pain.

Effects on Performance

Narcotics have no ergogenic or performance enhancing qualities. Athletes use Narcotics to mask pain caused by musculoskeletal injury, allowing them to compete and it is for this reason that they are listed as banned substances in competition but are permitted when out of competition.

Side-Effects of Narcotics

- Nausea
- Vomiting
- Dizziness
- Addiction
- Hypotension
- Drowsiness
- Mood disturbances

Influence of Stimulants: Caffeine:

Effects on Performance

During periods of 30-120 minutes caffeine has been shown to produce the followingbenefits:

Improved muscle contractibility

Increased time to exhaustion

Improved concentration

Enhanced alertness

Reduced fatigue

In the short-term (under 30 minutes) caffeine can have a detrimental effect on some aspects of performance, for example fine motor control and technique due to over- arousal.

Side-Effects of Caffeine

Abdominal pain

Diarrhea

Dehydration

Restlessness, anxiety & irritability

Headaches

High blood pressure

Interference with recovery and sleep patterns

Palpitations

Increased muscle tension

Influence of Stimulants: Ephedrine: Ephedrine is used for temporary relief of shortness of breath, chest tightness, and wheezing due to bronchial asthma. Ephedrine is a decongestant and

bronchodilator. Itworks by reducing swelling and constricting blood vessels in the nasal passages and widening the lung airways, allowing you to breathe more easily.

- In sports Ephedrine Claims,
- Increases body fat loss
- Improves athletic performance
- Improves concentration
- Because **ephedrine** is a sympathomimetic and a central nervous system stimulant, it is commonly used as an energy enhancer. Ma Huang-containing products are marketed and used to improve aerobic performance and endurance, reduce fatigue, increase alertness, improve reaction time, and even increase strength.
- Side effect - Dizziness; headache; nausea; nervousness; tremor; loss of appetite; restlessness; sleeplessness; stomach irritation.

Influence of Stimulants: Cocaine:

Cocaine is a stimulant which is more commonly used as a recreational drug than for performance enhancement. Cocaine produces feelings of euphoria and wellbeing, whichare usually followed by feelings of anxiety and depression when the effects of the drug wear off.

Uses of Cocaine: Cocaine has only one medical use, as a topical anaesthetic in eye and nose surgery.

Effects on Performance: The effects of cocaine on performance are minimal and are limited to increasing arousaland alertness with low doses. As the dose increases, detrimental effects such as reducedco-ordination and unwarranted aggression are frequently reported.

Side-Effects of Cocaine

- Myocardial infarction (heart attack)
- Cardiac arrhythmia (abnormal rhythm of the heart)
- Cerebral haemorrhage (ruptured blood vessel in the brain)
- Seizures (fits or convulsions)
- Confusion, paranoia & delirium
- Irritability & restlessness

Influence of Diuretics:

Diuretics (sometimes called water pills) are drugs including Furosemide, Chlorothiazide and Hydrochlorothiazide. Their purpose is to remove excess water from the body although each type of diuretic does this in a different way.

Medical Uses of Diuretics

- Diuretics are used in the treatment of a number of medical conditions including:
- Hypertension (high blood pressure)
- Oedema (fluid retention, swelling or bloating)
- Cardiac failure
- Liver cirrhosis (replacement of liver cells with fibrous scar tissue, as a result of liverdisease)

Effects on Performance

- Diuretics are not used to enhance performance. If anything, they have a detrimental effect on performance as they cause dehydration. Diuretics are used for two reasons. Firstly, to lose weight rapidly in sports which require the athlete to be within a set weight limit. For example, boxers and jockeys.
- Secondly, to dilute the presence of illegal substances and aid their excretion.

Side-Effects of Diuretics

- Dehydration.
- Hypotension (low blood pressure).
- Muscle Cramps.
- Electrolyte disturbances (alterations in the levels of electrolytes such as sodium, potassium, and chloride).
- Muscle weakness.
- Seizures (or fits/convulsions).
- Gout (caused by a build-up of uric acid).
- Fatigue.
- Calcium.