

ATHLETICS OMNIBUS – SYSTEMS FUNCTIONING IN THE HUMAN BODY

From the Athletics Omnibus of Richard Stander, South Africa

A BASIC UNDERSTANDING OF THE HUMAN BODY

The human body operates on several systems, such as the muscular system, the central nervous system, the fluid system and the hormonal system. Jointly the systems will provide most of what is required to perform an athletics achievement.

To understand how the systems enable the body to move, the athlete and coach need to have a better understanding of the human body's anatomy, physiology and chemistry. This knowledge does not have to be at the specialist level of a doctor. What is needed is a basic understanding of the functions of the human body, from the cell as the most basic live form, to advanced cell clusters such as the nervous system, to functional cell clusters such as muscles and bones in the body, to local functions of the hormone and fluid systems.

1. CELLS

A cell is a unit of living material and is the most basic building block of life. The human body consists of millions of tiny living cells which can consist of a singular cell or a cluster of many cells. The cells make up from the smallest red blood cell to clusters of cells such as bones, muscles, fluids and hormones to the larger organs in the body such as the skin, heart, lungs, etc. Together they form a highly complex "machine".

Some cells have a limited life span. The human body continuously replace some of the dead cells with new cells. When athletes are subjected to continuous strenuous exercise, the lifespan of some cells such as red blood cells are drastically reduced, and the replacement of cells has to be much faster. Some cells such as bones become harder with time.

The intake of supplements during continuous strenuous exercise is important to assist the human body to maintain, heal, manufacture and replace dead cells.

The cells have different functions in the human body and do not look all the same. The most common functions of the cells are to:

- 1.1. CARRY MESSAGES: The nervous system use cells to facilitate the electrical messages sent between the brain and the muscles. These electrical messages allow the muscles to contact the body to taste, smell, hear, feel, etc.
- 1.2. CARRY CHEMICALS: Cells carry air in the form of oxygen from the lungs to the muscles, food in the form of enzymes from the stomach to the muscles, disposables in the form of lactic acid or proteins from the muscles to the lungs and anus, etc.
- 1.3. SUPPORT THE BODY: Bone cells transform cartilage in the body of a new born baby to bones of an adolescent child. The bone cells also transform the weak areas, called growth plates, in the bones of a child, into strong solid bones of an adult that can handle high levels of work stress. The ears, nose and knee caps are examples of cartilage that never transform into bones. The bone cells also repair all bone fractures that may occur.
- 1.4. MOVE THE BODY: The power systems in the body create force to allow for breathing, eating, talking, running, etc. The most commonly used cell structures used to move the body are the muscles and bones.

2. THE SKELETON

Every human body has a skeleton within the body and is a system of bones and other connective tissue such as cartilages, ligaments and tendons. The vertebrae, consisting of 33 bones, are the largest structure of bones and form the back bone of the body. The muscles are able to move the bones at the joints with a high degree of precision and control.

2.1. BONES

The bones in the skeleton consist of an outer hard (compact) bone and an inner soft (spongy) bone. The compact bones are covered by a membrane.

Bones will adapt to training and will become stronger and robust. The adaptation takes place slowly and can take years. No training will cause the bone to become weaker and break easier.

- The human skeleton consists of more than 200 bones.
- The bones consist of hard tissue as opposed to muscles that consist of soft tissue.

The sketch illustrates how the bones fit together. The skeleton is the structure of the body and has three basic functions.

The functions are:

I. SUPPORT THE BODY

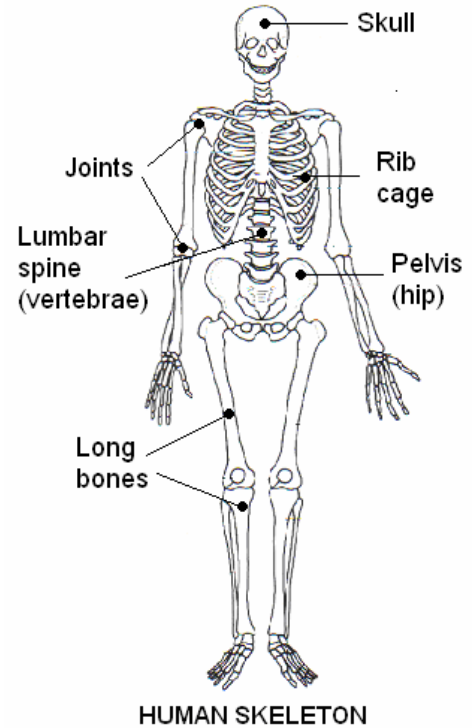
Without bones, the body will lose shape. The long bones of the limbs and the spine support the internal organs such as the digestive system (large intestine, small intestine, stomach, etc.).

II. PROTECT THE BODY

Without the bones, vulnerable organs would be left unprotected against any form of physical contact. The skull, the rib cage and the pelvis are some of the bone structures that protect the soft vital internal organs such as the heart, lungs and stomach.

III. FACILITATE MOVEMENT

Without bones, the body will not be able to stand up straight, walk or run. It provides anchorage to the muscles.



2.2. CARTILAGE

Cartilage covers the end of the bone and has a smooth, resilient surface. Cartilages are nourished and lubricated. They reduce wear and tear on the head and cavity of the bones.

Training keeps the cartilages strong. No training will make the cartilages soft, thin and easy to damage.

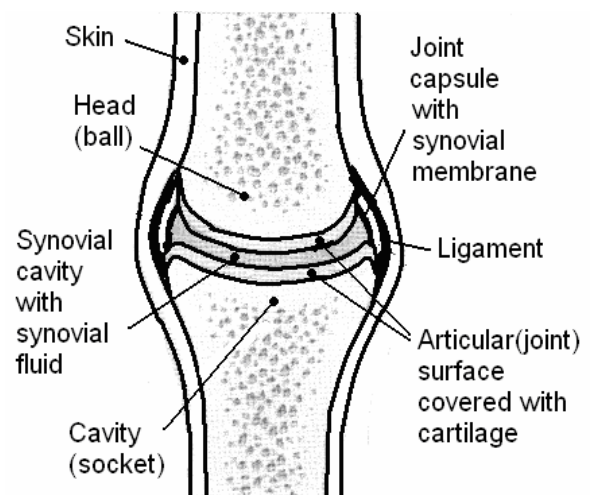
2.3. CONNECTIVE TISSUE

2.3.1. LIGAMENTS

Ligaments are a tough band of white fibrous connective tissue that links two bones together at a joint. They give stability and govern the movements of the joints.

Although tough, the ligaments are designed to be inelastic and the weakest part of the skeletal system. It will give way under severe strain before the bones break to ensure that vulnerable organs remain protected.

Training strengthens ligaments and increases the mechanical properties. Inactivity will cause the ligaments to shrivel and shrink, impairing mobility and putting inappropriate strain on the joints.



Example of the structure of a joint

2.3.2. JOINT CAPSULES

Joint capsules consist of fibrous outer tissue for stability and a thin inner membrane which produce the synovial fluids that lubricate the joints. Synovial fluids in the cavity act as lubricant between the bones in a joint in the same manner as oil in an engine.

During training the joints move with increased intensity and wear and tear on the head and cavity of the bones takes place. To counteract this wear and tear of the bones, the joint capsules produce more synovial fluid to fill the synovial cavity and keep the bones separated.

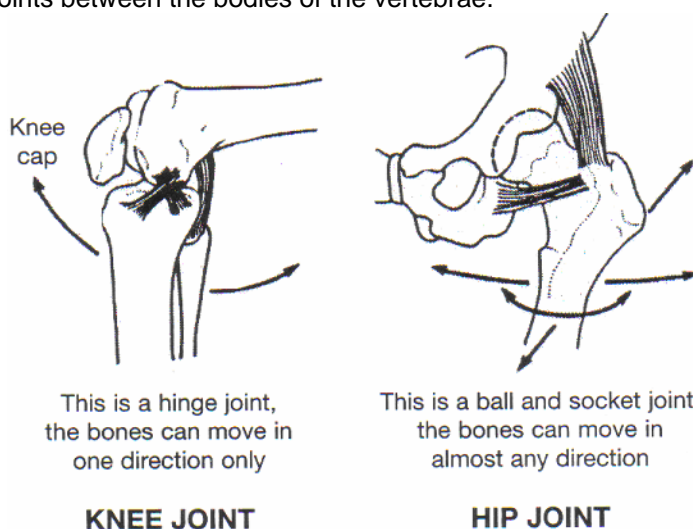
3. THE JOINTS

A joint is the point in the body at which two or more bones are connected. The various bones act as levers for the muscles to enable movement. The bones that fit close together are held together by means of ligaments and act as joints. There are three types of joints:

- Immovable joints such as the joint between the first rib and the sternum.
- Slightly moveable joints such as the joints between the bodies of the vertebrae.
- Freely moveable joints such as foot, knee, hip, shoulder and wrist joints. The freely movable joints are mainly used to facilitate movement of the body.

The freely movable joints have two main categories:

- 3.1. The hinge joint such as the knee joint that facilitate movement in a single line of movement.
- 3.2. The ball and socket joint, such as the hip joint, facilitate movement in several directions.



The bones are moved at the joints by means of contractions of the muscles attached to the bones. Factors that restricts the mobility of the joints:

- The temperature of the tissues and efficiency of the warm-up session
- The neurological system present in the muscles and around the joints
- The flexibility of the muscles, tendons, ligaments and joint capsules
- Muscular strength and degree of strength training it is subjected too
- Configuration of the bones in the joints
- Age – The older the athlete, the more disfiguration of the joints takes place
- Psychological features

4. THE MUSCLES

A muscle is simply a collection of cells. Muscles make up approximately 40% of the body weight.

The human body has approximately 434 muscles which have various functions. Only 75 pairs of muscles are involved in creating movement. Some muscles are used to keep the system of 32 bones in the vertebrae upright while others are keeping the blood circulation through the body.

The illustration shows how many muscle fibres are functional in the body. A balance must be maintained between the muscle and its opposing muscle (front and back), e.g. the pair of muscles that must contract and relax.

A balance must be maintained between the muscles on the right and the left side of the body.

The muscles consist of different fibre types. There are mainly 2 types of fibres:

- 4.1. Fast twitch fibres (white fibres) that deliver much more power and speed and is used for sprinting events.

The fast twitch fibres obtain their energy from glucose which is stored in muscular glycogen and converted into energy without the use of oxygen (anaerobic).

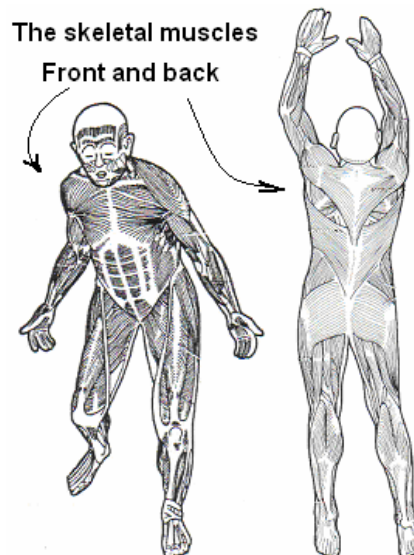
Fast twitch fibres respond well to static exercises of high intensity.

- 4.2. Slow twitch fibres (red fibres) are smaller in comparison to fast twitch fibres and produce less power and speed, but can operate for much longer periods than fast twitch fibres. Slow twitch fibres are used in endurance events.

Slow twitch fibres have a greater network of small blood vessels (capillaries), fewer nerves and have a lower level of endurance. Slow twitch fibres obtain their energy from oxygen via the blood stream. Slow fibres respond well to dynamic exercise.

In every muscle the mixture of fibre types will be different. The fibre types will also differ from person to person. The sprinter will have more fast twitch fibres and less slow twitch fibres in each muscle. The distance runner will have more slow twitch fibres and less fast twitch fibres in each muscle.

This mixture of fast and slow twitch fibres in the body is inherited and determined at birth. No amount of training can change this mixture between fast and slow twitch fibres.



5. THE FIBRES

The illustration shows how a muscle is made up. It consists of thousands of thin fibres. A group of fibres are enveloped by a layer of connective tissue called sheath, similar to the sheaths that envelops the nerves, arteries and tendons. In some muscles, such as in the illustration, several bundles are grouped together in a muscle belly.

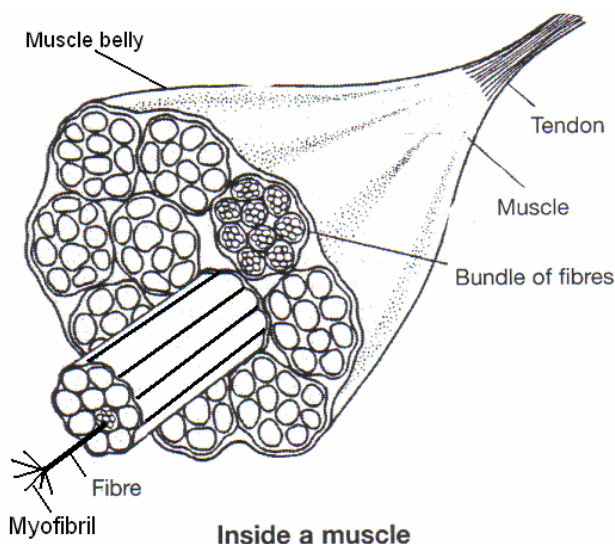
Within the muscle belly some bundles will remain in several parts and will have its own origin or head e.g. a muscle with:

- 5.1. 2 heads will be called biceps
- 5.2. 3 heads are called triceps
- 5.3. 4 heads are called quadriceps.

The bundles of fibres that are held together in a muscle belly form a strong muscle.

Each muscle tapers off towards the end to form a tendon. The tendons are attached to the bone close to the joints, and on both sides of the joints.

The muscles force the bones to move at the joints by means of contractions of the muscles.



6. TENDONS

Tendons can also be defined as connective tissue like ligaments and joint capsules and is a tough whitish cord consisting of numerous parallel bundles of collagen fibres.

The tendons are positioned at the end of the muscle and attach the muscle to the bone, close to the joint.

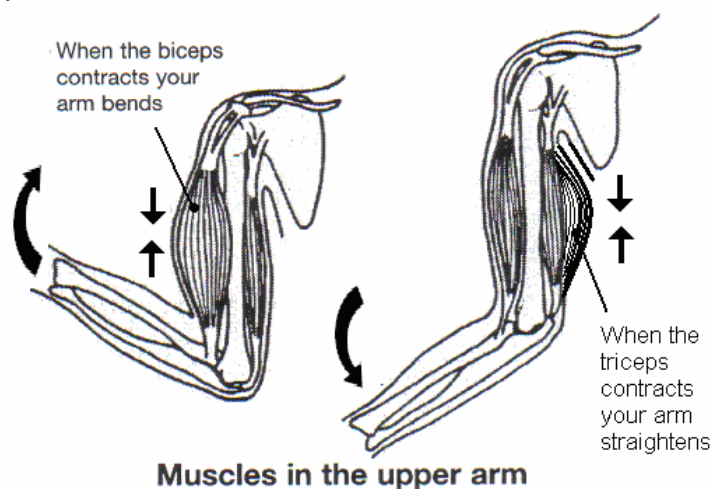
The tendon is formed in a flat zigzag shape like a flat sofa spring. The tendon acts as a back-up precaution in case the muscle is overstretched. In the case of overstretching, the tendon will unwind like spring and will regain its shape once the overstretching has stopped.

Muscles that are over-trained (overused) will cause the tendons to lose its flexibility. When muscles have to rely on its flexibility alone, muscle tearing is much more likely.

7. THE CONTRACTIONS

The illustration shows how the muscles are attached close to the joints. The muscles are soft tissue and can only pull. They cannot push. To overcome this problem, the muscles are arranged in opposing pairs, and operate in opposing pairs as shown in the illustration of the arm. One muscle will shorten, while the other muscle lengthens.

The combined action of the opposing muscles that shortens and lengthens in tandem controls the movement of the body.

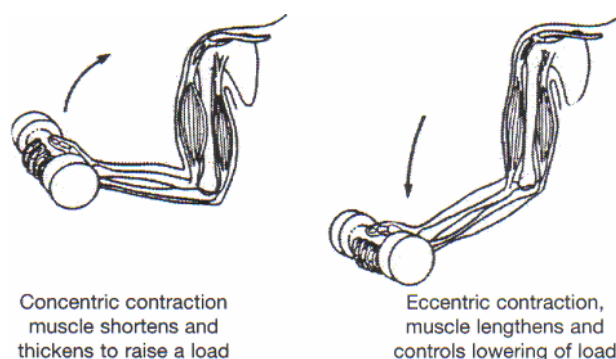


8. DYNAMIC AND STATIC CONTRACTIONS OF MUSCLES

Dynamic contractions are the muscles' actions that cause the muscles to change length and shape. There are 3 types of dynamic contractions; 2 types of dynamic muscle contractions and a static contraction.

8.1. CONCENTRIC MUSCLE CONTRACTIONS

Concentric contractions will shorten the muscles and in the process thicken, causing the muscle to appear bulky. It causes the limb to bend.



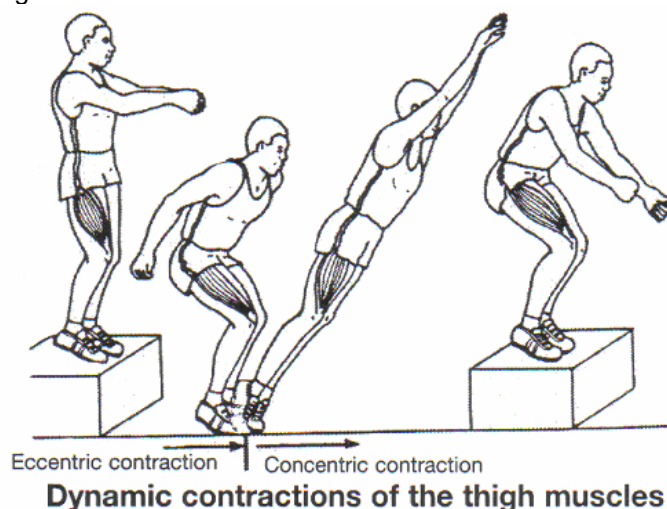
Dynamic contractions of the biceps muscle

8.2. CONTRACTIONS

Eccentric contractions will lengthen the muscles, causing the muscle to appear slim. As a result of the lengthening of the muscle the limb will straighten.

The change in muscle length results in the movement of the joints.

Another example of concentric and eccentric contractions is shown in the illustration of an athlete doing depth jumping exercises.



8.3. STATIC MUSCLE CONTRACTIONS

A static muscle contraction is a muscle not moving. When a muscle is held still in a certain position, e.g. in the 'set' position in the start, the contraction of the muscle will be static (also called isometric).



During the static period the muscle will not lengthen or shorten. As a result, there will be no movement at the joints either.

8.4. EXAMPLES OF THE 3 TYPES OF MUSCLE CONTRACTIONS

Examples of how some of the many concentric, eccentric and static contractions are applied in athletics are shown in the illustrations below.

Only some of the muscle contractions in each illustration are highlighted:

Sketch 1: The muscles of the sprinter in the 'set' position are static while the body generates driving force for the start.

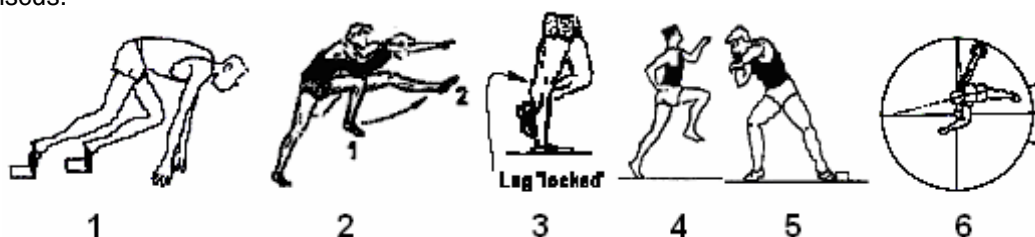
Sketch 2: The hurdler, when crossing the hurdle has the lead leg in a concentric contraction (1) when the lead leg is approaching the hurdle; when crossing the hurdle in an eccentric position (2), the lead leg is in a static position while allowing for the trailing leg to cross the hurdle (2).

Sketch 3: The Race Walker has the locked leg in a static position to allow for the lead leg to move forward.

Sketch 4: The long jumper, on take-off, has the lead leg in a concentric contraction to allow for a faster upswing, the trailing leg is in a static contraction, while the ankle muscles are executing a combined concentric/eccentric contraction.

Sketch 5: The Shot Putter (in the power position), has the leg and foot against the block in a static contraction, while the torso muscles are concentrically contracting to move the Shot forward.

Sketch 6: The Discus Thrower (in the power position), has the trailing arm in a static contraction, while the shoulder is in an eccentric contraction to create torque in the torso prior to final delivery of the discus.



9. THE NERVOUS SYSTEM

The brain and a network of nerves throughout the body form the nervous system as illustrated in the sketch. It serves as the body's own telecommunications system.

For the body to execute the desired movements to compete in athletics, an intricate series of signals needs to be sent and received from the brain to the nerves.

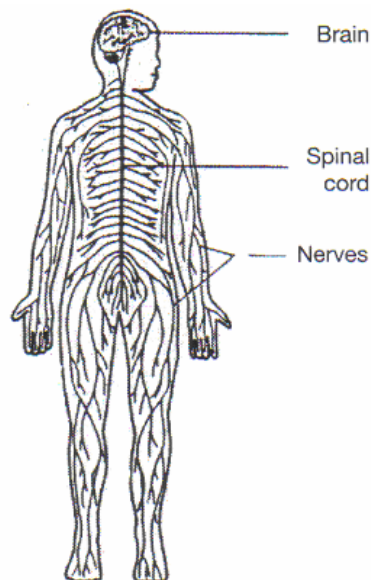
The nervous system acts as a two way communication system between the muscles and the brain to send and receive signals.

The muscles will act on the signals from the nervous system by means of concentric, eccentric or static contractions.

Once the action of the muscle is completed, the nervous system will signal back to the brain to what extent the muscles acted on the signals from the nervous system.

Based on the information received via the nervous system, the brain will co-ordinate or correct the movements of the limbs by means of a series of signals through the nervous system to the muscles. The information includes all senses, e.g. how fast and with what force muscles must contract.

The effectiveness and speed that signals are sent or received by the brain, need to be trained as frequently as the physical training of the muscles. Rhythm and muscle co-ordinations drills are frequently used as part of the training programme to improve the speed of the interaction between the brain and the muscles.



The nervous system

10. THE CARDIO VASCULAR AND RESPIRATORY SYSTEM

The Cardio Vascular System is a tubular network of channels and organs that transports the blood through the body. The blood carries food from the digestive system to where it is needed in the body.

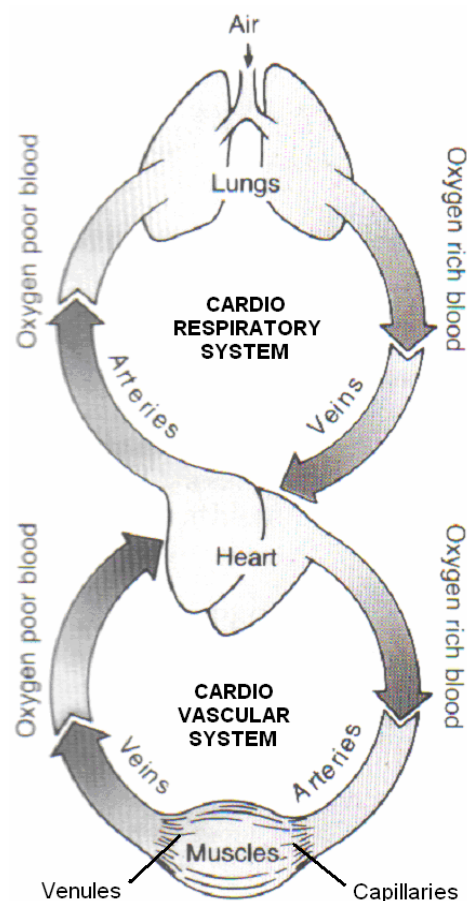
The Cardio Respiratory System is a tubular network of channels and organs that supply oxygen to the body.

During training, the athlete needs to increase air intake into the body, to ensure that the muscles have a constant supply of oxygen needed for the energy manufacturing that takes place within the muscles.

Developing the Cardio Vascular System and Cardio Respiratory System has the following value:

- The diffusion (extracting) rate of oxygen from air in the lungs is faster.
- The concentration of oxygen in the arteries is higher.
- Oxygen utilisation in the muscles is higher.
- Cardiac output of the heart increases.
- The blood flow rate through the arteries and veins is faster.
- Removal of disposables in the body is faster.
- The prevention of infection by healing wounds and fighting off germs is more effective

All the above will increase the work load and efficiency of the body.



10.1.HEART

The heart is a muscle with the primary function to pump blood through one way valves into the circulatory system around the body, 24 hours a day, from the day you are born to the day that you die.

The heart has 4 chambers, 2 on top and 2 below.

- The 2 lower chambers pump the blood to the muscles through a tubular network of channels called arteries. The blood from the lower chambers is oxygenated (oxygen rich) and flow through capillaries to the body organs and tissues.
- The 2 upper chambers receive the blood through a tubular network of channels called veins. The blood in the veins and upper chambers is deoxygenated (oxygen lean).

The cycle of the blood pumping through the 4 chambers is called a heart beat. Regular training requires a faster heart rate, and over time the size of the heart will become bigger and stronger to accommodate an increased volume of blood flowing through the heart.

The heart pumps the blood at an average of 72 beats per minute or less when the body is at rest. The pulse for advanced athletes may drop to lower than 50 beats per minute at rest after regular training over several years as a result of a stronger and larger heart.

During training, the beats per minute can increase to more than 200 beats per minute for adults, but will be less for masters and more for adolescents.

10.2.LUNGS

The body have 2 lungs to fulfil primarily 2 functions.

- Firstly, air is taken through the nose or mouth into the right lung. To ensure that the body receive enough oxygen during the inhaling process, the right lung is formed in such a way that the air flows through a network of wafer thin globular clusters inside the lung. The air will make contact with the globular clusters as many times as possible, and in the process extract as many oxygen as possible from the air into the blood.

After oxygenation (oxygen extracted from the air into the blood), the blood flow to the lower 2 chambers of the heart, from where it is circulated through the body.

- The 2nd function is executed by the left lung. Carbon dioxide needs to be discarded by the body. The carbon dioxide came as a by-product during the aerobic process, when muscles manufactured energy from oxygen in the blood.

The deoxygenated blood received from the upper chambers of the heart releases the carbon dioxide by making contact with the waver thin globular clusters in the left lung. From the left lung the carbon-dioxide is released into the air through the nose or mouth.

At rest, the body needs about 10 litres of oxygen. During training, the body will need more oxygen. To cope with this greater demand, an increased breathing rate will circulate 120-150 litres per minute through the lungs.

During this increased oxygen demand, it is better to take in air through the mouth rather than the nose, because more air can circulate through the mouth than the nose.

10.3.VEINS

Veins are a tubular network of channels transporting deoxygenated blood from the muscles to the heart and lungs. The upper two chambers of the heart are attached to the left lung with veins. The heart pumps the deoxygenated blood, which has a dark red colour, through the veins to the lungs from where the body can discard of the carbon dioxide through the mouth.

A network of veins is also attached to the heart with the muscles in the body. The veins collect deoxygenated blood throughout the body and transport it to the upper two chambers of the heart from where the deoxinated blood is pumped to the lungs.

10.4. ARTERIES

Arteries are a tubular network of channels transporting oxygenated blood from the lung and heart to the muscles. The lower two chambers of the heart are attached to the right lung with arteries. The heart receives oxygenated blood, which has a bright red colour, through the veins from the lungs.

As the blood flows through the arteries from the heart to the muscles, it loses oxygen as the muscles use the oxygen to manufacture energy. The by-products of this manufacturing process are waste products such as carbon dioxide and lactic acid and they remain behind in the muscles until they are carried away from the muscles by the veins to the heart to provide space for oxygenated blood from the arteries.

10.5. CAPILLARIES

Relying on the arteries alone to transport the oxygen to the muscles fast enough, or relying on the veins alone to transport the lactic acid away from the muscles is not enough.

Capillaries are an extension of the arteries. Their function is to transport the blood as fast as possible and as close as possible to the working muscle. There are normally 2-3 capillaries at the end of each artery.

There are approximately 3000 capillaries per square mm on cross section. Their function is to transport the blood as fast as possible and as close as possible to the working muscle.

When the muscle is at rest, 95% of the capillaries are closed but during training they open progressively to ensure an ample blood flow to the working tissue. It is therefore important to do warm-up exercises before training.

During training the heart rate will increase from 72 beats per minute to more than 200 beats per minute. At the same time the air intake will increase from 50 litres per minute to more than 150 litres per minute.

The increased heart rate and blood flow through the cardiovascular system will increase the width of the arteries and the veins.

The result of continuous training over many years will increase the amount of capillaries at the end of each artery to as much as 7-8 capillaries at the end of the artery, making the transport of oxygen to the muscles much more effective.

The value of the increased amount of capillaries is:

- Oxygen is transported much faster to the muscle.
- An increased amount of muscle enzymes (protein catalysts) are transported to the muscles.
- The number of units (mitochondria) in which energy conversion takes place increases in the muscle.
- Storage of fuel for the production of energy increases in the muscle.
- Muscular volume increases (hypertrophy)

11. VENULES

With the increase of capillaries between the muscle fibres, the need for more venules to transport blood away from the muscles to the veins also increases.

Relying on the veins alone to transport the lactic acid and other disposables away from the muscles is not enough. The amount of venules at the end of the veins needs to increase as well. The value of the increased amount of venules in the muscles is:

11.1. Disposables such as lactic acid are transported away from the muscle much faster.

11.2. The feeling of stiffness after a training session will be much less

11.3. The healing process in the muscles can take place much faster.

11.4. Oxygen can be made available to the muscles much more frequently, resulting in a better and more sustainable performance of the muscles.

12. FLUID SYSTEMS

There are several fluid systems with specific functions in the human body and are largely dependent on the presence of water in the body. The fluid systems are operational in specific organs such as:

- The system that eliminates urine through the kidneys
- The system that facilitates perspiration (sweat) through the skin
- The system that facilitates the inhaling and expiring of air through the lungs (breathing)
- The system that facilitates digestion and transportation of food and waste products through the intestines
- The system that provides lubrication to moving body parts such as the eyes, joints, etc.
- The system that transports nutrients and waste products between the heart and the muscles (blood plasma)

12.1. BLOOD PLASMA

The fluid system that must be monitored regularly, preferably on a monthly basis, is the blood that transports the nutrients and waste products between the heart and the muscles.

Blood plasma consist 90% of water and is straw coloured. White and red blood cells are some of the many cells suspended in the blood along with nutrients and waste products.

To give an idea of the complexity of blood, only one of the many substances found in blood is red blood cells:

- The average man has 5 000 000 red blood cells per cubic cm and the average woman has 4 500 000 red blood cells per cubic cm in the body.
- The average life span of a red blood cell is 120 days. The life span of a red blood cell can be reduced to as little as 20 days if the body is subjected to continuous intensive training, or during the period that children grow fast, or during a woman's pregnancy or menstruation.
- Each one of these red blood cells consist of approximately 280 000 000 haemoglobin molecules, the substance that release the oxygen from the muscles into the muscles during a series of enzymatic reactions. These enzymatic reactions ensure that energy is created to contract the muscles.

Blood plasma has two primary functions:

- 12.1.1. To transport oxygen, enzymes and other substances to the various cells such as muscles, bone and organs where a range of chemical processes take place in the body.
- 12.1.2. To transport disposable material away from the muscles as a result of the various chemical reactions in the body.

A by-product of the series of enzymatic reactions between the blood and the muscles is lactic acid.

Protein based disposables are also present in the blood as a by-product of messages sends in the neurological system, the transformation of cartilage to bone, friction between muscle fibres and other processes.

13. HORMONAL SYSTEMS (ENDOCRINE OR DUCTLESS SYSTEMS)

Hormones are highly specific chemical compounds produced by the endocrine (ductless) system of glands. The endocrine system senses changes in the body e.g. a rise in temperature, an increase of waste products in the blood, a shortage of red blood cells, etc.

The hormones regulate all functions of the organs in the body. They ensure that the body maintain the equilibrium between the body functions. The endocrine system will e.g. respond and adapt to all changes in the body to ensure that the body functions maintain its equilibrium.

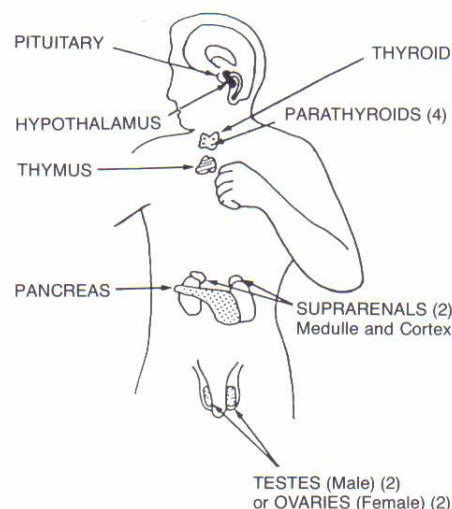
The hormones are transported by the blood to exert specific effects on cells in remote places in the body.

There are two types of hormones:

13.1. General hormones that are transported through the circulatory system (blood stream) to all parts of the body to maintain the equilibrium between the body functions.

13.2. Local hormones are utilized at or near to their site of origin e.g.

- Pancreas produces enzymes from the digestive system and release it in the blood stream
- Suprarenal (medulla and cortex) that produces adrenalin to prepare the body for fright, flight or fight
- Thyroid that produce hormones to regulate growth and development through the rate of metabolism
- Pituitary, attached to the base of the brain, that produces hormones that control growth and the functioning of other endocrine glands
- Thymus that produces hormones to maintain the immune system
- Parathyroid that produce hormones regulating the calcium levels in the body
- Hypothalamus situated in the forebrain that produces hormones to control body temperature, thirst, hunger, sleep and emotional activity.
- Testicles of men (ovaries in women) produce hormones for reproduction



THE HORMONAL OR ENDOCRINE SYSTEM

The endocrine systems do not operate independently. When the endocrine system senses e.g. a rise in body temperature as a result of training, a complex interplay of one endocrine upon another, which will initiates a compensatory effect e.g. heat loss through sweating.

14. CONCLUSION

In conclusion, the production of energy is closely linked with the performance of the athlete.

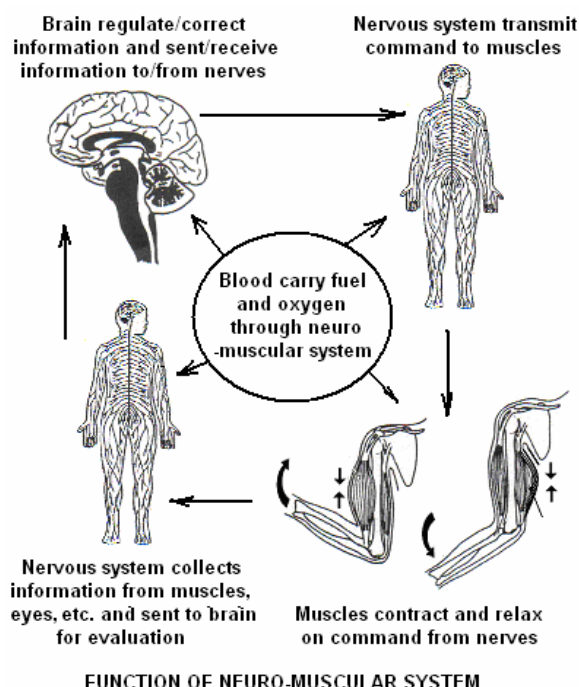
The conditioning of the muscles to acquire and use energy is a basic requirement for increased performance levels.

The central nervous system controls the specific patterns of contractions and relaxation of the muscular system.

Fuel from the digestive system and oxygen from the respiratory system are carried by the vascular system to the muscles, providing energy for contraction.

It is the contraction of the muscle and the resultant pull on the relevant parts of the skeletal system that provides the movements of the body.

The body's fluid systems and hormonal systems are the major influences in ensuring stability of conditions within the body, so that the other systems may function efficiently.



FUNCTION OF NEURO-MUSCULAR SYSTEM

A better understanding of the basic anatomy and physiology of the human body will contribute towards understanding the bio-mechanics of the human body better.

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