Module Two:

Anatomy of the Athlete

INTRODUCTION

The Level One course provided you with basic information about the skeletal and muscular systems of the body. This module studies these systems in more depth, applies this knowledge to the analysis of human movement, and looks at the application of analysis results to the development of conditioning programmes for athletes.

Upon completion of this module, you will be able to:

EXPLAIN THE STRUCTURE AND FUNCTIONS OF THE SKELETAL SYSTEM

UNDERSTAND THE STRUCTURE OF JOINTS AND THE MOVEMENTS POSSIBLE AT SYNOVIAL JOINTS

EXPLAIN THE STRUCTURE AND FUNCTIONS OF THE MUSCULAR SYSTEM

EXPLAIN MUSCLE ACTION IN THE HUMAN BODY

APPLY YOUR KNOWLEDGE OF THE SKELETAL AND MUSCULAR SYSTEMS TO ANALYSE MUSCLE ACTION

EXPLAIN THE STRUCTURE AND FUNCTIONS OF THE SKELETAL SYSTEM

THE SKELETAL SYSTEM

The framework of the human body is made up of just over 200 bones, which vary considerably in size and shape. Bones are often thought of as dry, inert structures, similar to a bone which has been dug up in the garden by the neighbour's dog! However, bone is not a dead structure. It is made up of living bone tissue, which is a type of connective tissue, the hardest of all connective tissues found in the body.

FUNCTIONS OF THE SKELETON

The skeleton has five important functions in the body:

1. **Protection**

   The bones protect internal organs by forming strong protective enclosures, e.g. skull, ribs, spine.

2. **Support**

   The skeleton gives rigidity to the body. Without the support of the skeleton, we would be shapeless lumps.

3. **Movement**

   The skeleton provides attachment for muscles.
   The bones serve as levers in pulley systems whereby movements can be produced by muscles at the moveable joints in the body.

4. **Blood cell production**

   Blood cells are manufactured in the red marrow within bones. Red blood cells transport oxygen around the body and white blood cells are responsible for the body's defence system to fight infection.

5. **Calcium storage**

   Bones are the storehouse for minerals, in particular calcium. This is important for strength of bones, for if these minerals are depleted, it may lead to stress fractures and osteoporosis (brittle bones).

CLASSIFICATION OF BONES

Bones are normally classified according to their shape, which is related to their function.

Long bones

Provide effective levers to facilitate movement, e.g. femur, humerus.

Short bones

Provide strength to resist compression, e.g. bones of the foot (tarsals) and wrist (carpals).

Flat bones

Provide protection to internal organs, e.g. ribs, cranium, pelvic girdle; and for attachment of large muscles, e.g. scapula.

Irregular bones

Usually have mixed functions, e.g. patella provides protection to the knee joint; collectively, the vertebrae provide support to the body and protect the spinal cord.

Sesamoid bones

Present in certain tendons to improve leverage by preventing friction, and by altering the angle of pull of the muscle, e.g. patella.

The skeletal system of the body is divided into two main sections: the axial skeleton and the appendicular skeleton.

The axial skeleton is the central axis of the body and is made up of the vertebral column, the skull, and the ribs and sternum. The skull encloses and protects the delicate structures of the brain and sensory organs, such as the eyes and inner ears.

The spine is a column of very complex irregular bones, stacked one on top of the other. This structure combines flexibility with strength and rigidity, allowing movement in certain parts of its length while providing protection

for the spinal cord most of the way down. The 33 vertebrae are divided into five regions: cervical (7), thoracic (12), lumbar (5), sacral
(5 fused vertebrae), and coccygeal (4 fused vertebrae). The shape and design of the vertebrae in each area are modified for the specific function of that area.

The spine is so important that it is worthwhile looking at the structure of a typical vertebra. As seen in Figure 2, each vertebra consists of a body to which is attached the vertebral arch. The vertebral arch encloses a gap in which lies the spinal cord. From the vertebral arch there are bony projections called processes; one on each side called transverse processes, and one at the back called the spinous process. These can act as short levers for some of the spinal muscles, and also as points of attachment for muscles and ligaments. The superior and inferior processes of adjacent vertebrae articulate with each other to form a joint.

Fig.1 The spinal column.

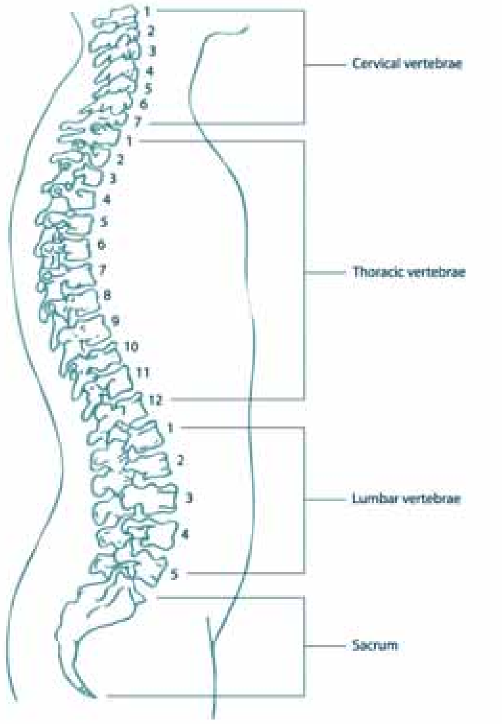
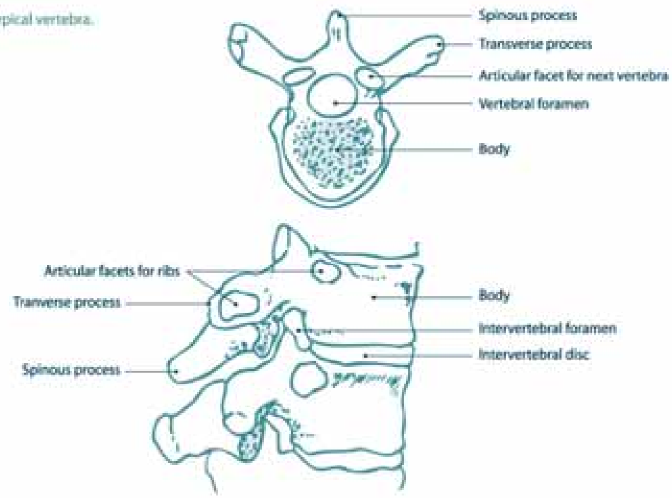


Fig.2 A typical vertebra.



The bodies of adjacent vertebrae are joined by a pad called an intervertebral disc, which is composed primarily of fibrocartilage with a small amount of jelly-like pulp filling the centre. It is these discs which are blamed for so much back pain. They are very firmly attached to the vertebral bodies and act as shock absorbers, preventing the skull and brain from being jarred when running or jumping.

The ribs and sternum are flat bones which form a protective cage around the heart and lungs. The ribs are connected at the back to the thoracic vertebrae by slightly moveable joints, and at the front to the sternum with cartilage. This flexible structure allows the movement necessary for breathing.

The appendicular skeleton is made up of appendages which are attached to the axial skeleton: the shoulder girdle (clavicle and scapula) and arms (humerus, ulna, radius, carpals, metacarpals and phalanges), and the pelvic girdle and legs (femur patella, tibia, fibula, tarsus, metatarsals and phalanges).

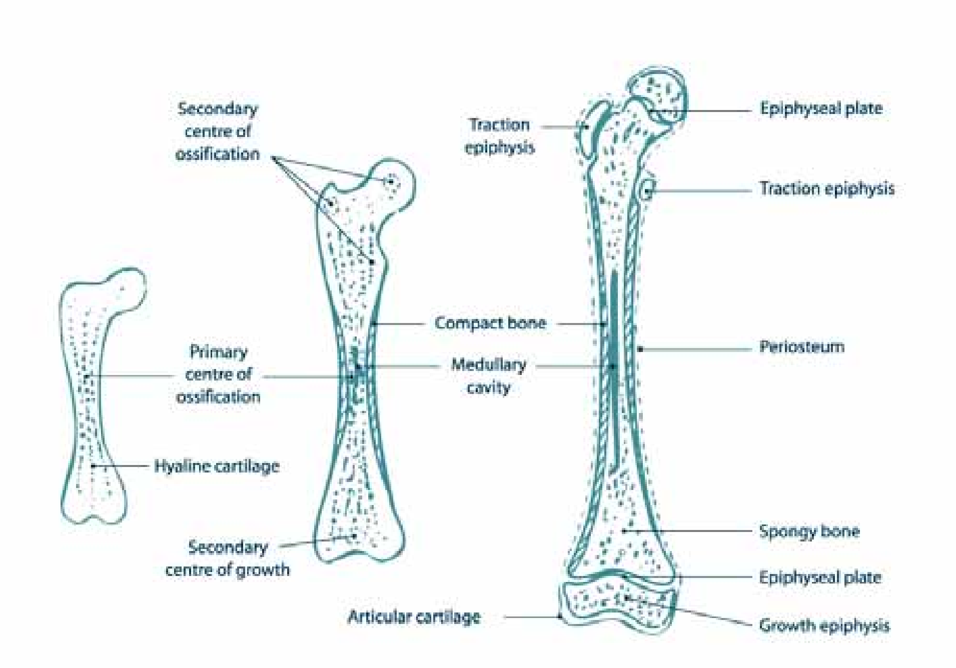
The shoulder girdle, with a bony connection between the clavicles and sternum, is otherwise suspended in muscle, which allows for a wide range of movement. Unlike the shoulder girdle, the pelvic girdle is a complete bony structure which is strong and rigid. This allows it to support the weight of the body, and to transmit very large forces which are developed by the actions of the legs. The two pelvic bones form a fixed joint at the front, the pubis, and are connected by slightly moveable joints with the sacrum at the back.

THE STRUCTURE AND GROWTH OF LONG BONES

A typical long bone, such as the femur, must be able to serve as mechanical lever during motion, while being strong enough to withstand the weight of the body, and the forces experienced during activity. The long bones are formed as strong, but light, tubular structures with enlarged ends called epiphyses, and a narrow shaft called the diaphysis. The outer shell of the bone is composed of hard, dense compact bone which provides support and protection. The epiphyses are filled with porous, spongy bone and red bone marrow. Within the shaft of the bone is a hollow cavity which is lined with a thin, delicate membrane and filled with yellow bone marrow.

Bone is covered by an outer fibrous layer known as the periosteum. This layer has a rich supply of nerves and blood vessels and enables the attachment of tendons and ligaments to the bone as well as serving as a site for nutrition, repair and bone growth.

The growth of bones occurs along the epiphyseal (growth) plates, which are bands of cartilage located between the diaphysis and each epiphysis. As the bone develops and grows, new bone cells are laid down along the epiphyseal plates while, at the same time, new cartilage is continually being formed allowing the bone to lengthen. As a person matures, this cartilage is replaced by bone.



There are three important periods in the development of bone:

1. **The formative period** – bone is formed from either cartilage or fibrous tissue by a process of ossification. This process starts around the fifth to twelfth week of embryonic life.
2. **The growth period** – from birth to puberty secondary growth centres appear in the bone. These occur close to the ends of the bone at the epiphyses. Any injury to the epiphyses during this stage, such as a fracture, may impair growth.
3. **The consolidation period** – this is from the 14th to the 25th year.

QUESTIONS & EXERCISES

You may find it useful to examine the structure of a bone. Use a long bone that has been sawn in half lengthwise (ask a butcher to do this for you).

Examine the bone and complete the following exercises:

- *identify compact bone, spongy bone, and bone marrow,*
- *describe the colour of the marrow and explain its functions,*
- *identify the periosteum and scrape a small section with a scalpel or sharp knife, to examine its structure, and*
- *examine any cartilage present and explain its functions.*

UNDERSTAND THE STRUCTURE OF JOINTS AND THE MOVEMENTS POSSIBLE AT SYNOVIAL JOINTS

JOINTS

A joint, or articulation, is the interface (coming together) of two bones. Usually the purpose of the joint is to allow some movement, but the bones of the skull, for example, are joined so tightly that there is no movement. The structure and type of joint will depend on its specific function.

Fibrous joints

Where fibrous tissue unites the bones, e.g. between the radius and ulna above the wrist, and the tibia and fibula above the ankle. A joint such as this seems to occur where movement is undesirable but a little ’give’ is necessary.

Cartilaginous joints

There are two types of cartilaginous joints: (a) hyaline cartilage, which is rigid and forms a bar uniting the first rib to the sternum (breastbone), and (b) fibro-cartilage which is less rigid, allowing freer movement, e.g. an intervertebral disc.

Synovial joints

The freely moving synovial joints are more specialised joints and functionally are the most important for you, as a coach, to know about and understand.

CLASSIFICATION OF SYNOVIAL JOINTS

The type of movement possible at a joint depends upon the shape of the bones where the joint surfaces fit together. Synovial joints are classified according to their movement potential. See the table below.

CLASSIFICATION OF SYNOVIAL JOINTS

Uni-axial **(one movement plane)**	**Bi-axial** **(two movement planes)**	**Multi-axial** **(many movement planes)**
Hinge joint – elbow, knee, ankle, interphalangeal joints of fingers. (tarsals).	**Condyloid** – the knuckles, joints, heads of metacarpals.	**Plane** joints – small joints where gliding movement occurs, e.g. between bones in hand (carpals) and foot
Pivot joint – upper end of radius movements, in forearm.	**Ellipsoid** – wrist.	**Saddle** joints – allow rotary e.g. the joint base of thumb.
	Sliding – between two vertebrae, carpal and metacarpal bones of the thumb.	**Ball and socket** – e.g. hip joint.

Table 1. Classification of synovial joints according to their movement potential.

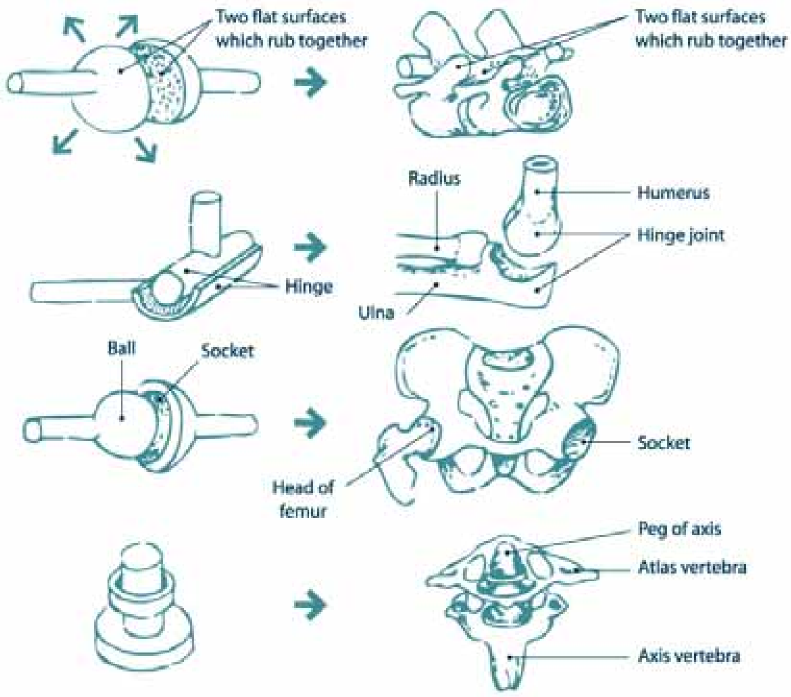


Fig.4 Examples of different types of synovial joints.

A SYNOVIAL JOINT IN DETAIL

Most sports rely on good joint mobility for optimal performance, so it is important that you have a knowledge of the basic structure of synovial joints and the factors that influence mobility.

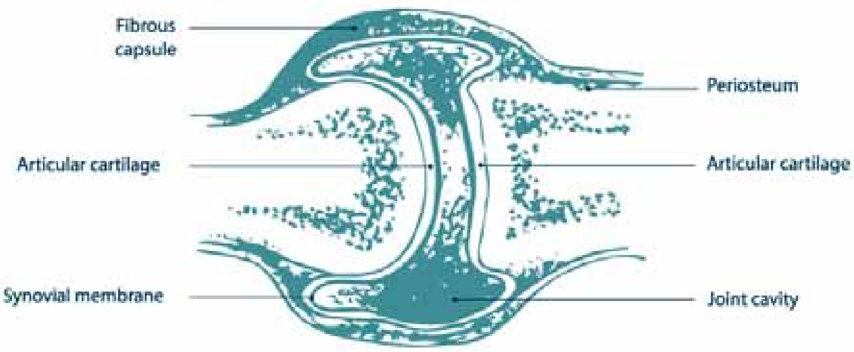


Fig.5 Scheme of a synovial joint.

(For clarity, two bones are pulled apart and the capsule is inflated.)

The Joint Surfaces

Joint surfaces are shaped to fit together, although
the exactness of the fit depends upon the type and function of the joint, e.g. the hip joint has a large deep socket in which the head of the femur fits snugly. This permits a good range of movement combined with great stability. The surfaces of the joint are covered with a layer of articular cartilage. This protects the bony tissue and is lubricated to help reduce friction between the bones

The Joint Capsule

The epiphyses of the bones on each side of a joint are held together by the joint capsule, which is composed of tough white fibrous tissue. The edges of this fibrous cuff merge with the periosteum of the bones, and the while structure is strong and stretch-resistant. The capsule adds stability to the joint, and prevents unwanted material from entering it.

The Synovial Membrane

The synovial membrane which lines the inside of the capsule has a rich supply of blood and nerve endings.
It secretes synovial fluid into the joint which acts as a lubricant to the moving surfaces and also nourishes them. When a joint is damaged, the synovial membrane becomes inflamed and there is an increase of fluid within the joint cavity, causing the joint to swell.

Ligaments

Ligaments are strong fibrous bands which run between the ends of the bones forming the joint. They protect the joint by preventing or restraining excess movement in an undesired plane. The ligaments are mainly white, non-elastic fibres, which are often injured in strains and sprains occurring at joints, e.g. lateral ligament of the ankle, cruciate ligaments of the knee. Ligaments also limit the range or extent of normal movement, thereby allowing more ’give’, e.g. ligaments of the spine. These ligaments are mainly yellow, elastic fibres.

Ligaments can exist either as well defined, localised thickenings of the capsule of a joint (capsular ligament), or as independent structures found outside or sometimes inside the joint space. At the knee (see Figure 6) the medial and lateral collateral ligaments are external to the joint and prevent excessive sideways movement, whereas the anterior and posterior cruciate ligaments are within the joint and prevent excessive forwards and backwards movement. With a severe twisting injury to the knee, both the cruciate and collateral ligaments may damaged, and the cartilage may also be torn.

The ligaments and joint capsule are very strong, but
if injured they may take a long time to heal because they are poorly supplied with blood vessels. Almost all sports performers have experienced ligament injuries at some time. Cases of severe ligament damage can result in permanent joint instability

Menisci

Pieces of cartilage of various shapes are sometimes found between joint surfaces. They improve stability, reduce friction on the articular cartilage, and in some instances absorb shock, e.g. the crescent-shaped wedges within the knee joint. The outer margins of these cartilages are tightly bound to the flat top of the tibia. This forms a deeper socket for the femur to enter. The menisci can glide back and forth and may be pinched or torn in a severe twisting injury on a bent knee. Anther example is in the shoulder joint, where a similar wedge-shaped cartilage surrounds the margin of the socket of the joint (the glenoid cavity), and likewise helps to deepen the socket and stabilise the joint. Cartilages increase in size slightly during warm-up work, which helps to add further stability to the joints.

Bursae

A bursa is a small flat sac made of white fibrous tissue and lined with synovial membrane. The synovial membrane secretes fluid into the free space within the bursa for lubrication. Their function is to eliminate friction where a muscle or tendon is likely to rub on another muscle, tendon, or bone during movement. The smooth lubricated inner walls of the bursae slide over each other, thus preventing wear and tear. Practically all major joints of the body have bursae associated with them.

Synovial Sheath

Where a tendon runs in a tunnel and is liable to friction on all sides, as in the hand and foot, the bursa surrounding the tendon is known as a tubular bursa or synovial sheath. This sheath has two walls: the outer lines the tunnel, and the inner is attached to the tendon. Movements of the contained tendon occur in a frictionless gliding of the two walls. The bursae or sheaths can become inflamed under direct pressure, or through overuse, e.g. ischial bursitis (bursa between gluteals and underlying bone) in cyclists, and hand tendon synovitis due to excessive gripping on handlebars.

Fat Pads

Small pads of fat are found in and around joints to accommodate spaces in the joint cavity which occur upon movement of the joint surfaces. These are firmly anchored, but they can occasionally become momentarily trapped which can lead to painful inflammation.

MOVEMENTS POSSIBLE AT SYNOVIAL JOINTS

The range and type of movement vary in different joints. There are three planes in which movement occurs:

1. **The sagittal plane** – divides the body into right and left halves. Movements occurring: *flexion* (bending, decreasing the angle between the two bones of a joint), *extension* (straightening, increasing the angle between the two bones of the joint), *dorsi flexion* (raising the toes and foot towards the tibia) and *plantar flexion* (pointing the toes), which occur at the ankle.
2. **The frontal plane** – divides the body into anterior (front) and posterior (rear) halves. Movements occurring: *abduction* (taking a limb away from the mid-line), *adduction* (taking a limb towards the mid-line), *eversion* (movement of the sole of the foot outward at the ankle) and *inversion* (movement of the sole the foot inward at the ankle), which occur at the mid-tarsal joints.
3. **The horizontal plane** – divides the body into superior (upper) and inferior (lower) halves. Movements occurring: *medial* (inward) and *lateral* (outward) *rotation* around a central axis, *supination* (movement of the forearm so that the radius and ulna are parallel; palms up or forwards) and *pronation* (movement of the forearm so that the radius and ulna are crossed; palms down or backwards) most often occur in this plane.

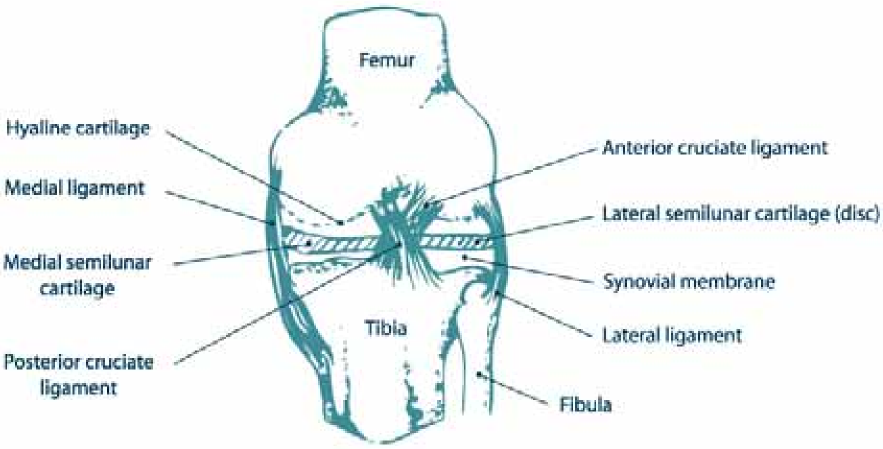


Fig.6 Ligaments of the knee joint. (Extended right knee from behind.)

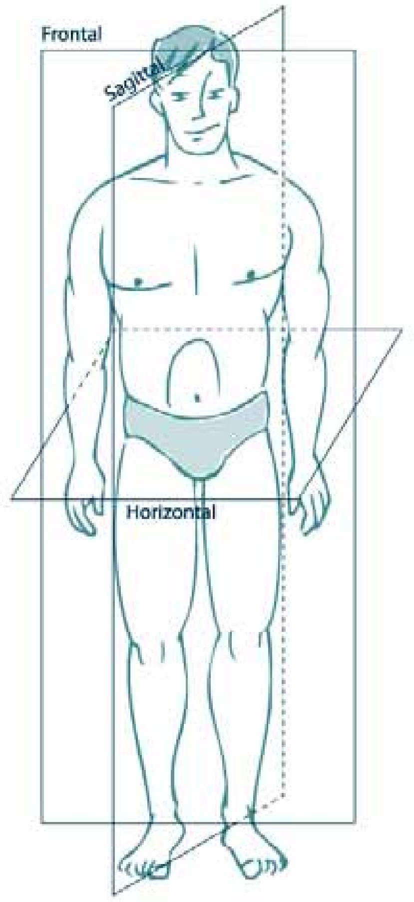


Fig.7 Planes in which movement occurs.

The movements which occur at each joint will be determined by the joint type and its planes of movement, e.g. the hip joint, which is a ball and socket joint, is multi-axial, therefore movements occurring here are flexion, extension, abduction, adduction, medial and lateral rotation.

The three planes of movement occur at right angles to one another, and can be combined to produce movements in intermediate planes, e.g. at the shoulder joint circumduction can take place, which is a combination of flexion, abduction, extension and adduction.

QUESTIONS & EXERCISES

Select basic actions from your sport and identify, using anatomical terms, the movements performed at each major joint. For example:

Upward phase of a vertical jump

Movements occurring at the:

ankles
knees
hip
trunk
elbows
shoulders

Netball goal shooting

Movements occurring at the:

ankles
knees
hips
shoulder
elbow
wrist

It may be useful to draw stick diagrams in completing this exercise.

EXPLAIN THE STRUCTURE AND FUNCTIONS OF THE MUSCULAR SYSTEM

TYPES OF MUSCLE

The muscular system constitutes about 45% of our total body weight. Muscles are made up of 30% protein and 70% salt solution. Without muscles all actions, including movements as simple as maintaining normal posture, breathing, and walking, would not be possible. There are three types of muscle in the body.

1. **Voluntary or skeletal muscle** is so called because it is under our direct control and the muscles are attached to the skeleton.
2. **Involuntary or smooth muscle** is found in the digestive tract, circulatory system, respiratory system, and other places where the movements required are outside our direct control.
3. **Cardiac muscle** is a highly specialised type of muscle which is only found in the heart.

All three types of muscle:

- are controlled by nervous impulses,
- are able to contract or shorten, becoming thicker as they do so,
- will stretch when a force is applied along their length,
- return to their original shape and size after being stretched or contracted,
- will atrophy (waste) if they have a restricted blood supply or are not used,
- will hypertrophy (enlarge) in response to an increase in workload, and
- have a good blood supply from the capillaries that penetrate their fibres.

The emphasis in this module is on those muscles which can be voluntarily contracted to effect movement of the body, rather than the involuntary smooth and cardiac muscles.

STRUCTURE AND FUNCTION OF SKELETAL MUSCLES

Skeletal muscles are composed of thousands of muscle fibres. Each muscle fibre is a long thin cell about the thickness of a hair. Each fibre consists of many contractile units called myofibrils, which run the length of the fibre and have characteristic light and dark bands or striations. Bundles of muscle fibres are bound together by connective tissues which, in turn, are united within a tough outer sheath to form the muscle belly.

Muscle Attachments

Muscles are attached to bones by a tendon, which is a tough cord or band composed of tightly packed fibres, or by an aponeurosis, which is a sheet-like tendon. Tendons are usually similar in shape to their muscles, i.e. a flat muscle has a flat tendon, while a rounder muscle is usually attached at a point by a cord-like tendon. Muscles generally cross a single joint, running between two bones, e.g. the deltoid muscle at the shoulder joint, They may also cross two or more joints, with attachments on more than two bones, thereby acting on all of the joints involved, e.g. quadriceps crosses and acts on both the hip and the knee joints.

Muscle Contractions

When a muscle contracts and shortens, it pulls on both of the bones to which it is attached, moving one or both of the bones towards the other. In most movements however, one bone is stabilised, either by other muscles or external restraints, and is therefore relatively stationary. The site on the more stationary bone to which the muscle attaches is called the muscle’s origin (nearer to the centre of the body), while the attachment to the more moveable bone is called the insertion (more peripherally situated).

The origin (stationary or fixed end) generally has a larger area of attachment, or more points of attachment, than does the insertion (moving end). The description of the origin and insertion is dependent on the specific direction of the movement and may be interchanged.

As a coach, you do not require a precise knowledge of a muscle’s origin and insertion to understand muscle action. It is sufficient to have a general know-ledge of the position of a muscle and the direction in which it pulls, in order to understand its actions.

Fast and Slow Twitch Muscle Fibres

Different types of skeletal muscle exist in humans, and each type has different functions. Red fibres appear to be adapted to suit slow aerobic activity, and are capable of a sustained work output. They are referred to as ‘slow twitch’ fibres. The paler, white fibres seem to depend upon stored energy sources within the muscle fibres themselves. They allow short bursts of high energy activity, but fatigue quickly when the energy store is depleted. These fibres are known as ’fast twitch’ fibres.

Between the two extremes of fast and slow twitch fibres exist intermediate fibres which can function both aerobically and anaerobically. Human muscles consist of mixtures of all of these fibres, but not in the same proportions in all individuals. Athletes who participate in activities with high anaerobic demands, such as sprinters, jumpers, and gymnasts, tend to have a high percentage of fast twitch fibres, while athletes who compete in endurance events, e.g. road cyclists, marathon runners and swimmers, and triathletes, have a similarly high percentage of slow twitch fibres. Typically, in training, most of the initial effort comes from the slow twitch fibres. As the workload is increased, the intermediate fibres come into effect. If the load or intensity is increased still further, the fast twitch fibres are made to work.

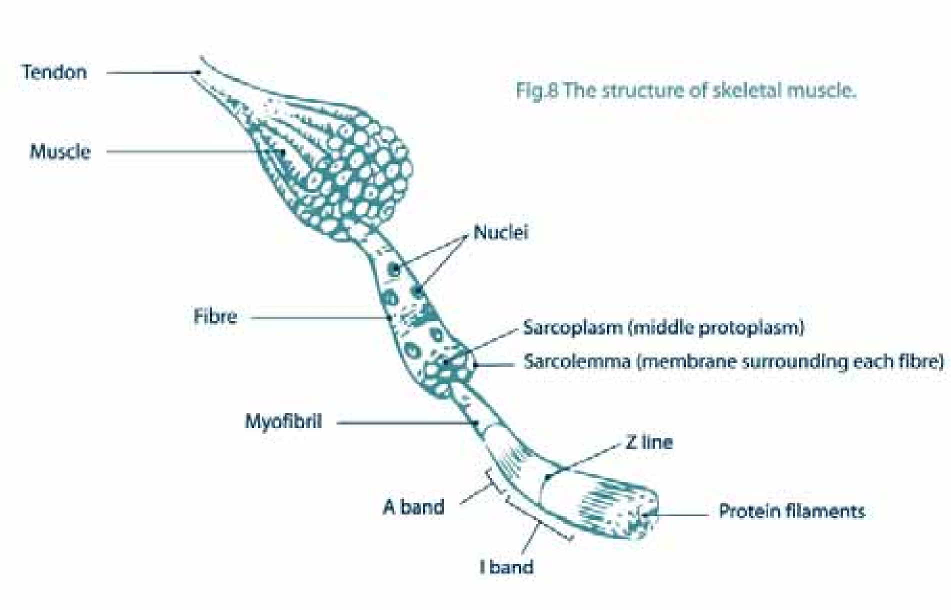


Fig.8 The structure of skeletal muscle.

QUESTIONS & EXERCISES

Locate on yourself some of the principal muscles in the body:

- *biceps,*
- *triceps,*
- *trapezius,*
- *deltoid,*
- *latissimus dorsi,*
- *pectorals,*
- *gluteals,*
- *quadriceps,*
- *hamstrings,*
- *gastrocnemius, and*
- *tibialis anterior.*

This will involve contracting the muscles by resisting their primary movement, and by touching the area to identify the site of the muscle.

Use the diagrams at the end of this module to help locate the muscles.

EXPLAIN MUSCLE ACTION IN THE HUMAN BODY

ACTIONS OF MUSCLES ON JOINTS

Muscles produce movement by pulling in different directions on the bones to which they are attached. The movement produced depends upon the type of joint. Muscles may work singly, or in groups, to produce movement at a joint. A muscle shortens on contraction, pulling the origin and insertion closer together. This pulls the bones attached to the muscle in the direction of the shortening, producing movement in a specific direction. This movement is called the muscle action, e.g. elbow flexion: the biceps, with its origin on the scapular and insertion
on the radius, flexes the elbow when it contracts.

Whenever a muscle, or group of muscles, produces a movement in one direction at a joint, a corresponding muscle or group of muscles produces movement in the opposite direction at that joint. e.g. triceps contracts to extend the elbow.

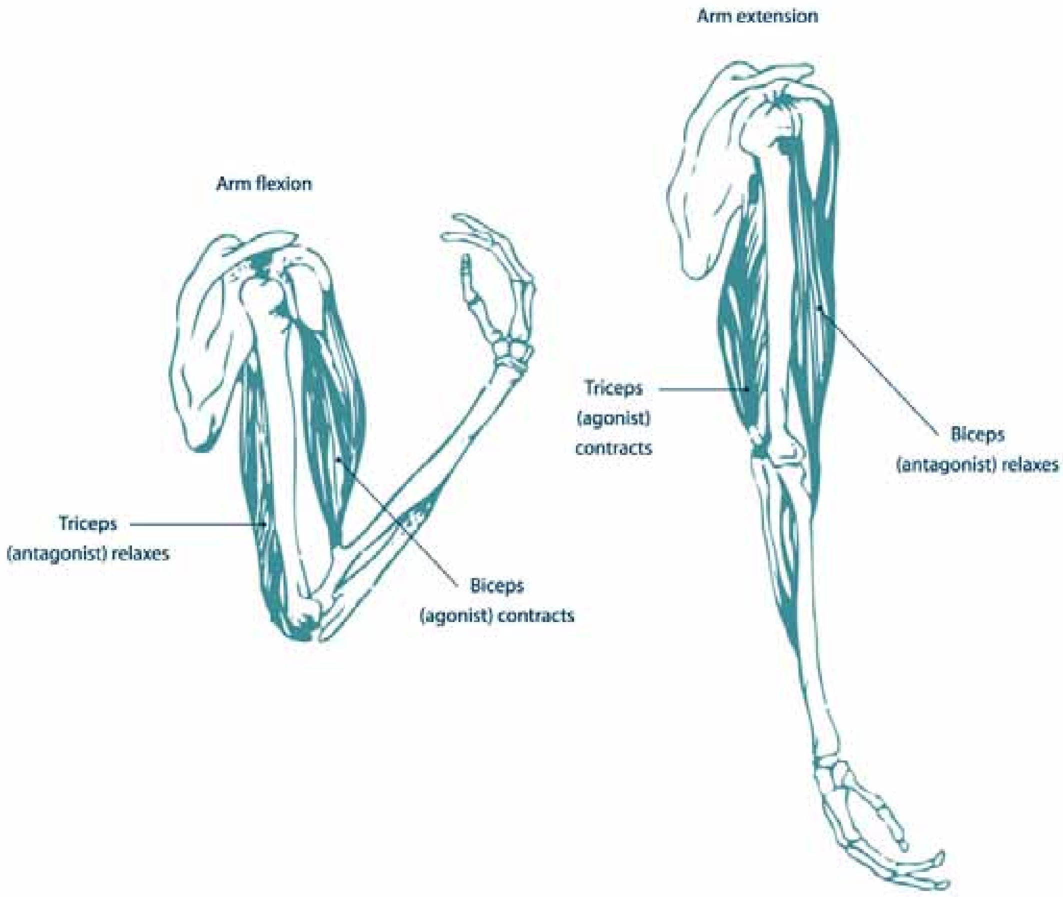


Fig.9 Muscle control of the elbow joint.

GROUP MUSCLE ACTION

When a muscle contracts to produce the desired movement, it is the called the prime mover or agonist. When a muscle contracts to oppose a prime mover, it regulates the speed and power of the prime mover and is known as the antagonist, e.g. the flexors have opposing (antagonistic) extensor groups, abductors are opposed by adductors.

A high degree of coordination must exist between opposing groups to allow the human body to move efficiently. For example, if you wish to bend your elbow rapidly, the triceps (antagonist) must relax so that the biceps (agonist) can flex without being impeded. However, if you make a slow, controlled movement, both the groups have a degree of contraction to give the required control. This coordination is controlled by the cerebellum in the brain.

Some muscles are small, or they may have a poor angle of pull. Contraction of these muscles, the assistant movers, assists the agonist to produce movement at a joint, e.g. brachialis and brachio radialis assist biceps in elbow flexion.

The performance of even the simplest movement demands the coordination of a number of muscles.
A great many muscles, which have nothing to do with the actual movement, come into play to ‘fix’ the position of the body. These are known as stabiliser muscles. Stabiliser muscles contract to allow other muscles to work effectively. They stabilise a joint at one end so that movement occurs at one attachment only, allowing the joint to move through its whole range of movement. Undesired movements may be produced by the agonist. Neutraliser muscles contract to eliminate or restrict this movement.

In most group movements, stabilisers and neutralisers play a part, e.g. if the elbow is to be flexed, it is necessary for the shoulder muscles to contract to steady the elbow region for an efficient contraction and pronator muscles contract to prevent biceps twisting the forearm (supination) as it contracts.

TYPES OF MUSCLE ACTION

All muscles act by contracting to exert a force which produces a movement. However, there are different ways that this may occur.

In a concentric contraction, the muscle actively shortens and thickens, pulling the two muscle attachments together and decreasing the angle between the two bones in the joint, e.g. biceps contracting to produce elbow flexion in a biceps curl.

An eccentric contraction works in reverse. The muscle lengthens as it develops tension and the origin and insertion are moved apart, keeping the load under control, e.g. biceps contracts to control elbow extension in the biceps curl.

In an isometric contraction or static contraction, the muscle develops tension, but there is no resulting movement because an opposing force acts to prevent it, e.g. attempting to shift an immoveable object.

An isokinetic contraction involves making a muscle work at maximum tension throughout its range of movement. However, it has been found that when a muscle contracts to produce a movement, the tension developed varies as the joint moves through its full range of movement. Isokinetic contractions do not occur naturally. They require specialised weight training equipment which provides varying resistance.

FORCE AND LEVERS

The body is made up of a system of levers which are utilised to perform an infinite range of movements.
A simple lever consists of three components: a pivot point or fulcrum (the joint at which movement is occurring), a weight to be moved (resistance), and a source of energy, effort or force (the contracting muscle).

The majority of levers in the body are third class levers. The force represents the point at which a muscle acts on the bone and the joint, causing the bone to move, e.g. in flexion of the elbow, the weight to be moved is the hand, the elbow joint is the fulcrum, and the force is represented by the contraction of biceps as it flexes the elbow.

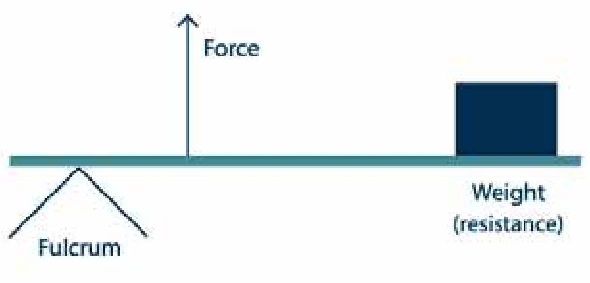


Fig.10 Third class lever.

The most common function of levers is to allow us to increase the speed at which a body moves, e.g. when using a golf club. Longer levers generate more speed. The body’s natural levers are extended by using implements such as oars, ski poles, and tennis racquets, which enable the users to generate more speed than their hands alone would.

Understanding the actions of levers in the body is important in developing correct technique and has implications for equipment choices and uses, e.g. keeping the elbow straight when serving in tennis, but bent and in close to the side when volleying at the net; selecting a suitable club in golf for a specific shot; and choosing a tennis racquet to suit an individual athlete's ability and strength.

QUESTIONS & EXERCISES

Perform exercises involving concentric and eccentric contractions that use the same muscle group, e.g. perform biceps curl; muscles involved – biceps and triceps.

Describe

- *any difference in tension developed in the contracting muscles during the two types of contraction, and*
- any difference in the effect on your breathing rate and heart rate.

APPLY YOUR KNOWLEDGE OF THE SKELETAL AND MUSCULAR SYSTEMS TO ANALYSE MUSCLE ACTION

RANGE OF MOVEMENT AT A JOINT

The range of movement at a joint can be classified into three areas. Knowledge of these areas is of interest when planning rehabilitation following a muscle injury.

1. **Inner range** – the first third of total joint movement where the muscle is moving into full contraction.
2. **Outer range** – the final third of movement where the muscle is moving from its fully extended state.
3. **Middle range** – the third of movement that separates the inner and outer ranges.

FACTORS AFFECTING JOINT MOBILITY

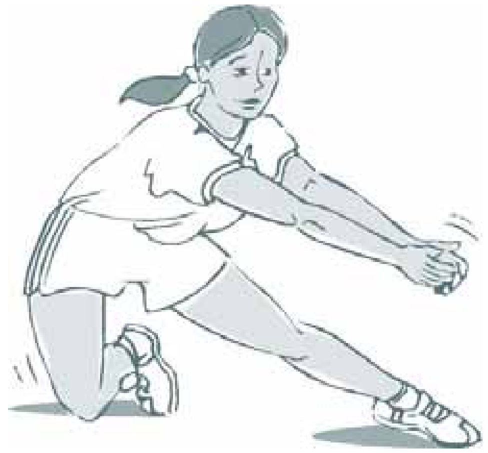
The various movements and the range of movement that occur at any joint are dependent on the shape of the articulating surfaces, the presence of restraining ligaments, and the muscles acting on the joint.

In some joints, the shape of the articulating surfaces and how well they fit together determine the extent and type of movement at those joints. For example, at the elbow, the hook-like shape of the upper end of the humerus, on full extension, fits into a hollow on the corresponding surface of the humerus, greatly restricting movement to one plane only. At the shoulder joint, only a small part of the ball of the humerus fits into the flat and small socket of the shoulder girdle, allowing a wide range of movement. In most joints, it is the non-elastic joint capsule and ligaments which stabilise the joint and eliminate excessive movement which may cause damage.

Other soft tissue, such as excessive fat and muscular bulk, can limit joint flexibility. Therefore it is important that coaches include flexibility exercises in their athletes' strength training programmes. Muscles acting on a joint can also influence joint mobility. When a muscle contracts to produce movement at a joint, an opposing group acts to control this movement. If movement is made suddenly at the extreme range of the joint, the opposing group will contract to protect the joint from being damaged. This is known as a stretch reflex.

Other factors that influence joint mobility are temperature, age, and gender. Joints are more mobile when they are warm, which is one reason why warm-ups are so important prior to vigorous physical activity. Joint mobility generally decreases with age, as we tend to become less active as we grow older.

Regular physical activity which includes flexibility exercises, will help prevent or slow this process. Women tend to have greater joint mobility than men, especially after puberty, although the reason for this has not been clearly established.



MOVEMENTS AT MAJOR JOINTS

Each joint has its own characteristic range and type of movement. It is important that you have a knowledge of these movements, and are able to relate them to the actions that muscles can produce.

Shoulder joint
A multi-axial ball and socket joint, allowing extreme mobility at the expense of stability. Dislocation of this joint is a common accident.

Movements possible – the large range of movement possible is really a combination of shoulder joint and girdle movement; flexion, extension, horizontal flexion and extension, abduction, adduction, medial and lateral rotation. A combination of movements allows shoulder elevation and circumduction.

Elbow joint
A hinge joint between the lower end of the humerus and upper ends of the ulna and radius.

Movements possible – flexion and extension occur at the humero-ulna joints. Pronation and supination occur at the superior and inferior radio-ulnar joints.

Wrist joint
An ellipsoidal joint.

Movements possible – flexion and extension.
The wrist can also move slightly from side to side - abducted (radial deviation) and adducted (ulnar deviation).

Hip joint
A secure ball and socket joint, with a strong fibrous capsule which is reinforced by three ligaments. The hip joint, like the shoulder, enjoys a wide range of mobility, but the movements are more restricted.

Movements possible – flexion, extension, abduction, adduction, medial and lateral rotation, and circumduction.

Knee joint
The largest and most complex joint in the body. Although not always classified as such, the knee is essentially a hinge joint.

Movements possible – flexion and extension.

Ankle joint
A true hinge joint. The strong ligaments stabilising this joint are frequently injured in a twisting injury of the ankle.

Movements possible – dorsi flexion and plantar flexion.

Spinal movements
Movement between two adjacent vertebrae is limited, but the vertebral column as a whole allows quite considerable movement.

Movements possible - the overall movements are flexion, extension, rotation, and circumduction, but not all parts of the vertebral column show these movements to the same extent. Flexion and extension occur mostly in the cervical spine and there is some in the lumbar region, but it is very limited in the thorax. Lateral flexion is most marked in the cervical and lumbar regions, but occurs throughout the vertebral column. Rotation is very good in the cervical and upper thoracic regions, but is very limited in the lumbar region.

MUSCLES ACTING ON MAJOR JOINTS

Muscles Acting on the Shoulder Girdle

Elevation	Upper Fibres of Trapezius Levator Scapulae Serratus Anterior
Depression	Pectoralis Major/Minor Latissimus Dorsi
Protraction	Serratus Anterior Levator Scapulae Pectoralis Major/Minor
Retraction	Middle Trapezius Rhomboids Latissimus Dorsi

Muscles Acting on the Shoulder Joint

Flexion	Pectoralis Major (clavicular head) Deltoid (anterior fibres) Coracobrachialis Biceps
Extension	Latissimus Dorsi Teres Major Pectoralis Major (sternal head) Deltoid (posterior fibres) Triceps (long head)
Abduction	Deltoid Supraspinatus
Adduction	Pectoralis Major (both heads) Latissimus Dorsi Teres Major Coracobrachialis Triceps (long head)
Medial Rotation	Pectoralis Major (both heads) Latissimus Dorsi Teres Major Subscapularis Deltoid (anterior fibres)
Lateral Rotation	Infraspinatus Teres Major Deltoid (Posterior fibres)

Muscles Acting on the Elbow

Flexion	Brachialis Biceps Brachio Radialis

Extension	Triceps	

Muscles of Pronation and Supination of Forearm

Pronation	Pronator Quadratus	
	Pronator Teres	
Supination	Supinator	
	Biceps	

Muscles Acting on the Hip Joint

Flexion	Iliopsoas	
	Sartorius	
	Pectineus	
	Rectus Femoris (quadriceps)	
Extension	Gluteus Maximus	
	Semitendinosis	
	Semimembranosus	Hamstrings
	Biceps Femoris	
	Adductor Magnus	
Abduction	Gluteus Medius	
	Gluteus Minimus	
	Tensor Fascia Lata	
Adduction	Adductor Magnus	
	Adductor Longus	
	Adductor Brevis	
Medial Rotation	Gluteus Medius	
	Gluteus Minimus	
	Tensor Fascia Lata	
	Adductor Magnus	
Lateral Rotation	Piriformis	
	Obturator Internus/Externus	
	Quadrator Femoris	
	Gluteus Maximus	

Muscles Acting on the Knee Joint

Flexion	Semimembranosis	
	Semitendinosis	Hamstrings
	Biceps Femoris	
	Gastrocnemius	
	Sartorius	
	Gracilis	
Extension	Rectus Femoris	
	Vastus Lateralis	
	Vastus Intermedialis	Quadriceps
	Vastus Medialis	
	Tensor Fascia Lata	
Medial Rotation of the Tibia	Popliteus (‘unlocking knee’)	
	Sartorius	
	Gracilus	When knee
	Semimembranosis	flexed

	Semitendinosis	
Lateral Rotation of the Tibia	Biceps Femoris	When knee flexed

Muscles Acting on the Ankle Joint

Plantar Flexion	Soleus Gastrocnemius Peroneus Longus
Dorsi Flexion	Tibialis Anterior Extensor Hallucis Longus

MUSCLES INVOLVED IN THE PERFORMANCE OF SPECIFIC SPORTS SKILLS

It is most useful for you to be able to analyse muscle action and determine which muscles are involved in the basic techniques of your sport. The analysis does not need to be detailed or complex. Establishing the major muscle groups involved in the performance of specific sports skills allows you to devise conditioning programmes specifically for your own sport, targeting the identified muscle groups.

A useful approach is to:

1. Identify the major joint systems being used.
2. Decide what movements are occurring at those joints (drawing stick figure diagrams may help).
3. Identify the muscles involved, consulting diagrams or tables as required (one is included in this module).
4. Develop a conditioning programme, targeting the identified muscles (muscular endurance, muscular strength, flexibility).

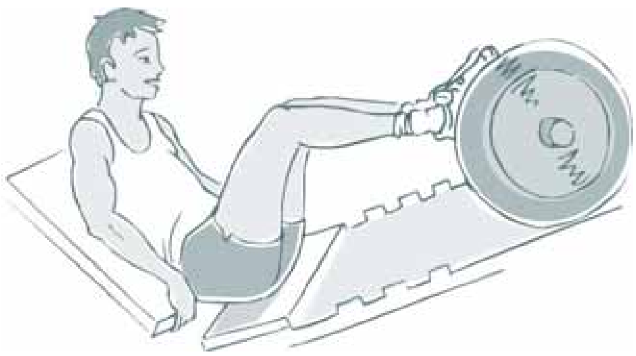
When developing a conditioning programme, it is important to remember that muscles generally work in groups to stabilise the joint and eliminate undesired movements while the prime mover, or agonist, is contracting. These muscles also need strengthening.

Analysis of muscle action may also be used, in conjunction with biomechanical analysis, to examine and correct faulty technique, both to improve performance and to help prevent injury.

QUESTIONS & EXERCISES

Using the movements you identified previously, write down the names of the muscles used to produce these movements.

Develop a small conditioning programme targeting the muscles that you identified. The programme should include exercises for muscular strength, muscular endurance, and flexibility.



GLOSSARY

It is important for you to have an understanding of basic anatomical terms. This makes it easier to discuss and provide effective descriptions of human movement. Terms which are commonly used to describe movements of the body, and direction or location in relation to the standard anatomical position, are defined below.

Term	**Definition**
abduction	movement away from the midline of the body
adduction	movement towards the midline of the body
anterior	towards the front of the body
circumduction	movement of a limb where the hand or foot traces a circle
depression	movement of a body part downwards
distal	further from the trunk
dorsi flexion	movement of the foot at the ankle to raise the toes and foot towards the tibia
elevation	movement of a body part upwards
eversion	rotation of the foot to turn the sole of the foot outwards
extension	movement causing an increase in the angle at a joint
flexion	movement causing a decrease in the angle at a joint
frontal plane	divides the body into anterior and posterior sections; or front and back halves
horizontal plane	divides the body into superior and inferior sections; or upper and lower halves
hyperextension	extension of joint beyond its normal range of movement
inferior	towards the feet
inversion	rotation of the foot to turn the sole of the foot inwards
lateral	away from the midline of the body
medial	towards the midline of the body
plantar flexion	movement of the foot at the ankle to point the toes
posterior	towards the rear of the body
pronation	movement of the forearm so that the radius and ulna are crossed; i.e. palms down or backwards
proximal	closer to the site of attachment or beginning of a body part
rotation	movement about an axis of the body, either medially (inward) or laterally (outward)
sagittal plane	divides the body into right and left halves
superior	towards the head
supination	movement of the forearm so that the radius and ulna are parallel, i.e. palms up or forwards

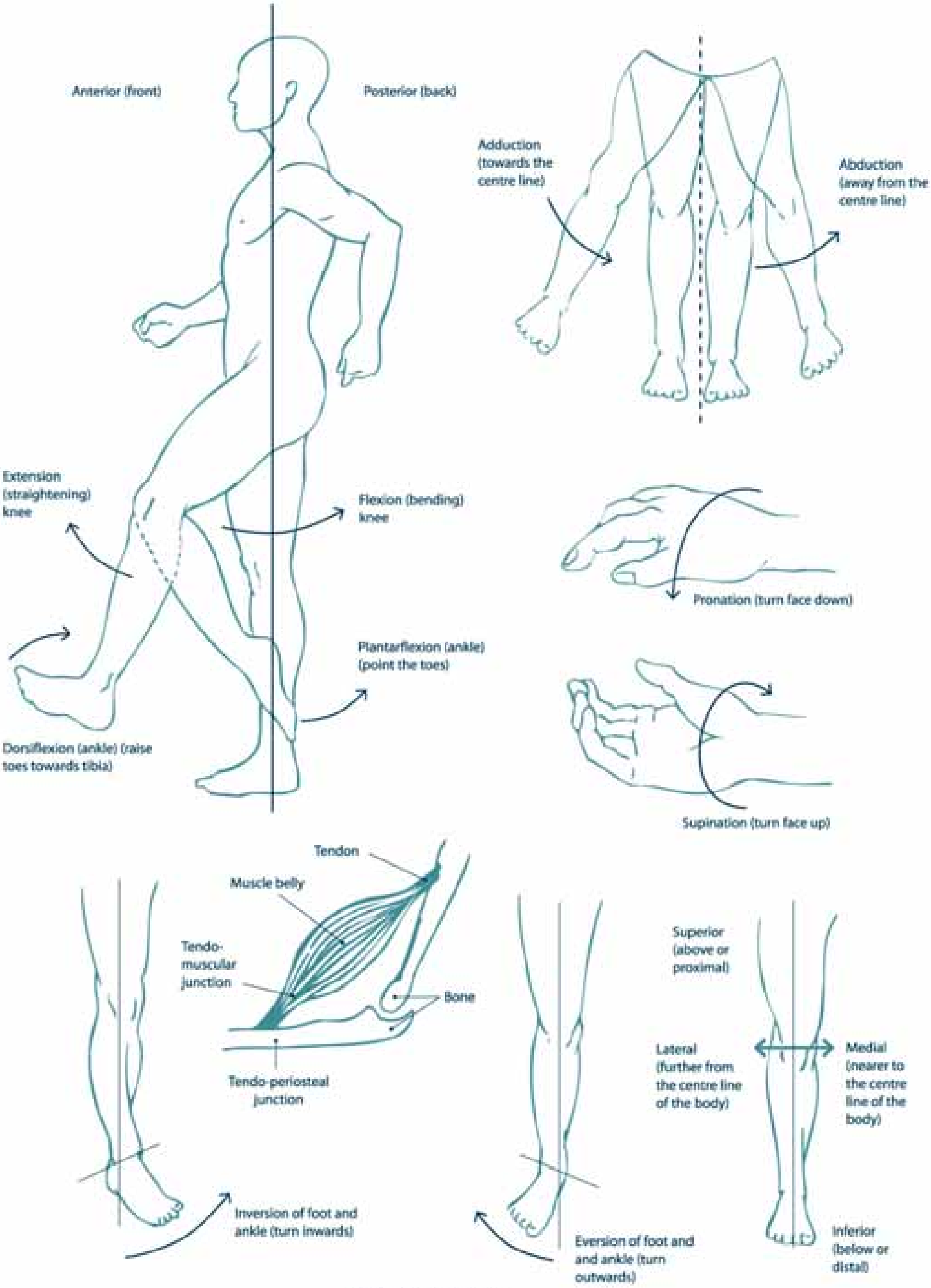


Fig.11 Anatomical terms.

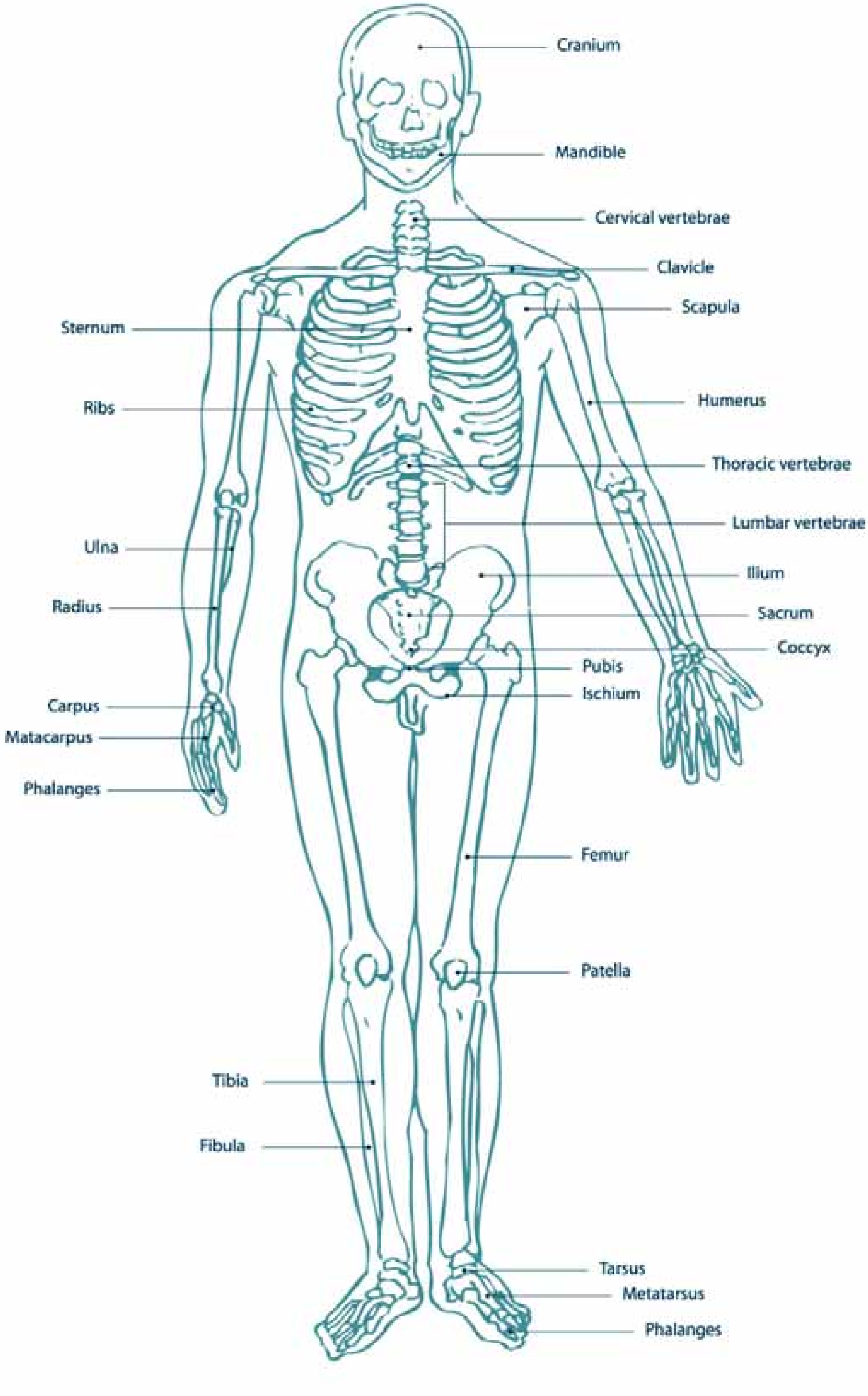


Fig.12 Human skeleton – anterior view.

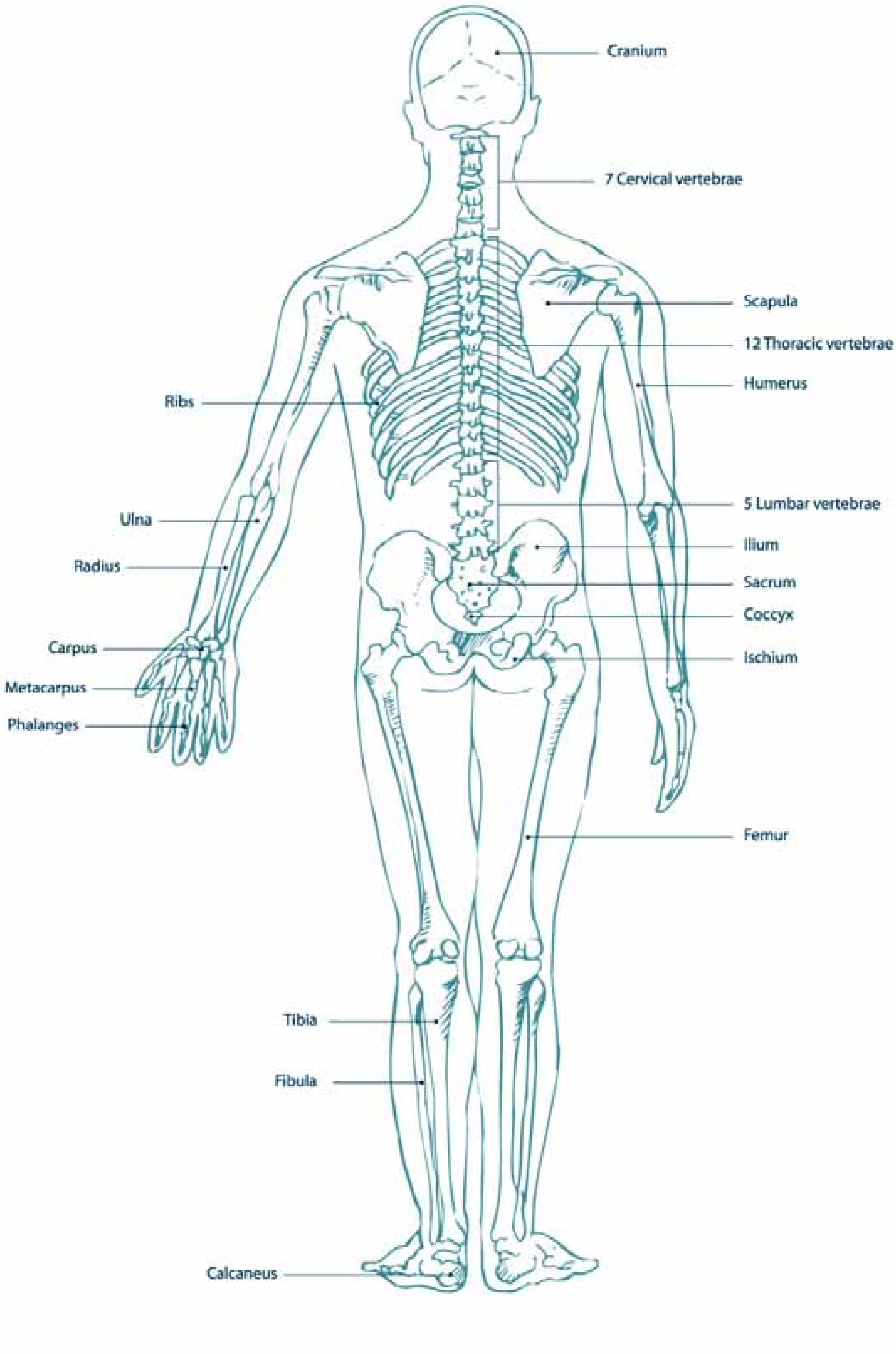


Fig.13 Human skeleton – posterior view.

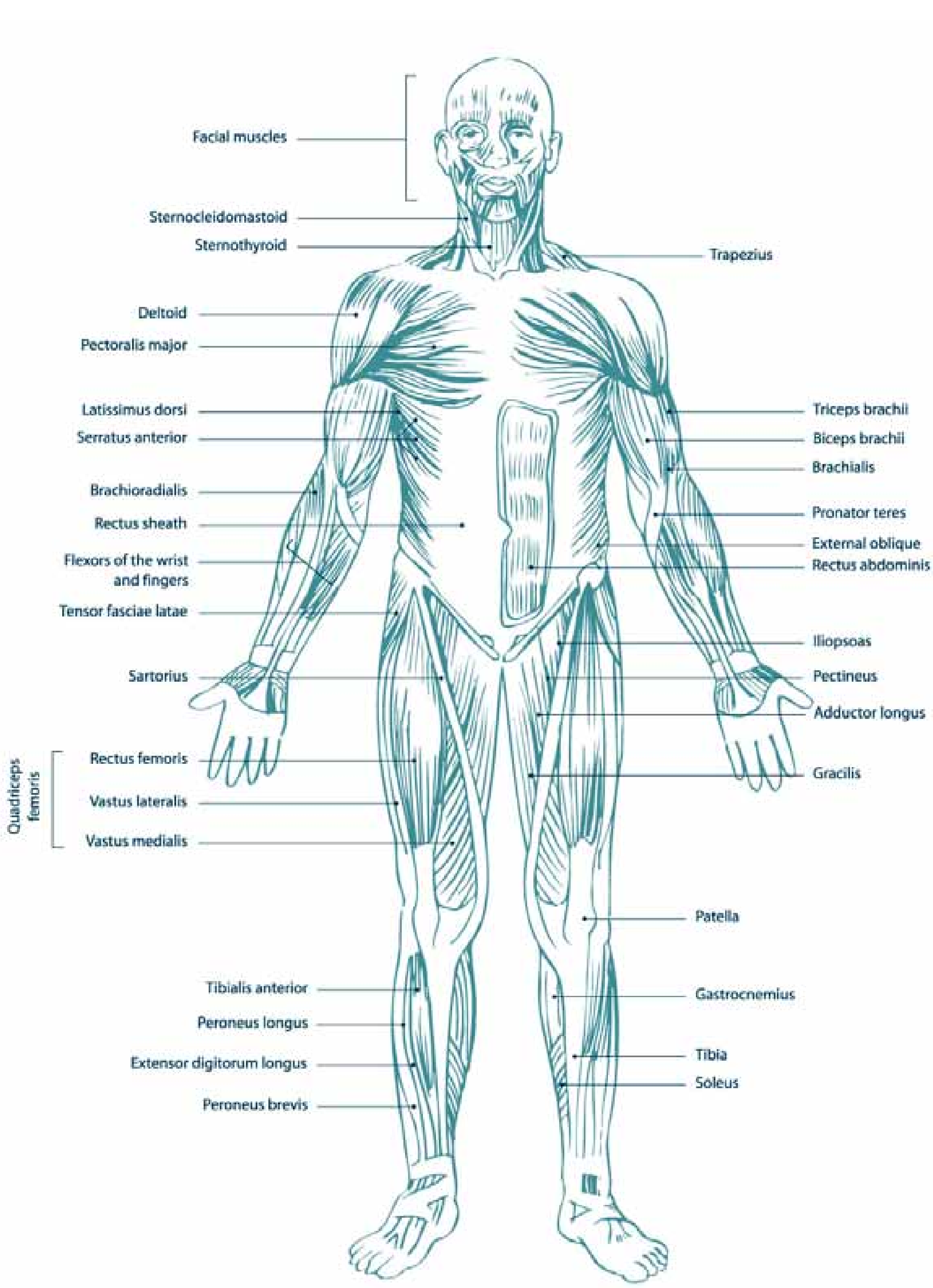


Fig.14 Muscles of the human body – anterior view.

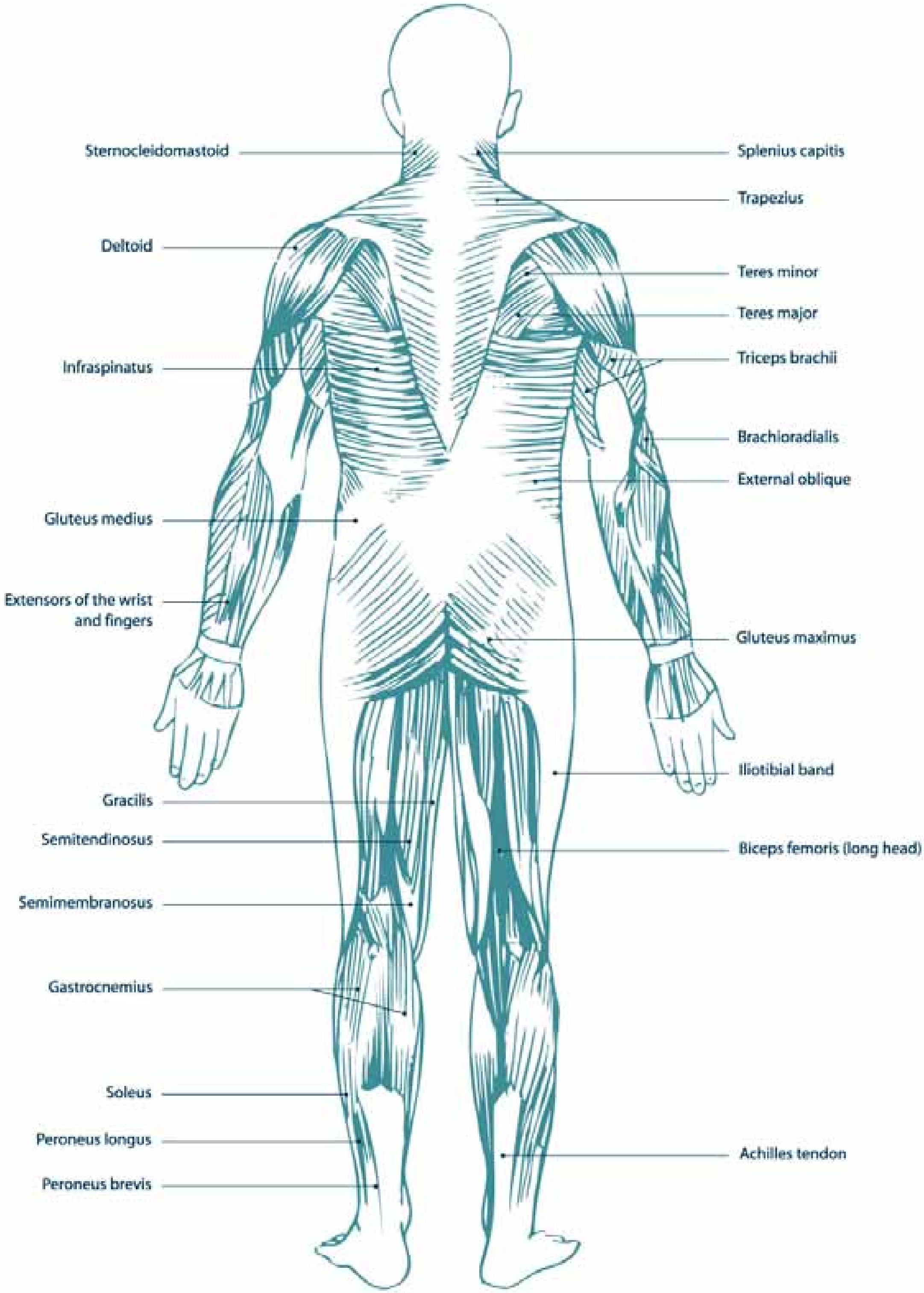


Fig.15 Muscles of the human body – posterior view.

ACKNOWLEDGEMENTS

SPARC acknowledges the sources of figures printed in this module:

Basmajian, J.V. (1981) Primary Anatomy. *Williams & Wilkins, Baltimore/London. (Figures 12-15).*

Thompson, C.W. (1981) Manual of Structural Kinesiology. *The C.V. Mosby Company (Figures 1, 2, 3, 5).*

Figures are reproduced with permission from the following:

Davis, D., Kimmet, T.& Auty, M. (1986)
Physical Education: Theory and Practise.
**The Macmillan Company of Australia.*
(Figures 4, 6, 8, 9, 11).

National Coaching Foundation (1986)
Coaching Handbook No. 3: Physiology and Performance. The National Coaching Foundation, Leeds. (Figure 2).

*Available from Coachwise Limited, Units 2/3 Chelsea Close, Off Amberlet Road, Armley LS12 4HW,
tel: +44 (0) 113 231 1310, fax: +44 (0) 113 231 9606.