Musculo-skeletal system

Components

The musculo-skeletal system is made up of the muscles and skeleton.

The skeleton is formed from bones and consists of an axial system, the skull and vertebral column, with the appendicular system (the limbs and limb girdles) attached to it.

Muscles are organs containing bundles of muscle fibres, connective tissues, nerves and blood vessels. They are arranged to bring about movement of bones at joints. Bones are also organs composed of living tissues, including a blood supply.

Figure 1 The musculo-skeletal system.

Functions

The muscles and skeleton support and protect body organs and allow movement. Heat generated by muscular contractions is important in the maintenance of a constant high body temperature. Calcium is stored in the bones. Blood cells grow and mature in the bone marrow.

Key mechanisms

Arrangement of muscles

Striated (skeletal or striped) muscle, bone, cartilage, ligament and tendon are connective tissues found in the musculo-skeletal system.

- Striated muscle tissue is organised in bundles of muscle fibres attached to bones by tendons.
- When the muscle fibres contract, a muscle will shorten.
- When they relax, muscles cannot expand and lengthen again.
- Muscles in the body are arranged in antagonistic pairs so one muscle can contract and stretch the previously contracted muscle.

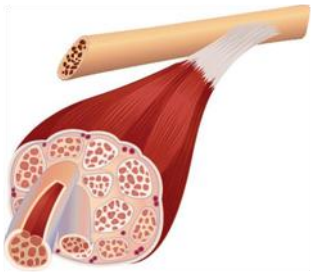

Figure 2 Muscle tissue is organised in bundles of muscle fibres.

For example, the biceps muscle contracts to bend the arm, but at the same time it stretches the triceps. Then the triceps is able to contract to straighten the arm and stretch the biceps.

In addition to striated muscle, the body contains smooth (or involuntary) muscle and cardiac muscle (found only in the heart).

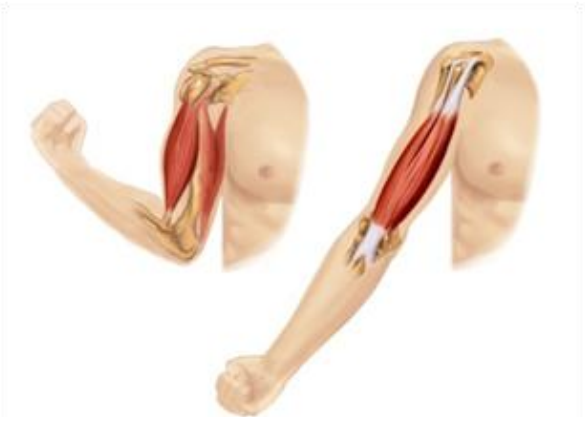

Figure 3 Biceps and triceps are an antagonistic pair.

Contraction of muscle tissue

Striated muscle is sometimes called voluntary muscle, as it is under the control of the nervous system. Effector neurones stimulate muscle fibres at neuromuscular junctions.

- The fibres (dendrons) of the neurones branch out into dendrites, which connect to flattened swellings called muscle end plates.
- There is a gap, the synapse, between the muscle end plate and the sarcolemma, the surface membrane of the muscle fibre.

When a nervous impulse reaches a neuromuscular junction:

- vesicles release acetylcholine into the synapse;
- a series of ionic changes take place which cause the sarcolemma to depolarise;
- the charge across the membrane is reversed generating an action potential, which is propagated along the length of the muscle fibre causing it to contract.

Repeated stimulation causes smooth, prolonged contraction. The sarcolemma contains the enzyme acetylcholinesterase which rapidly hydrolyses acetylcholine so that the muscle end plate can return to its original resting state once stimulation has ceased.

Striations in muscle fibres are due to overlapping bands of filaments of the proteins actin and myosin which slide over each other to shorten muscle fibres and cause contraction of muscles.

- Propagation of an action potential causes vesicles in the sarcoplasm to discharge calcium ions which bring about changes in the proteins which cause them to slide over each other.

The muscle fibres continue to shorten while action potentials continue. When action potentials cease relaxed muscle fibres can be stretched by an antagonistic muscle to lengthen them again.

Smooth muscle

The muscle found in blood vessels and many organs such as the bladder, stomach and intestines of the body does not form part of the musculo-skeletal system. Formed from spindle-shaped cells often arranged in sheets, smooth muscle is involuntary and non-striated, controlled and coordinated by the autonomic nervous system and contains actin and myosin filaments.

Bones

Bones are able to act as levers and resist the forces applied during movement.

- Bone tissue is strong and firm, with high tensile strength.
- Separate bones are held together by ligaments which allow movement between them at joints.
- Cartilage in joints protects the ends of bones from damage caused by friction when bones move.
- Cartilage also allows bones to grow during childhood.

Connective tissues are formed by cells which secrete a non-living matrix around them.

- Bone tissue is formed by osteoblasts which secrete protein (osein) and calcium salts (mainly phosphate) into the bone matrix.
- In hard bone this is laid down in concentric circles to resist tension and compression.
- Exercise causes bone tissue to be strengthened to resist the forces which are applied.

Role in homeostasis

Movements allow the body to interact with and manipulate its external environment. Food can be found, obtained and ingested. Harm can be avoided. Maintenance of a constant, high body temperature can be aided through increasing or decreasing muscular activity, finding shelter, entering hot or cooler places or through making clothing and wearing or removing it.

Bones are used as a store for calcium; Ca^{2+} may be absorbed from the blood if present in excess, or added to the blood if levels drop too low.[1]

Examples of what can go wrong

[1] See *Endocrine system.*

Arthritis

Arthritis affects the joints that connect bones in the musculo-skeletal system. It can cause pain, stiffness, inflammation and swelling of joints.

The most common form is osteoarthritis. It is a chronic condition characterised by the breakdown of the joint's cartilage which causes the bones to rub against one another. The most frequently affected areas are hands, spine, knees and hips. The cause is not fully understood. One, as yet unproven, theory is that some people have an increased chance of inheriting it from their parents.

Rheumatoid arthritis is a less common, more severe form of arthritis. It is caused by a fault in the immune system, which may be inherited, that makes the body attack its own tissues.

In the UK some 8.5 million people suffer from osteoarthritis. A further 400,000 suffer from rheumatoid arthritis. Although arthritis mainly affects older people, children may be affected.

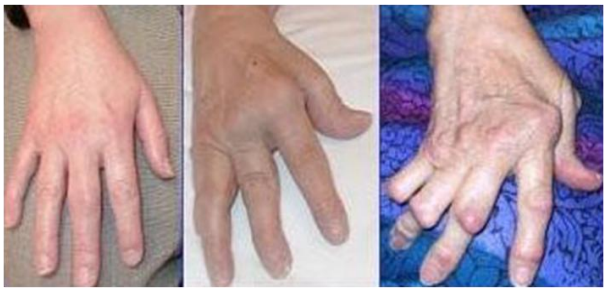

Figure 4 Hands affected by rheumatoid arthritis.

Muscular dystrophy (MD)

The disease is characterised by gradual muscular weakening caused by progressive degeneration of contractile elements and their replacement with fibrous tissue. In Duchenne muscular dystrophy, typically symptoms appear around 2 to 3 years of age; the victim becomes wheelchair bound at about 10 to 12 and dies before they reach 20.

About one in every 3,600 boys develops muscular dystrophy. It is caused by a recessive gene defect on the X sex chromosome. As males (XY) have only one copy, if a male inherits this from his mother he is fated to develop the condition. Girls, on the other hand have two X chromosomes (XX) and must inherit the defect from both parents, which is extremely rare (<1 in 100,000).

The normal gene produces dystrophin, a large protein that increases the stability of the sarcolemma (muscle cell membrane). This connects actin to the extracellular matrix and enables muscle cells to withstand stresses associated with contraction and stretching. Absence of dystrophin allows constant leakage of Ca^{2+} into muscle cells, activating proteases which damage muscle cell fibres, leading to muscle wasting and fibrosis.

With the discovery of the cause came a number of lines of research, including:

- Gene-therapy. The dystrophin gene at over 3 million base pairs is the largest yet discovered. It will not fit inside the viruses normally used to deliver genes into cells. Scientists have created a stripped-down mini-gene which still contains all the necessary code for the synthesis of dystrophin. Animal research trials have shown that using injections of the virus carrier, the disease can be slowed and even reversed. Human clinical trials have yet to be completed.
- Stem cells harvested from muscle can form new muscle fibres, but when injected they do not spread through the muscle. Pericytes from blood vessels in muscle spread and differentiate into muscle fibres. A technique may be developed to replace muscle tissue lost in MD.
- Utrophin, a naturally occurring protein very similar in structure to dystrophin can substitute for it in the sarcolemma. Mice with MD but genetically engineered to produce extra utrophin showed significant improvements in Ca^{2+} homeostasis, greater muscle strength and reduction in muscle degeneration. Human trials of drugs to increase utrophin production are yet to take place.
- Mutation bypass. In 2011, *Eteplirsen* (*AVI-4658*), a new drug was trialled in the UK. Designed to make the body bypass genetic mutations when producing dystrophin, in human trials it was found to lead to increased dystrophin. It is thought that that drugs which make the body skip over mutations could eventually be used to treat most Duchenne muscular dystrophy cases.

Finding out

In ‘rigor mortis’ muscles seize up and the limbs of a corpse become stiff and difficult to move.

Suggest how the cessation of respiration at death leads to rigor mortis.