CUNNINGHAM'S TEXTBOOK OF ANATOMY

ELEVENTH EDITION

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muscle which opposes the specified movement is called an **antagonist,** and often the antagonists play a leading part in the control of the movement [p. 263]. Muscles which help to prevent unwanted movements inherent in the attachments of the prime movers are called **synergists,** and the term is also applied to muscles which contract in order to provide a stable base for the action of the prime movers. A good example is afforded by the muscles which stabilize the scapula during movements of the upper limb [p. 336]. This kind of action is also spoken of as 'fixation' and the muscles performing it are termed **fixators.**

In most movements the role of the prime movers, antagonists, synergists, and fixators does not vary throughout the movement. For example, when the fist is clenched, the extensors of the wrist contract to prevent the flexors of the fingers from also flexing the wrist. This is a vital part of the action, for flexion of the wrist added to flexion of the fingers stretches the extensors of the fingers until they can stretch no more; continued flexion at the wrist then causes the fingers to open out and the grip to relax. This is how an opponent can be made to drop a weapon by forcibly flexing his wrist. The flexors and extensors of the elbow must also contract in order to fix the origins of the flexors of the fingers and the extensors of the wrist, and the scapula must be fixed in order to stabilize in turn the origins of the muscles stabilizing the elbow. In such a manner even an apparently simple movement can have repercussions throughout the musculature of almost the whole body.

In other movements the functional significance of a given muscle may change in successive phases of the movement. For example, in the initial stages of abduction of the humerus the supraspinatus acts as a prime mover, but later it has a more important function as an extensile ligament.

In many instances gravity acts as a prime mover. Thus, in lowering the arm to the side from an abducted position, there is no contraction of the adductor muscles unless the movement is conducted against resistance. Instead, the antagonist to the movement, the deltoid muscle [p. 308] gradually pays out and the movement is effected as a result of the combination of this and the action of gravity. When the arm is adducted against resistance, the deltoid become flaccid, and the adductors are thrown into contraction [PLATE 21 B].

The muscles in one part of the body often act in co-ordination with muscles in more distant parts, a phenomenon known as **associated action.** In walking, the balance of the trunk is maintained by the erector spinae muscles [p. 269] and the upper limb of one side swings in concert with the lower limb of the opposite side. Again, when we look round, the displacement of the head and eyes is accompanied by movements of the feet and trunk. Paralysis of a single muscle may thus upset movements which are not necessarily located in the vicinity of the muscle itself.

There is very little direct voluntary control over individual muscles without training; it is only the movement desired that is voluntary, and the pattern of activity of the executive muscles is automatically organized by the brain. A simple example emphasizes this. Stretch out the upper limb horizontally and then bend the forearm up towards the ceiling. In the phase before the forearm becomes vertical, the biceps can be felt contracting, and the triceps is relaxed. But as soon as the forearm reaches the vertical and starts descending towards the shoulder, the triceps is felt to harden while the biceps relaxes. We are completely unaware of the change-over.

Finally, it is important to distinguish between the actions of which a muscle is capable and the functions which it usually performs (MacConaill and Basmajian, 1969). The interossei of the foot [p. 386] can abduct and adduct the toes, but their chief function is probably to support the anterior arch of the foot and prevent pressure on the vessels and nerves running to the toes. The mere presence of some muscles is of functional importance. For example, in patients who are lying in bed, the gluteus maximus [p. 364] forms a soft pad intervening between the skin and the bony prominence of the buttock. If this muscle is thinned and atrophied by paralysis, the skin is exposed to pressure from the underlying bones, and this may lead to the production of bedsores.

Types of Movement. In most movements, the antagonists are in action throughout, relaxing in a graduated manner to control the activity of the prime movers. But in certain circumstances, as when a sprinter starts a race, a **maximum effort,** unrestrained by the antagonists, is suddenly required. In the initial stages of such movements the antagonists may be almost completely relaxed, so as to reduce the opposing force to a minimum.

Ballistic movements are those in which the prime movers relax once the effort has been made. This type of movement is well seen in serving at tennis, or in kicking a football. The 'follow-through' is due to the momentum produced in the limb at the time of impact.

Contrasting with these movements are the very **fine controlled movements** required by activities such as writing, sewing, painting, etc. Here the prime movers and the antagonists are set to oppose each other equally, and the actual movements are due to temporary slight alterations of the balance of power between the two groups. Movements can be very finely graduated by this means, and the net force exerted can be made very small.

Finally, the occurrence of **involuntary movements** and their occasional dissociation from voluntary movements must be noted. In certain cases of brain injury, muscles which are paralysed for voluntary movement may be found to contract during involuntary or emotional acts. For example, an upper limb which has become paralysed can be moved with its fellow on the other side during the stretching which accompanies a yawn, and facial muscles which cannot be voluntarily activated are found to contract when the patient is asked to smile. The medial rectus muscle of the eye [p. 284] may be unable to contract during convergence of the eyes, but yet be active when the eyes are turned to the opposite side (Beevor, 1904). The explanation of such phenomena is not yet established.

Methods of Investigating Muscle Action. It is often very difficult to determine the part played by a muscle in different movements, and there is still argument about the precise actions of many muscles.

The actions of a muscle may be deduced from its attachments, and it is sometimes helpful to imagine a sheet of elastic passing between them. The bellies and tendons of superficial muscles can be palpated during a given movement to find out whether they are contracting. The standard method of demonstrating a muscle is for the examiner to resist the movement concerned; then the muscles performing it will stand out as they exert their maximum effort. If the resistance is increased additional muscles may be recruited. Electromyography, in which the electrical activity taking place in a muscle during contraction is recorded, is only a more refined example of this method, and has the advantage that it can be applied to muscles lying deeper in the body.

In both cases it is difficult to be sure what the muscle is actually doing when it contracts; is it a prime mover or a synergist? For example, the tensor fasciae latae [p. 365] contracts during abduction of the thigh, but does not help to abduct the thigh when it is stimulated electrically.

Direct stimulation, whether electrical or mechanical—as when a muscle is pulled upon during a surgical operation—is open to criticism because, in naturally produced movements, muscles are never singled out in this way. However, the method does at least reveal what the muscle is capable of doing, though it does not necessarily show what its functions are in the intact body. A similar objection applies to observations made on the results of paralysis of single muscles or groups of muscles, for the loss of one member of a group at once creates an artificial situation, in which other muscles may take over some or all of its functions.

Testing for Paralysis. When a muscle is paralysed, the movements in which it normally takes part are weakened, some being more affected than others, according to the relative importance of its participation in them. The paralysed muscle may never contract again, or it may gradually recover its power, depending on the nature and extent of the damage inflicted upon it or upon its nerve supply. It is naturally important to be able to detect which muscles are paralysed following a disease or injury, and also to be able to follow the progress of recovery in them.

The only infallible guide to the integrity of a muscle is to see and feel it contract (Sunderland, 1944b), but this is not always possible. True contraction of a muscle must not be confused with displacement or distortion of a paralysed muscle caused by contraction of neighbouring muscles or by a pull imparted by fascial attachments. It is also very necessary to be on guard against **'trick' movements** (Jones, 1919; Sunderland, 1944b). These may be produced in several ways.

An intact muscle may be able to pull on the tendon of a paralysed muscle because it has an accessory slip of attachment to this tendon. Thus, the abductor pollicis brevis can be used to extend the terminal phalanx of the thumb when all the true extensors are paralysed because some of its fibres are inserted into the tendon of the extensor pollicis longus [p. 332].

Again, an intact muscle which does not normally take part in the affected movement may be recruited to help. The abductor pollicis longus, which does not normally flex the wrist, may do so when the flexors are paralysed because its position allows such an action.

A paralysed prime mover may be brought passively into action by its antagonist, providing the muscles concerned are 'two-joint' muscles. Perhaps the best example is seen when active extension of the metacarpophalangeal joints of the hand is paralysed [p. 334]. By flexing the wrist, the extensor tendons can be put on the stretch and the joints can be made to extend passively. Conversely, if the wrist is fully extended, the tendons of the flexors of the digits can be made to pull the fingers into mild flexion at the interphalangeal joints, even though their muscle bellies may be paralysed. Another important example is afforded in paralysis of the flexor pollicis longus (Sunderland, 1944b); by hyperextending the wrist and fully abducting the thumb the tendon of the flexor pollicis longus is put on the stretch and the terminal joint of the thumb flexes passively.

If the patient is allowed any leverage he may be able to deceive the examiner. For example, when the muscles of the lower limb are being investigated, the heel must not be allowed frictional contact with the couch since movements which are in reality completely paralysed may yet be produced by any muscle capable of taking a leverage from this fixed point (Jones, 1919).

Finally, a sudden relaxation of strongly contracted antagonists may allow a 'rebound' movement in the opposite direction which may simulate an active contraction. Thus, a degree of dorsiflexion of the toes may follow relaxation of the plantar flexors even though the dorsiflexors are paralysed.

When assessing the recovery of a muscle from paralysis, or when attempting to detect a degree of contraction in a grossly weakened muscle, it is obviously inappropriate to resist the movement concerned, as when trying to demonstrate muscle actions. Instead, the weakened muscle is put in a position where gravity does not act against it and the patient attempts to carry out the movement without any resistance. A weak muscle may be incapable of executing a voluntary movement but yet be capable of maintaining the part in a position into which it has been moved passively.

The recovery of muscles is often assessed by a grading system. Thus 0 represents no contraction; 1 represents a flicker or trace of contraction; 2 is active movement with gravity eliminated; 3 is active movement against gravity; 4 is active movement against both gravity and resistance, and 5 is normal power. Unfortunately such grading systems are by no means uniformly accepted (Salter 1955a).

It is a commonplace that muscle strength and size can be increased by use, but there is still controversy about the best method of increasing the power of normal muscles and assisting the recovery of paralysed ones. Isotonic and isometric training both have their proponents, but the results are often equivocal or conflicting (Salter, 1955b; Petersen, 1960).

Nomenclature

The name given to a muscle usually conveys valuable information regarding its position, structure, functions, etc. A muscle may receive its name because of its attachments (sternothyroid), its position (subclavius, supraspinatus), its shape (deltoid, trapezius), its construction (semimembranosus), its action (extensor digitorum), or its size (gluteus maximus). Many names involve a combination of features (extensor carpi radialis longus). Before the eighteenth century few muscles had names, and Galen and Vesalius used numbers, and Leonardo da Vinci letters, to designate the muscles in their illustrations.

Variations

All muscles are subject to a certain amount of variation, but some are more often affected than others. For example, one such muscle, the palmaris longus [p. 318] is not present in every individual, and is thought to be disappearing in the course of