Applied Muscle Action and Co-ordination

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To the best and wisest of fathers

James Playfair McMurrich

PREFACE

THE OBJECT OF THIS BOOK is to provide the basic knowledge of muscle action and co-ordination by which the student of Occupational Therapy can apply specific techniques to specific conditions of muscle insufficiency for the restoration of function. It is taken for granted that the use of this book has been preceded by the study of anatomy and physiology; therefore, anatomical data, such as the origins and insertions of the muscles, the course and distribution of the nerves of supply and the joints of the body, have been omitted as mere repetition of facts presented in authoritative textbooks of anatomy.

Use of handicrafts and games for curative purposes must be based upon knowledge of the muscles involved in such activities. Suggestions are made for those which will involve certain muscles or muscle groups, but these suggestions by no means form a complete list. The ingenious therapist with a sound knowledge of muscle action can constantly make appropriate additions. For the student it is hoped that the accounts of the signs of nerve lesions and of the falsifications of movement which so often accompany these lesions will be useful.

The book is the result of many years experience in teaching anatomy to students of Occupational and Physical Therapy. The difficulties of the subject-matter have been noted and the introductory chapter is an endeavour to clarify these problems for the beginner as well as to summerize existing knowledge of muscle action for the more advanced reader.

I am deeply grateful to Dr. J. V. Basmajian, formerly of the University of Toronto, now Professor of Anatomy at Queen's University, Kingston, Ontario, and to Dr. A. T. Jousse, Director of Physical and Occupational Therapy at the University of Toronto, for the interest and encouragement they have given me in connection with this textbook. Miss Muriel Driver, of Warm Springs, Georgia, Miss Amy DesBrisay of Sunnybrook Veterans' Hospital, Toronto, and Miss Isabel Robinson of the Staff in Occupational Therapy, University of Toronto, have kindly given much assistance about craft work. I should like to express here my thanks to Miss Margaret Murphy for typing the manuscript, to Mrs. N. B. Allan and Mrs. Marian Dougan for the drawings made for illustration, and to the Workmen's Compensation Board of Ontario and Toronto General Hospital for the photographs.

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K. I. McM.

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INTRODUCTION

THE ACTIONS of muscles have been noted for centuries by people studying the structure of the body. Until the fourteenth century, religious prohibitions prevented dissection of the human body. Aristotle (384–322 B.C.) and Galen (A.D. 129–199) stated frankly that their observations were made upon animals. The latter, a Greek physician and philosopher, gave us the first systematic account of muscles, so complete, indeed, that thirteen centuries elapsed before the appearance of any comparable work. It was Galen who noted that if a flexor muscle was cut, the limb remained extended. He also noticed that if a muscle was cut, the parts contracted away from the cut, that a nerve passed to each muscle, and that if such a nerve was cut, the muscle could no longer contract. He believed that psychic force entered the muscle through this nerve—we call it nerve impulse—and his term "innate contractility" was long in use.

Until the middle of the sixteenth century, Galen's works were the final authority. True, Leonardo da Vinci (1492–1519) left notebooks in which he had made drawings and notes on dissections of the human body, but these were mislaid and scattered so that it was not until the close of the nineteenth century that his anatomical studies were available to the scientific world. They revealed that Leonardo's observations were far in advance of his time in accuracy and extent. Apart from other important data which he noted, Leonardo must be credited with establishing the general rule that when one muscle contracts there is relaxation of its antagonist. This is an interesting foreshadowing of the law of "reciprocal innervation" of antagonistic muscles worked out by Sherrington at the beginning of this century.

Andreas Vesalius (1514–64) was the first anatomist to break away from the Galenic tradition in a published text. In his great and wonderfully illustrated work *De Corpora Humani Fabrica*, Vesalius turned attention to specifically human dissections and discussed muscles in groups according to their actions.

Since Vesalius, innumerable writers have paved the way for our modern text-books on anatomy and kinesiology. It might be mentioned that Fallopius (1523–62) was the first to ascribe to the Interossei of the hand the actions of flexion of the first phalanx and extension of the second and third phalanges. In 1749 there was published a text-book on anatomy which became so popular that it was translated into many languages. This was *An Anatomical Exposition of the Structure of the Human Body* by Jacques Bénigne Winslow. Winslow, who was Danish, held the post of "Professor of Physick, Anatomy and Surgery" at the University of Paris. In his book, a large section describes the muscles and their actions in such a way that, after 200 years, it is still worthy of study.

Until the discovery was made that muscles respond to stimulation by electric current, most of the information on muscle action could only be deduced from observations of the cadaver and the living body. When Duchenne of Boulogne (1805–75) walked the wards of the Paris hospitals during the Franco-Prussian war with his home-made faradic battery, he accumulated data on the actions of muscles that are still authoritative. He proved that no muscle acts alone; each is part of a functional complex. His book, *Physiologie des mouvements*, which can be found in most medical libraries and which has recently been translated into English (**1**), is an invaluable source of information for the student of kinesiology.

One of the important works setting forth the functional viewpoint was the lecture delivered in 1904 to the Royal College of Physicians by Charles Edward Beevor. This lecture, which was one of a memorial series known as the Croonian Lectures, deals with the upper extremity of the body only. It was published in book form but is no longer obtainable[1]; nevertheless, if a copy is available in an accessible medical library, it will be found to provide a searching study of the parts played by individual muscles in the movements of the upper limb.

Succeeding generations of anatomists, physiologists and neurologists have studied the muscles of the body and the problems of contraction and relaxation. Tests by sundry methods have been made but the last word has not been said. The complexity of the mechanics of movement is so great that research has yet to solve the problem fully. Too much stress has been laid, perhaps, on the actions of individual muscles. It is essential that these be understood, but in the simplest movement more than one muscle is almost invariably involved, each playing its specific part in the performance of the desired movement. Text-books of anatomy describe the actions of each muscle, give a general account of "how muscles act," and outline the intricate pathways of nervous control. Clinical observations have shown the effect that paralysis of certain muscles can have on the performance of certain movements. The variety of movements of the body is infinite, and the

[1]This has just been edited and reprinted by Macmillan & Co. Ltd. for the guarantors of "Brain."

study of how these movements are brought about has endless fascination.

The actions of muscles may be studied in several ways:

1. *In the anatomical laboratory on a cadaver.* The student in demonstration classes should take careful note of the features of each muscle studied under the following headings:

(*a*) The situation of the muscle in the body.

(*b*) The exact attachments of the muscle to bone or other structures and the form of each attachment, whether fibrous, by tendon, or by aponeurosis.

(*c*) The relationship of the muscle to a joint or joints. Does it pass over more than one joint? Does it pass over the joint anteriorly or posteriorly or at one side? Is the direction straight or oblique?

(*d*) The size of the muscle and its architecture. Do the fibres run straight from one attachment to the other or are they attached diagonally into the tendon? Do all the fibres run in the same direction? Is one part of the muscle larger or thicker than another?

(*e*) The relationship of the muscle to other muscles. Is it deep to other muscles or does it lie superficial to them?

(*f*) The nerve supply. From which nerve does the muscle derive branches of supply? Do these branches enter the muscle from below or above or from the side? Where does the nerve enter the muscle, in its upper part or its lower part?

(*g*) The relationship of the larger blood vessels to the muscle.

In this way, the student can provide himself with a mental picture of the muscles of the different regions of the body as a guide to the location of these muscles on the living subject. Further, certain muscles are so deeply placed that they are difficult or impossible to identify on the living subject; observation of their position and direction of pull on the cadaver provides information on their action. Gluteus Minimus is too deep to be felt, but it passes over the side of the hip joint and therefore it is assumed that it raises the lower limb to the side (abduction). The mental picture thus formed can be tested by making drawings from memory of the region studied and practice in this is urged upon every student.

2. *By observation and palpation on the living body.* By this method we can see and feel the various muscles when they are acting. Some muscles can be felt in their entirety, swelling and hardening as they contract, and some are best identified at their tendons: for example the tendons crossing the back of the wrist. Other muscles may only be demonstrated by the resulting movement, deduced from observations

in the anatomy class. Muscle identification on the living body requires practice—a great deal of practice—on yourself or on a partner. If a pathological condition exists, the inability to perform certain movements, or the unbalanced performance of a movement, indicates the muscular involvement. Accuracy in detecting this involvement of a few or many muscles in pathological conditions is of vital importance, as a clue to rehabilitation. The study of muscle action in the living should be intensive and should be preceded by anatomical knowledge.

3. *By electrical stimulation.* Muscular contraction can be induced by the application of electric current. Galvanic current stimulates the intrinsic contractility of the muscle fibres, independent of nerve supply. Faradic current affects the motor nerve and therefore elicits no response if the nerve is damaged. Faradic muscle-testing is commonly used to detect nerve degeneration in peripheral nerve lesions and also to determine regeneration following surgical repair, although voluntary contraction is usually detectable before there is response to faradic stimulation. A newer form of measurement of muscle power is chronaxie, using galvanic current but measured in time, the time required to produce contraction. These methods of eliciting muscular contraction, however, do not give accurate information on the action of many deep-seated muscles unless the superficial muscles are definitely paralysed. Moreover, the stimulus may spread to several muscles and thus blur the response of one definite muscle.

4. *By clinical observation.* Muscles are only too often either weakened or paralysed by disease or injury. The absence of contraction in a muscle may prove its function by allowing other muscles involved in a shared movement to overplay their part. Imbalance in the power of the muscles moving a joint can cause deformity. This occurs most markedly in the foot. Facts learned earlier in the anatomical laboratory and in study on the living body are proved—or perhaps disproved—in close observation of clinical cases.

5. *Electromyography.* This is a recent method of studying and proving the degree of contraction of a given muscle in the performance of a given movement in the living body. The "action potentials" of a muscle are picked up by an electrode and recorded with amplification in the same way as an electro-cardiogram is recorded.

Structure of Voluntary Muscle

The essential peculiarity of muscle tissue is its ability to contract and relax. The fleshy belly of a muscle is the part that has this characteristic. In order that a contraction may bring about movement, a muscle must be attached to the bony skeleton and pass over at least one joint. The attachments of a muscle are known as origin and insertion. The attachment nearer the mid-line of the body, to the usually fixed point, is called the origin; the attachment further from the mid-line, to the usually moving part, is called the insertion. Between these two attachments lies the contractile belly of the muscle.

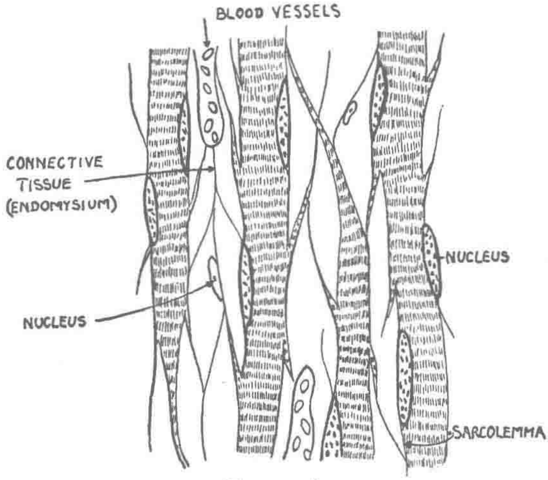

FIGURE 1

The belly of a muscle is composed of thousands of cells, threadlike, cylindrical or prismatic in shape, each fibre covered by a delicate elastic membrane called the sarcolemma which is considered part of the fibre. These cells, or fibres, are subject to great variation in diameter and length but are always larger than other cells of the body. The number of fibres in the various muscles may be anything from a few hundred to several thousand. Under the microscope, a muscle fibre shows a transversely striped appearance and many nuclei, normally at the periphery, hence it is described as a multi-nuclear cell. Two types of voluntary muscle fibres are described, red and pale, intermingled; some muscles are composed predominantly of red fibres (such as Soleus), while other muscles are predominantly white-fibred (Gastrocnemius).[2] Muscles that have a majorty of red fibres contract slowly but endure longer; muscles that are mainly composed of pale fibres can contract quickly but soon tire.

A muscle, as a whole, is enclosed in a sheath of connective tissue. From this covering, strands penetrate the muscle substance separating groups of muscle fibres into bundles (fasciculi). As these bundles

[2]Recent research by E. M. Walls would seem to reject this statement for human anatomy (**27**).

subdivide into smaller bundles, the connective tissue partitions become thinner until they eventually form a delicate network separating individual muscle fibres. The connective tissue element of a muscle supports the muscle fibres and retains the innumerable blood capillaries and is continuous with the attachments of the muscle.

These attachments take various forms: tendons, aponeuroses, raphae or fleshy. Tendons are cord- or bandlike lengths of white fibrous tissue, of varying lengths, such as the tendons of insertion of the muscles of the forearm. If the tendon is flattened and broad like a membrane, it is called an aponeurosis: for example, the aponeurosis of the External Oblique muscle of the abdominal wall. A few muscles begin in a fibrous band called a raphé: for example, the origin of the Buccinator muscle in the face. Some muscles arise from a considerable area and leave no appreciable mark on the bone, showing that the connective tissue that invests bundles of muscle fibres has blended with the periosteum of the bone. Brachialis is an example of this type of attachment which is known as a fleshy attachment. Tendons attaching to bone have been found to penetrate into the bone substance so that in the process of growth they have become incorporated with the bone. The site of the attachment of a tendon may be indicated by a protuberance such as the radial tuberosity, where force is concentrated upon a small area. Certain muscles are attached to structures other than bone: to cartilage, as in the larynx; to fascia, like Platysma, to the tendons of other muscles, like the Lumbricales.

Since muscles, like engines, work and move, they are provided with devices to help them avoid "wear and tear." In a region where pressure is great, or considerable friction would result from tendon rubbing against bone, protection is provided by *bursae*—small sacs containing a minimal amount of synovial fluid. Bursae are found between tendon and bone (between the tendon of Biceps and the radial tuberosity) or between tendon and ligament (between the tendon of Psoas and the capsule of the hip joint). Occasionally, as in the latter example, a bursa may open into the joint cavity. Bursae are also present between the skin and bony projections, such as the prepatellar bursa between the skin and the patella at the knee. Another protection against friction, which also increases the efficiency of the muscle, is provided by *sesamoid bones.* These are small, round bones imbedded in tendons (sesame = seed). Sesamoid bones are found regularly at the metatarso-phalangeal joint of the great toe, at the metacarpo-phalangeal joint of the thumb, and at the knee joint—the patella being actually a sesamoid bone though dignified with a title of its own. Occasionally they develop in other tendons. They lie against the proximal bone of the joint, never opposite the joint proper, and, by holding the tendon away from close contact with the joint, they increase the mechanical advantage of the muscle.

Where tendons are long, they must be retained in position and this is done by bands of dense connective tissue, thickenings of the deep, investing fascia of the limb, known as *retinacula*. To prevent the long tendons of the forearm or leg muscles from standing out like bow-strings when the wrist or ankle is flexed or extended, retinacula are present immediately above the joints, the tendons lying each in its own slot within the retaining band. On the flexor surface of the toes and fingers individual retinacula are found. These *fibrous sheaths* are attached to the borders of the phalanges, passing over the tendons of the long digital flexors. Where tendons are thus held in a bony hollow, a lubricating device is provided by the elongated bursae, called *synovial sheaths*. These are double-layered tubes containing synovial fluid which assures smooth gliding of the tendons in their confined position. Since movement stimulates the excretion of synovia, over-exertion of a specific muscle provided with a synovial sheath can cause a condition known as teno-synovitis—inflammation of a tendon or sheath. Typists and musicians not uncommonly develop this painful condition.

Every voluntary muscle must be connected with the central nervous system in order to receive the impulse to contract or to relax. Centres in the brain initiate and control this impulse to the muscles required for the desired movement. These impulses travel down the spinal cord to the specific level and are there transmitted to the cells of the anterior grey column and from thence, through peripheral nerves, to the required muscles. A nerve enters a muscle at a point where it will be least disturbed by the contraction of the muscle; this is called the "motor point," important for electrical stimulation. Within the muscle the nerve branches out until each muscle fibre receives at least one efferent nerve filament, sometimes more. Each efferent filament ends within the sarcolemma of the muscle fibre in a "motor end-plate" where minute amounts of acetylcholine are discharged by the filament.

Afferent (sensory) fibres accompany the efferent fibres into a muscle but are less numerous. Some end in small bundles of thin muscle fibres known as "neuro-muscular spindles" and convey to the central nervous system information on the state of tension within the muscle. Other afferent nerve fibres end at the junction of the muscle belly with its tendon in "neuro-tendinous spindles." Fibres from the autonomic nervous system also enter a muscle to innervate the walls of the blood vessels within that muscle.