The Croonian Lectures

MUSCULAR MOVEMENTS AND THEIR REPRESENTATION IN THE CENTRAL NERVOUS SYSTEM.

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LECTURE II.

THE RADIO-ULNAR ARTICULATIONS.

THE muscles producing pronation are the pronator teres and pronator quadratus, and if the resistance to the movement be applied to the hand as it usually is, the flexor carpi radialis and palmaris longus contract. The pronator quadratus cannot be felt contracting, but it is one of the muscles whose action must be inferred from its position. Supination is performed by the supinator brevis, biceps, and, when the resistance is applied to the hand, by the extensor carpi radialis longior and brevior and by the extensors of the thumb. The strongest supinator is the biceps, and its action as such was described by Winslow.¹ Ten years ago I published in *Brain*² an observation on the supinator longus, and I came to the conclusion that while it took an active part in flexing the forearm, no action in it could be discerned in the movement of pronation and supination. I think now, however, that on extreme pronation, and when considerable strength is used, there is some slight action at the end of this movement. This is a point which any one can prove for himself by supinating or pronating the forearm against resistance, taking care that no flexion of the forearm occurs. I think it will be found that no contraction of the supinator longus will be seen except in extreme pronation, but the moment that the slightest flexion is made the muscle instantly stands out in strong outline. I therefore conclude that the supinator longus, or the brachio-radialis, as it would be better to call it, does not take part in supination, and only in strong movements of pronation.

No doubt the biceps is a flexor as well as a supinator, and it may therefore be asked: Why does not the elbow flex in supinating the forearm when the biceps is contracting so strongly? There must be some opposing force to prevent flexion. We have here, in fact, an example of a muscle having two actions, supination and flexion, of which the latter is not required, and therefore the antagonist to this flexor action must be brought into the movement. The antagonists to the flexors of the elbow are the extensors of the elbow. In other words, it is not possible to have strong pure supination without contraction of the triceps. Apparently it is not the whole triceps which takes part in this movement, for of the three heads by which the triceps arises the fibres of the outer and inner head contract, but not those of the long head arising from the scapula; this head is an adductor of the humerus; now the only counteraction required in supination is extension of the forearm and not adduction of the humerus, therefore the part of the triceps which performs this movement of adduction does not contract. The pronator radii teres is also a flexor of the forearm on the arm as well as a pronator, and to neutralize its flexor action there is contraction of the triceps, but to a much less degree than in supination, as the flexor action of the pronator teres is much less than that of the biceps.

ELBOW: FLEXION.

The muscles which take part in flexion are the biceps, brachialis anticus, supinator longus, pronator radii teres; and when the hand is closed there is very slight action in the flexores carpi, but none in the extensores carpi. We have, therefore, the supinator longus and the pronator radii teres acting as a flexor pronators, and the biceps as a flexor supinator. The association of flexion or extension with pronation or supination produces some interesting combinations. For instance, if while flexing the elbow the forearm be supinated, the pronator radii teres, which was acting as a flexor of the elbow, seems to cease as soon as the movement of supination is required to be performed; but, on the other hand, the biceps does not cease acting in flexing and pronating at the same time. The biceps contracts during the com-

bined movements of extension of the elbow and supination of the forearm, and therefore the action of the extensors of the elbow must be stronger than the flexor action of the biceps, otherwise there would be no extension.

What part do the flexors and extensors of the carpus take in the movements of the elbow? My experience is that their action is exceedingly slight as flexors of the forearm on the upper arm. I have tested the amount of work done by flexion of the elbow when the flexors of the wrist took part in the movement and when they did not, and with the result that the power of flexing the elbow by the muscles of the carpus is very slight and is almost a negligible quantity. The extensor carpi radialis longior has been considered to be a flexor of the elbow-joint, but when the wrist is lax I cannot find that there is any contraction of this muscle when strong flexion of the elbow with the forearm pronated is made against resistance.

ELBOW: EXTENSION.

Extension of the bones of the forearm on the humerus is performed by the triceps and anconeus, and I am unable to find that the extensors of the wrist or fingers take any part in the movement.

HUMERUS AND SCAPULA.

In the antero-posterior plane, the humerus starting from the hanging position is moved forwards, flexed as it is also called, to the horizontal line and thence it is elevated to the vertical position, on the return journey the humerus is depressed through 180° to the hanging position, and thence it can be carried backwards or retracted. In the lateral plane the humerus can be abducted to the horizontal line and thence to the vertical, and on the return journey it is adducted through 180° to the hanging position. In the horizontal plane the humerus is horizontally adducted when it is moved towards the middle line and horizontally abducted when away from the middle line to the lateral plane, behind which it is horizontally retracted. Besides the above movements there is rotation in and out.

In advancing the humerus the anterior fibres of the deltoid, the clavicular fibres of the pectoralis major, the biceps, and probably the coraco-brachialis, contract and carry the humerus forward nearly to the horizontal line. This action tends to rotate the scapula and to push its inferior angle towards the spinal column, but this is prevented by the contraction of the acromial fibres of the trapezius—which Duchenne showed to be the fibres taking part in this movement and not the clavicular fibres—and also, as I consider, by the contraction of the inferior fibres of the trapezius.

Just before the horizontal line the serratus magnus comes to their assistance and draws the lower end of the scapula forwards, raises the acromion with the humerus, and thus the arm is elevated to the vertical position. Now, the serratus magnus is considered to fix the lower end of the scapula at the beginning of this movement; but I have seen cases in the last few years which seem to negative this idea.

CASE I, a girl who had wasting of the lower part of the trapezius, below a line drawn horizontally from the spine of the scapula to the vertebral column. The rest of the trapezius acted well, and the serratus magnus was not affected, which was well shown by the patient being able to push forward with the advanced arm against resistance. On telling the patient to advance the arm slowly, I observed that the first action on the scapula was to rotate it, so that the inferior angle moved $\frac{1}{2}$ in. towards the vertebral column and the posterior border of the scapula projected like a wing; this projection reached its maximum when the humerus was advanced through about 45°. Then the serratus magnus contracted, and as it drew the lower end of the scapula forwards the deformity diminished and finally disappeared.

The explanation that I would offer for this occurrence, which does not happen with normal muscles, is that, though the serratus magnus is mechanically in the position to fix the scapula and prevent its lower angle being rotated towards the vertebral column, it is not its function, when the movement is one of advancing the shoulder, to act on the scapula until the humerus has been moved by the deltoid through about 45°. The lowest part of the trapezius apparently is the proper muscle to fix the scapula in advancing the humerus, and when these inferior fibres are paralysed the serratus will not step into the breach, so to say, and do the work for the trapezius, which consequently is not done at all.*

CASE II.—I have lately had the opportunity of examining a case under the care of Dr. James Collier where the whole trapezius had wasted and practically disappeared from a lesion of the spinal accessory nerve in the

* A patient (under the care of Dr. Ormerod) who had paralysis of the inferior fibres of the trapezius was shown at the lecture to illustrate this movement of the scapula inwards.

neck, with the result that at rest the scapula was $\frac{1}{2}$ in. lower than on the other side and the acromion was rotated downwards and forwards so that the base of the scapular spine was 2 in. further away and the inferior angle was $\frac{1}{2}$ in. further away from the vertebral column than on the other side. On making this patient abduct or advance the humerus it was seen that the inferior angle moved inwards or backwards for $\frac{1}{2}$ in. and when the movement of the arm was resisted for as much as 1 in., until the humerus had moved through an angle of 45° , when the inferior angle of the scapula was drawn forwards by the serratus the deformity disappeared and the humerus was powerfully carried upwards to the vertical position.

In this case as the trapezius was the only muscle paralysed the deformity and backward movement of the scapula must be due to its absence, and the only conclusion that we can draw is that although the serratus magnus is in the anatomical position to be able to act and is generally supposed to fix the scapula, the will has apparently no power to make it act before its appointed time, otherwise why does it not take the place of the paralysed trapezius? Whether it would be possible to educate the serratus and by practice to induce it to contract sooner I am not in a position to state, but if the condition may be taken as the same as that of paralysis of the extensors of the fingers in lead paralysis, I should think it doubtful.

What determines the period at which the serratus begins to act it is difficult to say, but it seems to have some relation to the angle which the humerus makes with the scapula or to the degree of contraction of the deltoid and the tension it produces on the scapula. Normally in advancing the arm the scapula does not move till the humerus makes an angle of about 45° , and then the inferior angle begins to move outwards by the commencing action of the serratus, and when the humerus is horizontal the angle with the scapula remains constant, and the elevation of the humerus to the vertical position is completed by the serratus. If, however, the deltoid is paralysed or the shoulder is fixed, the serratus begins to act at once and the scapula moves outwards at once; so much so that this movement of the scapula is a diagnostic sign of one of the two above conditions. It is quite easy to imitate this movement normally by rotating the inferior angle of the scapula forwards and the acromion upwards without first moving the humerus, but in none of these conditions is the movement imitated by the action of the deltoid, and there is no displacement of the inferior angle of the scapula backwards or towards the spine.

Another point of interest, occurring incidentally, is that the projection or winging of the scapula may be caused by paralysis of the trapezius, and especially of its lower fibres, as well as by the well-known paralysis of the serratus magnus, and the difference between the two conditions is that the deformity due to the absence of the trapezius is less than that of the serratus, the scapula projecting only $\frac{1}{2}$ in., and that the projection reaches its maximum when the humerus is advanced through 45° , after which the deformity diminishes and disappears when the humerus is horizontal; moreover, the humerus can be elevated to the vertical position. With paralysis of the serratus magnus, the deformity increases as the arm is advanced and reaches its maximum when the humerus is horizontal, beyond which level there is no muscular power to raise it. The diagnosis of paralysis of the serratus is also confirmed by the ease with which the scapula can be displaced backward by pushing against the advanced arm, which is not the case with the trapezius paralysis.

The action of the upper fibres of the pectoralis major in advancing the arm is important and was described by Winslow.³ It is an action which does not appear in some people until the arm is advanced nearer to the middle line than the antero-posterior plane, and it can be best brought out by advancing the humerus to the horizontal line, and then carrying it inwards towards the middle line, and at a definite angle of the humerus, the muscle will be seen to come into action, when the arm is elevated above the horizontal line.

The description just given of advancing the humerus applies equally well to the movement of abducting the humerus with the exception that the middle part of the deltoid and the supraspinatus abduct the humerus and the pectoralis major does not act, but the same condition is met with in regard to the movements of the scapula and its relation to the trapezius and serratus, as in the movement of advancing the humerus. Advancement and abduction of the shoulder are also attended by contraction of the erectors spinae.

Depression of the humerus in the antero-posterior plane from the vertical position above the head through 180° is performed by the sternal fibres of the pectoralis major, the

pectoralis minor, the latissimus dorsi, the teres major, the teres minor the infraspinatus, and by the long head of the triceps, and perhaps by the subscapularis.

The superior or clavicular fibres of the pectoralis major are not from my observations depressors of the humerus, and I cannot agree with Duchenne⁴ that these fibres are at the same time depressors and elevators of the humerus according to the position of the limb, that is, depressors only from the vertical to the horizontal line, and that they are, as Duchenne gracefully describes, the agent used equally by the enemy to strike with a sword or by the priest to bless the faithful. I cannot discover that the upper fibres contract at all in forcibly depressing the humerus in any position, and I was glad to find that Winslow⁵ states that the superior fibres serve chiefly to raise the arm forward. Duchenne's opinion was evidently founded on the fact that if the humerus be elevated vertically, and the superior fibres be stimulated electrically, they will depress the humerus to the horizontal line; but according to my observations they do not contract voluntarily to depress the humerus, and although they are in the anatomical position to depress the humerus, they are not included in the group of muscles told off to perform this movement.

Of the other muscles depressing the humerus I would refer to the long head of the triceps. As it cannot contract without extending the elbow there is also, if only pure adduction be required, slight synergic action on the part of the biceps and supinator longus to neutralize the extensor action of the triceps. This action of the long head of the triceps is very well seen in cases—of which I have one under my care at the present time at the National Hospital—where the triceps is unaffected, while the flexors of the elbow are paralysed; here every time that the patient depresses or adducts the humerus, the elbow is extended by the unopposed long head of the triceps.

Retraction of the hanging humerus posteriorly to the vertical line is performed in addition to the depressors by the posterior half of the deltoid, and by the pectoralis minor, but not, I believe, by the pectoralis major, so this movement is a means of separating the action of these two muscles.

Adduction of the humerus is performed by the same muscles as take part in depressing the humerus, with the addition that both parts of the pectoralis major, and also the posterior fibres of the deltoid, act as adductors, as Winslow⁶ pointed out. According to Duchenne,⁷

electrical experiment shows that the posterior one-third of deltoid acts synergically with the other fibres of the same muscle to elevate the humerus, through an angle of 45° , but above this point the posterior fibres become depressors of the humerus and antagonists to the other fibres down to that point of elevation which results from the contraction of the posterior bundle. This justifies the opinion of Bichat,⁸ contested by many anatomists, that the deltoid can be at the same time both elevator and depressor of the humerus.

My observations would make me join the ranks of the contesters of this opinion, as I cannot find that the posterior fibres of the deltoid take any part in elevation of the humerus; they are, in my opinion, adductors. On this question I would again like to point out that, because a muscle can produce two opposite movements when stimulated by faradization, we cannot be certain that it performs these two opposite movements when acted on by the will. We have first to prove that the muscle is actually contracting in each of these opposite conditions.

In both movements of depressing the humerus and adducting it, the scapula has to be fixed by the rhomboids and the lowest fibres of the trapezius, so that when the former are absent the inferior angle of the scapula is drawn into the axilla by the teres muscles, as was first pointed out by Erb; and when the lowest fibres of the trapezius are absent, the scapula is lifted upwards by the rhomboid and the teres muscles. The contraction of the rhomboid is, however, stronger than that of the trapezius, and in some cases the latter appears not to act in adduction. Conversely, when the adductors are weak and the rhomboid is normal, it carries the inferior angle of the scapula to the spine in the movement of adducting the humerus.

The pectoralis minor also fixes the scapula in depressing the humerus, and when it is absent, as I have lately seen in a case, the scapula is elevated and the coracoid process projects under the skin.

In depression and in adduction of the humerus from the horizontal line there is contraction of the abdominal muscles, as was pointed out by Winslow,⁹ and especially of the rectus abdominis and external oblique, which fix the ribs, and prevent them from being drawn up by the pectoralis major. In depression I have found that the recti of both sides act, but

those of the same side much more, and sooner, than those of the opposite side, while in adduction the rectus of the same side only contracts, but in addition the erector spinae of the same side takes part. The question is whether the abdominal muscles are essential for the performance of the movements, or whether it is possible to perform them without co-operation of these muscles.

I find that the amount of work required to be done before the rectus abdominis contracts in the movement of depressing or adducting the upper limb from the horizontal line is exceedingly small, and that in the erect position with the arm in the horizontal position the rectus abdominis could be felt to contract when the scale only registered from 4 lb. to 7 lb., and as this includes the dead weight of the arm, which was found to be $2\frac{1}{2}$ lb., the actual work done by the muscles was $1\frac{1}{2}$ lb. to $4\frac{1}{2}$ lb., and this small amount was sufficient to bring in the fixing action of the rectus abdominis. The smallness of this amount is further shown when compared with the maximum amount of force which can be produced by this movement. In my case it was 30 lb., so that the earliest contraction of the rectus abdominis occurred when only about one-fifteenth of the maximum strength had been used. It therefore occurs not at the end of a strong movement, but so early that the movement can hardly take place without it. As this action of the rectus takes place equally well in standing, sitting, or lying down, its participation is not necessary for maintaining a certain position, and therefore I think it must be included in the list of muscles which are essential for the movement of depression and adduction of the humerus.

The movement of horizontal adduction which takes place when the humerus is advanced to the horizontal line is carried out by the anterior fibres of the deltoid, the coracobrachialis, and by the pectoralis major, and, where there is no resistance, by the upper fibres only, but where an obstacle is to be overcome both parts of this muscle act. The pectoralis major is a muscle consisting of two parts, clavicular and costo-sternal, which can either act in unison or in antagonism. The best way to bring out the actions of the two parts working together is to advance the upper arm passively to the horizontal line, and then to tell the patient to carry his hand towards the middle line against resistance. If he then raises his hand upwards against resistance the upper fibres alone contract, and if he depress his hand the lower fibres alone contract. In fact, as Winslow said, the pectoralis major may be looked upon as two distinct muscles, and I have published¹⁰ cases of complete absence of the lower fibres, due to infantile paralysis, with perfect preservation of the upper fibres. Associated with the loss of the lower pectoral fibres there was complete paralysis of the latissimus dorsi and triceps.

In horizontal abduction the different fibres of the middle part of the deltoid successively come into action until the posterior fibres act, together with the latissimus dorsi teres muscles and subscapularis.

Associated with horizontal abduction of the humerus is the fixation of the scapula by the trapezius, in which all but the clavicular and acromial fibres take part. This is the best movement to bring out the trapezius and particularly the middle part, which it is often very difficult to make out. For this purpose the upper limb is put in the advanced horizontal position parallel to the middle line, and it is then passively pushed backwards so as to make the posterior edge of the scapula visible. If now the patient be directed to abduct the humerus horizontally against resistance, the fibres of the trapezius, and especially those inserted into the spine of the scapula, are well seen against the sharp edge of the posterior border of the scapula, and they have a direction almost horizontal and not so oblique downwards and outwards as the fibres of the rhomboideus minor with which they might be confounded.

Of the rotators of the humerus, the rotators in are the pectoralis major both parts, deltoid anterior fibres, teres major, latissimus dorsi, and probably the subscapularis. In rotation in, especially when the humerus is horizontal, the rhomboid chiefly acts to fix the scapula, and in rotation out the lowest fibres of the trapezius perform this function. Consequently in paralysis of the trapezius there is great displacement of the scapula in rotation out of the humerus, but not with rotation in.

The scapula has also the movements which are independent of those of the humerus, namely, elevation, depression, advancing, retraction, and rotation with the acromion upwards, which has already been described.

Elevation is performed by the trapezius, and especially by

the acromial fibres, though the clavicular do also contract in some patients, though apparently not in all, and by the levator anguli scapulae. According to Duchenne,¹¹ the inferior part of the serratus magnus is an elevator of the shoulder, as shown by electrical faradization. Upon being stimulated the serratus first rotates the scapula with the acromion upwards and then elevates it. Nevertheless, Duchenne states that when he made a person elevate the shoulder and he applied strong resistance to its point, he found that the trapezius, rhomboid, the upper part of the pectoralis major alone contracted, but not the serratus magnus. Yet as soon as the patient raised his arm the muscle contracted at once. He explains that the reason why the serratus magnus does not act is probably because its contraction would interfere with respiration in keeping elevated the ribs on which it takes its origin. I venture to think that the will has not the power to leave a muscle out of a group if it is included in it, even if it interferes with respiration, and that the explanation is rather to be found in the fact that the serratus magnus is not an elevator of the shoulder, and also that the electrical results are not to be relied upon, unless they are corroborated by voluntary movements. I also think that Duchenne is not distinguishing between the two different movements of (1) elevation of the acromion where the scapula is rotated by the serratus magnus, and (2) elevation of the whole scapula as in shrugging the shoulders where the serratus magnus does not act.

The levator anguli scapulae, in some cases, takes part with the serratus magnus in advancing the scapula, and perhaps it counteracts the rotation of the scapula, with the acromion upwards, by the serratus magnus.

MOVEMENTS OF THE SPINAL COLUMN.

The chief movements of the lumbar spine are flexion and extension, lateral flexion to either side and rotation to either side.

The chief flexors of the spine are the recti abdominis with the pyramidales, and also the external obliques, but whether the internal obliques also take part I have had no means of ascertaining. In testing the action of the recti abdominis the person lies flat on his back and crosses the arms on the chest, and the thighs are then fixed by passive pressure. It is then often sufficient for the person to bend the head forwards for the recti to tighten up sufficiently to be felt. The complete movement of sitting up from the recumbent position consists of two stages; in the first, the sternum is approximated to the pubes by the recti abdominis flexing the lumbar spine, and then the pelvis with the spine is flexed on the femora by the psoas and iliacus and other flexor muscles. It is often important, especially in cases of tumour of the spinal cord, to know if any part of the recti abdominis is paralysed, as they are long muscles which are supplied from the sixth to the twelfth dorsal spinal roots.

I observed some years back a symptom which enables the observer to tell if there is any weakness of the upper or lower parts of the recti; this symptom is the movement of the umbilicus. In health, in the movement of sitting up the umbilicus does not alter its position, but if from a lesion of the lower part of the cord or its nerves the part of the recti below the umbilicus be paralysed, the normal upper part of the recti draws up the umbilicus sometimes to the extent of an inch. As the abdominal wall, and presumably the rectus, at the level of the umbilicus is supplied by the tenth dorsal root, any marked elevation of the umbilicus in the act of sitting up would show a lesion between the tenth and twelfth dorsal segments of the cord, or the roots coming off from them.

The extensors of the spine are the erectores spinae which can be well felt at their origin on either side of the lumbar spine but whose divisions into ilio-costalis and longissimus dorsi I do not think that it is possible to make out. The action of these muscles can best be made out by making a person, while lying down prone on a bed, lift up the neck and the upper part of the trunk, when the muscles can be felt and seen on either side of the lumbar spinal column; or by making the patient extend the spine from the position of bending forwards either in the standing or sitting position.

In connexion with the actions of the flexors and extensors of the lumbar spine are the muscular movements which regulate and maintain the erect posture, that is, standing with the feet together in the position of attention. These muscles have to be continually counteracting the influence of gravity, and although when work is being done, as in pushing forwards against an obstacle or as in keeping a door shut, the flexors

of the spine act yet when a person bends forwards from the erect position without having to overcome an obstacle, it is not the flexors of the spine which act but the extensors, and conversely in extending the spine as in leaning backwards from the erect position, it is not the extensors of the spine which act, but the flexors.

This condition has been, I venture to submit, much overlooked in books of general anatomy, and also in special books on anatomy for artists. In the one by the late Mr. John Marshall¹² I cannot find any allusion to this point. And in a recent similar work¹³ the following passages occur:

This bulging of the muscles on either side is particularly noticeable when these muscles (erectores spinae) are in a powerful state of contraction as when a person.....is bending backwards..... If the figure be bent backwards the median furrow is deepened and the erectores spinae are rendered more prominent, owing to the fact that they are now in a powerful state of contraction.

If in the above description each movement of bending backwards starts from the erect posture and is not made against resistance, I am afraid that I could not agree with it. Merkel¹⁴ also states that in bending forwards the groove in the middle of the back disappears and vertebral spines become visible, and the back becomes smooth and round; in bending the body backwards the long back muscles become very tense and appear in the lumbar region as thick swellings. On bending to the side (presumably without effort) the long back muscles of the bent side form a stronger projecting swelling than those on the stretched side.

On the other hand, according to W. Adams,¹⁵ the muscles of the spine are in a state of least action when the spinal column is in the erect position. Instead, therefore, of the muscles of the spine in this position being in a state of active tension, it is more correct to describe them as in a state of vigilant repose, as soon as the equilibrium is disturbed and the body is inclined to one side the spinal muscles on the convexity of the curve are put on the stretch. Richet¹⁶ also states that on bending forwards the extensors come into action, and, on bending backwards, the flexors of the spine, so that the action is somewhat of a paradox. But we must go further to find similar opinions expressed by Winslow,¹⁷ who stated that

The muscular recti serve to support the trunk of the body when inclined backwards.....for when we stand straight they have no hand in bending the body forward, except we be striving to overcome some resistance.

And going further back still we find that Galen,¹⁸ in describing his fourth movement of muscles, refers to the contraction of a muscle where there is no movement as in the case of maintaining the advanced arm in that position against gravity, so that he evidently recognized that the behaviour of a muscle is different according to whether gravity has to be overcome or not. I agree with the opinion expressed above by W. Adams that in the erect position there is a state of least action of the muscles, as very little action is to be felt in the erectores spinae or in the recti abdominis; but by producing a forward movement of the trunk, as by bending the head forward so as to displace the centre of gravity, the erectores spinae instantly contract, and prevent the trunk moving further in the direction of flexion, whilst the flexors of the recti abdominis relax. In the same way, by extending the head backwards, the centre of gravity is displaced backwards, and the recti abdominis contract and check any further movement in a backward direction, whilst the erectores spinae are relaxed; but, if it be desired to bend the trunk gradually forward, the contracted erectores gradually relax and let out the weight of the trunk in the same way as a heavy weight is slowly lowered to the ground by a crane. This action of these muscles can best be illustrated by the upper limb. If, when the upper limb is in horizontal extension the forearm be slowly flexed on the upper arm, the flexors of the elbow contract until the forearm is just past the vertical line, when they cease to act and become quite flaccid, while the triceps then contracts and lets the forearm gently flex on the upper arm. Conversely, if in that position the forearm be slowly extended the triceps contracts until just past the vertical line, when it ceases, and then the biceps and the other flexors contract and let the forearm be gradually extended. So that in flexing the forearm in the horizontal position the first half of the movement against gravity is done by the flexors, and the second half with gravity by the extensors. This applies to all the muscles of the body, and it may be expressed thus: In every slow movement which is made in the direction of gravity the muscles which act in the direction of the movement are relaxed, while their antagonists contract and sup-

port the part, and if the movement is continued they gradually relax to their full extent.

The contraction of the erectores spinae when the body falls forward occurs automatically, and apparently without any effort of the will, and it can be demonstrated by leaning forwards, supporting the weight of the body on one hand. On suddenly taking the supporting hand away the body falls forward, and the erectores spinae instantly contract. The contraction is an instinctive preservative action, performed automatically, and it takes place unless a voluntary effort is made to inhibit the contraction, when it can be prevented from acting.

In lateral flexion to one side, where an obstacle has to be overcome, the rectus abdominis and erector spinae of that side can be felt to contract, together with the external oblique, and probably the quadratus lumborum, but in inclining the trunk to one side in the direction of gravity, where no obstacle has to be overcome, the muscles of that side are relaxed, and the muscles on the opposite side—the antagonists—contract, just in the same manner as the erectores spinae contract in flexing the spine forwards. In rotation of the spine to the right the left external oblique acts, but neither the erector spinae nor the rectus abdominis can be felt to contract, but whether the internal oblique of the same side right contracts it is difficult to say.

While speaking about the movements of advancing or abducting the humerus, it was stated that these were attended by contraction of the erector spinae. This is a point to which attention has been directed by Dr. Hughlings Jackson.¹⁹

When a person stands erect so that there is no contraction of the erectores spinae, and then advances one upper limb, with or without a weight in the hand, to the horizontal line, both erectores spinae contract, and if the advanced arm be slowly carried outwards through an angle of about 45° the erector spinae on the same side as the advanced arm ceases to contract, and on the arm being carried through another 45° the rectus abdominis of the opposite side will be felt to take part in the movement.

The question arises whether this contraction of the erectores spinae is an essential part of the movement of advancing the shoulder in the same way as the right abdominal muscles take part in depressing or abducting the humerus—that is, whether it is possible to advance the humerus without bringing the back muscles into action. I think the matter can be proved in the following way: If, when the arm is advanced and the erectores spinae are felt contracting the spine be extended, the erectors will be felt to relax when the weight of the trunk behind the centre of gravity just balances the weight of the advanced arm in front; and if now the arm be dropped and then advanced again no fresh contraction of the erectores will be felt. I think that this shows that the contraction of the erectores is not an essential part of the movement of advancing the humerus, as it does not always occur, but is of the nature of a postural contraction, and only takes place to prevent the equilibrium of the trunk being disturbed.

This point, whether the erector spinae muscle of, say, the left side is an essential component of the movement of abducting the right arm is interesting in relation to hemiplegia. In right hemiplegia, where a patient has lost the power of abducting the right arm, the question arises as to whether he has any paralysis of the left erector spinae, which, as we have seen, acts when the right arm is abducted. If the action of the erector spinae were an essential component of this movement of the arm, one would expect that when the movement of the arm was paralysed all the components of this movement would also be paralysed, including the erector spinae; but if the action of the erector spinae were not an essential component, but only acted to preserve the equilibrium of the spine, then we should not expect it to be paralysed. I have not examined a sufficient number of cases to say whether the left erector spinae is paralysed or weakened in right hemiplegia. Dr. Hughlings Jackson²⁰ has, however, expressed the opinion that in some cases of hemiplegia the erector spinae on the side opposite to the paralysis is weaker than on the other side, that is, in right hemiplegia the left erector spinae is the weaker, and that the muscle is probably supplied by the direct (ventral) pyramidal tract.

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Paris, 1846. ⁹ Loc. cit., Section III, p. 290. ¹⁰ *Med. Chir. Trans.* ¹¹ Loc. cit., p. 30. ¹² *Anatomy for Artists.* ¹³ *Anatomy for Art Students*, by Professor Arthur Thomson, 2nd edition, 1899, pp. 37, 121. ¹⁴ *Topographische Anatomie*, Zweiter Band, 1895, p. 185. ¹⁵ *Curvature of the Spine*, 2nd edition, p. 41. ¹⁶ *Anatomie Artistique*, 1890. ¹⁷ Loc. cit., p. 171. ¹⁸ Loc. cit., Part VII, Book I, p. 339. ¹⁹ BRITISH MEDICAL JOURNAL, March 5th, 1892. ²⁰ BRITISH MEDICAL JOURNAL, March 5th, 1892.

THE RAPID ESTIMATION OF THE QUANTITY OF CHLOROFORM VAPOUR PRESENT IN MIXTURES OF CHLOROFORM VAPOUR AND AIR.

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A METHOD for the rapid estimation of CHCl_3 vapour in mixtures of CHCl_3 and air by means of the alteration of pressure produced by absorption of the CHCl_3 vapour by olive oil is described in the BRITISH MEDICAL JOURNAL of July 12th, 1902, and was demonstrated last July to the Physiological Society.¹

It was then stated that the method is applicable to mixtures of chloroform and air between 2 and 10 per 100, and the statement was confirmed by Professor Dunstan for amounts between 3 and 12 per 100.²

The original purpose of the present observations was to test the method for mixtures below 2 per 100. The actual determinations have been made in this laboratory by Dr. Victor Geets, of Brussels, who has, in prosecuting the inquiry, adopted a very simple method of control, which is in itself a very satisfactory laboratory method for the quantitative estimation of the percentage of chloroform vapour in a mixture of chloroform and air.

This method consists in the direct weighing on a chemical balance of a flask of known capacity (*circa* 500 c.cm.), (a) filled with air, (b) filled with the mixture of chloroform and air.

The adequacy of this datum as regards an estimation of percentage will be made clear by the following considerations: 500 c.cm. of a 1 to 10 per 100 mixture of chloroform and air implies 5 to 50 c.cm. of CHCl_3 vapour, weighing (on the assumption that 1 gram of liquid CHCl_3 = 200 c.cm. CHCl_3 vapour) 25 to 250 mg. *minus* the weight of the volume of air displaced by the CHCl_3 vapour.

The weight of a litre of CHCl_3 vapour at 0° C.

$$= \frac{12 + 1 + 106}{2} \times 0.0895 = 5.325 \text{ grams.}$$

Ditto, of a litre of air = 1.293 grams.

So that a litre of chloroform vapour is 4.032 grams heavier than a litre of air. Or each c.cm. of chloroform vapour replacing 1 c.cm. of air gives an increased weight of 4.032 mg.

Taking, then, 4 mg. as the additional weight due to the presence of each 1 c.cm. CHCl_3 in the mixture of air and chloroform (corrections for temperature and pressure not included), we have: In a 500 c.cm. flask each 1 per cent. (= 5 c.cm.) giving an increment of 0.020 gram.; and in a 250 c.cm. flask each 1 per cent. (= 2.5 c.cm.) giving an increment of 0.010 gram.

For practical purposes we can avoid calculation and estimate the percentage of CHCl_3 vapour by a direct reading of the difference of weight of a 250 c.cm. flask, (a) filled with air, (b) filled with the mixture of chloroform and air to be titrated. The excess of the latter, counted in centigrams, gives the percentage of the mixture:

Thus, an excess of 0.010 gram = 1.0 per 100

" " 0.050 " = 5.0 "

" " 0.027 " = 2.7 "

The weighing is easily made within the error of ± 1 mg., equivalent to an absolute error of $\pm \frac{1}{10}$ of 1 per cent., and to a relative error of ± 10 per cent. to ± 2 per cent. for absolute percentages between 1 and 5.

Both the manometric and the gravimetric methods are rapid and mutually control each other, giving estimates in reliable steps of at least 0.1 per cent. The manometric estimate is adapted to hospital use in the absence of a chemical balance; the gravimetric method is more rapid and more exact.

The chief practical advantages of a rapid method of estimating chloroform in air differ according as the chloroform question is viewed from the experimental or from the clinical standpoint. Experimentally it is important to possess a ready

means of frequently gauging the percentage of chloroform administered and exhaled. Clinically it is important to possess a ready means of familiarizing students with the smell of mixtures of known percentage. It is an easy matter for a laboratory expert to distinguish by smell whether there is more or less than 1 or 2 per 100 of chloroform vapour in a given atmosphere. Until it is possible to rapidly verify the percentage and to offer to inhalation by his students mixtures of known percentage, even the most experienced teacher of anaesthetics is not entitled to use clear arithmetical language, and to say that chloroform for the safe induction of anaesthesia in ordinary cases should be maintained between the limits of 1 and 2 per 100. But with a rapid method of estimation at hand, this all-important fact can be taught by smell, which after all is, and must remain, the most valuable indicator immediately at command of the practical anaesthetist.

The following table gives the comparative results of a preliminary series of parallel estimates by oil-absorption and by weighing:

Weight Readings and Calculations by Dr. Geets. Manometer Readings by Mr. Shapiro.

Percentage by Manometer.	Percentage by Weight.	Percentage by Manometer.	Percentage by Weight.
5.20	5.95	1.50	1.49
4.50	5.08	1.50	1.49
4.50	4.96	1.50	1.49
3.50	3.72	1.50	1.49
3.50	3.72	1.50	1.44
2.00	3.47	1.50	1.44
2.85	3.10	1.50	1.39
2.80	2.98	1.60	1.36
2.80	2.98	1.50	1.36
2.80	2.73	1.50	1.34
2.15	2.48	—	1.30
2.30	2.28	1.60	1.30
2.60	2.11	1.60	1.30
2.00	2.08	1.45	1.29
2.00	1.98	1.45	1.26
1.50	1.86	1.48	1.12
1.50	1.61	1.30	1.12
1.50	1.59	1.30	0.99
1.50	1.54	—	—

The individual discrepancies in the two series of this table are such as might be expected from experimental errors occurring in a first trial of two new methods by two independent observers. The error has been relatively more considerable at the lower percentages (below 2 per cent.) but is also considerable at the higher percentages. It is more probably attributable to imperfect graduation of the manometer than to incorrect weighing. To determine this point will, however, require further observations.

Corrections for temperature and pressure are of secondary importance in determinations of the present character. The temperature error for $+15^\circ$ is within $\frac{1}{2}\%$ of the nominal percentage, and can be practically eliminated by taking flasks = 260 c.cm capacity, that is, the usual 250 c.cm. flask + 10 c.cm. of its neck above the mark.

The usual corrections for T and H are, however, readily made, in accordance with the following formula, applicable to any flask capacity:

$$\log P = 1.8391 + \log m - \log v + \log T - \log H$$

P being the required percentage, m the observed increment of weight in mgs., v the flask capacity in c.cms., T the absolute temperature, H the barometric pressure, and 1.8391 a constant derived from the density of chloroform vapour at 0° (273° T) and 760 mm. Hg.

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THE PHYSIOLOGICAL ACTION OF ETHYL BROMIDE AND OF SOMNOFORM.

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THE object of the experiments described below was the investigation of a new anaesthetic sold commercially under the name of "somnoform." This is a mixture containing ethyl chloride 65 per cent., methyl chloride 30 per cent., ethyl bromide 5 per cent. It has been largely used in France for producing anaesthesia for minor operations, and the