recorded (at least by Apuleius) that anything happened to the dog (Fig. 3). Of this plant the Anglo-Saxons had of course no practical knowledge; they merely translated the account in the Latin manuscript. These features are clearly seen in some copies now exhibited of the drawings from the manuscripts.

This seems the opportunity to say something about the botanical knowledge of the Anglo-Saxons generally. It must not be supposed that they derived their knowledge of their native plants from Latin and Greek sources. A large number of medicinal herbs are named in the various prescriptions of the *Leechdoms* which are not included in the translated herbals. We have another source of knowledge in the "glossaries" which give the Anglo-Saxon equivalents for Latin and Greek names of plants.

Of these glossaries no less than six, written before the middle of the twelfth century, which may be taken as the extreme limit of Anglo-Saxon literature, have been preserved. They show the keen interest which our forefathers took in the knowledge of herbs. From these and other sources, Mr. Cockayne has compiled an exhaustive list of the Anglo-Saxon names of worts and trees, amounting in all to between 700 and 800. Omitting all mere transcriptions of Latin names, synonyms, and some names which do not strictly belong to the period now considered, about 500 remain, which are either pure English names or Latin and Greek words so altered as to have become vernacular. This is a very large number. The herbarium of Apuleius, with the additions from Dioscorides, gives only 185 names; and of these some were exotic plants which the Anglo-Saxons could not identify. Evidently, then, a large surplus remains which represents an original English nomenclature of native plants.

That the Anglo-Saxons had 500 botanical names would not necessarily show that they knew 500 species, for some may have been inaccurate or synonymous; but it is evidence of a much more extensive knowledge of botany than they have been generally credited with. Indeed, this science seems to have stood at a higher level in those days than in mediaeval times, when little was added except some French names, and much was forgotten. On the whole, we must agree with the hard saying of Professor Earle that "there was a great decadence of botanical knowledge in England between the eleventh and the sixteenth centuries."

In the next lecture some other books in the Anglo-Saxon medical library will be considered, and also the charms and magical rites which occur in many of them.

The Croonian Lectures

ON

MUSCULAR MOVEMENTS AND THEIR REPRESENTATION IN THE CENTRAL NERVOUS SYSTEM.

Delivered before the Royal College of Physicians of London.

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LECTURE III.

[ABSTRACT.]

MOVEMENTS OF THE HEAD.

I HAVE not much to add about the muscles which are usually given as flexors and extensors, adductors and rotators of the head, except with regard to the sterno-mastoids which are the chief flexors of the head, and they can be seen strongly acting when a person is told to raise his head from the pillow when lying on his back, and when this is done powerfully the recti abdominis also contract to fix the sternum, as was pointed out by Winslow.[1] These two sets of muscles are associated together in certain rhythmical spasmodic contractions, as in a case which was under my care lately, where a man had clonic spasm of both recti abdominis, and also in both sterno-mastoids. In addition to the sterno-mastoids the platysma myoides, the omo-hyoids, and the other depressors of the hyoid bone act. The only muscles which can be felt to contract on extension of the head are the clavicular part of the trapezii, the complexi, splenii capitis, and probably the trachelo-mastoids. The sterno-mastoids have been described as extensors of the head, when the head is in the extreme position of extension, but I made some observations on this point, and I failed to find that they acted in any position as extensors of the head.

THE RESPIRATORY MUSCLES.

In dyspnoea one of the first extraordinary muscles of respiration to come into action are the sterno-mastoids, and as these muscles then take their fixed point from the skull, the head has to be fixed by the extensors of the head. I have never seen any action of the pectoralis major in dyspnoea, and I think that the action which is attributed to this muscle is really performed by the pectoralis minor. The origin of the pectoralis major from the cartilages of the ribs and the direction of its fibres is also against its having much power as an inspiratory muscle, and it does not come into action till the end of a forced inspiration. Of the other extraordinary muscles, the latissimus dorsi, the serratus magnus, the scaleni, and the claviculo-occipital fibres of the trapezius are the chief that can be observed. The serratus magnus I have observed not to be acting in one case of severe dyspnoea.

With reference to the expiratory muscles, and especially those used in such violent efforts as coughing and sneezing, I would refer to the latissimus dorsi. I observed a few years back that it is a powerful expiratory muscle, and this is an action which any one can prove for himself by putting the hand on the posterior fold of the axilla, and on coughing a strong contraction of the latissimus dorsi will be felt. This muscle acts also as an inspiratory muscle, using the fibres which take origin from the lower ribs to elevate them, and therefore it is a muscle which acts in both inspiration and expiration, a circumstance which it is rather difficult to explain. In expiration it doubtless acts by compressing the posterior part of the abdomen, in which action it is joined by the external obliques and recti muscles, so that the abdominal cavity is compressed in all directions; and as the origin of the latissimus dorsi from the lower ribs interdigitates with the origin of the external oblique, and as this contracts violently in expiration, it seems probable that the costal origin of the latissimus dorsi in expiration acts to fix the ribs to allow the external oblique muscle to act with precision. The lower part of the trapezius also contracts in expiratory cough, but whether its action is for the purpose of fixing the scapula it is difficult to say. The action of all the respiratory muscles is bilateral, and the relation between the bilateral and the unilateral actions of the latissimus dorsi will be referred to later on, but the time at my disposal will not permit me to say anything about the movements of the lower limb or of the ocular or facial movements.

ACTION OF THE ANTAGONISTS.

It is necessary in any account of the action of muscles to consider the various views which have been held as to the action of antagonists. The antagonists of a movement are those muscles which move the joint in a direction which is diametrically opposed to the movement.

Winslow considered that to move a part all its muscles, including the antagonists, co-operate, but he makes the important proviso that the want of their action is supplied by the weight of the part or by external resistance. This limits very considerably the occasions when, according to Winslow, the antagonists act, for if they do not act when a movement is being performed against gravity, or when any resistance has to be overcome, the occasions are narrowed down to unopposed movements taking place in the horizontal plane, where gravity cannot act. Such a movement would be that of flexion or extension of the terminal phalanges of the fingers in the horizontal diraction, or of the elbow in the same plane, or of rotation of the head to the right or the left.

In his Croonian lecture before the Royal Society, John Hunter[2] describes the actions of muscles as immediate, producing immediate action of the part, the secondary producing the assistant supporting regulating actions, as in walking, when the right leg moves, the muscles of the left side of the trunk act to support the whole on the left leg.

Duchenne states that he has

> demonstrated experimentally that all the movements of the limbs and trunk result from a double nervous excitation by virtue of which the two orders of muscles......the impelling and the moderating associations are put simultaneously into action, one to produce the movements, the others to moderate them. Without......this *entente* of the antagonists the movements lose inevitably their precision and certainty.

I gather from this that Duchenne considers that in all voluntary movements the antagonists take part. On this subject interesting papers have been published by Beaunis[3] and by Demeny[4] The latter has made some most important observations by means of two Marey's myographs fixed on to the biceps and triceps by which tracings of these muscles under varying conditions were obtained. He concluded that if static resistance is made against an effort tending to produce flexion or extension, the antagonists of this movement relax. The antagonists are relaxed also during the movement every time that an external resistance acts in the way of their action whether this resistance be overcome or not by the muscles contending against it, and whether these muscles shorten or elongate. In natural movements (where there is no resistance), where they are of a slow and uniform rate, there is a simultaneous action of the antagonists; where the rate is variable, the antagonists act as moderators of the rate and come into play a little before the movement has ceased or changed its character. Demeny's observations are, therefore, in confirmation of Winslow's rather than those of Duchenne.

On the other hand, experiments have been made by Sherrington[5] on the action of the antagonists by electrical stimulation of the excitable cortex, and he has found that in addition to contraction of the principal muscles taking part in a movement there is not only relaxation but inhibition of the tone of the antagonists of this movement. Sherrington and Hering[6] have also more recently shown the same thing by electrical stimulation of the part of the cortex where movements of flexion of the elbow were represented. They found that when the biceps contracted there was relaxation of the triceps. It therefore seems probable that the inhibitory action of the antagonists starts in the same part of the cortex and takes the same course in the pyramidal tract as the excitatory action of the principal movers. Sherrington's observations therefore agree with those of Demeny so far as strong opposed movements are concerned. With regard to weak movements, Sherrington has informed me that even with minimal stimulation he still obtains relaxation of the antagonists, there is therefore apparently a difference between the results produced by stimulating the excitable cortex in the monkey and those of making a person perform a slow unopposed movement, as the antagonists were found to be relaxed on stimulation according to Sherrington, and to contract in the case of slow voluntary movement according to Demeny.

From my own observations I have held that, in strong movements against resistance, the antagonists are always relaxed, and I expressed that opinion in a paper which I wrote in 1891.[7] This power of relaxing a group of muscles by getting the patient to powerfully contract the antagonists against resistance I have for some time employed for clinical examination, and the cases in which it is most useful are affections about the shoulder-joint, where a patient is unable to abduct the arm without the inferior angle of the scapula moving outwards at once, a sign that either the deltoid is paralysed or that it is not acting owing to painful rheumatic changes in the joint, or that the joint is ankylosed. If the deltoid be contracted, it can be relaxed by first passively abducting the humerus as near the horizontal line as possible, and then directing the patient to actively adduct the humerus against resistance, when the deltoid will be relaxed; on then again directing the patient to try and keep the arm abducted the deltoid will be felt to contract if it is not paralysed.

With regard to the question as to whether the antagonists act in all unopposed movements as the experiments of Demeny would seem to show, I should like to point out that in the movement of rotation of the head we have an exceptional opportunity of examining the sterno-mastoid muscles, and, in addition, the movement of the head being in the horizontal plane, there is no chance of any error from the action of gravity. Here one of the muscles is a principal mover while its fellow of the opposite side is its antagonist, so that in rotating the head with the face turned to the patient's right, the left sterno-mastoid is a principal mover and the right sterno-mastoid is its antagonist. On rotating the head slowly or quickly I am unable to find either on inspection or on palpation that there is any contraction of the right sterno-mastoid; and, further, if the head be turned very quickly and be suddenly checked there is still no contraction of the right sterno-mastoid. It is quite possible that some of the other rotator muscles may act as a check to the movement, but I should say that the right sterno-mastoid certainly did not, and the muscle is so superficially situated that it would hardly be possible to escape observation.

To sum up: I should myself agree with Winslow that in all movements where there is extreme resistance, or where the weight of the limb has to be moved against gravity, the antagonists do not act. On the other hand, in the unopposed movements of rotating the head to the right where gravity does not act, I cannot find that there is any action of the right sterno-mastoid the antagonist to this movement, and also Sherrington found by cortical stimulation that the antagonists to the resisting movement were relaxed.

Before leaving the question of the antagonists, I should like to mention a clinical case where these muscles acted in a way which I have not seen before:

It was the case of a girl, aged 18, who had incomplete right hemiplegia and hemianaesthesia. She had, however, no signs of organic disease, and the case was considered to be one of functional or hysterical paralysis. The great point of interest about the case was that whenever she was asked to perform a certain movement the first action observed was that of the antagonist muscles. For instance, on being told to extend the elbow, the first muscle observed to contract was the supinator longus, one of the antagonists to the movement of extension. This contraction of the supinator longus was followed immediately by that of the triceps, and there was then a confusion with to-and-fro movements due to the alternate contraction of the extensors and flexors of the elbow. A similar thing occurred when she was told to flex the elbow, then the triceps was felt to contract first, and was followed by a movement of the flexors of the elbow, and then the joint moved to and fro with much confusion.

I have observed a similar condition occur in dorso-flexing the ankle, a joint in which the typical to-and-fro, hesitating, confused movement is so often seen in these cases of hysterical paralysis.

In another case on asking the patient to extend the knee, the first contraction was felt in the flexors of the knee. In all these cases as the patient improves this symptom passes off, and the joint is then moved in the normal way.

This condition of the antagonists acting before the principal movers begin I have never seen in any other conditions besides those of so-called hysterical or functional paralysis. I therefore venture to think that it is a diagnostic symptom of this condition.

PARALYSIS OF A MUSCLE FOR ONE MOVEMENT AND NOT FOR ANOTHER.

A muscle may take part in two different movements, as for instance the biceps brachii takes part with the supinator brevis in the group of muscles set apart for the movement of supination, and also takes part with the brachialis anticus, supinator longus, and pronator teres in that for the performance of the movement of flexion of the forearm. It is therefore possible that if one of these movements is lost by an organic lesion of the central nervous system and not the other, the biceps, which takes part in both movements, may be paralysed for the one movement and not for the other. I have seen cases of hemiplegia where the movement of supination was lost but not that of flexion of the elbow. Another movement which is often lost in hemiplegia when the arm is paralysed is that of elevation of the shoulder. Now, the muscles which take part in the elevation of the shoulder can also, taking their fixed point from the shoulder, draw down the head and neck to that side, such muscles are the trapezius (clavicular fibres), and levator anguli scapulae. I have observed cases of hemiplegia where these muscles were paralysed when they acted as elevators of the shoulder but not when they acted as lateral flexors of the neck. A condition which would probably signify that the movement of elevating the shoulder was represented in a different part of the excitable cortex to that of adducting the head to that shoulder. The same thing occurs with the ocular muscles where each internal rectus can act when it takes part in conjugate movements with the external rectus of the opposite eye, but when the two internal recti act together in converging the eyes they are paralysed.

Some of the above cases are instances of paralysis of a muscle for one form of unilateral action and not for another, but there is another class where a muscle may be paralysed for a unilateral movement of the arm, but not when it takes part in the bilateral action of respiration.

Dr. Hughlings Jackson was the first to call attention to the paralysis of the clavicular fibres of the trapezius in elevating the shoulder in hemiplegia, while it was still able to act as a bilateral muscle in deep inspiration. I have already described how the latissimus dorsi takes part in inspiration and expiration, and that it can be readily felt to contract on coughing. The muscles of both sides here act together, and, as far as I know, it is not possible for a person to inspire voluntarily or expire as in coughing, using only the muscles of one side of the chest. Besides this bilateral movement there is the unilateral action of the muscle as an arm muscle, where it takes part in the movement of adducting the humerus. As I pointed out in a paper read before the British Medical Association in 1898,[8] the latissimus dorsi of both sides takes part in the violent expiratory movement in the production of a cough or a sneeze. A cough can be produced reflexly or voluntarily, but a sneeze only reflexly, and we have, therefore, three conditions under which the latissimus dorsi may act, namely:

1. Acting with the muscle of the opposite side as an expiratory muscle.
   (1) Reflex coughing or sneezing.
   (2) Voluntary coughing.
2. Acting independently of the other side as an arm muscle.

The next question is what will be the action of this muscle in cases of hemiplegia. I have examined a great many cases of hemiplegia in which the arm was paralysed and in which there was complete loss of the movement of adducting the humerus to the chest wall and where consequently the action of the latissimus dorsi as an adductor was absent. Of the 12 cases which I described in my original paper, in 10 the lesion was presumably cerebral and probably in the internal capsule, while in 2 the lesion was ascertained and was in 1 case a tumour of the ascending frontal convolution and in the other a tumour of the centrum ovale. In all of these cases with the exception of two the following conditions were found:

1. In reflex coughing or sneezing the expiratory action of the latissimus dorsi was about equal on the two sides.
2. In voluntary coughing the action of the latissimus dorsi was obtained on both sides, but it was frequently diminished in action or occurred later on the paralysed than on the normal side.
3. On attempted voluntary adduction of the humerus there was no action of the latissimus on the paralysed side.

In two of the cases of hemiplegia where there was an exception to the general rule given above it was found that no movement was obtained on the paralysed side in voluntary coughing, but in reflex coughing or sneezing the latissimus dorsi on the paralysed side was seen to contract. A lesion, therefore, of the, let us say, left motor cortex or of the internal capsule will paralyse the right latissimus dorsi as a unilateral arm muscle, but will not paralyse it when it acts as a bilateral muscle of respiration reflexly, and in most cases when it so acts voluntarily.

This bilateral action of the latissimus is of value in diagnosing cerebral lesions from those of the spinal cord and peripheral nerves in those cases in which the arm and leg of one side are involved without the face. In the case of a lesion, as a tumour, pressing on one side of the spinal cord between the respiratory centre and the brachial enlargement, all the movements of the latissimus dorsi, including unilateral arm movement, bilateral voluntary coughing, and reflex coughing would be lost, while in lesions above the level of the respiratory centre the reflex bilateral movement of coughing would be preserved.

Another example, but of a different kind, of paralysis of a muscle for one movement and not for another I have observed in the case of the upper or clavicular fibres of the pectoralis major. This muscle I have already referred to as one which has two actions: it acts with its lower or sternal fibres in adducting the humerus to the middle line, and it also acts with the deltoid in advancing the humerus. In certain cases where the deltoid is paralysed, although the clavicular fibres of the pectoralis major can be felt to act well in conjunction with its sternal fibres in adducting the humerus, they make no attempt to advance the humerus, or when it is passively advanced to contract and keep it in that position. The first case which I published[9] was one of paralysis after an accident, and was due to lesion of the brachial plexus or of the cells of the anterior horns of the spinal cord. I have seen several other cases occurring in lesions of the cord or brachial plexus.

This class of case differs from the preceding in that we have here paralysis of a muscle for one movement and not for another, arising not from a cerebral lesion, but from a lesion of the cord or of the brachial plexus. This selective paralysis from a lesion of the cells of the anterior horns is in favour of the theory that these cells are arranged in a physiological rather than an anatomical manner, but as there are reasons against this theory is it possible that there is any other explanation? Is it possible that the upper fibres of the pectoralis major which act with its lower half are not the same as those which failed to act with the paralysed deltoid? I do not think so, because there were no signs of degeneration to electrical testing in the pectoralis major, and it is not probable that the same fibre should have a double nerve supply from different parts of the brachial enlargement. Another explanation might be that when the upper fibres of the pectoralis major act with the deltoid in advancing the arm, they can only do so after the deltoid has acted first, and that, as the deltoid does not act at all, the pectoral will not start the action; but against this explanation is the observation that normally the weight of the arm is sufficient to bring out the action of the upper fibres of the pectoralis major and that strong resistance is not required, as in the case of the relation of the extensors of the wrist to that of the extensors of the fingers, in the movement of extending the wrist. At the present time I am not able to give a definite explanation of this selective paralysis of the upper fibres of the pectoralis major.

Action of a Muscle in Diametrically Opposite Movements.

Another question which has arisen in the examination of the actions of muscles is whether a muscle ever takes a principal or direct action in a movement which is diametrically opposed to its usual action.

In considering this point it is obvious that the query could not be made in the case of a hinge joint, such as the elbow, as the triceps could not possibly take a direct part in the action of flexion of the elbow. It is, however, in joints like the radio-ulnar (rotatory) articulations, or in ball and socket joints, that it would be possible for a muscle to take part in two opposite movements. If a list be made of the muscles which are considered by anatomists to have this double action, it would be found to contain the following muscles: The supinator longus, the pectoralis major (clavicular fibres), the deltoid (posterior fibres), and both sterno-mastoids acting together. As I have pointed out, the supinator longus has been considered by many anatomists to be both a pronator and a supinator. With this opinion I find that I cannot agree, as from the examination of the muscle on the living subject I consider that it certainly does not take part in extension, and I cannot find that it contracts in supination, its action besides flexion of the elbow-joint being, perhaps, very slight pronation at the end of a strong movement. The clavicular fibres of the pectoralis major were considered by Duchenne to be both elevators and depressors of the humerus, when the arm was above the horizontal line. From my observations these fibres do not act in depressing the humerus, a movement which is performed by the inferior or sternal fibres of the pectoralis major.

The posterior fibres of the deltoid were considered by Duchenne to be elevators of the hanging humerus as far as an angle of 45° to the vertical, beyond which they became depressors and antagonists to the rest of the deltoid; in other words, after an angle of 45° the posterior third of the deltoid suddenly changes its mind, so to say, and takes part in a movement which is diametrically opposed to the action of its previous movement. From my observations I consider that the posterior third of the deltoid only takes part in adduction and never in abduction, an opinion which I was glad to find was expressed by Richer.[10] The last movement which I have cited is that of the two sterno-mastoids acting together. Their ordinary action is to flex the head forwards as in lifting the head from a pillow, but most anatomists describe that when the head is put back far enough these muscles act as extensors of the head. I have already expressed the opinion that I do not think that this action occurs. In cases of progressive muscular atrophy affecting the extensor muscles of the head at the back of the neck, but not the sterno-mastoids, the head falls forwards till the chin rests on the chest, due to the inability of the extensors to hold up the head against gravity; but if the patient leans far back in a chair, so that the head can be allowed to extend backwards as far as it will go, there will still be a slight contraction of the flexors—namely, the sterno-mastoids—to counteract gravity. Now if while in that position the patient be told to extend the head further against resistance, he cannot do so, owing to the paralysis of the extensors at the back of the neck, but the sterno-mastoids, so far from contracting, actually relax.

There may be other muscles which might act in two opposite ways, but of those which I have cited I cannot find that any one of them takes a principal part in a movement which is diametrically opposite to its usual action.

There is, however, one muscle which certainly takes part in two opposite movements—namely the latissimus dorsi, which contracts in both inspiration and expiration, though the action is stronger in expiration than in inspiration. I have already referred to this point, and I would only say now that I think the part of the muscle arising from the three lower ribs must have a different action to the main part arising from the spine and the iliac crest. In inspiration this costal origin acts by elevating the ribs; on the other hand, in expiration these costal fibres fix the ribs and enable the external oblique muscles, whose origin interdigitates with that of the latissimus dorsi, to vigorously contract, while the main part of the latissimus acts within the external oblique as a principal mover in compressing the abdominal cavity. I should therefore look upon the costal fibres as prime movers in inspiration and as synergic muscles in expiration. I think, therefore, that one is justified in making the statement that a muscle does not take a principal part in a movement which is diametrically opposed to its usual action, or, in other words, in two movements which are opposite in direction.

I make this qualification with regard to muscles taking a principal part in a movement, as in my paper in *Brain*[11] I did not make this qualification; but I had not then noted the various muscles which act as synergic muscles in a movement. For instance, in both supination and pronation of the forearm the triceps acts to counteract the flexor action of the biceps and of the pronator teres; but as the triceps is not a principal mover in either of these movements its action would not be against the statement I have made.

Association of Muscles.

I believe that in the case of a single muscle which is stimulated through its nerve, physiologists hold that all the fibres of the muscle contract, and that the minimum amount of work is produced not by using only some of the muscle fibres, but by using all the fibres to a slight degree of contraction, while when the maximum work is required the same fibres contract strongly. According to Gotch this must be modified.[12] The question arises whether the same principle can be applied to groups of muscles, and we have to determine, in producing the minimal force, whether all the muscles taking part in the movement contract, or only certain muscles in the group. Or, to take a simile from marine engineering, whether, when a ship is travelling at half speed, all the boilers are working at half their full prespressure, or only half the boilers are working.

It is not very easy to find a group of muscles the individual members of which can be examined, and the order in which they take part in a movement noted. I think that the movement of supination, which is effected by the supinator brevis and the biceps, is one in which it is possible to ascertain how soon the biceps takes part in the movement. For this purpose, if the elbow be rested on a table and the forearm be kept in a vertical position midway between flexion and extension and at right angles to the upper arm, it will be found that the forearm can be supinated, if there be no resistance, without any contraction of the biceps, a point which can be ascertained by hooking the forefinger round the tendon of the biceps at the elbow. If, now, resistance be made to the supinating forearm, the biceps will be felt to contract after the resistance has reached a certain amount. I have measured this amount, and find that it comes to 1 lb. It therefore appears that the supinator brevis will do the work of supination when only the inertia of the bones has to be overcome, but as soon as work over 1 lb. is required to be done, the biceps is called in to help. The relation of the extensores digitorum to the extensores carpi in extending the wrists is another illustration.

These two examples, I think, show that there is a definite order in which the muscles for the performance of a movement come into action. All the muscles which are grouped together for the performance of a movement do not come into action when only slight effects are required, but a certain increase of work has to be encountered before they all act.

In connexion with this it is interesting to note that Sherrington[13] has found a similar condition in reflex actions, as on stimulating electrically the posterior root of the fifth cervical nerve with a Kronecke secondary coil at 15, good contraction of the supinator group was obtained in the monkey; but to evoke contemporaneous action of the biceps with the supinator a much stronger current of 90 was required.

Besides the muscles directly concerned with the movement other muscles are put into action. In performing the different movements of flexing the fingers, of flexing the fingers and thumb as in grasping, and of flexing or extending the wrist we put into action only the muscles which are directly concerned with these movements, if the force exerted is slight or moderate; but if these movements are performed more powerfully other muscles are seen to join in the movement. These other muscles which are brought into the movement are the flexors and extensors of the elbow. I have therefore made some observations to ascertain which of the movements of the wrist and digits are accompanied by contraction of the flexors of the elbow, which by the extensors of the elbow, and which by both these sets of muscles. I have also measured the amount of force required to be exerted before these muscles acting on the elbow join in the movement, and also to test the influence of position the observations have been made when the forearm was in the position of pronation and when in that of supination.

Sequence of Movements in Upper Arm to Movements of Hand in Positions of Supination and of Pronation.

Movement Performed.	Position of Forearm.	Amount of Work required to be done before Triceps Contracts	Amount of Work required to be done before Biceps Contracts.
Fingers flex ... ... Traction at right angles to line of forearm ...	Supinated	No contraction	18 lb.
" "	Pronated	$1\frac{1}{2}$ lb.	No contraction to 18 lb.
Fingers extend	Supinated	4 lb.	No contraction
Fingers extend	Pronated	No contraction	No contraction
Thumb extend	—	No contraction	—
Thumb and fingers flex (grasping)	Supinated	24 lb.	33 lb.
Thumb and fingers flex (grasping)	Pronated	13 lb.	30 lb.
Wrist flex	Supinated	No contraction to 32 lb.	22 lb.
Wrist flex	Pronated	2 lb.	No contraction
Wrist extend	Supinated	4 lb.	No contraction to 24 lb.
Wrist extend	Pronated	No contraction	22 lb.

In these observations the forearm was laid flat on a table in the position of pronation or supination, the elbow was placed at a right angle and relaxed, and the amount of work done was either registered by a dynamometer, which was grasped in the hand, or traction was made on the joints under observation, by a band passed over the phalanges or the metacarpal bones, and connected with a spring balance which registered the amount of work which the movement had to resist before the biceps or triceps contracted. The contraction of the biceps was ascertained by the finger hooked round its tendon near its insertion, and the contraction of the triceps was easily felt by the finger and thumb placed on either side of it just above the elbow.

In some cases a very slight amount of resistance brought out the cooperation of the triceps. For instance, in the position of pronation the triceps is called into action when the resistance to the flexion of the fingers or wrist was only $1\frac{1}{2}$ lb. to 2 lb., and in the position of supination the triceps contracts when the resistance to the extension of the fingers and wrist was only 4 lb.

First, taking the forearm in the position of supination, it will be seen on looking at the table that in flexion of the fingers, whereas the biceps contracts when the resistance to the movement of flexion amounts to about 18 lb. (8 kilos), the triceps does not contract at all. Also in extension of the fingers the triceps contracts when so little resistance as 4 lb. ($1\frac{3}{4}$ kilos) is experienced, and no contraction of the biceps occurs even with a pressure which can overcome the extension of the fingers. These observations show that in the supinated position of the forearm flexion of the fingers, when opposed, is followed by contraction of the biceps, and extension of the fingers, when opposed, is accompanied by contraction of the triceps. Secondly, that in grasping with the fingers and thumb, which, as we have seen in a previous lecture, is performed by the flexors of the thumb and fingers and the extensors of the wrist, the contraction of the biceps and triceps both occur, but that of the triceps first. Thirdly, in extension of the thumb only, a movement which would probably not affect the elbow-joint, I could not discover any contraction of the biceps or triceps. In other words, the muscles producing flexion or extension of the elbow are brought into a movement which is in the direction of flexion or extension respectively, either to reinforce it or to counteract the tendency of the resistance to move the elbow in the opposite direction. While in a movement like grasping, which is not in the direction of flexion or extension, both sets of muscles (triceps and biceps) contract and the elbow is kept fixed. That this sequence is very much due to position is shown by the opposite results which were obtained according as the forearm was pronated or supinated. For instance, in flexion of the fingers or of the wrist in the supinated position the biceps contracted at 18 lb. and 22 lb. respectively, but not at all in the pronated position. This is probably because when the fingers or wrist are flexed against resistance with the forearm supinated, the opposition to movement of flexion of the fingers or wrist is in the direction of extension of the elbow, and the biceps contracts so as to prevent the elbow being extended when the pressure on the wrist or fingers reaches a certain amount. But when the forearm is in the pronated position the conditions are reversed, the direction of the opposition to the flexion of the wrist is now in the direction of flexion of the elbow, and to prevent the elbow being flexed it is now the triceps which contracts and not the biceps.

To elucidate still further the question of position I have made experiments on the movement of grasping with the fingers and thumb, (*a*) with the forearm resting free on a flat surface, (*b*) with the forearm fixed immovably. It will be seen on looking at the table that in the movement of grasping the contraction of the triceps occurs sooner than that of the biceps. As there was evidently some disturbance of the position of the elbow which necessitated contraction of the triceps before that of the biceps, the forearm was fixed to prevent any movement of the elbow. It was found that in the position of supination, whereas with the forearm resting freely, the triceps contracted when the grasp registered 24 lb.; with the forearm fixed, it did not contract till the grasp was almost doubled, that is, 45 lb. In the position of pronation with the forearm free the triceps contracted when the grasp was 13 lb., and with the forearm fixed at 29 lb. The same conditions were obtained when the forearm was in the mid-position between supination and pronation. The contraction of the biceps was not influenced by the position of the forearm being free or fixed. These observations showed that the contraction of the triceps must be to counteract some action of flexion of the elbow by the muscles taking part in grasping, and on carefully watching the movement of grasping when the forearm rested free on a flat surface, a certain degree of flexion of the elbow was seen. I have measured the force of this flexion of the elbow by a band round the lower end of the forearm, which was attached to a fixed point with a spring balance interposed, and I find that the force exerted by the flexion of the elbow in grasping amounts to 1 lb. I have also ascertained that it makes no difference whether the grasp is 24 lb. or the maximum 54 lb., as the amount of force produced by this slight flexion of the elbow is in both cases 1 lb. This would mean that in the supinated position whatever the strength of the grasp, the triceps so adapts itself that it will not permit flexion of the elbow of more strength than 1 lb.

Another question which arises is, Why in the supinated position does the triceps not co-operate till the grasp has reached 24 lb., whereas in the pronated position it takes part in the movement when the grasp has reached 13 lb., and in the mid-position at 20 lb. between the two other figures? It means probably that in the position of pronation the forearm muscles produce flexion of the elbow sooner than in the position of supination, and, therefore, that the triceps must intervene sooner to prevent flexion of the elbow. If this be true it is in harmony with what was stated in a previous lecture—that patients who have lost their proper flexors of the elbow manage to flex this joint by first putting the forearm into the position of pronation and using their forearm muscles.

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THE ETIOLOGY OF NEW GROWTHS.

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ALTHOUGH it is not unusual to speak of the cell growth of benign tumours as typical and that of malignant tumours as atypical, such terms are applied to cell relationships and not to cell types. That new growths are composed of aberrant cells, often markedly different morphologically from those of the organ of origin, is long recognized; from the physiological side, also, it has been shown that the vegetative properties of such cells are developed at the expense of the specialized functions of those of the organ of origin. So far is this alteration in type recognized that many pathologists have assumed a reversion to an "embryonic" state as an essential in all tumour growth. The use of the term embryonic has been with reason condemned by Adami; if the term is used in any strict sense it is inaccurate; the cells of many new growths have no demonstrable morphological resemblances to embryonic types, and physiologically their one resemblance is the preponderance of the vegetative properties.

It appears to be correct to state that all tumour growth is error, typically speaking; it is the purpose of this paper to examine this type variation and its significance.

CELL ACTIVITY.

All cellular activity is the resultant of bio-chemical action and reaction, and, did our knowledge admit, all cell phenomena would be definable in terms of this action and reaction from a comparatively simple phenomenon, such as that of secretion, to the infinitely elaborate processes which result in the evolution of the body and its parts from a simple cell. During this evolution, cell types are continuously built up of wide morphological differences and performing ultimately widely different functions.

Such characteristic cell types maintain themselves in virtue of an inherent selective activity on the assimilable material available to them, enabling them to build up characteristic chemical compounds.

Cell potentiality may be stated conversely—all cells react to bio-chemical stimulation, and the result depends on two factors, the nature of the stimulus and the inherent capabilities of the cell to form chemical combinations in response. By the term stimulus is to be understood any incidental condition which calls forth chemical change of whatever character in the cell. The secretory cell of a salivary gland depends for the performance of its characteristic functions on the availability of suitable assimilable material, and also, at any rate as regards its degree of activity, on impulses transmitted through the nervous system—an example of the transformation of energy.

The discoveries of Professor Ehrlich in his investigation of immunity have thrown much valuable light on the question of cell activity generally. It is perhaps too early to generalize on this matter, but it may be provisionally stated that the selective power of a specific cell type in presence of the available food material, depends on its possession of "receptor" groups corresponding to "haptophore" groups in the assimilable material, and the production as a chemical reaction of molecular combinations which may be used up in cell maintenance, or under other circumstances, and in the case of other cell types, in the formation of a secretion of approximately constant character. A consequence of the reaction of receptor and haptophore groups is the reproduction of receptors, and this saturation and reproduction would appear to exercise an influence of first importance on the variations of cell activity and their cyclical regulation.

CELL PROLIFERATION.

The response of cells to "stimulation" is frequently expressed as reproduction. A great variety of forms of stimulation, using the term in the sense already defined are capable of initiating this reproduction; alteration of chemical conditions such as those evoked by heat and moisture are well recognized methods of encouraging multiplication among the simpler form of animal and vegetable life, and among these forms the influence of a variety of organic and inorganic salts on this multiplication has been the subject of researches.

The same class of conditions also governs multiplication of the tissue cells of the human body—examples of such conditions are to be found in (1) increase of available food material of normal type, (2) the alteration of physico-chemical conditions which is brought about by mechanical irritation, and (3) the activity of certain microparasites and their products. Almost all cells of the body are capable of multiplying in response to such stimuli, the probable exceptions are the more highly specialized cells of the nervous system, and possibly others similarly specialized; others in varying degree appear to retain a vegetative function.

This vegetative function is part of the normal life-cycle of the parenchyma of the ovary and testis; in other tissues it is, for the most part, potential; in this function, as in all cell activity, the nucleus appears to exercise a controlling influence, and its changes are readily demonstrable histologically.

First, a word on the most simple of the three conditions named above—proliferation as the result of increased, or