the outbreak of the revolution. At the railway station our guard was deprived of his shoulder straps showing the number of his regiment, and his cap badges were also removed. Trains flying the red flag, crowded with troops without arms and badgeless, passed through the station. The red flag was flying over an aeroplane factory at Gotha, over the station and over various barracks. Aeroplanes flying low dropped leaflets over all towns and villages requesting the troops to join in the movement.

As a result of this change we were informed on arrival at our destination by a private soldier wearing a red armlet that he was now head of the hospital, and that all requests must be addressed to him. A new *Chef-arzt* of socialistic opinions was introduced to the hospital, but as he was closely supervised by the *Soldatenrat*, or soldiers' council, he was more or less powerless, and we had few dealings with him beyond drawing his attention to various matters in connexion with the sanitation of the hospital.

We left this hospital on Christmas Day by hospital train, taking all the British with us. Lying cases were conveyed to the station in pantechnicons, the floors of which were covered with mattresses. The hospital train provided by the Germans was good of its kind, and had enough bunks, with clean bed-linen, for the majority of the patients. A day and a half later we ran alongside the naval hospital ship *Garth Castle* at Stettin, where we were warmly welcomed, and on her we travelled in all comfort.

We returned from Germany with a higher opinion of British organization than ever before.

THE ADJUSTMENT OF RESPONSE TO NERVE STIMULUS IN VOLUNTARY MUSCLES.

BY

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THIS paper is founded on the result of tests made upon many hundreds of men wounded in the present war, in the electricity departments of two of the largest military orthopaedic hospitals. The patients pass through these departments to be tested and treated for every grade of nerve injury, ranging from slight shock or compression to complete division. Nerves are sutured in the operating theatres, and their subsequent regeneration and the reaction of the muscles they supply observed through all the stages of recovery, while oncoming compression from formation of fibrous tissue in healing wounds may be observed with all its resulting effects upon the response of the muscles to various forms of stimulus.

The observations here recorded were made by means of an apparatus the essentials of which are a transmitting rod resting upon the skin over the muscle observed and attached to a tambour connected with a pen tracing its movements upon a revolving drum. This apparatus records the character of each muscle contraction with accuracy and reliability.

The electrical stimulus used was the closure of the circuit of a galvanic current by a metronome interrupter with mercury make and break. This gives a stimulus of indefinite duration.

Unless otherwise stated, both electrodes were placed over the muscle. When the term "normal" occurs in describing the contraction of a muscle, it is used to denote equality with the opposite and uninjured side. The metronome has in all cases been timed to interrupt sixty times a minute, so that the resulting contraction can, when desired, be expressed in fractions of a second.

It has not been considered necessary to record the temperature of the room or other details which might alter the character of the response in a small degree, because the value of the tests depends upon the comparisons between the muscles of the two sides, and the conditions have been identical for these in all cases. The tracings are reproduced from the original records made by the pen on the paper of the revolving drum.

The Contraction of Normal Muscle.

The first tracing (Fig. 1) shows the contraction of a normal muscle (biceps brachialis). The upstroke and

downstroke show that the contraction and decontraction of the muscle occupy practically the same length of time.

FIG. 1.

Never in this long series of tests has a muscle supplied by a normal nerve been found to show any visible difference in character from the same muscle on the opposite side, even though it may be so much wasted (as in a limb splinted for long periods for compound fractures) that a galvanic response is only obtained with great difficulty.

FIG. 2.

Fig. 2 shows the succession of contractions in a normal muscle produced by stimuli the strength of which has been gradually increased, and the tracings show that the smallest contraction produced by the weakest stimulus is exactly equal in length to the greatest contraction produced by the strongest stimulus. In other words, it shows that within certain limits the duration of contraction in a muscle is the same whatever its strength.

On one side of this limit are contractions excited by a stimulus so small that the resulting movement is partly lost by the yielding of the surrounding tissues, and on the other, contractions so violent that the surrounding tissues take appreciable time in returning to their resting position.

The wide range in the records shown in this figure are enough to demonstrate that slight variations in the height of the contraction when comparing two sides are quite immaterial. Another fact observed is that, except in cases of disease of the muscle, which do not come within the scope of this paper, successive contractions recorded from any muscle, whether the nerve be injured or not, are always the same length at any given observation.

FIG. 3.—Polar reversal (extensor carpi radialis longior).

Fig. 3 shows tracings taken when one electrode was placed over the normal muscle and the other at a distance. By means of a reversing key the poles were reversed before each stimulus, so that the contractions were excited alternately by the short sharp stimulus produced at the negative pole, and the diffuse stimulus of a virtual negative deep in the tissues. It will be seen that the length of the resulting contraction is the same in each case.

Abnormal Contraction of Muscle.

Palmaris longus (affected side).

Palmaris longus (normal side).

Flexor carpi radialis (affected side).

Flexor carpi radialis (normal side).

FIG. 4.

Figure 4 shows tracings taken from the palmaris longus and flexor carpi radialis of a patient whose median nerve had been involved in scar tissue. An exploratory operation had been performed, and the nerve was inspected and found to be as stated.

In this case, although the fibres of the nerve were compressed by the scar, they were not destroyed, because they were found to transmit a stimulus to the muscles they supplied when excited immediately below the constriction by the faradic current.

On comparing the contractions of palmaris longus on the affected side with the normal side, it is seen that

though the contraction producing the upstroke of the graphic record is equally brisk in each case, the downstroke produced by the decontraction of the muscle is slightly longer on the affected side, showing that the contraction has lasted for a longer period in the muscle with the impaired nerve supply than in the muscle with the normal nerve supply. On testing the muscle by means of the interrupted faradic current it was found to give somewhat weakened response, showing that its nerve fibres were still functioning. In short, it was a case of slight interruption to the motor nerve, and it showed a slight lengthening of contraction in the muscle.

On the other hand, the flexor carpi radialis gave no response to the faradic stimulus, showing that its fibres were further implicated than those of palmaris longus. Accompanying this sign we see that the curve of contraction is very much more lengthened than that of palmaris longus.

FIG. 5.

Fig. 5 shows tracings of the contractions of the extensor carpi radialis longior after complete division of the musculospiral nerve. The contractions are lengthened to about the same degree as those of flexor carpi radialis in the preceding figure.

FIG. 6.

Fig. 6 exhibits the contraction of the tibialis anticus and tensor fasciae femoris of an officer who had slightly displaced his right sacro-iliac joint. After this he suffered from weakness in the muscles supplied by the fourth and fifth lumbar nerves, of which the above two were selected for the test. The response of the muscles to faradic stimulus was apparently normal, but the tracings show that on the affected side both these muscles gave lengthened contraction. The fourth and fifth lumbar nerves cross the sacro-iliac joint, and their slight involvement in the inflammation of the joint had resulted in a slight inhibition of their function. The tracings of tensor fasciae femoris are reversed owing to its action in retracting the surface of the thigh.

FIG. 7.

Fig. 7 records the contraction of the flexor carpi radialis in another case of nerve compression. There was a weak response to faradic stimulus, showing incomplete interruption of the median nerve, and the curve shows that the contractions, though lengthened, are not of such length as is reached in complete reaction of degeneration. A few days after this record was taken, as the ulnar nerve gave signs of complete interruption, an operation was performed for its suture, and the median nerve was found to be slightly involved in scar tissue.

Observation shows that in a case of oncoming compression the first sign to be observed in the muscle supplied by that nerve is a slight lengthening of the response, which increases as the nerve becomes more involved, until a point is reached when the lengthening proceeds no further. This stage occurs while a faradic response is still obtainable. The contractions then last commonly a third of a second. In a case of complete nerve division the response quickly becomes this length and remains so until nerve regeneration has taken place. When the new

axis cylinder has grown down to the muscle after nerve suture, the response to faradic stimulus of the nerve is again established, but it is not until some time after this (several weeks) that the length of contraction in the muscles starts to shorten. The shortening then gradually takes place until (usually after a space of several months) the myograph shows the response to be reduced to normal length.

Having now shown that in cases of motor nerve interruption, partial or complete, the contractions of the muscle supplied by it are lengthened, and having stated that of the many hundreds of cases examined no single case has occurred in which this sign has been absent, I will deal next with cases in which contraction of the muscle has been observed to be shorter than the normal.

FIG. 8.

Fig. 8 is a myogram from a case typical of those described by Babinski and Froment and shown by them to be of reflex origin. The patient was an officer who had sustained a simple fracture of his radius. The limb was splinted and the bone united in good position. When union had taken place a condition of tetanic contracture arose in the flexor carpi radialis, none of the other muscles of the forearm being affected. The condition persisted for ten months without relaxation, causing the fullest possible flexion of the wrist.

In order to distinguish the case from one of hysterical contracture, I had the patient deeply anaesthetized, and it was seen that there was not the slightest relaxation of the affected muscle. The case was, in fact, typical of an irritative lesion of afferent nerve fibres, causing a reflex contracture of flexor carpi radialis through the median nerve. It will be seen that the curve of contraction made by the affected muscle is shorter than on the normal side.

FIG. 9.

Fig. 9 is a tracing of another reflex contracture, involving the semitendinosus. The contracture came on shortly after a wound of the hamstrings, and had persisted for two months when the myogram was made. This patient also was deeply anaesthetized, and no relaxation of the affected muscle took place. The shortening of the response in the affected muscle in this case is much more pronounced than usual. Observations made upon several of these reflex contractures have produced a like result in each case.

FIG. 10.

Fig. 10 is a tracing made from the contractions of tibialis anticus in a patient who had suffered from cerebral haemorrhage four years previously. This upper neurone affection had produced hemiplegia, from which he was still suffering at the time of observation, but only to a slight degree. His movements were weak on the affected side, and his reflexes much exaggerated in the leg observed. Here it is seen again that the contractions of the muscle recorded from the affected side are shorter than on the normal side. This result is typical of other cases observed.

In all these cases of an abnormal shortening of muscle

contraction, the difference from the normal is not nearly so great as in the cases of lengthened contraction, but it is perfectly clear.

FIG. 11.

Fig. 11 records the contraction of the tibialis posticus in a case of hysterical contracture which had persisted for over twelve months. The muscle was tensely contracted, leading to equino-varus position of the foot, and the condition had begun after injury to the thigh. Unlike true reflex contractures, this condition was cured after a short course of psycho-therapy. It will be seen that the contractions of the affected muscle are of exactly the same length as on the normal side, and it was this observation that led to the adoption of psycho-therapy as the suitable treatment.

Conclusions.

In the foregoing records I have shown that after injury to a motor nerve the muscles supplied by the injured fibres respond to stimulus with a contraction longer in duration than that of normal muscle, and that this has been observed in every one of the many hundred cases tested. It appears to me that this lengthening of the contraction is due to hyper-excitability in the muscle following a definite sequence of events, though there is an alternative conclusion which I am at present investigating.

It is a matter of common knowledge that when for some pathological reason the stimulus from the upper motor neurone weakens or ceases, the anterior horn cells of the lower neurone become hyperexcitable, and the muscle tone is increased.

In health there must always be a delicate adjustment between the irritability of the upper and lower neurones, so that the lower respond in a proper degree to the stimuli passed down from above. For this reason it is a natural sequence for the lower neurone to become hyperexcitable when for any reason the upper stimuli become less intense, and we know that in upper neurone impairment this hyper-excitability is increased to a pathological degree, as shown in the exaggerated reflexes of such cases as cerebral tumour, certain injuries of the cord, etc.

There must also be an adjustment of irritability between the lower neurone and the muscle. As an instance of lower neurone interruption the most typical case to cite is one of complete division of a nerve.

In Fig. 5 the record of the contraction of extensor carpi radialis longior after division of the musculo-spiral nerve shows a great lengthening of the period of decontraction, and that is exactly what one would expect if the excitability of a muscle were increased. That it is not a slowness of contraction is made evident by the angle of the upward line showing the contraction of the muscle. It is true that frequently this upstroke is more slanted than normal in tracings of muscles whose nerve supply has been retarded, but this difference is always very slight compared with the difference in the length of the line showing the decontraction, and I ascribe it to slight tissue changes owing to disuse. At any rate, in many cases, as in that shown in Fig. 5, there is no slowing of contraction displayed while the period of decontraction is much prolonged. I think this lengthening of the period of response of parietic muscle is not to be associated with the chronaxie (rapidity of excitability) of a muscle, because it has been abundantly proved by Lapique and others that the chronaxie of these muscles is increased to as much as thirty or forty times the normal, whereas I have shown that the response to the stimulus lasts at most three or four times as long as the normal. In fact, the chronaxie would appear to bear no further relation to the contraction of the muscle than the flash point of an explosive to the explosion.

In the examples exhibited above, it has been shown that when the nerve impulse is slightly retarded, the muscle responds with a slightly lengthened response; that when the nerve impulse is further retarded, the muscle responds with a further lengthening of the response; that when the nerve retardation reaches a certain point, the muscle reaches a limit of response beyond which it cannot go, and this response is the same in cases of severe nerve compression or of complete division of the nerve. We have

seen also that after suture of the nerve, and its subsequent regeneration, response to faradac stimulus first appears in the muscle, proving the dawn of the new nerve supply. Then after a period the muscle begins to respond first with a slight shortening of the contraction, and then, following the gradual establishment of nerve influence, with a gradual further shortening until, following the complete regeneration of the nerve, the muscle response is restored once more to its normal length.

It is not intended here to dwell upon the great value as an aid to the more exact diagnosis of delicate nerve lesions which is to be found in the phenomena above described, but rather to look upon the subject from a purely scientific standpoint.

Having stated that probably the excitability of the muscle is increased as a result of decreased stimulus from the nerve, and that this is in the nature of an attempt at adjustment on the part of the muscle, it now remains to be shown in support of the latter statement that when the excitability of a lower motor neurone is increased that of the muscle is reduced. For this purpose I have selected the three cases given above—one of upper neurone affection, with the exaggerated reflexes common to these cases, and the others of contracture of the muscle due to reflex irritation, and in each of these cases the duration of response in the affected muscles has been shown to be shortened. These instances present a picture of protective hypo-excitability in muscles supplied by hyperexcitable nerves.

Summary.

1. A muscle undergoing a succession of stimuli of varying strength responds with a succession of contractions of varying intensity but of equal duration.
2. The duration of the contraction of a muscle is the same whether it occurs in response to a short sharp stimulus or to a long diffuse stimulus.
3. When the conductivity of a motor nerve is slightly reduced by slight compression or injury the duration of response in the muscle it supplies is slightly lengthened.
4. When the conductivity of a motor nerve is much reduced or entirely destroyed the duration of response in the muscle is much lengthened.
5. When the stimulus from a motor nerve is abnormally and persistently increased the duration of the response in the muscle supplied by it is shortened.

A CONTRIBUTION TO THE STUDY OF ACUTE RHEUMATISM.

BY

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THE case here briefly recorded was remarkable in its clinical course, but medical literature abounds with so many surprises that this in itself would not justify publication. It is because it adds one more link to the chain of evidence upon the cause of acute rheumatism that I believe it to be of value to the student of the disease.

R. K., a girl aged 17, machinist, was admitted to the hospital July 2nd, 1918, suffering from weakness, nervousness, palpitation, and dyspnoea on exertion. A pale, thin, delicate girl, she was obviously the victim of Graves's disease and organic heart disease. The cardinal symptoms of enlarged thyroid, exophthalmos, tachycardia, and tremor, with von Graefe's sign, were all present. The heart was considerably enlarged, and there was a double mitral murmur. The history was of some interest, for the heart disease dated from an attack of rheumatic fever two years previously, and at the same time the thyroid enlargement was noticed by her doctor. The association of Graves's disease and acute rheumatism is one that is well recognized, but it is exceptional for the two conditions to be noted simultaneously.

The course of the case was at first uneventful, treatment by x-ray applications and sedatives producing some gradual improvement. On August 19th, however, she developed a severe sore throat, the temperature rose, and multiple arthritis affecting the ankles, wrists, and shoulders followed, and it was clear that she was commencing another attack of rheumatic fever. A rheumatic erythema developed, followed by cardiac dilatation, and on September 1st pericardial and pleuro-pericardial friction.

From this date onward her condition became extremely grave, the pericardial friction became general, and there followed all the signs of an unusually copious pericardial