

“The Minute Anatomy of the Brachial Plexus.” By W. P. HERRINGHAM, M.B., M.R.C.P. Communicated by W. S. SAVORY, F.R.S. Received March 8,—Read March 25, 1886.

It has for some time appeared probable that the spinal nerves which form the brachial plexus do not become confounded one with another, but retain each its separate course and its separate functions.

To the naked eye a nerve is a bundle of parallel threads bound together, and at the same time divided by a sheath of connective tissue. It seemed to me possible that the course of the spinal nerve roots could be traced by a dissection which should follow each through the plexus to the nerves which branch therefrom, and in these to its final destination.

My dissections were partly upon foetuses or stillborn children, partly upon the adult. The plexus of an infant is in some respects better, in some worse than that of an adult for an investigation of this kind. On the one hand its minuteness needs the confirmation of larger tissues, but on the other hand the fibrous sheath uniting the nerves is very much weaker and less perfect, so that as in the case of the pectorals, the serratus magnus, and coraco-brachialis muscles, arrangements which in the adult need great care in dissection, can be seen in the infant without using the knife at all.

Adult bodies are best fitted for tracing fibres down a long nerve.

The present paper is based upon the dissection of fifty-five plexuses, thirty-two being foetal or infantile, and twenty-three adult.

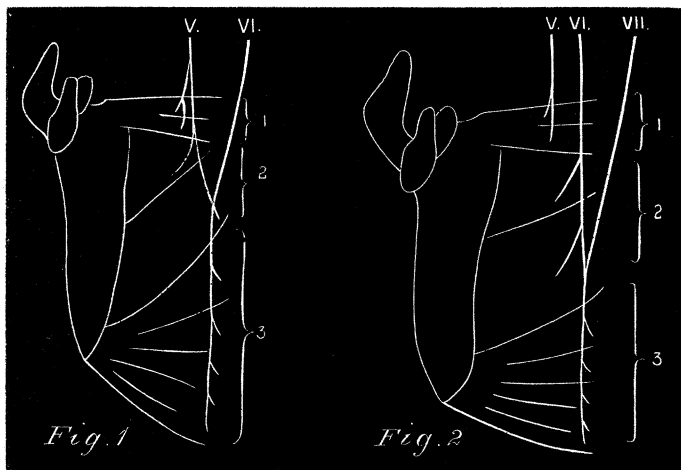
The 5th cervical nerve as it lies between the scaleni gives off a branch which divides into the nerve to the rhomboids, and the upper root of the *posterior thoracic*. The latter is joined by the root from the 6th, and lower down by one or sometimes two branches from the 7th.

In the adult the 5th and 6th usually join before the first digitations of the serratus magnus are reached, and receive the 7th about the level of the first rib. It can generally, even in adults, be seen that the 7th joins the nerve below the twig given to the first part of the muscle formed by the two upper digitations, and it is often easy to separate the 5th from the 6th, and this from the 7th, so far as to show that the first part of the muscle is supplied wholly by the 5th, and the second by the 6th alone, or by the 5th and 6th, while the 7th does not give twigs until the third part is reached. I have several times been able to show this to students in the dissecting room. But in the foetus there is no dissection necessary. The branch to the first part is given off before the 5th reaches the 6th, and the 7th does not enter

the nerve until it has descended to the third or lowest part of the muscle. The connective tissue which in the adult binds all the nerve together has not in the foetus yet grown up, and the system of the nerve is naturally exposed. The supply of each nerve is variable. If the 5th root is large it will send on fibres to supply with the 6th the middle of the muscle. If it is small it spends itself entirely on the upper part, but however the different roots may vary in size I have never in the numerous dissections I have made seen them alter their relative positions.

Two typical examples from adults may be quoted. In one, the 5th gave twigs to the first three digitations, and then a small fibre to the 6th. There was no root from the 7th. In the other, the 5th supplied the first two, the 6th alone supplied the next two, and the 6th and 7th the remaining digitations. In these there was no splitting of the nerve necessary. The drawings shown were made from them.

Diagrammatic Sketch of Posterior Thoracic from two Adults.



V, VI, VII = Branches from 5th, 6th, and 7th roots.

1, 2, 3 = First, second, and third parts of serratus magnus.

As the 5th leaves the scaleni it receives a communicating branch from the 4th, which therefore does not enter the rhomboid branch, or the posterior thoracic. The communicating branch varies considerably in size. I have at times been scarcely able to recognise the twig, at others it is a sixteenth of an inch thick. In the remainder of the paper this branch is not separated from the 5th.

Soon after this the 5th root joins with the 6th. It is usually at their junction that the *suprascapular* nerve is given off, but it is not

uncommon to find it springing from the 5th before the junction is made. When this is the case it contains no fibres from the 6th, but when given off at the junction it usually, though not always, receives a minute fibre from the 6th which passes either behind or through the fibres of the 5th to reach the suprascapular. The 6th therefore exercises sometimes an extremely small influence, and sometimes none at all over the supra- and infra-spinatus.

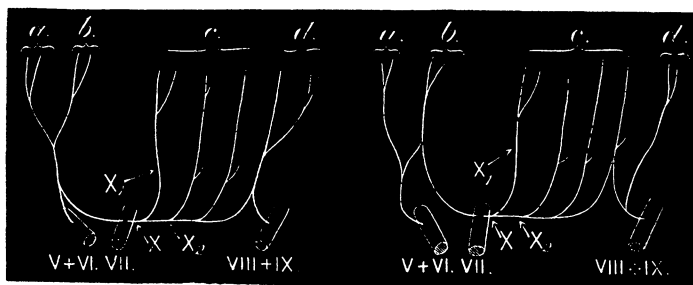
The united 5th and 6th then divide into an anterior and a posterior branch.*

The anterior joins with an anterior branch of the 7th to form the outer cord. Just before their junction the united 5th and 6th gives off one, and the 7th two branches for the pectorals. The upper branch from the 7th joins with that from the 5th and 6th to form the *external anterior thoracic*, which, piercing the costo-coracoid membrane, supplies the clavicular and the upper piece of the sternal part of the muscle as far down as the fibres which arise from the 2nd costal cartilage. The lower 7th branch forms that which is usually called the *communicating branch* of the external anterior thoracic. It has, however, a separate origin from the 7th trunk, and contains no fibre of the 5th or

Diagram of Anterior Thoracics.

FIG. 3.—As seen in Adults.

Fig. 4.—As seen in a Fœtus.



V, VI, VII, VIII, IX=5th, 6th, 7th, 8th cervical and 1st dorsal roots.

V + VI, VIII + IX=Trunks formed by union of these roots.

a=Twigs to clavicular division of pectoralis major.

b, c, d=Twigs to upper, middle, and lower parts of the sternal division of the muscle.

X="Communicating branch," of which X₁ goes over, X₂ under, the pectoralis minor.

6th. It runs under the costo-coracoid membrane over the axillary artery, and at the upper border of the pectoralis minor divides into two, of which one branch passes in front, running with the branches

* Or the nerves may each divide before they join.

of the acromial thoracic artery, to supply the pectoralis major; the other goes behind the pectoralis minor, sends two twigs through it which supply it and the next parts of the pectoralis major, and close to the lower border of the muscle joins with the *internal anterior thoracic* which appears from under the artery. The united nerve now supplies the lowest part of the pectoralis minor, and turning round its edge serves the lowest fibres of the pectoralis major.

This arrangement was constant in eight consecutive adult cases that I dissected. I was, however, able in one of the foetal dissections to see more than this. The branch from the 5th and 6th, before joining the branch from the 7th, gave a twig which ran to the clavicular portion and which alone supplied that part. The union of the 5th, 6th, and 7th supplied the upper part of the sternal muscle. The 7th served the middle as in the adult, but the internal anterior thoracic before receiving the 7th gave off a twig which supplied the lowest fibres of the pectoralis major, its union with the 7th serving the fibre next in order above these.

Of the nerves interested in the anterior thoracics the 7th always contributes. Of thirteen dissections the 5th and 6th both gave branches to the external in five, the 6th alone in eight cases. Of ten dissections the 8th and 9th both gave branches to the internal in eight cases, the 8th alone in two. It appears, therefore, that the pectoralis major does not usually receive from the 5th, and does usually receive from the 9th.*

Below these branches the 7th joins the 5th and 6th, thus forming the outer cord, which bifurcates into the musculo-cutaneous and the outer head of the median. I have seen three cases where the musculo-cutaneous when about to pass under the biceps to the outer side of the arm gave back a large bundle to the median. Two of these cases were adult, and in them the returned bundle consisted in one wholly of the 6th root, in the other of fibres from both 6th and 7th.

The *musculo-cutaneous* is usually described as supplying the coracobrachialis. In the adult the nerve to this muscle is given off before the musculo-cutaneous enters it. If traced up it is seen to come from the outer cord before the musculo-cutaneous leaves it, and ultimately from the 7th root in the outer cord. It passes under the cord to get to the muscle.

Here again the system is very much clearer in the foetus, for in the foetal plexus the coraco-brachial nerve can be seen running from the 7th before it joins the 5th and 6th, and passing under the 5th and

* The first dorsal I have here called, and shall henceforth call, the 9th spinal root, the 2nd and 3rd dorsal the 10th and 11th respectively. The 9th receives at its origin a small branch from the 10th in the majority of cases. It is too small to dissect in the foetus, and the conditions of a dissecting room do not allow of its dissection in the adult. I have therefore included it in the 9th root.

6th to reach the muscle. It is therefore quite distinct not only from the musculo-cutaneous, but from the 5th and 6th also. I have found this arrangement constant in the fœtus in more than twelve consecutive cases, in fact ever since I first recognised it. I have also seen it in the adult.

In one case, however, I found the muscle supplied not only by this nerve from the 7th, but also by a fibre from the 6th in the musculo-cutaneous.

The rest of the musculo-cutaneous, or as should be said, the musculo-cutaneous nerve proper, hardly ever contains any fibres other than those of the 5th and 6th. In thirty-nine cases, twenty-one fœtal and eighteen adult, the 7th only contributed to the musculo-cutaneous four times, twice in the fœtus, and twice in the adult. Of these four exceptions, in two the 7th could not be traced down the nerve, in a third it ran to the short head of the biceps, and in the fourth, an adult case, it entered the cutaneous branch only.

Twenty-eight cases were examined to see if both 5th and 6th entered the nerve. In twenty-seven this was found to be the fact, in one, only the 5th was traced into it.

In eight cases the 5th and 6th were traced down the nerve. Four of these were fœtal, and four were adult. The biceps was found to be served by both 5th and 6th in seven instances, in one the 5th alone was traced to the muscle. The brachialis anticus was supplied by both the 5th and 6th in four cases, and by the 5th alone in four. The cutaneous branch was found to contain fibres from both roots in six cases; in one it was formed by the 6th and 7th. The bundle from the 5th was noted as very small in two cases, and in two more was found to supply the skin over the outer condyle and the head of the radius, the nerve in the forearm being wholly derived from the 6th root. In another case it ran down the forearm over the flexor carpi radialis in front of the branches from the 6th.

The remaining nerve given from the outer cord is the outer head of the median. Into this the 5th does not enter. Thirty-one dissections showed no exception to this rule. The supply of the 5th by its anterior branch ends therefore with the musculo-cutaneous nerve.

The *median* is formed by two heads; into the outer the 6th and 7th always enter, while the inner is formed always by branches of the 8th and 9th, sometimes with the addition of some bundles of the 7th. This variety depends upon whether the anterior branch of the 7th bifurcates or goes wholly to the outer cord. In order to see whether both 8th and 9th contribute to the median, twenty-eight dissections were made, fourteen in infants, fourteen in adults. In one fœtus, and in one adult, no branch from the 9th was found. These two were, however, the only exceptions to the rule that both roots send fibres to the nerve. The median then is made of the 6th, 7th, 8th,

and 9th. But these roots do not send to it a constant proportion. There is little variation in the size of the 6th bundle, the 7th varies considerably, the 8th is sometimes equal to, sometimes smaller than, and sometimes larger than the 9th.

The 6th bundle runs down the outer side of the nerve from the top to the bottom, though in dissection the nerve generally becomes so twisted that it seems otherwise. In the lower third of the arm a pair of fibres are seen crossing from the outer to the inner side. These are the nerves to the pronator teres and the flexor carpi radialis. They are given off almost always by the 6th, and they usually run over in front of the nerve to reach the muscles.

I have, however, dissected them running through the nerve and separating the other bundles. The nerve to the pronator usually divides into two before it reaches the muscle, and is sometimes double from the beginning. With the nerve to the flexor carpi radialis runs a nerve to the other flexors, but this comes from a lower root. In eight cases where the 6th and 7th were not separated, these two muscles were supplied by the combined bundle. The nerve to the pronator teres was traced seventeen times to the 6th, once to the 7th; that to the flexor carpi radialis thirteen times to the 6th, twice to the 7th; neither to any other nerve. The 6th does not supply any other muscles in the forearm.

The 7th was traced nine times to the flexor sublimis, and in four of these it also contributed to the anterior interosseous. It is to be noted that in two of these four it also formed part of the ulnar. Of the five cases when it did not go to the anterior interosseous the ulnar was traced in four, and did not in any of these receive from the 7th. Where then the 7th goes to the anterior interosseous it is probable that it will form also part of the ulnar; when it is excluded from the ulnar it probably does not contribute to the anterior interosseous. In seven cases no branch could be traced to the flexor sublimis.

The 8th and 9th usually supply the flexor sublimis, and always the deep flexors. In seventeen instances the flexor sublimis received from them fourteen times, and three times did not receive from them. The two nerves were separated six times in adults, with the result that they seemed to mingle in all muscular branches in the forearm, and that no muscle could be said to belong to the one and not to the other.

After the forearm muscles have been supplied, the remainder of the median which comes from under the flexor sublimis always contains fibres from the 6th, 7th, and 8th roots, and sometimes a bundle from the 9th.

The 6th was traced separately eleven times, and the 7th seven times in this part of the nerve. Neither was ever found absent. The distribution of the lower two roots in the hand was traced in eleven cases. In six of these they were not separated; in the other five the

9th ran to the hand in two only; in three of these, and in one other case, it was seen to end in the muscles of the forearm. Of these six cases two were foetal, the rest adult. The 8th always ran to the hand. As a rule then the median in the hand contains only fibres from the 6th, 7th, and 8th.

The palmar cutaneous branch was five times noted, twice coming from the 6th, three times from the 7th.

The branch to the superficial muscles of the thumb was eleven times dissected. In eight cases it came from the 6th, in three from the undivided 6th and 7th, never from the 8th or 9th.

The five digital branches* were more variously distributed. The first branch was traced fourteen times, nine times to the 6th, and five times to the united 6th and 7th.

The second was traced fourteen times, six times to the 6th, five times to a united 6th and 7th, twice to both 6th and 7th, and once to the 7th alone. The third was traced eleven times, twice to the 6th, five times to a united 6th and 7th, once to both 6th and 7th, and thrice to the 7th. The fourth was traced eleven times, once to a united 6th and 7th, three times to the 7th, twice to the 8th, once to a united 8th and 9th, and in four the radial side of the cleft was supplied by the 7th or the united 6th and 7th, and the ulnar side by the lower nerves. The 5th was traced eleven times; in one the 7th served the radial side of the cleft, the other side being supplied by the united 8th and 9th, in three the 8th alone, in five the undivided 8th and 9th, in one both 8th and 9th (the latter taking the ulnar half), and in one the 9th alone supplied it.

These figures are confusing to read, but the table shows that the first branch is always supplied by the highest nerve, the last always from one of the lowest, and that in no case is there a break in the order of supply from the one to the other.

No. of case.	1.	2.	3.	4.	5.	13.
Digital branches.						
1.....	} 6+7†	6	} 6+7	} 6+7	6	6
2.....		6			7	6
3.....		7			7	..
4.....	7, 8+9	7, 8+9	8	6+7, 8+9	8+9	..
5.....	8+9	8+9	9	8+9	8+9	..

* 1st, radial side of thumb; 2nd, ulnar ditto; 3rd, radial of index; 4th, cleft between index and 3rd finger; 5th, cleft between 3rd and 4th finger.

† The sign + means that the two nerves were not separated. In Case 1 the first three branches arose from the bundle formed by the union of the 6th and 7th, the fourth had two roots, one from the 7th alone, the other from the bundle formed by the union of the 8th and 9th.

No. of case.	14.	15.	23.	42.	43.	52.	53.	54.
Digital branches.								
1.....	6	6	6	6	6	6	} 6+7	} 6+7
2.....	6	6	6	6	6, 7	6, 7		
3.....	..	..	6	6	6, 7	7	} 6+7, 8	} 8+9
4.....	..	..	7	7	8	7		
5.....	..	..	7, 8+9	8	8, 9	8	8	

The origin of the *ulnar* nerve was traced in thirty-two cases, of which fourteen were adult.

It was found to arise in four different ways. Its most common origin is from the 8th and 9th together. This occurred in twenty-three cases, eleven foetal and twelve adult. With these is sometimes combined a strand from the 7th, as shown in five cases, four foetal and one adult. In three foetal cases it arose from the 8th only, and in one foetal, and one adult case from the 7th and 8th. The 7th is only added to the nerve in some of those cases where it gives a branch to the inner cord. In several cases the branch from the 8th was much larger than that from the 9th. I have never seen the reverse.

The nerve was split down in seven instances, of which two were foetal. One of these had fibres of the 7th in it which, however, were not traced separately. Branches were traced to the muscles of the forearm from both nerves in five cases, in two from the 8th alone. The anterior cutaneous branches were in four cases from the 9th, in one apparently from the 8th. The dorsal cutaneous was in all seven a branch of the 8th. The superficial division in the hand going to the fingers was traced in all, and in three contained fibres from both 8th and 9th, in the other four was wholly from the 9th, while the deep or muscular branch traced in six was in five wholly from the 8th, and in the sixth received also from the 9th.

According then to these dissections the 8th and 9th usually both supply the forearm muscles, the 8th gives the dorsal cutaneous, and serves the intrinsic muscles of the hand, while the 9th gives sensation to the skin on the palmar surface of the hand, and of the lower third of the forearm.

The origin of the *internal cutaneous* was noted twenty-three times in my dissections. Nine times it contained a fibre from the 8th as well as the 9th, fourteen times it sprang from the 9th alone. In two cases of the former class the 8th was separated from the 9th in the nerve. In the one the 9th alone supplied the skin of the arm, the 8th not entering the skin until below; in the other the 9th was seen to supply the skin of the arm and of the front of the forearm, while the 8th ran to the back of the forearm.

The *lesser internal cutaneous* is derived in all but very rare exceptions from the 9th alone. In twenty cases it only once received from the 8th also.

The posterior branches of the nerve roots unite to form the *posterior cord*. Each of the four upper roots contributes to the cord, but the 9th rarely joins it. Out of forty-five cases where the point is noted, a fibre from the 9th occurs only six times, three times in foetal, three in adult cases. In one of these there was an unusually large root from the 10th nerve. In many adults the branch to the posterior cord can be seen to leave the 8th root before this is joined by the 9th. It may be taken then, as a rule, that the 9th does not contribute to the posterior cord. In the six exceptions the fibre from the 9th was invariably very small, and ran with the 8th, from which it was not isolated.

The branches of the posterior cord are the three subscapulars, the circumflex, and the musculo-spiral.

The *first subscapular*, which serves the subscapularis muscle, is often double, sometimes triple. It never receives from the 7th or 8th root, and is often wholly or partly given off from the 5th and 6th before they are joined by the 7th. Dissection shows that even when given off after the junction the 7th has still no share in it. This rule was invariable in forty-one cases. In twenty-three of these a dissection was made to see to which of the two upper roots the nerve was to be traced. It was found to come from the 5th in eleven cases, from the 6th in three, and from both in nine. I believe that owing to my not being sufficiently mindful that the muscle often receives more than one nerve, I have referred too large a number to the 5th alone. Whether this be so or no, it does not represent the whole supply given to it, for the lower part of the muscle always receives fibres from the *second subscapular* on its way to the *teres major*.

This is a nerve of rather lower origin than the preceding. It was traced three times to the 5th, all foetal cases; thirteen times to the undivided 6th and 5th; four times to the 6th alone, one being an adult case; nine times to both 5th and 6th, seven being adult cases; nine times to both 6th and 7th, seven being adult cases; and thrice it was formed by a branch from the cord of the upper two roots, and one from the 7th. This shows out of forty-one cases twelve in which the 7th contributed to the nerve, and twenty-nine in which it was excluded. There were only three in which the supply lay above the 6th, and thirteen where it lay wholly below the 5th.

The question then arose—When the 7th enters the nerve, does it form part of the twigs which supply the subscapularis? I divided the nerve in three such cases, and found that in each the 7th went entirely to the *teres major*.

The lower part of the subscapularis, however, is served, though not

by the 7th, yet by a nerve which is of lower origin than the first subscapular. Thus in four instances, three of them adult, where the first subscapular came from the 5th alone, the second contained no 5th, and in these cases the lower part of the muscle was supplied by a lower nerve. This confirms also three other adult dissections of the first subscapular. In one it was triple; the first twig going to the upper fibres of the muscle ran from the 5th, the next to the middle fibres from the 5th and 6th, and the third from the 6th alone, below which came a twig from the second subscapular. In the two other cases the nerve was double, the upper twig coming from the 5th, the lower from the 6th root.

The *third subscapular* going to the latissimus dorsi was traced in forty-two cases. Once it came from the 5th and 6th alone, three times it was formed by the 7th and a branch from the undivided 5th and 6th, four times by the 7th and a branch from the 6th (once with an addition from the 8th also), twenty-one times from the 7th alone, and thirteen from both 7th and 8th.

It is to be noted that in these three muscles there seems a regular progression from above downwards. The latissimus dorsi is usually served by a lower nerve than the teres, and this by a lower than the subscapularis, and though they are occasionally equalised their positions in the series are never reversed.

The *circumflex* nerve was shown in forty-three cases to be derived from the 5th and 6th alone. It never received a fibre from the 7th. In six cases, two of them adult, it came from the 5th alone, in twenty-two from both 5th and 6th, and in the remainder it was undivided. It never arose from the 6th alone, and in many cases where both nerves helped to form it the branch from the 6th was so small that it could not be traced without breakage. I dissected the nerve three times. In all these the teres minor was supplied by the 5th only, and the deltoid by both 5th and 6th. The cutaneous branch was in one from the 5th alone, in the other two received a fibre from the 6th also.

The *musculo-spiral* is formed sometimes by all four of the upper roots, usually by the 6th, 7th, and 8th alone. Out of forty-six cases the 5th and 6th were undivided in twelve, in nine of the remaining thirty-four the 5th helped to form the nerve. Two of these were adult. In twenty-five, fourteen of which were adult, it was excluded.

In one adult case where the 5th entered the nerve it was found by dissection to run to the external cutaneous branch alone.

The branch first given off is the nerve to the long head of the triceps, with which sometimes goes the internal cutaneous branch. The former was twelve times given from the 8th root, thrice from both 7th and 8th, and once from the 7th alone. The internal

cutaneous was seven times noted separately, in all of which it came from the 8th alone. That part of the muscle which arises below the musculo-spiral groove, commonly called the inner head, receives the ulnar collateral nerve on its inner part, and another branch which also serves the anconeus in its outer part. These two nerves were in six instances derived from the 8th only, in three from both 7th and 8th, in two from the 7th only, and in one from the 7th with the addition of a fibre from the 6th. In eleven cases where the supply of the outer head of the triceps was traced separately, it came from the 8th alone once only, from both 7th and 8th twice, from the 7th alone twice, from the 6th and 7th once, and from the 6th alone in five cases. In fourteen instances the nerves to the separate heads were not traced apart, but the whole muscle together with the internal cutaneous branch was in all supplied below the 6th. In three more the inner and outer heads were taken together, and in these also the supply was from the 7th and 8th.

The 6th therefore only entered the triceps in five out of twenty-eight cases, and it is to be noted that in No. 19, the only case where the 6th entered the inner head, it wholly supplied the outer.

The next branches given off are the two external cutaneous. The short branch was noticed in fourteen cases. Eight times it was shown to come from the 6th alone, once from both 5th and 6th, and in the remaining five from the first two roots, the 5th not being excluded. The long branch sprang from the 6th five times, in two of which the 5th was not excluded, from both 6th and 7th once, from the 7th thrice, from the 7th and 8th four times,* and from the 8th thrice.

The nerve then supplies the brachialis anticus. The branch, or branches, going to this muscle, which are very small, were isolated eight times. They were traced each time to the 6th, but in three cases the 5th was not excluded.

The branch to the supinator longus was traced twenty-two times, always to the 6th, but in twelve cases the 5th was not excluded.

The extensor carpi radialis longior was served twelve times by the 6th alone (in eight the 5th was not excluded), once by both the 6th and the lower nerves, and ten times by the lower part of the musculo-spiral, in four of which the 7th alone was traced to it, in five the 7th and 8th were not separated, and in one both were found supplying it.

The breviar was supplied by the 6th six times, in four of which the 5th was not excluded, once by both the 6th and the lower nerves, and nine times by the lower nerves alone, in four of which the 7th was the agent, and in one both 7th and 8th.

* In one case formed by the 7th and 8th the twig from the 7th ran nearer the radial border than that from the 8th.

The nerve to the supinator brevis was traced thirteen times, in every case to the 6th, but in five the 5th was not excluded.

The two remaining divisions are the radial and the posterior interosseous. The former was composed by the 6th alone thirteen times, in seven of which the 5th was not excluded, twelve times it was partly formed by the lower nerves. In all the seven cases when the two lower nerves had been divided the 7th alone was found to share in the radial.

I was able in only one case to dissect the radial consisting of both 6th and 7th. In it the 6th supplied the ball and dorsum of the thumb and the radial side of the index, while the 7th took the remainder.

The posterior interosseous was in seven cases formed by the lower nerves entirely. In four it received also part of the upper nerves. The question arose whether the 8th ever entered the muscles of the forearm. Out of sixteen dissections, eleven foetal and five adult, twelve of which four were adult showed the 8th to cease before the forearm muscles were reached, four of which two were adult showed the 8th coming round to the back of the arm.

In two of these latter the 7th and 8th formed equal parts of the posterior interosseous; in the other two cases the 8th gave so minute a fibre to the nerve below the triceps that I could not trace it separately.

In several of these cases the 5th was not excluded from the musculo-spiral, and must therefore be considered as a possible source of the supply, but it must be remembered that the probability of its taking part in the nerve is only, as before shown, nine in thirty-four, and that when dissected in the nerve it was found only to enter the short external cutaneous branch.

These results show considerable variation in the distribution of the nerve roots, although I do not think it is greater than in any other of the structures of the body. But this variation is not extravagant. If a type be composed from the foregoing materials and compared with the varieties, it appears that if a muscle or a piece of skin is not supplied by the typical nerve, the place is filled only by one of its neighbours, not by a nerve far removed from it in the series. The *teres major* usually supplied by the 6th is on occasion supplied by the 5th, and sometimes by the 7th, never by the 8th or 9th.

Again, some muscles seem to bear definite relations to each other, and their nerve supply seems also to vary solidly, so that the relative position of the muscles judged by their nerve supply does not alter although they be not served by the usual nerve. The best example of this is in the three muscles which are attached along the inner side of the bicipital groove, the *subscapularis*, *teres major*, and *latissimus dorsi*. The first is usually supplied by the 5th and 6th, the

second by the 6th, and the last by the 7th, and however much they vary above and below their typical place, they do not change their relations to each other. A similar relation exists between the two supinators and the two radial extensors. These last are sometimes supplied by the 6th, sometimes by the 7th, but they are never in any case placed above the supinators. These are always supplied by the 6th alone. The flexor group in the forearm show a similar fixed relation.

From consideration of the usual regularity of the nerve supply, and of the limits within which alone it varies, I conclude that the nerve roots are not always composed of the same fibres, but that what is in one case the lower bundle of the 5th may be in another the upper of the 6th, and what is now the upper bundle of the 8th will at another time be the lower of the 7th root. This may be expressed as a law.

LAW I.—Any given fibre may alter its position relative to the vertebral column, but will maintain its position relative to other fibres.

It is to confirm laws that exceptions are important. One of my infants showed on both sides a larger root from the 10th or 2nd dorsal nerve than was usual. On the right side the nerve was slightly bigger than the natural, but on the left it was as large as the 9th, and this as large as the 8th, whereas the natural proportion of the 8th to the 9th is about 2 to 1, and the 10th root is a minute fibre only. On the right side the only abnormality in the plexus was that the 9th sent a branch to the musculo-spiral. But on the left the musculo-cutaneous received from the 7th, the median received no 6th, the teres major was supplied by the 7th alone, the circumflex received from the 7th, and the musculo-spiral was formed by the 7th, 8th, and 9th. In the ulnar both 8th and 9th entered the deep branch in the hand. Nevertheless the 4th sent a communication to the 5th, and the suprascapular and subscapular were given off normally.

It appears that in this case the representation of the muscles in the spinal cord began at the ordinary level, but was more than usually lengthened out, its lowest point sinking so far that the 10th nerve conveyed an excessive proportion of fibres to the plexus. This unusual formation of the peripheral nerves still maintains the relative position of the muscles.

I do not, however, find that every muscle comprised in the table holds fixed relations with all others. There appear to be groups of muscles which are not intimately related. Thus the rise or fall of the three subscapular nerves does not entail a like movement in the nerves of the forearm.

I have drawn up from my dissections the following table, giving the usual supply of the muscles of the upper limb.

Usual nerve supply.	Muscles.
3rd, 4th, and 5th	Levator anguli scapulæ.
5th.	Rhomboids.
5th, or 5th and 6th.	Supra-spinatus. Infra-spinatus. Teres minor.
5th and 6th.	Subscapularis. Deltoid.
	Biceps. Brachialis anticus.
6th.	Teres major. Pronator teres. Flexor carpi radialis. Supinator longus and brevis.
	Superficial thenar muscles.
5th, 6th, and 7th.	Serratus magnus.
6th or 7th.	Extensores carpi radialis.
7th.	Coraco-brachialis.
	Latissimus dorsi.
	Extensors at back of forearm.
	Outer head of triceps.
7th and 8th.	Inner head of triceps.
7th, 8th, and 9th.	Flexor sublimis.
	Flexor profundus, carpi ulnaris, longus pollicis, and pronator quadratus.
8th.	Long head of triceps.
	Hypothenar muscles.
	Interossei. Deep thenar muscles.

The pectoralis major receives from the 6th, 7th, 8th, and 9th; the minor from the 7th, 8th, and 9th.

The question next arises upon what system are these muscles innervated? Is it a system of form or of function? Are muscles supplied by the same nerve because they act together or because they lie near one another?

In the first place the movements of the arm are so varied that there is hardly any combination of muscles unrepresented. In the commonest and most necessary of all acts, that of putting a piece of food into the mouth, the food is grasped by the small muscles of the thumb and the interossei, the carpus is flexed upon the forearm, the forearm is half pronated and flexed upon the arm, and the pectoralis major draws the limb forward across the chest. Doubtless many other muscles take an unrecognised share also. But of those here mentioned the anatomy of ordinary text-books shows that some, the flexors of the elbow, are served by the outer cord, the 5th, 6th, and 7th, whilst the interossei are supplied by the ulnar from the 8th and 9th. According to my dissections that one action is brought about through every nerve in the plexus, and there is no action which does not involve several nerves at once.

Looking at the theory from another point of view, is it true that muscles which cause the same movement, or which continually con-

tract together, are supplied by the same nerve? The action of the two pronators is indistinguishable, but the teres is supplied by the 6th, and the quadratus by the 8th and 9th; the thumb is always acting with the fingers, yet the superficial thenar muscles are served by the 6th, and the others by the 8th.

It seems then certain that the place where functions are represented is higher than the peripheral nerves, and that these are distributed according to some other plan.

The other system that suggests itself is the system according to place, and I find that the nerve supply of the muscles of the upper limb obeys three rules.

LAW II.—A. Of two muscles, or of two parts of a muscle, that which is nearer the head-end of the body tends to be supplied by the higher, that which is nearer the tail-end by the lower nerve.

B. Of two muscles, that which is nearer the long axis of the body tends to be supplied by the higher, that which is nearer the periphery by the lower nerve.

C. Of two muscles, that which is nearer the surface tends to be supplied by the higher, that which is further from it by the lower nerve.

The first rule has been already clearly exemplified in the supply of large flat muscles which receive more than one nerve, such as the pectoralis major and serratus magnus. The subscapularis is also an example. In all these muscles it was shown that the upper parts were supplied by upper, the lower by relatively lower nerves. It remains to show how it is exemplified in the remainder of the muscles belonging to the limb.

It has been laid down that in the first position of the foetus the great tuberosity and the external condyle of the humerus, the radius and the thumb are turned towards the head; the lesser tuberosity, the internal condyle, the ulna, and the little finger towards the tail. The first set of points have been called pre-axial, the latter post-axial. The muscles corresponding with the pre-axial points will be found to be supplied by higher nerves than those connected with post-axial points at the same level of the limb.

Of the muscles which connect the scapula to the spine, the highest is the levator anguli scapulæ. This is supplied by the 3rd and 4th, and slightly by the 5th. Below this come the rhomboids supplied by the 5th alone. Of the muscles which join the humerus to the scapula those inserted into the outer or pre-axial tuberosity are supplied by the 5th, with very slight, if any, aid from the 6th. Of those going to the post-axial part, the subscapularis, which is the highest, is supplied by the 5th and 6th; the teres major below it is supplied by the 6th, the latissimus dorsi which comes from lower down the body, and the

coraco-brachialis continuing down the post-axial border, are served by the 7th.*

Of the muscles running to the upper end of the forearm, the biceps and brachialis anticus are supplied from the 5th and 6th; the triceps by the 7th and 8th, and it is remarkable that of the three heads of the triceps the outer, which is nearest to the pre-axial border, is the highest in the series.

At this point the 5th ends.

Of the muscles arising about the outer condyle, the highest in rank are the two supinators inserted into the radius, next the extensors of the carpus going to the radial side of the hand. Of those coming from the internal condyle, the two outermost, nearest, that is, to the radius, are supplied by the 6th. The innermost, the flexor carpi ulnaris, is supplied by the 8th and 9th (and at this point the 9th first begins to share in the system); the flexor sublimis, between the two, is supplied by the 7th and the lower nerves. None of the deep muscles are served by the 6th, and the 7th seldom runs to them. They are as a rule innervated by the lowest of the series.

Passing to the hand, the superficial muscles on the outer side are supplied by the 6th, the superficial on the inner side by the 8th, the deep muscles being again supplied by the lowest of the nerves supplying the hand, namely, the 8th.

It is remarkable and unexpected that the 8th and not the 9th should be the nerve going to the muscles of the hand. The explanation I would suggest is that the motor part of the 9th is rather an auxiliary nerve than an integral part of the plexus. The extremely small part which it often plays in the ulnar, and the fact that in two cases none of its fibres could be traced thither at all, confirm this view.

The cutaneous supply of the limb exemplifies still more clearly the first of the rules laid down for the motor system. Over the deltoid runs the descending branch from the 3rd and 4th, below this comes the circumflex from the 5th, or from the 5th and 6th. The branch of the 5th in the musculo-cutaneous, and the short external cutaneous of the musculo-spiral given by the 6th, supply the skin over the outer condyle and head of the radius. Down to the end of the radius it is served by the musculo-cutaneous, either from the 6th alone, or as in one case by the 5th and 6th; the thumb is supplied by the 6th in the median and radial.

On the inner side, the highest part, the skin of the axilla, is served by the 10th, the area below this by the junction of the 9th and 10th (the intercosto-humeral with the nerve of Wrisberg), next by the 9th

* The deltoid, which would also exemplify the law, is omitted. I consider it uniform with the pectoralis major, not truly part of the long muscles of the limb.

in the internal cutaneous which runs down to the wrist. The little finger is supplied by the 9th in front, and by the 8th behind; the front of the three middle fingers by the 7th and 8th, the back by the 6th and 7th.

In the sensory system, therefore, as in the motor, the upper nerves can be traced down the pre-axial, and the lowest down the post-axial border; but a remarkable difference appears between the sensory and the motor system. Whereas in the latter it seemed the tendency for the lowest nerves to supply the lowest muscles, in the sensory nerves the extreme are nearest the upper, the middle nerves nearest the lower extremity of the limb.

Thus, if the limb be seen from the front the two highest nerves on the outer and inner sides respectively are the 4th and the 10th. Lower than these the 5th and 6th take the outer, the 9th and 10th the inner side. Below the elbow the 6th alone takes the outer, and the 9th alone the inner. In the hand, while the 6th and 9th continue their positions, the 7th and 8th for the first time begin to join in the supply.

Below the elbow a distinction begins to appear between the dorsal and palmar surfaces. If a line be drawn round the lower third of the forearm from the middle of the front surface to the radial border, across the dorsum, round the ulna, and so to the middle line again, it will cut in order cutaneous branches of the 6th, 7th, 8th, and 9th. Thus on the outer side behind the 6th in the musculo-cutaneous comes the musculo-spiral cutaneous from the 7th, and on the inner side behind the 9th in the internal cutaneous comes the dorsal cutaneous formed by the 8th. When the 8th was dissected in the internal cutaneous it was found going to the dorsum, and where the 7th and 8th joined to form the musculo-spiral branch the 7th lay nearest of the two to the radial border.

In the fingers, again, the 8th is the lowest nerve supplying the back. The 9th the lowest in front. The extremes therefore are on the palmar, the dorsal area occupies an intermediate position. Above the elbow the 8th in the internal cutaneous of the musculo-spiral, holding a position intermediate between the 10th in the intercosto-humeral, and the 5th and 6th in the circumflex, is an example of the same law.

The sensory nerves therefore obey the following rules:—

- A. *Of two spots on the skin that which is nearer the pre-axial border tends to be supplied by the higher nerve.*
- B. *Of two spots in the pre-axial area the lower tends to be supplied by the lower nerve, and of two spots in the post-axial area the lower tends to be supplied by the higher nerve.*

This, however unexpected, is not very difficult to understand. The

epiblastic layer which forms the skin ensheaths the mesoblast, from which the deeper structures are developed. Suppose nerves, or what will afterwards become nerves, to be distributed to both. The mesoblast now begins to grow and pushes before it the enveloping sheath of epiblast. But, as may be seen with a piece of india-rubber, in any such process the points furthest from the centre of pressure remain nearest the top of the tube, and the point which was in the middle when the stretching began, will be at the furthest point of the sheath when it is finished. If in the arm the centre of pressure be supposed opposite to the area supplied by the 7th nerve, this nerve will always tend to supply the parts lying nearest the axis of the limb, and furthest from the axis of the body, while the 6th, 5th, and 4th in the pre-axial, and the 8th, 9th, and 10th in the post-axial area, will in that order approach the trunk. This is the case.

It appears then that in both sensory and motor systems the pre-axial area is supplied by higher nerves, the post-axial by lower; that the supply of the skin follows rules which obtain in any membrane subject to the same conditions, but that the supply of the muscles is modified by laws peculiar to themselves.

This subject has not to my knowledge been before this investigated by human dissections.

Ferrier's* classification of the muscles by means of electric stimulation of the spinal roots in monkeys, though he explains the system as one of function, is not far removed from that now put forward.

Forgue,† who stimulated not the spinal roots, but the branches which they gave to the nerves of the plexus, and who watched the contraction of dissected muscles, draws up the following list for monkeys:—

Median.‡

Médian externe.	{ 5 and 6 7	{ Biceps. Brachialis anticus. Clavicular part of deltoid. Pronator teres. Flexor carpi radialis.
		{ Biceps slightly. Pronator teres. Flexor carpi radialis.
Médian interne.	{ 8 and 9	{ Pronator teres and flexor carpi radialis slightly. Flexor sublimis. Flexor profundus. Flexor carpi ulnaris. Intrinsic muscles of hand.

* 'Roy. Soc. Proc.,' vol. 32, 1881, p. 12.

† 'Distribution des Racines Motrices dans les Muscles des Membres.' Emile Forgue. Montpellier, 1883. Page 45.

‡ Forgue's median is both median and musculo-cutaneous. Médian externe is the musculo-cutaneous and the outer head of the median, médian interne the inner head.

*Radial.**

- 5 and 6 { Deltoid from scapula. Supinator longus. Extensores carpi
 radiales.
- 7 { Latissimus dorsi. Teres major. Triceps. Extensores carpi
 radiales. Extensors slightly.
- 8 and 9 .. Latissimus dorsi. Triceps. Extensors.

Cubital.†

Flexor profundus. Flexor carpi ulnaris. Intrinsic muscles of hand.

He lays down also the following laws:—‡

1. Each root furnishes branches to two systems, an anterior and a posterior.§
2. As the stimulus approaches the dorsal pairs, the contraction occurs in lower segments of the limb.
3. As the stimulus approaches the dorsal pairs, the contractions pass from the radial to the ulnar border.

He also adds—

“It is a secondary law that the superficial layers are supplied before the deep.”

Both these observers worked with monkeys, and Forgue’s laws are, with the exception of the first, identical with those which human dissections have produced for me. That the details should exactly correspond is not to be expected in two different genera when individuals of the same vary so widely.

Electrical stimulation does not show the sensory supply.

I have often tried to complete this account by dissecting the nerves upwards to the spinal cord. I have, however, never been able to rely on the results. The connective tissue permeating the nerve separates and protects the bundles of nerve fibres composing it, and renders their dissociation impossible. But as the nerve nears the intervertebral foramen this tissue very rapidly diminishes, and in the foramen the root consists of nerve bundles with hardly any connective tissue between them. The nerve bundles in the adult might perhaps be separated even here from one another, but in the fœtus, and these alone are for this purpose accessible to me, their minuteness and their softness have prevented any satisfactory dissection.

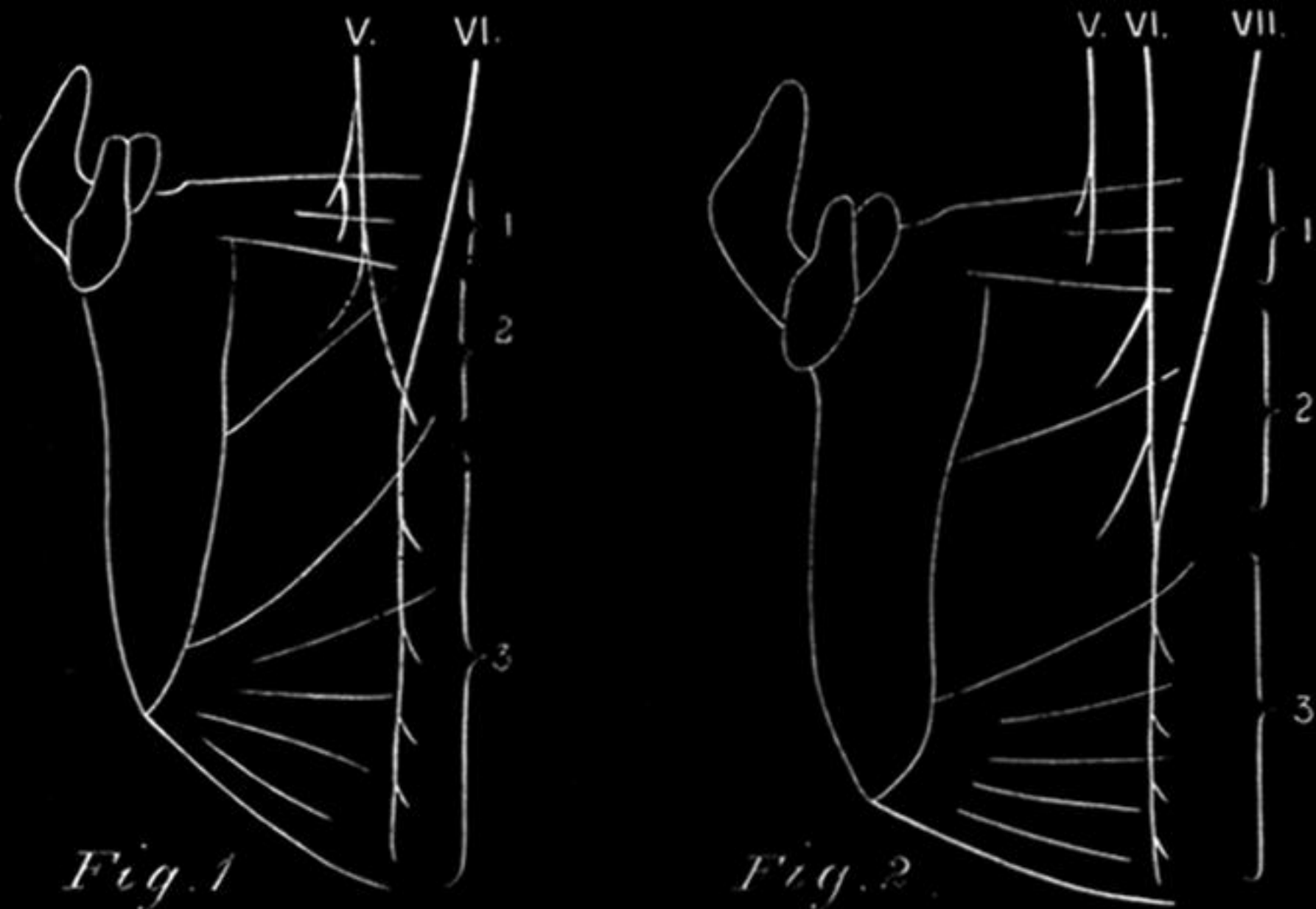
* The radial here means the posterior cord of the plexus.

† Ulnar.

‡ Pp. 41–43.

§ This refers to the adult position. A truer view is to take the earliest observed position in the fœtus.

Diagrammatic Sketch of Posterior Thoracic from two Adults.



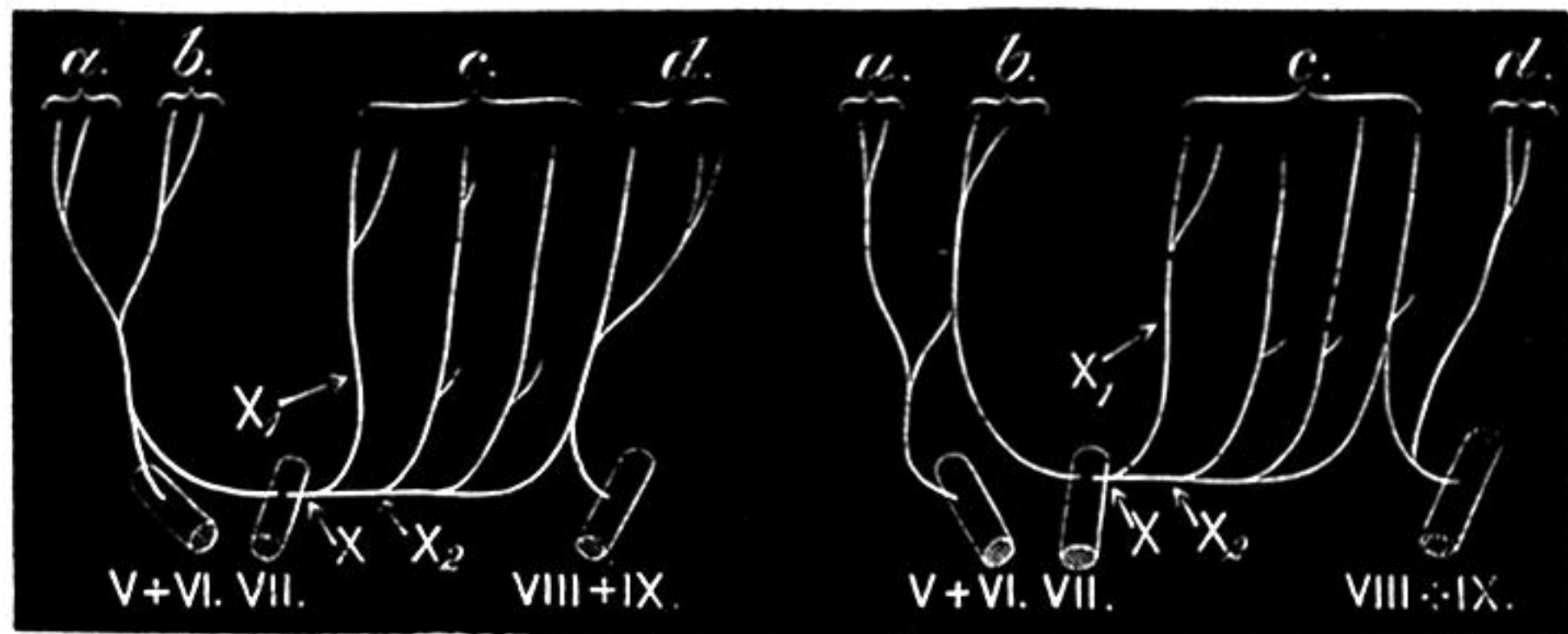
V, VI, VII=Branches from 5th, 6th, and 7th roots.

1, 2, 3=First, second, and third parts of serratus magnus.

Diagram of Anterior Thoracics.

FIG. 3.—As seen in Adults.

Fig. 4.—As seen in a Foetus.



V, VI, VII, VIII, IX = 5th, 6th, 7th, 8th cervical and 1st dorsal roots.

V + VI, VIII + IX = Trunks formed by union of these roots.

a = Twigs to clavicular division of pectoralis major.

b, c, d = Twigs to upper, middle, and lower parts of the sternal division of the muscle.

X = "Communicating branch," of which X_1 goes over, X_2 under, the pectoralis minor.