THE INNERVATION OF THE VESSELS OF THE LIMBS. By W. M. BAYLISS, B.A., B.Sc. and JOHN ROSE BRADFORD, M.D., D.Sc. (Plate I.)

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THE origin and course of the vaso-constrictor nerves for the fore-limb have been the object of relatively little investigation. Schiff[1], Bernard[2], and Cyon[3] have observed the effects of section of the roots of the brachial plexus and of extirpation of the upper thoracic and inferior cervical ganglia in the dog and state that a rise of temperature of the limb in question is the result. According to Schiff, who was the first to attempt extirpation of the ganglia, which he did by introducing his finger into the thorax and destroying the ganglia with his finger-nail, the rise of temperature in the interdigital membrane amounted to 4·5° C. to 6·75° C. Bernard found no effect on the vessels of the limb on dividing the three last cervical and two first thoracic nerve-roots in the spinal canal, but considerable vascular dilatation on dividing the nerves of the brachial plexus in the axilla. Destruction of the 1st thoracic ganglion by means of a hook also produced vascular dilatation. Electrical excitation of the ganglion caused vascular constriction, shewn by pallor and cooling of the paw, and the same effect was produced by excitation of the peripheral end of the cut sympathetic trunk. He found a rise of temperature in the limb to follow section of the 3rd or 4th thoracic nerve-roots within the spinal canal but did not make any observations on the lower roots.

Schiff found after section of the four lowest cervical and three uppermost thoracic nerve-roots a considerable rise of temperature on the paralysed side. He distinguishes nerves for the vessels of the paw,

[1] Schiff. *Unters. z. Physiol. d. Nervensystems*, 1855, p. 176, and *Comptes Rendus*, LV. p. 425, 1862.

[2] Cl. Bernard. *Compt. Rend.* LV. p. 305.

[3] E. Cyon. *Ber. d. sächs. Ges. d. Wiss.* 1868, p. 73.

fore-arm and thorax from those for the shoulder and a part of the fore-arm; the former comes from the anterior roots of the plexus, the latter directly from the thoracic ganglia without joining the plexus.

Cyon found slight rise of temperature in the paw after section of the three lowest cervical and upper two thoracic roots, and in agreement with Schiff and Bernard a considerable rise after extirpation of the thoracic ganglia. Section of the sympathetic chain between the 2nd and 3rd ribs or between any ribs down to the 7th and 8th caused as considerable a rise of temperature as extirpation of the 1st thoracic ganglion, but section of one ramus communicans only produced very little vascular dilatation, that of several together being necessary for any marked effect; he concludes that the vascular nerves for the brachial plexus pass out through several rami communicantes of the middle thoracic region, varying however in different individuals as to the exact situation.

With respect to the hind-limb Bernard found[1] that after section of all the roots of the lumbo-sacral plexus of the dog or of the sciatic nerve, vascular dilatation of the limb took place; whereas no effect was produced on section of the sacral roots or 4 or 5 last lumbar roots. Section of the sympathetic chain between the 5th and 6th lumbar vertebræ produced the effect. Schiff[2] found rise of temperature after section of the two last lumbar and the three first sacral roots, but much less than after section of the sciatic, and he concludes "that the vascular nerves of the sciatic arise from nerve-roots which are situated either higher up or lower down than those which supply the sciatic nerve with its sensory and motor fibres." Brown-Séquard[3] found vascular dilatation to follow section of the five lower thoracic nerve-roots. Ostroumoff (Heidenhain)[4] found that the lumbar roots contain many vascular fibres for the foot. Schiff states further that the sciatic plexus enters into communication with the spinal nerves of higher segments partly by communicating branches of the spinal plexus and partly by rami communicantes of the sympathetic chain. Ostroumoff and Heidenhain shewed that section of the abdominal sympathetic caused considerable rise of temperature in the limb, whilst excitation of the same

[1] Cl. Bernard. *Ann. d. Sciences Nat.* ser. 4, I. p. 186, 1854, and *Compt. Rend.* LV. p. 228, 1862.

[2] Schiff. *Unters. z. Physiol. d. Nervensystems*, p. 168, 1855, and *Compt. Rend.* LV. p. 462, 1862.

[3] Brown-Séquard. *Gaz. méd. de Paris*, 1856. No. 16.

[4] Ostroumoff (Heidenhain). *Arch. f. d. ges. Physiol.* XII. p. 219, 1876.

caused fall of temperature. They also found that the vascular nerves reach the limb through the sciatic, for after section of that nerve excitation of the abdominal sympathetic produces no longer vascular constriction. They state that vascular nerves pass into the sympathetic above the lumbar cord, for after section of the cord above the 1st lumbar nerve-root rise of temperature in the hind-limb can be produced reflexly by excitation in the anterior part of the body. In the dog, according to Stricker[1], and in the cat, according to Puelma and Luchsinger[2], vascular nerves for the foot run in the roots of the sciatic.

Langley[3], when working on the sweat glands, found vascular effects on the toes and pad from every nerve that caused secretion; he found that the 3rd thoracic once had vaso-motor fibres and that the 5th, 6th, 7th and 8th gave most effect on the fore-foot, while the 13th thoracic and 1st and 2nd lumbar gave most on the hind-foot: and in a paper on pilo-motor nerves[4] he mentions that in a cat with posterior plexus the 4th lumbar had both secretory and vaso-motor fibres for the foot. These results were published after our work was completed, although unpublished, and it is satisfactory to find an independent observer in so close an agreement with the results we have obtained and give in detail below.

The observations recorded in the present paper formed part of a series carried out in part by one of us (Bradford) during the past four years on the course pursued by the vaso-constrictor fibres in passing from the central nervous system to their distribution. As mentioned in previous papers[5] these experiments have been carried out exclusively on dogs inasmuch as they owe their origin to Gaskell's anatomical work on the sympathetic which as is well known was carried out on this animal.

Our communication will be divided into the following sections:

I. Method.

II. The vaso-constrictor nerves of the limbs, (*a*) fore-limb, (*b*) hind-limb.

III. Some reflex phenomena.

IV. The effects of asphyxia.

V. Conclusion.

[1] Stricker. *Sitzungsber. d. Wiener Akad.* LXXIV. p. 173, 1876.
[2] Puelma and Luchsinger. *Arch. f. d. ges. Physiol.* XVIII. p. 489, 1878.
[3] Langley. This *Journal*, Vol. XII. p. 375, 1891.
[4] Langley. This *Journal*, Vol. XV. p. 227, 1893.
[5] Bradford. This *Journal*, Vol. X. Bradford and Dean. *Proc. Roy. Soc.* 1889.

I. Method.

It seemed to us that the plethysmographic method was the most suitable, although it has the great disadvantage of recording only the total change of volume of the part, not enabling us to differentiate the effects on the cutaneous vessels from those on the muscular vessels. Our purpose however being to a certain extent a morphological one we did not consider that this objection outweighed the many advantages of the method. Dogs of from 15 to 25 lbs. in weight were used. They were anæsthetized with chloroform, and morphia was then injected subcutaneously in doses of about ½ grain, and after the operative procedure was completed, curare was injected into the external jugular vein. The vagi were divided, tracheotomy performed, the carotid artery on one side prepared and connected with a mercurial manometer in the usual manner. The fore-limb or hind-limb was then shaved, greased with vaseline, and inserted into a glass plethysmograph filled with warm water; the apparatus was rendered water-tight by means of a thin india-rubber junction which did not exert sufficient pressure on the limb to interfere with the circulation in any way. The change of volume of the limb was recorded by connecting the plethysmograph with a Marey's tambour. In the experiments requiring the exposure of the nerve-roots these were prepared as described in a former paper by one of us[1] and it will suffice to say that the spinal canal was opened by removal of the neural arches, the nerve tied outside the dura mater and divided centrally to the ligature, so that a considerable length of the peripheral end was available for excitation. It is to be understood that in these experiments the peripheral ends of both anterior and posterior roots were excited together, in other words, if the posterior roots contain efferent fibres as asserted by Stricker these would be excited in our method; it must be remembered however that ordinary methods of excitation (i.e. rapidly interrupted induction currents) fail to produce any effect on the vessels when applied to the peripheral ends of isolated posterior roots, so that the results obtained in our experiments are due to the excitation of fibres in the anterior roots.

II. The Constrictor-fibres of the Limbs.

A. *Fore-limb.* In these observations the plethysmograph enclosed the whole of the fore-limb as far as the axillary folds except in a few

[1] Bradford. This *Journal*, Vol. x. p. 358, 1889.

cases to be mentioned below. The spinal nerves, prepared and divided, were excited one by one from the 2nd dorsal downwards. The 2nd dorsal produced no marked effect and the 3rd dorsal a very slight contraction of the limb, not infrequently absent. With the 4th nerve the result is decided, and when the electrodes are applied to the roots from this downwards, a well-marked contraction of the limb ensues, accompanied by a small rise of blood-pressure. The general result with the 5th, 6th, 7th, 8th, 9th and 10th is much the same in all, viz. diminution in volume of the fore-limb and rise of general blood-pressure, but as one passes from the middle of the series of nerves to the lower ones the effect on the bulk of the limb diminishes, while the rise of blood-pressure increases in amount. The middle nerves, i.e. the 6th, 7th and 8th, give the maximum result on the limb, the constriction produced by the 9th and 10th being slight, although perfectly distinct and more marked than that produced by the 3rd dorsal; this is the more remarkable seeing that the 10th dorsal nerve causes a great rise of blood-pressure dependent on excitation of vaso-constrictor fibres for the viscera, which would in itself tend to cause a passive expansion of the limb. When the 11th nerve-root is excited the blood-pressure rises but the fore-limb expands, thus shewing either that the 11th nerve contains no fibres, for the vessels of the limb, or that the local effect on the limb is so slight in amount as to be overcome by the great rise of blood-pressure dependent on the visceral constriction produced at the same time. That the latter is the true explanation is shewn by the following experiment. The blood-pressure and the volume of, say the right fore-limb, are recorded as usual and the right 11th dorsal nerve arranged for excitation, but previously the right great splanchnic has been divided at the level of the 12th rib, so that the fibres it derives from the 11th nerve-root are cut. When the 11th nerve is now excited there is very little rise of general blood-pressure but a quite distinct diminution in the volume of the limb, thus shewing the presence in the 11th nerve of some vaso-constrictor fibres for the fore-limb. This however is the lowest nerve, excitation of which is followed by any constrictor effect on the fore-limb either with or without previous section of the splanchnic. We see then that the fore-limb in the dog derives its vaso-constrictor fibres from a series of nine spinal nerves, commencing with the 3rd dorsal and terminating with the 11th dorsal, both inclusive; and notwithstanding this extent of origin, all these nerve-roots contain vaso-constrictor fibres, that is to say there are no gaps in the series. As in the case of the kidney and other viscera the first and last roots do not produce so marked an effect as the intermediate ones. In other words, the outflow of vaso-motor fibres to the fore-limb although sudden is not quite sudden, the 4th nerve producing a greater effect than the 3rd, and the 5th than the 4th. The constrictor effect produced by each of the nerves from the 5th to the 9th is large, and no one of these nerves produces a sensibly greater effect than any other on the volume of the limb, although the lower nerves 8th and 9th produce a greater rise of general blood-pressure than the upper ones; this of course is dependent on the fact of the visceral fibres being more abundant in the lower dorsal than in the upper dorsal roots, and hence the 8th and 9th nerves contain more of such fibres than the 5th, 6th and 7th nerves. It must be remembered however that a rise of blood-pressure will neutralize to a certain extent the local constrictor effect produced in the limb; as mentioned above, moreover, the constriction of the fore-limb obtained from the 10th and 11th nerves is quite small in amount.

Although the fore-limb derives its vascular nerves from such an extensive area of the cord we have been unable to obtain any evidence of the upper roots supplying the proximal part of the limb and the lower ones the distal part or *vice versâ*. If the fore-paw and about half the fore-arm be enclosed in a short plethysmograph, distinct constriction of this distal portion of the limb can be obtained by exciting the 9th and 10th nerve-roots.

The fore-limb of the dog therefore derives its vaso-constrictor nerves from the 3rd dorsal to the 11th dorsal inclusive, but the 3rd, 4th, 10th and 11th nerves produce but a small effect compared to that observed with the 5th, 6th, 7th, 8th and 9th dorsal nerves[1].

B. *The hind-limb.* In our observations on the hind-limb the plethysmograph reached to the junction of the upper and middle thirds of the thigh as it is difficult to adjust the instrument in such a way as to include all the uppermost part of the hind-limb. The highest nerve producing a distinct effect on the volume of the hind-limb is the 11th dorsal. We have not obtained any constriction of the hind-limb from the 10th dorsal. If the volume of the fore and hind-limbs be observed together and 10th, 11th and 12th nerves excited successively, the 10th

[1] Of course the 3rd and 11th dorsal nerves were not exposed in the same animal on account of the shock that would result from so large an area of spinal cord being laid bare, so that it is quite possible that when the 3rd nerve contained vaso-constrictors the case was one called by Langley anterior arrangement of nerves, and where the 11th dorsal contained such fibres the case was one of posterior arrangement of nerves; in one case therefore the origin might be 3rd to 10th dorsal inclusive, and in the other 4th to 11th dorsal inclusive.

is seen to cause constriction of the arm and expansion (passive) of the leg, the 12th expansion of the arm and constriction of the leg, and the 11th slight constriction of the leg and either slight constriction or slight expansion of the arm dependent on the amount of the synchronous rise of general blood-pressure. The constriction of the hind-limb produced by the 12th and 13th dorsal and the 1st and 2nd lumbar roots is much more marked than that obtained with the 11th dorsal. Finally, with the 3rd lumbar we reach the lower limit of the nerves producing any marked constrictor effect on the limb. With the 4th lumbar we have usually obtained no effect on the volume of the limb but occasionally a slight expansion; excitation of the 4th lumbar produced no rise of blood-pressure. We reach in this nerve the end of the long series of dorsal nerves containing vaso-motor fibres; hence the expansion sometimes observed on excitation of the 4th lumbar is not dependent on constriction of other areas but is an active expansion dependent probably on the presence of vaso-dilator fibres. We must however remark that in by far the greater number of experiments excitation of the 4th and successive lower lumbar roots has not given us any effect on the volume of the hind-limb. It is possible that the vaso-dilator phenomena were not shewn owing to the curare used or the method of excitation employed; an ordinary induction coil with a rapid rate of interruption is not appropriate to demonstrate vaso-dilators and we were in this research mainly concerned with vaso-constrictors.

On comparing the results described above, three main facts stand out. *First*, that although both fore-limb and hind-limb receive their vaso-constrictor nerves from an extended area of the spinal cord, yet this area in the case of the hind-limb is somewhat less extensive than in the case of the fore-limb; the latter receives its vaso-constrictor nerves from 9 roots, 3rd to 11th dorsal, and the hind-limb from 6 roots, 11th dorsal to 3rd lumbar. It must be remembered that in the case of the fore-limb two of these 9 nerves give very slight effects, viz. the 3rd and 11th dorsal, and also that the whole of the hind-limb was not enclosed in the plethysmograph, so that it is possible that future research may demonstrate a few vaso-constrictor fibres in the 10th or even higher dorsal nerves. We have however not been able to detect any. The *second* fact of more interest is that not only is there no gap between the innervation of the vessels of the fore-limb and those of the hind-limb but they actually overlap, the 11th dorsal causing constriction of both limbs. It is true that the effect of this nerve on the fore-limb is small, necessitating previous section of the splanchnic to demonstrate it in order to eliminate the rise of blood-pressure, but it is perfectly unmistakeable.

The *third* fact is that the innervation of the limb vessels, and hence probably of the vessels of the body-wall generally, is derived from approximately the same region of the spinal cord as the innervation of the vessels of the abdominal viscera. Observations on the general blood-pressure shew that the chief outflow of vaso-constrictor fibres occurs from the 6th dorsal to the 1st lumbar, and that the roots from the 2nd dorsal to the 6th dorsal and from the 1st lumbar to the 3rd lumbar do not produce on excitation any considerable rise of blood-pressure. Thus, for instance, the kidney derives its nerves from the 6th dorsal to the 2nd lumbar, so that its area overlaps both that of the fore-limb and that of the hind-limb.

III. Reflex Phenomena.

(*a*) *Central end of sciatic nerve.* Excitation of the central end of an afferent nerve leads generally to a diminution in the volume of the limb unless the simultaneous rise of blood-pressure be large enough to counteract the vascular constriction in the limb and passively distend the vessels. Thus excitation of the central end of the sciatic leads to constriction of the opposite hind-limb and of the fore-limbs accompanied by a moderate rise in general blood-pressure. Similar phenomena follow excitation of the central ends of the roots of the brachial plexus.

(*b*) *Central end of splanchnic nerve.* On the other hand excitation of the central end of the divided splanchnic is followed by a great rise of general blood-pressure and considerable increase in the volume of the limbs. This expansion of the limbs is evidently passive and not of active origin, as is seen by modifying the experiment as follows. The central end of one splanchnic is arranged for excitation and the opposite splanchnic exposed and a loose ligature placed under it at the level of the 12th dorsal nerve, so that it can be cut at any given time; the volume of the limbs is observed in the usual manner. On exciting the central end of the divided splanchnic the blood-pressure rises enormously and the volume of the limbs increases, although occasionally this expansion may be preceded by a slight and transitory constriction. The opposite splanchnic is now cut and the experiment repeated; under these conditions the volume of the limb undergoes during the excitation an obvious diminution and the rise of general blood-pressure is exceedingly slight, since the great bulk of the visceral vessels are separated from the vaso-motor centre owing to the section of both splanchnics; the vessels of the limbs however are still in connection with the vaso-motor centre since the fibres for the fore-limb issue from the 3rd to the 11th dorsal and those for the hind-limb do not run in the great splanchnics, but reach the sacral plexus viâ the main chain of the sympathetic. These experiments demonstrate in the first place that the expansion of the limbs observed on reflex excitation through the splanchnic when the other splanchnic is intact is not an active vaso-dilatation, but simply dependent on the rise of blood-pressure produced by constriction of visceral vessels overpowering the constriction of the limb vessels. Secondly, we see that constriction of the limb-vessels only, even when considerable in amount, is not sufficient to cause any material rise of general blood-pressure.

It is only however when the visceral constriction is considerable that the constriction of the limb vessels is overpowered and that passive dilatation is seen. Excitation of the central end of the sciatic causes as is well known visceral constriction, but as mentioned above constriction of the limbs is simultaneously produced. The rise of blood-pressure, and hence the visceral constriction, is much less with excitation of central end of the sciatic than in the case of central end of the splanchnic, so that the constrictor mechanism of the limb is powerful enough to manifest its existence in the presence of visceral constriction unless this latter is very considerable in amount.

(*c*) *Central end of a posterior root.* Excitation of the central end of one of the posterior roots produces somewhat similar results, i.e. constriction of the limbs, unless the accompanying rise of blood-pressure is very great, when a passive expansion results. As described by one of us in a former paper the rise of blood-pressure produced by excitation of the central ends of certain posterior roots is remarkable for its magnitude, and for the rapidity of its production and for its long duration. The rise of blood-pressure produced by reflex excitation in the case of most afferent nerves is gradual in its rise and of varying amounts, dependent on strength, duration of stimulus, etc.; in the case of the lower dorsal and upper lumbar posterior roots however the rise of blood-pressure is much greater, and what is more characteristic it is extremely sudden in its onset so that the curve of the rise approximates to a vertical line. With this great rise of blood-pressure the limbs as would be expected undergo a passive expansion, which like the rise of blood-pressure continues for some minutes after the cessation of the excitation. These effects are well seen on excitation of posterior roots as low as the 3rd lumbar. The posterior roots below this produce a strikingly different effect; thus the central end of the posterior root of the 4th lumbar produces a quite small rise of blood-pressure, whereas the same excitation of the nerve above causes the great rise just mentioned. In other words, just as we have seen that the 3rd lumbar is the lowest nerve of the series containing efferent vaso-constrictor fibres in any sensible number, so we find that it is also the last nerve that contains many afferent fibres in the posterior root capable of producing a great rise of blood-pressure. The great difference between the rise of blood-pressure produced by excitation of the central end of a posterior root above the 3rd lumbar nerve and that produced by one below the 4th lumbar must be due either to the nerves below the 3rd lumbar containing but few afferent fibres capable of affecting the vaso-motor centre, or else to the nerves above the 3rd lumbar and between it and the 5th dorsal containing some special afferent fibres not present in other afferent nerves.

Excitation of the central ends of lower lumbar and sacral posterior roots produces constriction of the hind-limb accompanied by a moderate rise in blood-pressure. We have not observed any active reflex dilatation of the limbs following the excitation of the central end of any posterior root.

(*d*) *Depressor effects.* As is well known the excitation of various afferent nerves in the dog, vagus, sciatic, and intercostal posterior roots occasionally causes a depressor instead of a pressor effect. Under these conditions we have not observed any active dilatation of the limbs, the curve of the limb volume following that of the blood-pressure, and the probable interpretation of this is that the dilatation produced in the splanchnic area is such as to drain blood from the other parts of the body and amongst them from the limb vessels to such a degree that the volume of the limbs undergoes a passive diminution.

The main conclusion from the study of the reflex phenomena is that there is a struggle between the local effect (usually constrictor) and the general effect which is mainly of visceral origin, and that if the latter is at all considerable the rise of blood-pressure produced by it overcomes the constriction produced in the limb vessels and hence they dilate passively. At the same time it must be remembered that owing to the method used (i.e. plethysmograph) we could not excite the nerves of the same part the volume of which was being measured. We could not, for instance, investigate the effect of afferent stimuli from the actual portion included in the plethysmograph. It is however rather remarkable that the posterior roots of the sacral plexus did not produce a reflex dilatation in the hind-limb.

IV. Asphyxia.

The volume of the limbs does not undergo in asphyxia the great changes that we are familiar with in the case of such viscera as the kidney or spleen. Most frequently the volume of the limbs undergoes a slow, gradual and slight increase during and accompanying the well-known rise of blood-pressure produced by asphyxia. With the final rapid fall of blood-pressure at the end of asphyxia there is a great diminution in the volume of the limbs. The well-known Traube curves which are so obvious on the blood-pressure traces are also seen on the record of the limb volume, but in the case of the limb they are passive, that is to say, the volume of the limb increases synchronously with the rise of blood-pressure and decreases with the fall of the Traube curve; hence the curves in the limb tracing and the blood-pressure tracing are similar instead of opposite, as is the case with the kidney or spleen. In other words, the rhythmical alterations in the volume of the vessels of the kidney or spleen are concerned in the production of the Traube curves, whereas the limb vessels do not take this active share in producing the Traube curves, but are, on the other hand, passively distended and contracted by the rhythmical oscillations of the general blood-pressure. The limb vessels during asphyxia are affected somewhat similarly to the brain vessels as described by Roy and Sherrington[1], but there is no evidence in the case of the limbs that the expansion observed is an active one, on the contrary, it is purely passive, as shewn by the fact that if the effect of asphyxia be observed after section of both splanchnics the limb volume diminishes, since under these circumstances the rise of blood-pressure is very small and is not sufficient to overcome the constriction of the limb vessels.

Asphyxia brings us to the same conclusion as the results of reflex excitation, viz. that the vessels of the limbs are affected similarly to those of the viscera but not to the same extent, and hence the limb constriction is overpowered by the high blood-pressure produced by the visceral constriction. Occasionally and more especially if the general rise of blood-pressure during asphyxia is but slight, the volume of the limbs undergoes scarcely any change until the final fall in arterial pressure during the last stage of asphyxia, when, as stated above, the

[1] This *Journal*, Vol. xi. p. 91, 1890.

limb volume diminishes greatly. In these cases the result is easily accounted for by supposing that the rise of blood-pressure does not overpower the local constriction to the same extent as in the more usual cases when the limbs expand. If artificial respiration be again supplied during the final stage of asphyxia when the blood-pressure is rapidly falling, it is well known that the blood-pressure rises rapidly to even a greater height than any to which it had attained during the asphyxia, and synchronously with this great rise of blood-pressure the limbs undergo a great expansion; the advent of oxygen causes the heart to beat with increased vigour, and the visceral vessels being strongly contracted by the asphyxia there is for a few seconds a very high blood-pressure, and it is interesting to observe that here again the limb vessels are overpowered and passively dilated. No such dilatation of the kidney is seen during the great rise of blood-pressure produced by advent of air after asphyxia, the kidney remains strongly contracted at the very moment that the limbs are undergoing the passive expansion just described. Soon the kidney and no doubt all the viscera expand slowly and simultaneously, the blood-pressure falls gradually to its former height and the limbs contract again. These experiments shew the antagonism between the visceral and limb vessels, but this is not an active antagonism in which the visceral vessels are actively contracted and the limb vessels actively dilated, but one in which the visceral vessels are actively constricted, and the great rise of blood-pressure so produced distends the limb vessels passively notwithstanding that they are actively constricted. This effect may be due simply to the fact that the visceral vascular area is so much larger than the limb vascular area, but it may also be due to the fact that the limb vessels are not so freely supplied with vaso-constrictor fibres as the visceral vessels.

V. Conclusion.

The main conclusions may be summarized as follows:

I. The limb vessels like those of the kidney derive their vaso-motor nerves from a very extended area of the cord, far more extended than previous researches would have led one to expect[1]. This area is the same as that supplying the vessels of the viscera, and may be

[1] Since writing the above, a paper by Langley has appeared in which a table occurs (this *Journal*, Vol. xv. p. 227) shewing the areas of the cord from which vaso-motor nerves are given off to be very extensive.

shortly described as that part of the spinal cord extending from the cervical plexus to the lumbar plexus, although more accurately from the 2nd dorsal to the 3rd lumbar nerves.

II. Whatever antagonism there is between the visceral vessels on the one hand, and the limb vessels on the other, it is not one of an active physiological character but is rather dependent upon the vessels of the limbs being influenced passively by the great changes produced in the aortic blood-pressure by the prepotent visceral effects; the local effects in the limbs being overwhelmed by these aortic results.

EXPLANATION OF PLATE I.

In all the experiments dogs were used and they were anæsthetized with chloroform and morphia, then curarized. The vagi were divided and the limb or limbs placed in the plethysmograph and the latter connected to the tambour.

Fig. 1. Carotid B.-P. and volume of fore-limb.

A. Effect of excitation of the peripheral end of the 3rd dorsal nerve.

B. Effect of excitation of the peripheral end of the 4th dorsal nerve.

Fig. 2. Carotid B.-P. and volume of fore-limb.

A. Excitation of the 5th dorsal.

B. Excitation of the 6th dorsal.

Fig. 3. Carotid B.-P. volume of fore-limb and hind-limb; effects of excitation of the 9th, 10th, 11th and 12th dorsal nerves.

The 9th and 10th produce diminution in volume of fore-limb.

The 11th produces slight diminution in volume in both fore- and hind-limbs. The 12th marked diminution in hind-limb and passive expansion of fore-limb.

Fig. 4. Effect of excitation of 13th dorsal on hind-limb and on fore-limb.

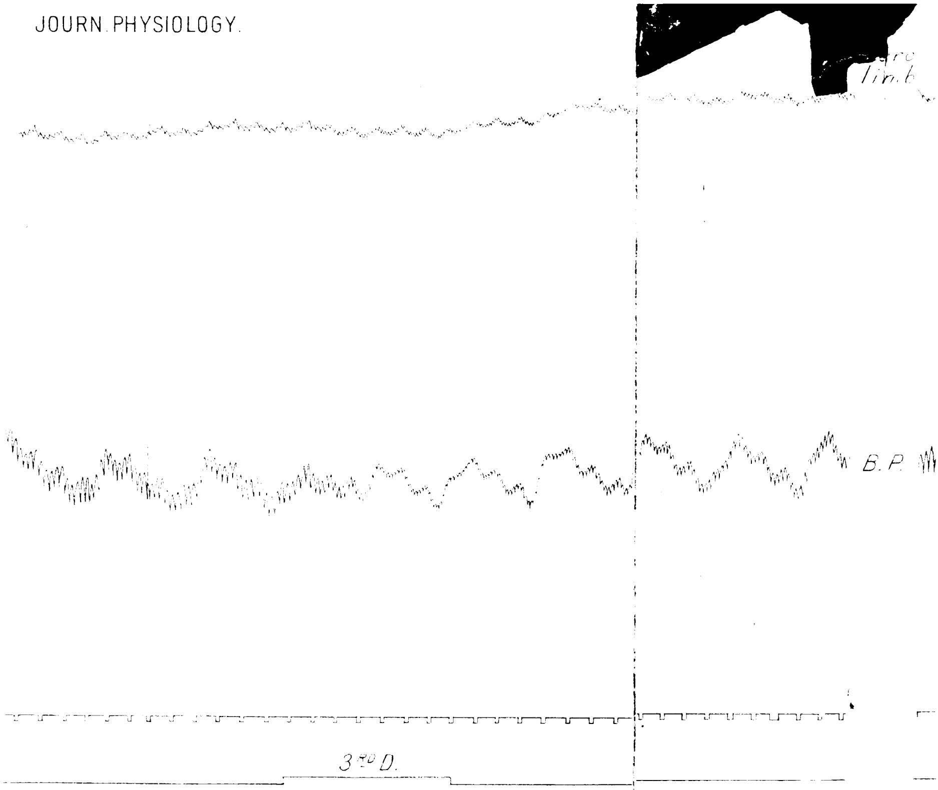


Fig. 1 A.

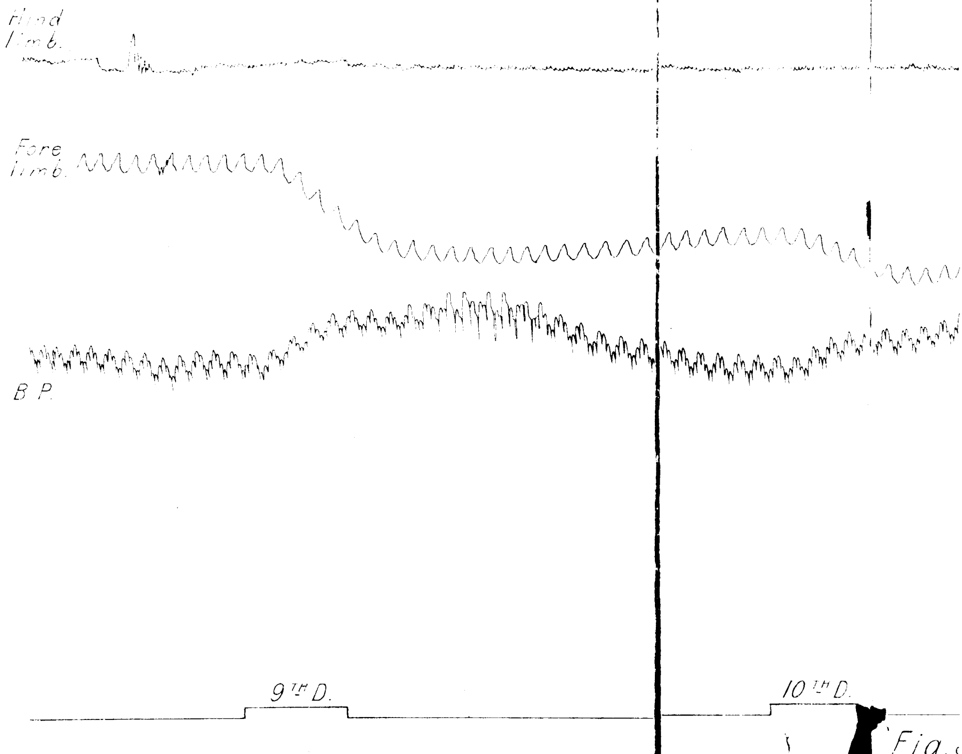


Fig.

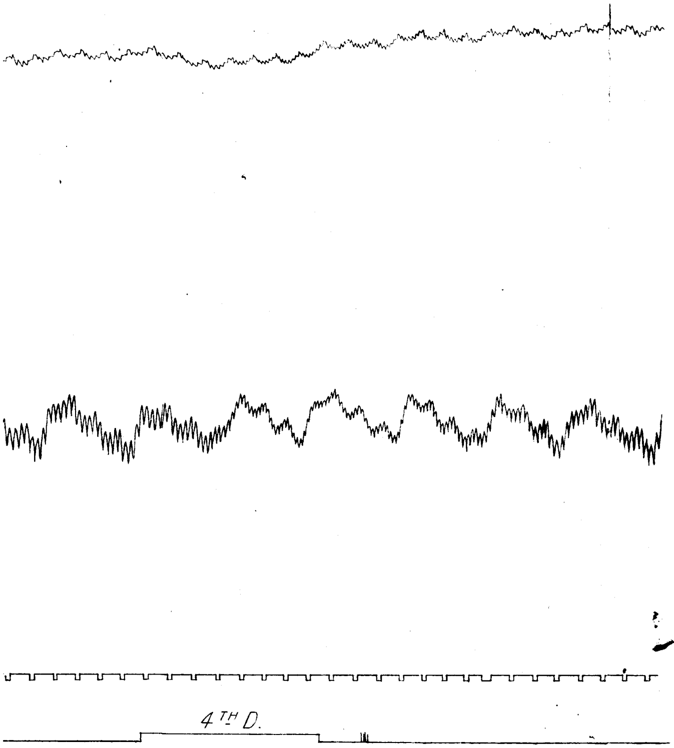


Fig. 1 B.

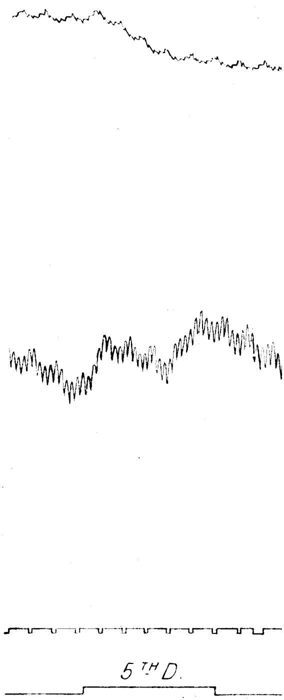
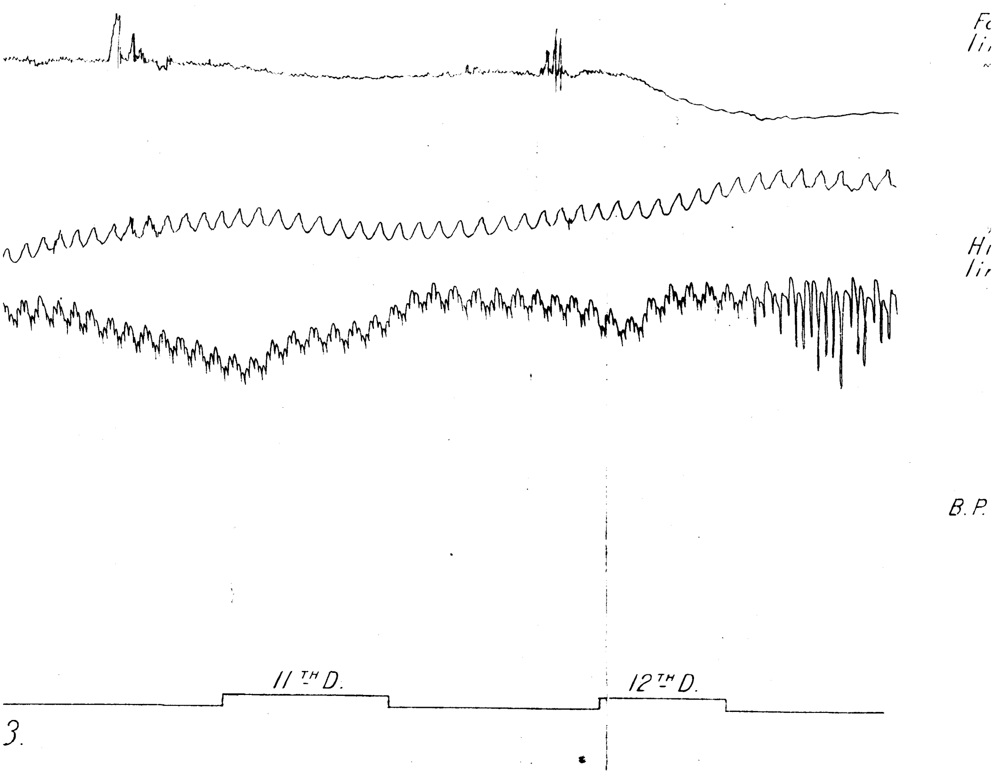


Fig. 2 A.



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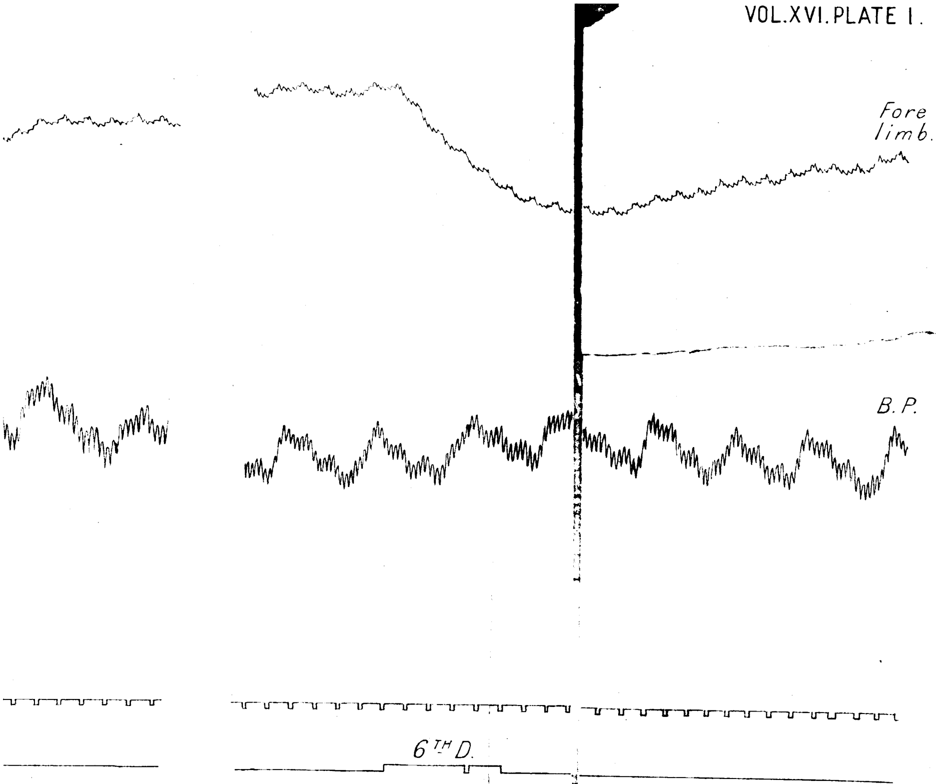

Fig. 2 B.

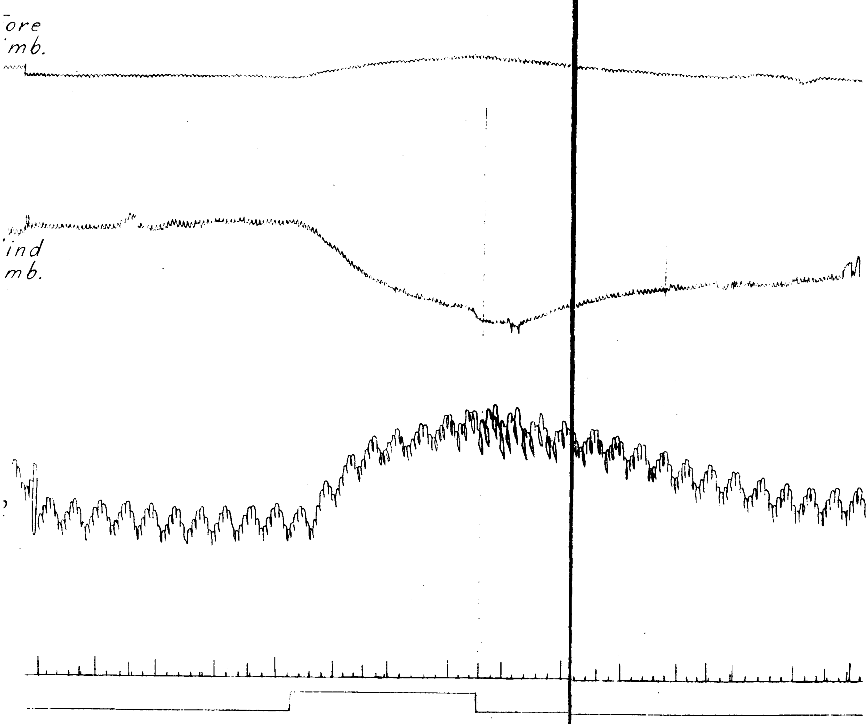

Fig. 4.

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