	Dextrin.	Sugar.
Fluid to which bile salts had been added as well as pancreatin.....	0·30 gram.	1·315 gram.
Fluid to which pancreatin only was added.....	0·24168 ,,	1·042245 ,,

The addition of bile salts therefore had increased the production of sugar in the proportion 5 : 4, and that of dextrin in like proportion.

Experiment E.—This experiment was conducted with the same proportion of each ingredient and in the same manner, with the exception that the fluids were dialysed in a stream of (tap) water; the total residue, after evaporation and treatment with absolute alcohol in the manner previously described, was estimated by drying and weighing. The residue in the fluid containing bile salts weighed 0·314 gram, in the fluid to which pancreatin alone was added, it weighed 0·517 gram. These residues contained starch and a trace of peptone, but no bile salts nor sugar.

Our *conclusions* may thus be briefly stated:—The effect of fresh and dried bile in hastening the pancreatic digestion of starch in the pig is due to the bile salts; these salts possess the power of increasing the amount not only of dextrin, but of sugar estimated as dextrose.

The authors are not at present in a position to explain this influence of bile salts; the pancreatic solution of starch proceeds more rapidly at first in laboratory experiments, and the retardation after a short interval is very marked. It is possible that the bile salts may favour its continuance by entering into combination with the bodies which have this retarding effect.

II. "The Innervation of the Renal Blood-vessels." By J. Rose Bradford, M.B., D.Sc., George Henry Lewes Student. Communicated by E. A. Schäfer, F.R.S. (from the Physiological Laboratory of University College, London). Received February 1, 1889.

The following work was undertaken in order to map out the origin, course, and nature of the renal nerves more accurately than had hitherto been attempted. It was considered (more especially in the light of Gaskell's well-known work on the sympathetic) important to decide whether the renal and other abdominal vascular nerves were of two kinds, *i.e.*, vaso-constrictor and vaso-dilator, or whether the latter nerves could not be demonstrated to exist. This research was carried out exclusively on the dog, inasmuch as this was the animal used by Gaskell in his work.

The principal conclusions arrived at in this communication will be arranged under the following three headings :—

I. *The Origin and Course of the Vaso-constrictor Nerves.*

II. *The Origin and Course of the Vaso-dilator Nerves.*

III. *The Reflex Phenomena of the Renal Vessels.*

It will be necessary, however, to describe shortly the method employed. The general blood pressure and the volume of the kidney as measured by Roy's oncometer were recorded simultaneously, together with a time tracing and a lever marking the moment and duration of the nerve excitation. In this manner both the general and the local effects of any given stimulation were determined simultaneously. The method of preparation of the nerves was as follows: the roots of the nerves were exposed inside the spinal canal, the posterior roots were then divided inside the dura mater, and the entire nerve outside the dura mater arranged for stimulation with suitable electrodes. In some cases the nerves were cut and ligatured and the distal ends excited. By the use of one or other of these methods, the danger of the exciting current spreading to the cord, and so producing reflex effects, was reduced to a minimum. In many experiments this danger was further eliminated by dividing the cord above the level of the nerves excited.

In this communication a nomenclature is adopted which assumes that the dog has twenty dorso-lumbar vertebræ, of which thirteen are dorsal and seven lumbar. For excitation an ordinary Du Bois coil was used with Helmholtz's modification, and the rate of interruption was varied, as will be mentioned more fully below from fifty per second to one per second.

The anæsthetics used were chloroform and morphia, and after the completion of the necessary operative procedure, the animals were curarised, artificial respiration and anæsthetisation being maintained in the usual manner.

It is well known that, when either the renal nerves or the splanchnic nerves are excited, a contraction of the kidney accompanied by a rise of blood pressure is observed. On exciting the lower dorsal nerves inside the spinal canal the same general facts are observed, provided the posterior roots have been divided and care be taken to prevent the spreading of the exciting current to the cord. Before entering into further detail it is necessary to state that in order to get these effects the rate of excitation must not be slower than five per second. Hence, unless otherwise mentioned, it is to be understood that the rate of stimulation was a rapid one, *i.e.*, fifty per second.

I. *Origin and Course of the Vaso-constrictor Nerves.*

No effects have been observed to follow the excitation of the peripheral end of a divided posterior root. Furthermore, the same

result is seen to follow the stimulation of the divided anterior root, and the stimulation of the entire nerve outside the dura mater after previous section of the posterior root. Hence we may conclude that no efferent vasomotor fibres are contained in the posterior roots.

Excitation of the anterior roots, or of the entire nerve after previous division of the posterior root, is followed by contraction of the kidney and rise of general blood pressure when any nerve from the 6th dorsal to the 2nd lumbar is placed on the electrodes. Excitation of the higher nerves, *e.g.*, the 4th or 5th dorsal, produces but slight effects on the general blood pressure, and in the higher ones still, *i.e.*, the 2nd or 3rd, the accelerator fibres are met with in abundance, and hence a small rise of pressure (due to this cardiac effect) is produced. On the other hand, the 3rd lumbar has in many cases yielded no result on excitation, but occasionally a slight rise of general blood pressure has been observed. So that the 6th dorsal and the 2nd lumbar are practically the limits of the series of nerves, the stimulation of which causes any marked effects either on the kidney or on the general arterial tension.

The effects, however, are not equally marked with all these nerves. The lower dorsal nerves, *i.e.*, from the 10th to the 13th, produce much greater effects, both on the kidney and on the general blood pressure, than either the nerves above them or those immediately below them. So that although all the nerves from the 6th dorsal to the 2nd lumbar may contain fibres for the renal vessels, still their main supply is derived from the 10th, 11th, 12th, and 13th dorsal nerves.

It follows from the above description that there is no very great separation between the paths followed by the nerves for the kidney vessels and those destined for the vessels of the other abdominal viscera. However, the lower dorsal not only produce greater effects on the kidney and on the general blood pressure than the upper dorsal nerves, but what is more important the two effects do not vary directly with one another. Although usually a nerve producing a large renal contraction causes simultaneously a great rise of pressure, yet this is by no means invariably the case, and a small renal contraction may be accompanied by a great rise of pressure and *vice versâ*. The 12th and 13th dorsal nerves, for instance, cause usually a great renal contraction, but the accompanying rise of blood pressure is not so high s with some of the nerves above them. Hence we must conclude that in individual cases there may be small variations in the number of fibres going on the one hand to the kidney and on the other hand to the other abdominal viscera.

The contraction of the kidney occurs after a short latent period, and in a typical case it is sudden, marked, and very persistent, often lasting long after the excitation has ceased. The kidney then commences slowly to expand and along with this expansion the blood

pressure falls to its normal height. Generally the kidney does not quite regain its former volume, in other words, its vessels remain slightly contracted as a more or less permanent after-effect. This effect is so small that it is not accompanied by any appreciable rise of blood pressure. In some cases after the excitation has ceased, the blood pressure falls slowly but slightly below its previous height and then slowly regains its normal level. That is to say, the sudden and great rise of arterial tension is followed by slight, slow, and gradual fall. This fall of blood pressure is accompanied by a slight contraction of the kidney, the volume of the latter following exactly the fall and subsequent rise of blood pressure. This result is only occasionally seen when quick rates of excitation are used, but it becomes more frequent when such a rate as five per second is employed.

It has been seen with most of the nerves, but it is more common with the upper than with the lower dorsal. Its full significance will be alluded to later, but this result is no doubt due to the excitation of vaso-dilator fibres, the kidney effect being a passive one due to changes of blood pressure produced in other organs.

In a very small proportion of cases a rise of blood pressure is produced as usual, but the kidney effect is a mixed one, *i.e.*, there is first a slight expansion then a marked contraction. In a still smaller number of cases a renal expansion has been observed, generally accompanied by a slight rise of the general blood pressure, but occasionally no such rise has occurred. When the kidney expansion is accompanied by a rise of general arterial tension, it is no doubt due to the kidney vessels being passively dilated owing to active contraction having taken place elsewhere. When, however, the expansion of the kidney is unaccompanied by any rise of pressure, it is difficult to avoid the conclusion that it is due to the excitation of actual vaso-dilator fibres; however, better evidence than this will be adduced in support of the existence of these nerves.

II. *The Existence and Course of the Vaso-dilator Fibres.*

Hitherto no definite evidence has been adduced in support of the existence of vaso-dilators for the vessels of the kidney. If, however, the 11th, 12th, or 13th dorsal nerves be excited by slow rhythmical shocks, *i.e.*, one per second, it will be found that expansion of the kidney occurs unaccompanied by any rise of blood pressure. This renal expansion is marked in character and rather persistent in its duration, that is to say, the organ does not return completely to its original volume after the cessation of the excitation. It is clear that the renal expansion is an active one, since the nerve stimulation has produced no obvious effect on the blood pressure. This striking result is not so easily obtained with the higher nerves; with these the same excitation produces a fall of blood pressure, accompanied

not by any expansion, but by a passive contraction of the kidney vessels. In other words, with these higher nerves a dilatation is produced, not only of the kidney vessels, but also of the vessels of a much larger area, and hence the renal dilatation is unable to manifest itself.

This view is confirmed by the results obtained on excitation of the splanchnic nerve. When this nerve is stimulated with quick rates, the kidney, as is well known, undergoes great contraction, and there is at the same time a large rise in the general blood pressure. With slow rhythmical stimulation, however, I have never succeeded in getting any renal expansion. This slow stimulation, however, causes a large fall in the blood pressure, accompanied by a marked renal contraction. This renal contraction is obviously passive, since it not only exactly follows the fall of blood pressure, but, when the exciting current is shut off, the blood pressure undergoes a sudden and temporary rise, and this rise is accompanied by a correspondingly transitory renal expansion. In other words, the dilatation is one produced in a large area, and the kidney vessels are affected secondarily. Hence just as the renal constrictor fibres are best marked in the 11th, 12th, and 13th dorsal nerves, so the same is true for the dilator. These, however, like the constrictors, probably exist in the higher nerves, but for the reasons given it is almost impossible to demonstrate their existence positively, as they run with the dilator fibres for the vessels of the other abdominal viscera.

Excitation of the peripheral end of the divided vagus in the neck causes of course marked contraction of the kidney, owing to its inhibitory action on the heart, which action is not obviated by the doses of curare employed. After small doses of atropine the stimulation of the cervical vagus has no effect on the volume of the kidney. Stimulation of the vagus in the thorax, *i.e.*, beyond the point where it gives off its cardiac fibres, has also no effect on the volume of the kidney. Thus we may conclude that there is no evidence to show that the vagus supplies any fibres to the renal vessels.

III. *The Reflex Phenomena of the Renal Vessels.*

Excitation of the central end of the divided *sciatic* causes, as shown by Roy, a contraction of the kidney accompanied by a rise of blood pressure. This result I can confirm, as it occurs in by far the greater number of cases. Occasionally, however, this nerve causes a slight expansion of the kidney, but this is not only very small in amount, but it is also very rare. Sometimes, as is well known, the central end of the sciatic causes a fall of blood pressure, and when this occurs it is accompanied by a renal contraction. The central end of a divided *intercostal nerve* causes a slight rise of blood pressure, accompanied by a small contraction of the kidney vessels.

The central end of the divided *vagus* in the rabbit causes a contraction of the kidney, accompanied of course by a rise of blood pressure. In the dog this is also by far the most common result. In the cat, however, and occasionally in the dog, the excitation of this nerve causes a depressor effect, *i.e.*, a fall of blood pressure, and with this fall a passive shrinking of the kidney. The central end of the *depressor* in the rabbit or of the vagus in the cat causes, as just mentioned, a great fall of blood pressure, accompanied by a passive contraction of the kidney. Although the blood pressure fall is always a large one, the effect on the kidney volume is but slight. Here again this effect is probably simply the result of the great dilatation of the other abdominal vessels, neutralising, so to say, the renal dilatation, and so causing an actual diminution in the volume of the kidney. In a few cases in the rabbit, where the blood pressure fall has not been very great, an initial slight expansion of the kidney has been detected.

The stimulation of the central end of a divided *posterior root* produces in almost all cases a great rise of general blood pressure. This rise is not only large in amount, but it is very sudden, and also of rather short duration. The pressure remains at the maximum height but a few seconds, and when the excitation is over falls towards its normal height; there is, however, generally a persistent after-effect, that is to say, the pressure remains a little higher than it was previously to the stimulation. There is no very material difference between the results obtained with the lower dorsal nerves and those seen with the upper ones, in both cases a large rise of pressure is obtained; on the whole, however, the reflex rise seen with the lower nerves is somewhat greater than that obtained with the upper nerves. As a rule the rise of pressure is accompanied by a contraction of the kidney, marked in amount, but not of such a persistent character as that described above as following the excitation of the peripheral end of an anterior root. Frequently the kidney effect is a mixed one, *i.e.*, a contraction followed by an expansion; not uncommonly, however, there is an initial expansion, the subsequent course of which is interrupted by a contraction. More frequently still no contraction of the kidney is seen, it is replaced by a pure expansion, accompanied as before, however, by a great rise of blood pressure. This effect, however, is most often obtained with the lower dorsal nerves, *e.g.*, the 10th to the 13th. Sometimes when the stimulation of a posterior root gives the renal expansion and rise of blood pressure, the application of the electrodes to the posterior surface of the cord gives an equal rise of blood pressure, accompanied, however, by contraction of the kidney. Hence the former effect, *i.e.*, the renal expansion, is the result of a more local excitation. When the reflex excitation causes expansion of the kidney there is profuse hæmorrhage from the spinal wound. Now this hæmorrhage

is not altogether to be explained as resulting simply from the heightened blood pressure, since an equal rise, produced say by the sciatic and accompanied by contraction of the renal vessels, is not followed by this profuse hæmorrhage. Hence it is probable that not only is there a dilatation of the kidney vessels, but also of the vessels in the lumbar region of the body wall, hence the hæmorrhage.

Rarely excitation of a posterior root causes a depressor effect, there being a great fall of blood pressure, and then as usual the kidney undergoes a passive contraction, owing to the large dilatation elsewhere.

The results of reflex excitation can then be summed up shortly by saying that the excitation of an afferent nerve causing a rise of blood pressure is accompanied by a renal contraction, unless the nerve is one of what may be called the renal area. In this case the rise of blood pressure is accompanied as a rule by either a renal expansion or else by a mixed kidney effect. If the afferent nerve causes a depressor effect due to dilatation of the abdominal vessels, the kidney vessels probably share in that dilatation, but this is not seen by any actual renal expansion owing to this being overpowered by the dilatation elsewhere, and hence the kidney undergoes a passive shrinking.

The other conclusions of this paper are that the renal constrictor fibres leave the cord through the anterior roots of the nerves extending from the 6th dorsal to the 2nd lumbar inclusive.

That, secondly, there are vaso-dilator fibres, as can easily be demonstrated with such nerves as the 11th or 12th dorsal, but that in all probability they also extend from the 6th dorsal to the 2nd lumbar, and for the reasons given above they cannot be demonstrated with certainty in the upper nerves, since here they run with the vaso-dilator fibres for the vessels of the other abdominal viscera.

Hence there is no evidence to show that the vaso-constrictor fibres and the vaso-dilator fibres reach the kidney by different routes.

Finally, the great splanchnic nerve contains not only vaso-constrictor, but also vaso-dilator fibres, for the vessels of the abdominal viscera.

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