SOME POINTS IN THE PHYSIOLOGY OF GLAND NERVES.

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In previous communications[1] it has been shown that excitation of the nerves of the salivary glands is accompanied by electrical changes which are opposite in sign, according as to whether the nerve excited contained in greater abundance so-called secretory or trophic fibres. The electrical change following the stimulation of the former fibres consists of a positive variation of the current of rest, whereas a negative variation is seen on stimulation of the so-called trophic fibres of Heidenhain. It was further shown that the former effect was closely connected with the flow of liquid through the gland cells and ducts, and that the latter effect was similarly related in all probability to the elaboration of the organic constituents of the saliva. These results were obtained from a comparison of the effects in different glands, i.e. the submaxillary and parotid glands of the cat and dog, under different conditions. From certain apparently anomalous results, as, for instance, the occasional free secretion of parotid saliva on sympathetic secretion, it was felt that the difficult question of the nature of gland nerves was one that required further investigation.

The present paper details the result of work which was of the nature of an attempt in this direction. This question of the nature of gland nerves is intimately connected with the vexed question of the origin of the paralytic secretion, and hence some experiments were carried out on the effects following the division of the gland nerves. The effects of section of the chorda, sympathetic etc. were observed on thirty cats and dogs, and in all cases full antiseptic precautions were taken to ensure healing by first intention. In the experiments detailed below on the results of nerve stimulation, the gland was, in the great majority of

[1] Bayliss and Bradford, *Internat. Monatsschrift. für Anat. u. Physiologie*, 1887. Bradford, This *Journal*, vol. VIII. p. 86.

cases, examined from the electrical standpoint as well as from the secretory. In the later experiments, observations were only made on the secretion, but these were only a small proportion of the total number of cases. The electrical method was used, because, thanks to it, changes were detected which otherwise would have passed unnoticed. The actual method of experimentation was as follows: the animal was anaesthetized with chloroform and then from $\frac{1}{5}$ to $\frac{1}{3}$ of a grain of acetate of morphia injected hypodermically. A cannula was placed in the trachea and the cervical sympathetic exposed, ligatured and divided. A cannula was then inserted into Wharton's or Stenson's duct, the chorda tympani or the tympanic plexus was then exposed, in the former case the conjoined tympanico-lingual was always divided centrally to the point where the chorda was actually stimulated. The flow of saliva was registered in the following manner: a glass tube of even bore (size 2·5 mm.) was fitted with an ebonite piston, which worked in the tube easily but accurately. To the piston rod a light lever was attached at right angles, and this lever was arranged to write on the recording surface horizontally below two chronographs. One of these recorded the moment and duration of the excitation, whilst the second marked two second intervals.

This piston recorder was connected to the cannula in the duct by a short piece of india-rubber tube, hence any flow of saliva was registered by a movement of the piston, recorded on the moving drum, as a curve. The piston recorder was fitted with a T piece, by means of which the saliva could be run out when the tube became filled. In some cases the percentage of solids in the saliva was determined for me by my friend Dr Halliburton to whom my best thanks are due. The electrical changes were frequently observed simultaneously with the record of the actual secretion, and the gland was led off in the manner described in former communications. By the above method a graphic record was obtained of the actual amount of secretion, also the rate at which the fluid was secreted, as well as the latent period of the secretion, and further the accompanying electrical changes were observed. No doubt, the method employed is open to objection with regard to the measurement of the latent period, since a more or less variable interval must elapse between the actual commencement of the secretion and the first movement of the piston recorder. Inasmuch however as the instrument used was a delicate one and the latent period is long, the error is in all probability a small one, and it is further diminished in importance from the fact, that the same recorder was used in all the experiments. Fre-

quently curare was not used, as even when the electrical phenomena were investigated it is quite possible by careful arrangement of the exciting and leading off electrodes to avoid any error due to muscular twitchings etc. In those cases where no electrical observations were made, curare was of course unnecessary. In many cases, it was found that the morphia alone (after the preliminary anaesthetization with chloroform) was quite sufficient to render the animal completely unconscious, no further administration of chloroform being necessary. It is important to mention this, as by this means a considerable source of error due to variations in the amount of anaesthetic was eliminated.

We will now pass on to the consideration of the results obtained.

I. *Excitation of the chorda of the dog by single induction shocks.*

As shown in previous communications, excitation of the chorda in the usual manner, i.e. rapid shocks, is accompanied by a large electrical effect, showing the surface of the gland to have become negative to the hilus. Occasionally a small second phase is seen and this is particularly to be observed when the above large first phase has been abolished by a small dose of atropin, e.g. 5 mgrms.

Single induction shocks do not so far as I have seen produce any very obvious secretion, although it is probable that there is really some, only it is too small in amount to be readily detected. A single induction shock of moderate intensity produces, however, an electrical effect in the gland, thus showing the advantage of this double method of investigation. The electrical change is a diphasic one and the actual difference of potential produced is quite small. The galvanometer (Thompson High Resistance) gives a deflection of some ten to fifty scale divisions, the hilus of the gland becoming first positive and then negative to the gland surface. If the strength of the excitation be diminished, it will be found that the electrical variation then becomes a single one, the hilus becoming positive to the surface. It will, however, not unfrequently be found, that the first two or three excitations of the nerve produce no effect, the succeeding stimulation giving the typical diphasic result described above. If the strength of the induction shock be now increased so that it cannot be borne on the tongue, the variation will still be diphasic, but the second phase will now be distinctly the larger. In some cases and more especially if the shocks be repeated slowly one after the other, the second phase may become very large indeed. That

is to say, there is a kind of summation of the effect, but of such a character, that only the second phase is observed on the galvanometer. These facts are illustrated by the following experiment. In this case four shocks, two make and two break, were thrown into the chorda, at intervals of about one second.

Weak	−10, −12, −8, −10.
Moderate	−12, +50.
Strong	−20, +250.

It must however be understood that, although a single strong shock would also have given a diphasic variation with the second phase the larger, yet it would not have been as much as 250 scale divisions, unless the shocks had been repeated.

II. *Stimulation of the chorda of the dog by slow rhythmical shocks.*

A great number of observations were made as to the effects of slowly repeated excitations. By slow rates is meant any rate up to, but not exceeding, five excitations per second. Stimulation of the chorda by such rates as these, causes a large electrical effect showing the hilus to become negative to the surface, that is to say, the opposite phase to that usually seen on chorda excitation. Frequently the deflection amounts to between two and three hundred scale divisions, and sometimes the spot of light has actually gone off the scale. As a rule this rate of excitation causes no obvious secretion, or at the most an extremely minute quantity less than a drop. If the rate of excitation be now increased to twenty shocks per second, the gland will yield a free secretion and an electrical effect of opposite sign. In a very few instances a rate of five shocks per second has caused a slight secretion, and in these cases the electrical effect observed has been a diphasic one, the large second phase described above being preceded by a first phase of variable amount. Even in these exceptional cases, however, a further diminution in the rate of stimulation will cause the disappearance of the first phase and the accompanying secretion, so that here also slow rates of stimulation produce opposite effects to quick rates. Similarly slightly more rapid rates of excitation, i.e. 10 per second, will generally yield a diphasic variation, but not at all unfrequently the transition from the second phase produced by slow rates, to the first phase produced by quick rates (i.e. 20 per second), is quite sudden, intermediate rates not producing always a diphasic variation.

Thus we see that by different rates of excitation, we can get one and the same nerve, i.e. the chorda of the dog, to yield either a pure second, or a pure first phase, a free secretion accompanying the latter, but not the former. In other words, were it not for the electrical disturbance, we might conclude that slow rates were not capable of acting as a stimulus to the fibres of the chorda.

The excitation of the sympathetic of the dog with these slow rates, i.e. five per second, also causes a large electrical variation consisting of a second phase. It is however only under exceptional circumstances that the sympathetic can be made to yield a first phase with quick rates, still if this nerve is yielding a diphasic variation, by slow rates a second phase only can be obtained.

III. *Stimulation of the chorda of the dog by subminimal but rapid excitation.*

Very frequently, although not always, excitation of the chorda by a stimulus just too weak to cause an obvious flow of saliva, causes the same electrical variation as that described above as resulting from slow rates of stimulation; that is to say a pure second phase, often large, e.g. 300 galvanometer scale divisions.

It is certainly remarkable what a different effect can be produced by slight alterations in the strength of the current employed. In all the observations on subminimal stimulation, the rate of the shocks was 50 per second. Under these circumstances it was often found, that moving the secondary coil one centimetre from the primary, was sufficient to cause the first phase seen with the stronger stimulus to become replaced by a second phase with the weaker stimulus. However, in certain cases where the chorda was very excitable and the gland very active, I have failed in getting any second phase with these subminimal stimuli, but this is decidedly exceptional. It is to be remarked that the transition is always a sudden one, the stronger stimulus producing a fair if not copious secretion, and the weaker one causing no obvious secretion, and what is perhaps more important no first phase. This is a much more delicate test of the actual presence of secretion than the mere inspection of the cannula in the duct, since, as shown in previous communications, a secretion never occurs without being accompanied by this phase of the electrical variation.

IV. *Stimulation of the chorda of the dog by rapidly interrupted shocks of moderate strength.*

It is needless here to describe the effects following this, the usual mode of excitation, and the only point of any importance with regard to the present paper is that the electrical variation under these circumstances consists of a large first phase (hilus + to surface) and that after this has been abolished by a small dose of atropin a small second phase is seen, which is subsequently abolished by a further dose of atropin.

V. *Beneficial effect of previous stimulation of the chorda.*

It will often be found that, at the beginning of an experiment, a rather strong stimulus is necessary in order to produce an at all copious secretion of saliva and a correspondingly well-marked electrical variation.

Dog. Chloroform. Then morphia. Interrupter 50 per second.

Time	Nerve	Saliva (Amount of)	Electrical Variation	Stimulus Strength	Stimulus Duration
12.25	Chorda	2 drops	– 200	60 mm.	14″
12.28	,,	3 to 4 ,,	– 400	80 ,,	7″
12.32	,,	3 to 4 ,,	– 300	100 ,,	12″
12.35	,,	5 ,,	– 400	120 ,,	12″
12.42	,,	6 ,,	– off scale	140 ,,	13″
12.45	,,	4 to 5 ,,	– 400	160 ,,	10″
12.48	,,	4 to 5 ,,	– 400	180 ,,	14″
12.50	,,	4 to 5 ,,	– 400	200 ,,	15″
12.55	,,	5 ,,	– 300	220 ,,	15″
12.58	,,	3 to 4 ,,	– 150	240 ,,	14″
1 P.M.	,,	3 to 4 ,,	– 150	250 ,,	18″
1.3	,,	1 to 2 ,,	– 60	260 ,,	18″
1.10	,,	6 ,,	– off scale	100 ,,	10″

In the above table the sign – signifies that during excitation the surface of the gland became negative to the hilus.

Now under these circumstances it will be found, that although a given strength of current fails to produce any secretion, yet if this same stimulus be thrown into the nerve three or four times in succession it will ultimately cause a very obvious if not copious secretion. Further, it will now be possible to greatly diminish the strength of the exciting stimulus, without in any way diminishing the amount of the actual secretion produced.

It might at first sight be urged that all these effects are due to variations in the amount of anaesthetic, but, as mentioned before, in these experiments morphia was the agent used and hence this disturbing element of variations in the amount of chloroform, etc. was removed.

This experiment is however an extreme case; in no other instance, as far as I have observed, has it been possible to so greatly diminish the strength of the stimulating current and yet obtain so copious a secretion. But in almost every experiment it is possible to diminish considerably the strength of the current without diminishing the amount of secretion obtained, and further a stimulus at first subminimal becomes after a few repetitions an effectual one.

Very frequently not only has a stimulus early in an experiment failed to produce any obvious secretion, but it has also given only a very small electrical effect, which has subsequently become much larger in amount with the same excitation, and has then been accompanied by a perceptible amount of saliva. This investigation of the gland both galvanometrically and by observing the amount of secretion is of great value as the one method serves as a check on the other. It might be urged that the duct was not full at the commencement of the observation, or that it became kinked etc., but that this is not the case is shown by the fact, that a corresponding increase in the amount of the galvanometric deflection is to be observed *pari passu* with the increase in the physiological activity of the gland. The significance of this beneficial effect of excitation will be discussed more fully below.

Before passing on to the consideration of the sympathetic there is another curious point which is sometimes to be observed, both in the normal gland, and in a gland the nerves of which have been divided some days previously. Occasionally, during the stimulation of the chorda no secretion is observed, and either there is no electrical effect or a small second phase only is observed; when however the stimulating current is shut off one or even two drops of saliva appear and a small first phase is seen. The latter may amount to as much as 100 galvanometer scale divisions, but is much more often only half this in amount.

What the circumstances are which lead to this effect being obtained is not clear. It is certainly more often to be detected in a gland where the chorda has been divided some three or four days previously, but on several occasions I have seen the same thing in a perfectly normal gland.

It will be convenient to summarize here the principal results arrived at by the above methods of excitation, all the facts being understood to refer to the chorda tympani of the dog.

1. Single induction shocks produce a diphasic variation and no obvious secretion.
2. Slowly interrupted shocks and quickly interrupted shocks of subminimal intensity produce a large second phase and no obvious secretion.
3. Stimulation of the chorda has a beneficial effect on the physiological activity of the gland, even when this stimulation is unaccompanied by any actual secretion.

Although it is possible, as has been shown above, to produce by certain stimulation of the chorda an effect resembling more or less the usual effects seen on sympathetic stimulation, it is not possible to so excite the sympathetic as to get from this nerve a chorda-like effect, unless the latter nerve be previously excited as will be mentioned more fully below.

Slow rates of excitation applied to the sympathetic produce the same results as quick rates, that is to say a pure second phase. Of course as mentioned in former communications the sympathetic sometimes yields a diphasic variation, more especially when the secretion is a little more abundant than usual. In these cases, the slow rates of excitation have caused only a second phase, but it has not been found possible, by any method of excitation used, to increase the amount of the first or water phase. This is of course in marked contrast to what obtains for the chorda.

In the case of the sympathetic as in the case of the chorda the occasional secretion described above as occurring at the moment of shutting off the exciting current is to be observed, and in fact it was with this nerve that this result was first seen.

On Heidenhain's hypothesis of gland nerves we can explain most of the above facts by supposing that the so-called secretory fibres respond only to quick rates of excitation, and the so-called trophic fibres to both slow and quick rates, since according to the well-known hypothesis of this distinguished observer, the chorda contains both

secretory and trophic fibres, whereas the sympathetic consists of almost pure trophic fibres only. It seems to me however that this hypothesis is inadequate to explain the marked improvement in the physiological condition of the gland after previous excitation of the chorda. This question however opens up the subject of anabolic nerve fibres and hence it will be more convenient to discuss it below.

We will now pass on to the question, as to whether the stimulation of one nerve previously to the other modifies in any way the results obtained on subsequent stimulation of the second nerve, and first of all we will consider whether previous stimulation of the chorda modifies the sympathetic effects.

In a previous communication[1], instances were cited where the sympathetic of the dog yielded a copious secretion of submaxillary saliva, and as was then pointed out this apparently abnormal result was observed only after prolonged stimulation at intervals of the chorda. Since then I have on several occasions got this result, but I have not yet succeeded in being able to get it in every instance. Although in no case has this copious flow of sympathetic saliva been observed without previous stimulation of the chorda, yet frequently however after such stimulation of the chorda it has not been possible to obtain any abundant secretion on excitation of the sympathetic.

This occasional flow of sympathetic saliva is also to be obtained from the parotid after previous excitation of the tympanic plexus and this fact Mr Langley[2] has recently confirmed. There are two points about this flow of sympathetic saliva which are of some importance. In the first place it is at times exceedingly abundant, even exceeding the amount obtained by stimulation of the cerebral nerve, and secondly it occurs only after a long latent period. As mentioned in the previous paper as much as fifteen or even twenty drops have been obtained from the submaxillary gland with a strength of stimulus that usually would only cause a secretion of some two drops. Langley's results with the parotid do not quite correspond with mine, since he has observed a secretion always to follow sympathetic excitation, provided the tympanic plexus be stimulated immediately before the electrodes are applied to the sympathetic. In both the submaxillary and the parotid I have been unable always to obtain this copious sympathetic secretion, even after prolonged excitation of the cerebral nerve. Further, according to Langley in the case of the parotid, the latent period of the secretion

[1] This *Journal*, Vol. VIII. p. 93.

[2] Langley, *Proc. Phys. Soc.* Feb. 1888.

is not remarkably long, nor is the actual amount of saliva great. In my own observations and more especially in the case of the submaxillary the great length of the latent period, i.e. several seconds, was very striking. In several instances the length of the latent period was such that at first one might have thought that the stimulus was not going to produce any effect, then suddenly the gland would begin to secrete copiously. Now although in different cases the actual amount of this abnormal sympathetic saliva varies, yet I would expressly state that sometimes it is extraordinarily copious, and this seems to be a point of some importance with regard to its causation. Of course the observation of this occasional sympathetic secretion is not entirely new, as Heidenhain and other observers mention incidentally its presence, but apparently they did not lay much stress on its significance. When this flow of saliva occurs, there is of course an electrical variation of opposite sign to that usually seen on sympathetic stimulation. The latent period of this secretion is so long that frequently during it the usual second phase is seen, and then suddenly the galvanometer indicates a large positive variation, or first phase, accompanied by the secretion. Hence here again by the electrical method we have a means of testing more delicately the gland changes, and it will be found that, even in those cases where previous stimulation of the chorda has apparently not modified the effects of subsequent sympathetic excitation, by observing the electrical phenomena we shall detect some change although perhaps only a slight one. That is to say, in those cases where the sympathetic has been yielding a diphasic variation, previous chorda excitation will cause the first phase to be increased on subsequent sympathetic stimulation. Further when only a second phase is being observed, as a result of sympathetic stimulation, this variation can be rendered diphasic (i.e. preceded by a first phase) by previous chorda stimulation. Hence it may be concluded, that previous stimulation, especially if repeated, of the cerebral nerve tends to cause on subsequent sympathetic excitation a more abundant and watery secretion than usual, and this can be demonstrated not only by inspection of the flow of saliva, but also by observing simultaneously the electrical phenomena, remembering that a first phase indicates a flow of liquid.

We will now pass on to the converse question as to whether previous stimulation of the sympathetic modifies the character of the saliva obtained on subsequent excitation of the cerebral nerve. As is well known, Heidenhain determined that in the parotid at any rate previous stimulation of the sympathetic caused the saliva obtained

on subsequent stimulation of the cerebral nerve to contain a higher percentage of organic matters; this fact he explained on his well-known hypothesis.

There is however another effect produced, since the saliva obtained on stimulation of the cerebral nerve is not only more highly charged with organic material, but it is also distinctly less abundant. This fact refers more especially to the submaxillary gland; as yet the truth of it as regards the parotid has not been tested. As regards the submaxillary, however, previous stimulation of the sympathetic distinctly tends to diminish the amount of secretion obtainable on subsequent chorda excitation as is seen from the following extract from the notes of an experiment.

Dog. Chloroform and Morphia. Coil 20 shocks per second.

Nerve	Time	Electrical variation	Coil	Saliva
Chorda	5.11	− 100	80 mm.	4 to 5 drops
Sympathetic	5.12	+ 50	,,	nil
,,	5.14	+ 40	,,	nil
Chorda	5.15	+ 50	,,	1 drop
,,	5.16	− 100	,,	3 drops
Sympathetic	5.17	+ 50	,,	nil
Chorda	5.19	− 30	,,	1 drop
,,	5.20	− 70	,,	1 to 2 drops

In this case earlier in the afternoon the chorda had been yielding a copious secretion, this had diminished, but at 5.11 as is seen it was again pretty free. Stimulation of the sympathetic markedly diminished the amount of saliva obtainable on chorda excitation, this nerve however yielded more saliva on a second stimulation probably owing to the beneficial effect resulting from the first excitation. From the consideration of this, and several other similar experiments, it seems to me probable that in the dog at any rate previous stimulation of the sympathetic not only causes the subsequent chorda saliva to be more viscid, but it also causes it to be secreted in diminished quantity. This observation probably has some connection with the fact, noted by several observers, that simultaneous stimulation of both gland nerves in the dog

at any rate tends to diminish the amount of secretion obtainable or even to arrest it. This observation however is only true for the dog, since Langley showed that in the cat simultaneous excitation of the chorda and sympathetic did not tend to diminish the amount of secretion obtained, since as a matter of fact the amount obtained was at least equal to the sum of the amounts following separate stimulation of each nerve. If we accept the view that, in the dog at any rate, simultaneous excitation of both gland nerves tends to diminish the effects of the separate stimulation of the cerebral nerve, the results described above are due to a kind of after effect, following sympathetic irritation, which has a similar antagonistic effect on the secretion producible by subsequent stimulation of the cerebral nerve.

We must then conclude, that just as previous stimulation of the cerebral nerve tends to cause a watery secretion to follow sympathetic stimulation, so previous stimulation of the sympathetic tends to make the saliva, obtained on subsequent excitation of the cerebral nerve, less abundant. Langley[1] has explained the parotid secretion seen by him on sympathetic excitation (after previous stimulation of the tympanic plexus), as a result of the vascular dilatation produced by the cerebral nerve improving the physiological activity of the gland structures, that is to say, he holds that the sympathetic of the dog normally contains so-called secretory fibres for the parotid, but that these are usually unable to act owing to the vascular constriction produced by the nerve excitation. If we accept this vascular explanation for these facts we may similarly reason that the constriction produced on sympathetic stimulation so affects the gland structures that subsequently the secretory fibres of the chorda are unable to effect their usual result. No doubt this hypothesis is perfectly able to explain some of the facts observed, but I am loth to believe that a nerve previously giving some two drops of viscid saliva can, owing simply to a persistence of a vascular dilatation, produce some fifteen or twenty drops. Further this explanation quite fails to account for what in most cases is one of the most remarkable points about this sympathetic secretion, i.e. its long latent period. Again, if the sympathetic of the dog normally contains secretory fibres for the submaxillary in such abundance as to produce the amount of secretion mentioned above and yet unable to manifest their presence owing to the vascular constriction produced, stimulation of the sympathetic after its previous section ought to produce similar results to these following its excitation after previous stimulation of the cerebral nerve.

[1] *Proc. Phys. Soc.* Feb. 1888.

In both cases a vascular dilatation is produced, but I am not aware that an increased watery secretion is seen on sympathetic stimulation after its previous section; to get this result previous excitation of the cerebral nerve seems essential. Again it is to be observed that the antagonistic effects of simultaneous excitation of both gland nerves are only observed in the dog not in the cat. Now there is, as far as is known, no difference in the physiology of these nerves in the two animals as regards their vaso-motor fibres, but with regard to their glandular nerve fibres there are as is equally well known great differences. In the one case we find the two nerves more or less antagonistic, in the other case we do not, so that this effect at any rate can scarcely be due to vaso-motorial phenomena.

It might be urged that the vascular dilatation produced by section of the cervical sympathetic is not comparable to that following the stimulation of the vaso-dilators of the chorda, but even granting that the latter effect is the greater, the former ought to produce some effect, although possibly only small in amount, and this effect, even if small, would be detected by the galvanometric method used, but as mentioned above no difference has been detected. Again, Langley considers that the vascular dilatation produced by the cerebral nerve improves the condition of the gland structures, by the production of a kind of local apnoea, i.e. the gland receives a better supply of oxygen, and it is this that enables the secretory fibres of the sympathetic to manifest their presence. Apnoea, as far as I have observed, is by no means a favourable condition for the production of a copious secretion; on the contrary I have often found when working with curarized animals anaesthetized with morphia that when the artificial respiration apparatus was being driven at a greater speed than normal, a diminished amount of secretion was obtained on chorda excitation, and that this was markedly increased when the respiration was effected at a slower rate. This result is not due to differences in the amount of anaesthetic, since morphia was used, as it is quite possible to thoroughly anaesthetize with this drug provided chloroform be used at first. That is to say, chloroform is first given and subsequently to this a hypodermic injection of morphia. It is quite possible by this means to have an animal so thoroughly narcotized that no further administration of chloroform is necessary.

Langley himself has shown that apnoea tends to abolish and dyspnoea to increase the amount of the paralytic secretion, and this secretion according to him is due to an increased activity of certain peripheral nerve cells. Now accepting this view of the nature and origin

of the paralytic secretion, these peripheral nerve cells form a sort of mechanism placing the nerve fibres in connection with the gland cells, and inasmuch as they are affected in the manner described above with regard to the paralytic secretion, it seems scarcely probable that apnoea should have two exactly opposite actions in the two cases. That is to say, that apnoea should on the one hand inhibit the secretory impulses generating the paralytic secretion, and on the other hand enable the supposed secretory fibres for the parotid in the sympathetic to act.

In the next place it seems that the more we know of secretion the less do we find it dependent on vascular phenomena. A free secretion can be obtained from a gland nerve that causes a vascular dilatation, and an equally free secretion can be obtained from another gland nerve causing a vascular constriction. It is true that the example of the first case is found in the dog, and of the second in the cat, and that there may be some difference in the cells, etc. of the cat's submaxillary to what obtains in the dog. But this is really the main point at issue, that is to say that really the secretion is independent of the vascular changes and is due to differences in the gland cells, or in the gland nerve-cells. Hence this occasional sympathetic saliva seen after previous stimulation of the cerebral nerve and the diminished cerebral secretion seen after sympathetic irritation, are not due to local vascular changes, but are probably due to changes in the gland cells or gland nerve-cells produced by the antecedent stimulation of the other nerve. That is to say, that just as in the cat's salivary glands there is something different to what obtains in the same glands of the dog, so that a copious secretion is obtained in the one case with vascular constriction and in the other with vascular dilatation, so in the dog an analogous condition can be temporarily produced in the gland structures by previous stimulation of the cerebral nerve. No doubt the view of Langley's that this occasional sympathetic secretion is due simply to a persistence of a vascular effect is by far the simpler, but as discussed above it seems to me that such a view is untenable and that therefore we must seek elsewhere for an explanation of this abnormal secretion.

Before however going into this point further, it will be more convenient (having established the proposition, that the amount and character of the secretion following the stimulation of a gland nerve can be modified by an antecedent excitation of the other gland nerve), to pass on to some points connected with the paralytic secretion and the effects following the section of the nerves of the submaxillary and parotid glands of the dog and cat.

It is of course well known that section of the gland nerves of the submaxillary is followed by the appearance of this curiously slow and continuous secretion. Bernard, by whom this secretion was discovered, considered its cause to be the actual degeneration of the nerve-fibres. This observer also showed that section of the chorda alone was sufficient to produce this secretion. Heidenhain however found that the paralytic secretion began long before the nerve fibres were degenerated, and he was inclined to attribute the secretion to some effect produced on the gland cells by the stagnant saliva.

Langley, however, who has re-investigated the question of the origin of this secretion in the submaxillary of the cat, has propounded a third hypothesis, which would assign to the nerve cells in the gland the rôle of being the chief agents in the production of this secretion. He considers the activity of these peripheral nerve cells to be increased by the section of the chorda, so that they are stimulated to pour forth a constant secretion by the condition of the blood circulating in the gland vessels. This view is partly based on the fact that the paralytic secretion is increased in amount by dyspnoea and diminished by apnoea. This observer also thinks that the activity of a central secretory centre is increased by the nerve section for two reasons. In the first place, the paralytic secretion is diminished in amount during the first few days of its presence by section of the sympathetic. Secondly, section of the chorda as shown by Heidenhain not only produces a paralytic secretion on the same side, but a slight continuous secretion is also found on the opposite side, the so-called antilytic secretion. Both these effects are however quite temporary when compared with the paralytic secretion. Langley[1] also showed that, after section of the chorda in the cat, excitation of the duct close to hilus produced a copious flow of saliva as long as thirteen days after the division of the nerve. He also found that stimulation of the superior cervical ganglion nineteen days after division of the cervical sympathetic still produced a free secretion. This last fact was based on one experiment and was considered by him to show that nerve fibres for the gland entered the superior as well as the inferior cervical ganglion. Gaskell[2] has however since demonstrated that the superior cervical ganglion does not receive any white rami, at any rate in the dog. Hence this result of Langley's is rather to be explained by stating that the nerve fibres degenerate up to, but not beyond, this ganglion after division of the nerve in the neck.

[1] This *Journal*, Vol. VI. p. 71.
[2] This *Journal*, Vol. VII.

These being the results hitherto obtained, experiments were first made on the cervical sympathetic, since Langley had only divided this nerve once. In three cats the cervical sympathetic was exposed as low down in the neck as possible, and then divided. Full antiseptic precautions were always taken, and the wounds all healed by the first intention. This is a point of considerable importance, for it is not at all improbable that carelessness in this respect may lead to fallacious results. As will be mentioned below, any irritation at the seat of the wound will lead reflexly to a secretion of saliva that is liable to be confused with the paralytic secretion. Hence, it is to be understood that all the results described below were obtained in animals where the wounds healed without any suppuration, and in the two or three cases where the antiseptic failed the animals were immediately killed and the results of the operation not accepted. In the case of the division of the sympathetic in the three cats mentioned above, the results of the nerve section were examined three, five and six days after the operation respectively. A cannula was placed in Wharton's duct, and the divided sympathetic arranged for excitation. It was found that even three days after the operation, stimulation of the sympathetic failed to produce any secretion whatever, although the application of the electrodes to the superior cervical ganglion immediately called forth an abundant secretion. Hence, three days after section, the fibres of the cervical sympathetic going to the submaxillary gland are completely degenerated, as tested physiologically, from the point of section up to the superior cervical ganglion. This fact is in marked contrast to what obtains for the chorda; where, as mentioned above, the nerve yields a copious secretion on stimulation for as long as thirteen days after division.

In none of the cases in which the cervical sympathetic was divided was any paralytic secretion observed, and what is more important in cases where the animal was kept alive for as long as six weeks after the operation, there was no atrophy of the submaxillary gland to be detected. If the chorda had been the nerve divided instead of the sympathetic the gland would in this time have lost from one-third to one-half in weight. Even six weeks after the division of the cervical sympathetic, the branches from the superior cervical ganglion to the gland are not degenerated and yield a free secretion on stimulation.

Division of the cervical sympathetic having failed to produce effects at all analogous to those observed after division of the chorda, the next experiments were made on the superior cervical ganglion. This ganglion was extirpated in a number of cats with antiseptic precautions

as before, and in all cases except one the wound healed perfectly and by the first intention, this one exceptional case was, however, of considerable interest, and further reference will be made to it below. In removing the ganglion the vagus was divided as well, otherwise it is difficult to ensure complete extirpation. The piece removed was always carefully examined, and in some cases sections were made of it, in order to be quite certain that the whole ganglion had been removed. The animal was also carefully examined post mortem in order to further verify the results. In this way there were only two failures, in one a small portion of the ganglion was not removed, and in the other (to which reference was made above) the wound suppurated, and the animal died of pyaemia.

After extirpation of the superior cervical ganglion no paralytic secretion was observed, and no atrophy of the submaxillary gland followed. As a matter of fact the gland on the operated side was slightly heavier than the one on the other side. In one case forty-six days after the removal of the ganglion on the right side, the right gland was found to weigh 1·3 grms. and the left gland 1·1 grms. This difference in weight in favour of the gland on the operated side may be due to some accidental causes, but it has been observed in every instance and I am inclined to think that the removal of the ganglion is followed by some slight increase in the size of the corresponding gland. If it should be established that the submaxillary or other gland increases in size after removal of the superior cervical ganglion, it would be a point of some interest with regard to the differences existing between the chorda and sympathetic nerves. However this may be, the important point is that in cats ablation of the superior cervical ganglion is not followed by any atrophy of the submaxillary gland, nor is there any paralytic secretion, and this is true even if the gland be examined after as long an interval as seven weeks after the operation.

After removal of the ganglion excitation of the sympathetic filaments on the gland artery fails to produce any secretion, showing that the nerve fibres are degenerated at least right up to the gland.

In the case mentioned above, where the wound made in removing the ganglion suppurated, the operation was followed by a copious secretion, the saliva constantly dripping from the animal's mouth during the six days following the operation. I think that in this case there can be but little doubt that the dribbling of saliva was really a reflex effect due to the irritation produced in the wound. It also seems not unlikely that the so-called antilytic secretion is also produced reflexly owing to

irritation. A point in favour of this view of its origin is the fact that it is transitory in its duration.

In all the cases in which the ganglion was extirpated, there was of course well-marked contraction of the pupil and paralysis of the nictitating membrane. Both these effects are much more marked after removal of the ganglion than after division of the cervical sympathetic. Further, on the side on which the ganglion had been removed there was a great deal more lachrymation than on the sound side; in fact there was a continuous and copious secretion of tears. These effects were all observed for as long as seven weeks after the operation, no animal having been kept alive for a longer period than that.

In the light of Gaskell's researches, it is perhaps not to be expected that section of the cervical sympathetic should cause any marked effects, since in all probability the great majority of the cut fibres do not degenerate beyond the ganglion. Still if the gland were normally constantly receiving impulses from the central nervous system through the sympathetic, the section of this nerve would probably produce some change in the gland. Hence, since extirpation of the superior cervical ganglion fails to produce any change in the gland of an atrophic nature, we may conclude that in the cat no impulses normally pass down the sympathetic of such a nature that their removal causes an atrophy of the gland. Further, inasmuch as no paralytic secretion is caused by either the removal of the ganglion or by the division of the cervical sympathetic, it is clear that the section of this nerve does not lead to any increase in the excitability of either the central secretory centre or of the peripheral nerve cells in the gland itself.

We will now turn to some of the effects following the division of the chorda. As mentioned above, it is well known, that section of this nerve is followed very shortly, i.e. within twenty-four hours, by the appearance of the paralytic secretion and *pari passu* with this secretion the gland diminishes in size. It is interesting to note that this atrophy is very rapid in its onset and in its cause, so that it is readily appreciable within a few days, and in a fortnight or three weeks, the gland has diminished by quite a third of its bulk as estimated by its size and weight. One of the most interesting facts brought out by Langley was that after division of the chorda, the excitation of the duct near the hilus caused a secretion as long as thirteen days after the section. This delayed degeneration is in marked contrast to what obtains for ordinary motor nerves, and also for the nerves reaching the gland through the sympathetic. The first question that arose was whether or not the observed secretion was due

to any escape of the exciting current to the sympathetic filaments on the gland artery. To eliminate this source of error, experiments were made as follows: the superior cervical ganglion was removed and the tympanico-lingual nerve divided on the same side. The results were tested at intervals varying from three to eleven days in different cases. In all these cases, it was found that stimulation of the duct still caused a free secretion, notwithstanding the fact that excitation of the gland artery, i.e. of the sympathetic on this vessel, failed to do so. Hence the sympathetic filaments were completely degenerated at a time when the chorda fibres were still capable of responding to a moderate stimulus.

From these observations it is clear that in the cat the chorda does not degenerate rapidly after section like most nerves. There are, however, as is well known many nerve cells scattered along the course of this nerve, in addition to the submaxillary ganglion. There is however some difference of opinion as to the exact relations of this ganglion to those fibres of the chorda that are distributed to the submaxillary gland. This arises from the fact that in the dog a large proportion of the chorda fibres apparently passes over the ganglion, without becoming connected with the nerve cells. It is probable however that there are differences in the anatomical relations of the submaxillary ganglion in the animals since the division of the chorda in the two cases is not followed by the same results. In the dog, as will be described more fully below, there is not that great delay in degeneration that is seen in the cat.

In order to investigate further the nature of the action of the submaxillary ganglion in the cat, the following experiments were made. In the first place the tympanico-lingual nerve was divided as high up as possible, i.e. at the border of the internal pterygoid muscle, so that a clear length of three-quarters of an inch of nerve intervened between the point of division and the submaxillary ganglion. A second set of observations was made on the effects of extirpation of the submaxillary ganglion. The results of this latter procedure, however, were not so satisfactory as those following the former.

If the tympanico-lingual has been divided high up and this nerve is then excited from three to six days after its division, it will be found that no secretion follows the stimulus, as long as this is applied to the tympanico-lingual. If, however, the electrodes are applied to the chorda just where it leaves the lingual, or anywhere between this point and the hilus of the gland, a copious secretion is obtained, in fact just as much as if the nerve had not been previously divided. Hence, section

of the chorda in this part of its course is followed by degeneration of the distal end as far as the position of this ganglion, but not beyond it, and this degeneration is so far advanced at the end of three days that excitation of the nerve is then without effect. It is probable then, that the nerve cells of the ganglion and also those scattered along the nerve exert a trophic influence on the fibres of the chorda hence delaying their degeneration after section. In order to further test this view the second set of observations on the results following extirpation of the ganglion were made, these results, although confirmatory of the view just mentioned, were not completely satisfactory. The extirpation of the submaxillary ganglion was performed in the following manner: the tympanico-lingual was divided, and then the triangular area of tissue bounded by the lingual nerve, the chorda, and Wharton's duct was dissected up and removed after careful cleaning of the duct. In this manner it was possible to ensure the removal of the ganglion. As regards the effect of this operation on the lingual nerve, no difference could be detected between the results following it and those occurring after simple division of the lingual above the submaxillary ganglion. As a result of both operations sores are found on the border of the tongue in the anterior two thirds of its extent. Although in different cases the amount of injury to the tongue varied considerably, yet in no case could any difference be detected between those animals in which the nerve had been cut above the ganglion, and those in which the ganglion had been removed as well. As mentioned above, the results of extirpation of the submaxillary ganglion on the fibres of the chorda distributed to the gland were not found to be quite constant. This is no doubt due firstly to the difficulty of the operation, and secondly to the fact that nerve cells are found scattered along the nerve for some distance, so that it is probable that there are considerable anatomical differences in different cases. In two cases, examined three and six days respectively after the extirpation, excitation of the chorda even right down to the hilus failed to produce any secretion, although the sympathetic yielded a copious flow as usual with the same stimulus. In one case, however, the nerve not only gave a copious secretion when stimulated close to the gland four days after the operation, but the cut end next the ganglion also yielded a free secretion. That is to say, the nerve was not degenerated in any part of its course, although as far as could be determined the entire nerve had been cut. The fibres of the chorda do not always reach the gland in one compact bundle, a series of loops sometimes existing. It is then possible that in this case the

whole nerve had not been divided, but I am inclined to believe from a careful examination of the part at the time, that this was not the case and that really the nerve had been completely divided. Again in other cases the following facts were observed: some days after section it would be found that stimulation of the nerve yielded no effect up to a certain point on the duct. Immediately however the electrodes were placed on the gland side of this point, a free secretion was obtained. Just as if in fact the nerve had not been divided some days previously.

It seems probable then that the nerve cells scattered along the chorda and those of the submaxillary ganglion must exercise a trophic action on the fibres of the chorda going to the submaxillary gland. It is probable that the action of the nerve cells of the ganglion is supplemented by that of the nerve cells scattered along the course of the nerve, and this may be the explanation of the differences mentioned above. This trophic action of the nerve cells is shown by the delay in degeneration of the chorda fibres, and it is interesting to note that it is only a delay and not a complete prevention of degeneration. Thus in one case Langley found the chorda completely degenerated forty-two days after section. This is in marked contrast to what obtains for the sympathetic, since stimulation of the superior cervical ganglion seven weeks after division of the cervical sympathetic still causes a copious flow. Whether this result is due to some difference in the action of the nerve cells in the two cases, or whether it is due to only some of the chorda fibres being connected with these nerve cells, the fact remains that their action tends rather to delay than actually to prevent the degeneration of the nerve fibres. Further, in all the cases where a secretion was obtained on excitation of the chorda after its division, some three to six days previously, it was noticed that the saliva obtained was markedly less viscid than normal, although obtained with quite weak stimuli. Langley also noticed this in one of his experiments, so that the result may be due to the trophic fibres degenerating more rapidly than the secretory; before this could be settled, however, more observations would be required.

Two observations were made on the effects following intracranial section of the seventh nerve in the cat. The operation was performed as follows: a vertical incision was made behind the mastoid process, and the occipital bone exposed, this was then trephined in such a place as to avoid the lateral sinus, i.e. the trephine was applied below the position of this. The cranial cavity being opened the hole in the bone was enlarged with bone forceps in a direction downwards and

outwards towards the petrous of the temporal line. The dura mater was then opened and the nerve raised on a hook as it entered the internal auditory meatus. In order not to make any mistake it was excited previously to division, and then cut with scissors, the cerebellum being gently held aside. The wounds remained perfectly aseptic as full antiseptic precautions were observed. It was found that three and four days respectively after division of this nerve at the internal auditory meatus, stimulation of the tympanico-lingual produced as abundant a secretion as ever. Vulpian[1] had previously shown that stimulation of the seventh intracranially caused a secretion of submaxillary saliva. We may then probably conclude from these facts that by intracranial section of the seventh, the chorda fibres are really divided, and that they do not reach the facial via the large superficial petrosal. Inasmuch as the distal part of the nerve is not degenerated four days after such intracranial section, the geniculate ganglion probably has also a trophic action on the fibres of the chorda. It is possible however that the chorda may receive an accession of fibres from the tympanic plexus which would account for the secretion observed on stimulation after previous intracranial section of the seventh. It is of course to be understood that in these two cases the auditory nerve was also divided, and hence section of the pars intermedia, which in all probability contains the chorda fibres, was ensured.

Before discussing the results of these observations it will be more convenient to describe the results of a similar set of experiments carried out on the nerves of the parotid both in the cat and dog.

VI. *Effects of removal of the superior cervical ganglion on the parotid of the cat.*

In two cats the superior cervical ganglion was removed on the right side in the usual way and the wounds having healed up by the first intention, the cats were killed thirty-four and twenty-eight days respectively after the operation. In both cases there was not only no atrophy, but the parotid gland on the operated side seemed distinctly the larger of the two. This result tallies with what was described above with regard to the effects of the same operation on the submaxillary glands. It will be remembered that in the cat the sympathetic

[1] *Comptes Rendus*, Tome 101, p. 851.

contains so-called secretory fibres for the parotid, since the excitation of the nerve is followed by a free secretion of parotid saliva.

Having thus determined that the results of division of the sympathetic were similar in the case of the parotid to those described for the submaxillary, the next observations were made on the results of destruction of the tympanic plexus.

VII. *Effects of the destruction of the tympanic plexus in the dog.*

These observations were made on the dog, since owing to the larger size of the parts in this animal, it is easier to perform the operation than it is in the cat. Various methods of destroying the plexus were used. The tympanic bulla was exposed in the usual manner by turning aside the digastric muscle, it was then trephined and the opening enlarged with bone forceps. The interior of the tympanum was then scraped out with a small Volkmann's sharp spoon and then the cavity was scrubbed out with a solution of chloride of zinc of the strength of forty grains to the ounce. This, as is well known from surgical practice, destroys everything it comes into contact with, but it does not penetrate to any considerable depth, so that by its use there is no danger of considerable sloughing. By this means the plexus was very effectually destroyed, but it was found that it was exceedingly difficult to manipulate the sharp spoon in such a way as to avoid injuring the membrani tympani. If this membrane were injured it is obvious that the experiment was useless as the wound would in all probability become septic and so invalidate the result. Hence, although this method was exceedingly successful in a case to be mentioned below, it was abandoned for the above reason and the following used instead. The bulla was opened in the usual way, and then by means of a capillary pipette three or four drops of *pure* carbolic acid were allowed to run into the tympanic cavity. It is very essential in destroying the plexus in this way to be sure that none of the acid comes in contact with the tissues exposed in the wound, as owing to its powerful local action there would be great danger of extensive sloughing. The wound was then scrubbed out with chloride of zinc sewn up and dressed antiseptically with salalembroth gauze and collodion. In no case did the wound fail to unite by the first intention, but in one case a very small collection of pus, not more than two or three drops, formed around one of the superficial silk stitches, but in this case the deeper parts of the wound

had perfectly united, so that this superficial pus did not vitiate the result in the least.

After destruction of the tympanic plexus, there is marked atrophy of the parotid gland, thus in two cases where the animals were killed thirty-eight and twenty days respectively after the operation, both the parotid and submaxillary glands on the operated side were found markedly diminished in size. In the case where the tympanic plexus had been destroyed thirty-eight days previously the glands had diminished by quite a third of their post mortem bulk.

In both cases stimulation of the sympathetic failed to cause any secretion of parotid saliva, and in both cases it was found on post mortem examination that the contents of the bulla had been very thoroughly destroyed. In these cases not only was the tympanic plexus destroyed, but the carbolic acid had also destroyed the chorda as was shown by the atrophy of the submaxillary gland. This result is not I think to be explained by supposing the chorda to receive fibres from the tympanic plexus but rather as the effect of the carbolic acid directly on the chorda itself.

In two other cases the results of the operation were examined five and seven days respectively after the destruction of the tympanic plexus. In both cases an obvious paralytic secretion of submaxillary saliva was present, but no paralytic secretion of parotid saliva was observed, although it is quite possible that this was present but obscured by the morphia used to anaesthetize the animal. In neither case did excitation of the contents of the bulla cause any secretion of saliva. Stimulation of the cervical sympathetic failed to produce any secretion of parotid saliva although it caused a fairly free flow of submaxillary saliva, i.e. three to four drops. As mentioned above the destruction of the plexus involved that of the chorda as well, as was shown by the presence of the paralytic secretion of submaxillary saliva, and the effects following the destruction of this nerve in the dog were not found to be quite the same as those occurring in the cat. This point was well illustrated in the two cases just mentioned.

In the dog in which the plexus had been divided seven days previously, stimulation of the chorda, even close to the hilus of the submaxillary gland with strong currents, failed to cause any but the very scantiest secretion. In the other case where the plexus had been destroyed but five days previously, the strongest current applied quite close to the hilus caused generally no effect and at the most one small drop of secretion after the excitation had ceased. It is important to

note that in both cases excitation of the sympathetic caused a free flow of saliva, i.e. three or four drops. Thus the absence of secretion on chorda excitation was not due to any effect of the anaesthetic on the gland, but was due to actual degeneration of the nerve fibres. This degeneration of the chorda as early as five days after its previous destruction, is in marked contrast to what obtains for the cat, and hence the following experiment was made to investigate this matter further. In a dog, the right submaxillary ganglion was removed and the chorda divided on the same side. On the left side the tympanico-lingual was divided above the ganglion and the condition of the nerves examined on the seventh day. On both sides even strong stimulation of the nerve close to the hilus failed to cause any abundant secretion. On the right side one drop and rarely two were observed after the excitation had ceased. On the left side rather more was obtained but not anything at all comparable to what would have been obtained in a cat under the same circumstances. It is curious that this difference in the rate of degeneration of the same nerve in two such closely allied animals should exist, and it is another instance of differences that would scarcely be expected to be found in the physiology of the same secreting structure in the two animals. Whether or not there are any marked anatomical differences in the chorda of the two animals, I do not know, but the result described above for the dog, i.e. the early degeneration of the chorda, quite corresponds with the anatomical fact that in the dog most of the fibres of the chorda pass over rather than through the submaxillary ganglion. Hence in all probability most of the chorda fibres are not connected with the nerve cells of this ganglion, and hence the nerve degenerates rapidly after its section. In the cat, on the other hand, there are many nerve cells scattered along the course of the nerv. and here after section the nerve degenerates slowly. The period at which a nerve fibre loses its excitability after section is differently stated by different observers. Bowditch[1], however, in some recent experiments on vaso-motor nerves found that five days was the outside limit, that is to say that on the fifth day the excitation of the nerve failed to produce any effect whatever. On the other hand although the third day was the earliest period at which the degeneration of the nerve could be detected histologically, yet on the second, the excitation of the nerve would give evidence of degenerative change. In my own experiments on the sympathetic of the cat I found that three days after section excitation of the nerve failed to cause either any secretion, or any

[1] This *Journal*, Vol. VII. p. 416.

galvanometric deflection. This also holds good for the chorda when the nerve is cut above the submaxillary ganglion and tested physiologically as far as the point at which it leaves the lingual. In both the cat and dog the chorda degenerates rapidly down to this point, after its division higher up, i.e. either at the edge of the internal pterygoid muscle or in the tympanum. It is only when the nerve is divided distally to the point where it leaves the lingual, that variations are to be detected in the duration of the period elapsing between the section and the loss of excitability. It is precisely at this point of divergence from the lingual, that the chorda ceases to be a nerve in the strict sense of the word, since nerve cells are here scattered along its course. Having thus detailed the observations that have been made we will now conclude by summing up the main results arrived at.

In the first place, it is seen that it is only by the destruction of the *cerebral* nerve that a paralytic secretion, accompanied by an atrophy of the gland substance, is produced. This is true for all the salivary glands both in the cat and dog. This paralytic secretion may from Langley's experiments be considered to owe its existence to a heightened activity of a peripheral mechanism situated in the gland itself. This mechanism consists probably of the numerous nerve cells that are found in the gland.

The atrophy of the gland following the section of the cerebral nerve has been shown by Langley to be associated in the submaxillary of the cat at any rate with a diminution in the protoplasmic part of the gland cells. The question that requires to be answered is, How comes it that the activity of this peripheral centre becomes so increased after the section of the cerebral nerve? The division of such a nerve as the chorda, connected as it must be with this peripheral mechanism, may affect this mechanism in one of two ways. Either the section produces a more or less irritant effect, i.e. produces an impulse, or else it effects the removal of impulses that were previously passing down the nerve. Inasmuch as both the cerebral and the so-called sympathetic fibres must be connected to the peripheral gland mechanism, if the paralytic secretion owed its origin simply to the irritative effects of the nerve section, one would expect atrophy to follow destruction of the sympathetic fibres. This however is not the case, either for the submaxillary or the parotid gland.

Hence we may conclude that the section acts not by the generation, of new impulses, but by cutting off impulses normally reaching the glands through their cerebral nerves. Lastly inasmuch as the chorda, tympanic plexus and sympathetic of the cat contain both secretory and

trophic fibres of Heidenhain, and yet the atrophy only follows destruction of the cerebral nerve, it is clear that these impulses do not in all probability descend along these so-called secretory and trophic fibres. In other words, the chorda and tympanic plexus of the cat differ fundamentally from the sympathetic in the same animal in regard to the results of section, although the phenomena following the stimulation of the two nerves greatly resemble one another as regards the nature of the secretion obtained.

Hence, I would suggest that the chorda for the submaxillary and sublingual glands and the tympanic plexus for the parotid contains anabolic fibres distinct from the so-called secretory and atrophic fibres of Heidenhain. In the following pages the terms anabolic and katabolic are used in the sense in which they have been employed by Gaskell and worked out by him with reference to the heart. It will no doubt be urged that we cannot go on multiplying the fibres present in gland nerves in this way, but it must be remembered that in all probability some differences which physiologists recognize between nerve fibres are really differences in their peripheral connections only. Further the evidence on which the existence of distinct anabolic fibres is based is rather too strong to be ignored. Thus, as previously mentioned, repeated stimulation of the chorda at the commencement of an experiment, is frequently accompanied by a great improvement in the amount of secretion obtained. An objection to this fact being due to the excitation of anabolic fibres is that the observed result is due to differences in the anaesthetic. This objection however is untenable since in my experiments no anaesthetic but morphia was used, no chloroform being found necessary after the operation. Inasmuch as a long interval, sometimes as much as half an hour, was allowed to elapse between the actual operation and the observations described above, it is clear that the results cannot be explained on the view of variations in the amount of anaesthetic. Another point in favour of anabolic fibres is that frequently increased activity is seen after the employment of subminimal excitations where no secretion has been obtained, but where the subminimal stimulus has soon become minimal.

Secondly, section of these nerves is followed by diminution in size of the glands supplied by them and there is also a diminution in the protoplasmic portion of the gland cells. In other words after the section of these nerves katabolic changes go on leading to the production of the paralytic secretion but these are unaccompanied by any anabolic phenomena and hence the glandular atrophy.

Thirdly, during rest the protoplasmic part of the gland cells in-

creases in size, hence here we have the opposite condition to the paralytic secretion, in the latter only katabolism, in the former anabolism.

It is on these three facts that the view of the existence of anabolic fibres mainly rests. No doubt most physiologists are prepared to grant the existence of anabolic gland fibres, but they mostly tend to one of two beliefs, either that these fibres are present in both nerves, cerebral and sympathetic, or that they are probably not distinct from the so-called secretory and trophic fibres. On either of these views they would urge that the chorda and tympanic plexus only contain relatively more secretory and hence more anabolic fibres than the sympathetic. In other words the differences between the two nerves are differences of degree and not of kind.

An insuperable difficulty to this view is that ablation of the superior cervical ganglion in the cat fails to produce any atrophy whatever, either in the submaxillary or the parotid, and not only is this so but as mentioned above the glands on the operated side are actually slightly larger and heavier than those on the sound side. These facts seem also to point to the conclusion that distinct anabolic fibres exist in the cerebral nerves for all the salivary glands.

Granting then the existence of anabolic fibres in the cerebral nerve only and also granting the existence in the gland of a local secretory mechanism, we may I think get a more satisfactory explanation of the nature of the paralytic secretion. As mentioned above the evidence of a local secretory mechanism is based on Langley's work on the paralytic secretion, in which he advanced the view that this secretion was due to the nerve section causing a heightened excitability of this peripheral mechanism. We have discussed above this view and have arrived at the conclusion that the division of the chorda acts more by removing impulses normally reaching the gland than by generating fresh impulses. If now the chorda contains anabolic fibres as advanced above, it is fair to assume that normally impulses are continually reaching the gland through these fibres and so building up the gland protoplasm. On the other hand we know that impulses are not constantly reaching the gland through the secretory and trophic fibres of Heidenhain, since the gland only secretes in response to a stimulus generally of reflex origin. These secretory and trophic fibres of Heidenhain we can group together under the term katabolic, although perhaps it is not strictly accurate to class them together. We could then say that whereas impulses only occasionally go down the katabolic fibres, there are always anabolic impulses reaching the glands. Further knowing that there is a peripheral secreting mechanism in the

gland capable of manifesting its presence under certain circumstances, e.g. after section of the chorda, it is probable that normally these anabolic impulses inhibit the activity of this local mechanism. In secreting glands such as the salivary glands there is then an intrinsic mechanism thanks to which the gland protoplasm is able to manifest its special function, i.e. secretion. This mechanism is connected to the central nervous system by two sets of nerve fibres, the anabolic and the katabolic, the former are only present in the cerebral nerves the latter in both. The anabolic fibres tend to inhibit the activity of this local centre, the katabolic to increase it. On this view the paralytic secretion would be caused by the removal of these inhibitory impulses, and would be simply the manifestation of the activity of this peripheral centre normally held in check by the central nervous system. As mentioned before this peripheral mechanism is probably represented anatomically by nerve cells, since these are always found wherever a paralytic secretion has been demonstrated. If this view of the origin of the paralytic secretion is correct the secretion ought to commence soon after the division of the cerebral nerve. Heidenhain has observed this secretion as soon as four hours after division of the chorda, and this relatively long time is perhaps the strongest argument against this view of its origin. Four hours however is not so long a time for an independent activity to manifest its presence, whereas it is rather a short period for a more or less pathological increase of activity to take place in. Again granting that the paralytic secretion is due to the activity of a peripheral and presumably nervous mechanism, it seems more in accordance with recent physiology to regard this activity as something inherent in these cells, than to regard it as Langley does as due to the action of the blood on these nerve cells. Although, the fact, that conditions of the blood such as dyspnoea and apnoea increase and diminish the amount of this secretion, affords evidence of the nervous origin of the paralytic secretion, yet these facts can scarcely be adduced as proving that the secretion itself is produced by the action of the blood on the nerve cells in the gland.

Conclusions.

On the view shortly advanced above we would picture to ourselves a peripheral secreting mechanism in the gland the activity of which is normally held in check by impulses descending certain fibres of the cerebral gland nerve. These impulses are of an anabolic nature and probably descend along fibres distinct from the so-called secretory and

trophic fibres of Heidenhain. On the other hand the activity of this peripheral mechanism can be increased by impulses descending the other fibres of the chorda, these impulses being of a katabolic nature, and the nerve fibres which convey them are not restricted to the cerebral nerve but are found more or less abundantly in the sympathetic channels also.

The relations of these katabolic fibres to the peripheral mechanism must be very complex; since firstly, such a nerve as the chorda of the dog can by different methods of excitation be made to yield diametrically opposite electrical variations, and secondly not only the character but the amount of secretion obtainable on the excitation of a given nerve can be largely modified by the previous excitation of the other nerve. This last fact seems to point to the conclusion that the condition of the peripheral mechanism, at the moment at which it receives an impulse, largely modifies the result of that impulse. That is to say, that if the previous stimulation has been of such a kind as to cause a watery secretion, any subsequent stimulus tends to cause a like secretion, this effect however being transitory. Further the large amount of secretion sometimes seen under these circumstances and the great length of latent period seem to indicate that the energy of the sympathetic impulses is diverted into quite a new and unfamiliar channel. That is to say, instead of leading to the elaboration of mucin the energy of the nervous impulses causes the elimination of a large quantity of water. These facts are explicable if we assume, that the chorda and sympathetic fibres are connected to this intermediate mechanism and that the condition of this mechanism largely modifies the results of any given nerve excitation. Finally whereas the nerve cells of the superior cervical ganglion seem to maintain a permanent trophic action on the fibres of the nerve distributed to the gland, the nerve cells scattered along the chorda only delay the process of degeneration after division of the chorda. This delayed degeneration only obtains in the cat; as mentioned above the chorda of the dog degenerates rapidly after section.

In conclusion it will be well to state that the observations on which the above views have been advanced have been carried out during the last four years and that they have been very numerous. It is necessary to state this as it might be thought that the above conclusions had been rapidly drawn from the considerations of a few experiments only.

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