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THE SYMPATHETIC INNERVATION OF THE STOMACH.

I. The effect on the stomach of stimulation of the thoracic sympathetic trunk.

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THERE is in the literature considerable disagreement as to the effects of stimulation of the sympathetic system upon the movements of the stomach. Both inhibitor and augmentor effects have been described. Veach [1925] attributes the inhibitory effects to vaso-constriction, and points out that motor effects can occur if vaso-constriction be absent. McCrea and McSwiney [1928], who reviewed the literature, found that the response of the organ depended largely upon the pre-existing tonic condition, an atonic stomach responding with contraction, and an active stomach with relaxation. The present investigation was undertaken originally with a view to finding the effect of sympathetic stimulation on the stomach divided at the incisura into body and antrum. This technique was employed by McCrea and McSwiney [1926] when studying the effects of vagal stimulation.

METHOD.

Preliminary experiments showed that anæsthetics had a profound influence upon the effects of sympathetic stimulation, and that motor or inhibitor responses could be obtained according to the anæsthetic employed. The details of the effects of anæsthetics will be published later. Spinal or decerebrate cats and dogs were therefore used throughout. The rabbit, in view of its peculiar gastric structure and function, was not considered suitable.

Cats were anæsthetized with ether, tracheotomized, and the common carotids ligated. The cord was divided between the atlas and the axis, and the brain destroyed with a probe. Artificial ventilation was given by means of a Starling pump. These operations were performed as expeditiously as possible, and the animals were left at rest for half an hour to one hour to ensure removal of the anæsthetic and to allow of some recovery from shock. The blood-pressure was recorded from the right carotid artery, and registered in the majority of animals between 100 and 120 mm. Hg at the commencement of the abdominal operations. The abdomen was opened, and the stomach was divided completely at the incisura angularis. The duodenum was ligated immediately distal to the pyloric sphincter, and a wide-bore glass tube was secured by a purse-string suture in the proximal end of the pyloric antrum. The distal end of the body of the stomach was closed with a Czerny-Lembert suture, and a tube passed into it through a cervical œsophagotomy. The movements were recorded by attaching the tubes from the two portions of the stomach to manometers and filling the whole system with saline. In the majority of experiments the abdomen was held open and filled with Ringer-Locke solution. The thoracic sympathetic was exposed by removal of three to four ribs on the right or left side and dissected out to within 1 cm. of the diaphragm. The chain was cut and its distal end secured. These manipulations produced a fall of blood-pressure, but in most animals the pressure was not below 80 mm. after opening the thorax. Platinum electrodes in a vulcanite shield were used for stimulation. A calibrated induction coil with a known amperage in the primary was used, and the frequency of stimulation was varied from 1 per 2 seconds up to 65 per second by means of a metronome, the Lewis contact breaker or the vibrating hammer of the induction coil.

Dogs. Both spinal and decerebrate dogs were used. The preparation of the spinal dogs was carried out in the same way as the cats. The decerebrate dogs were prepared by trephining the skull and severing the brain stem in the region of the corpora quadrigemina. The other operative procedures were as described for cats.

All animals were deprived of food for 12 hours before the experiment.

RESULTS.

(*a*) *Cats.* Stimulation of the sympathetic chain caused either relaxation or contraction of the body of the stomach of the cat, according to the type of stimulation employed.

Inhibition of the movements and tonus of the body of the stomach was the invariable result of stimulation at a frequency of between 10 and 60 per second with induction shocks of such a strength as to be distinctly painful when applied to the tongue (Figs. 1*b* and 2*a*). The gastric inhibition was synchronous with a rise in blood-pressure.

Contraction of the body of the stomach, on the other hand, resulted

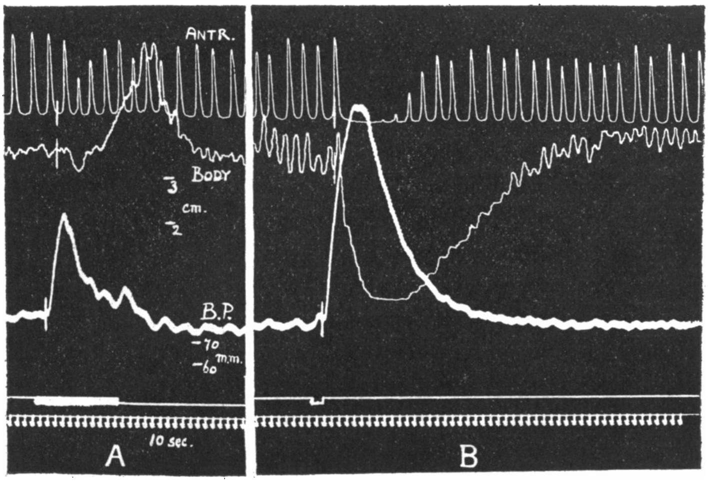

Fig. 1. Spinal cat. Consecutive stimulations of right sympathetic. (A) At 2 per sec. Coil distance, 10 cm. (B) At 40 per sec. Coil 10 cm.

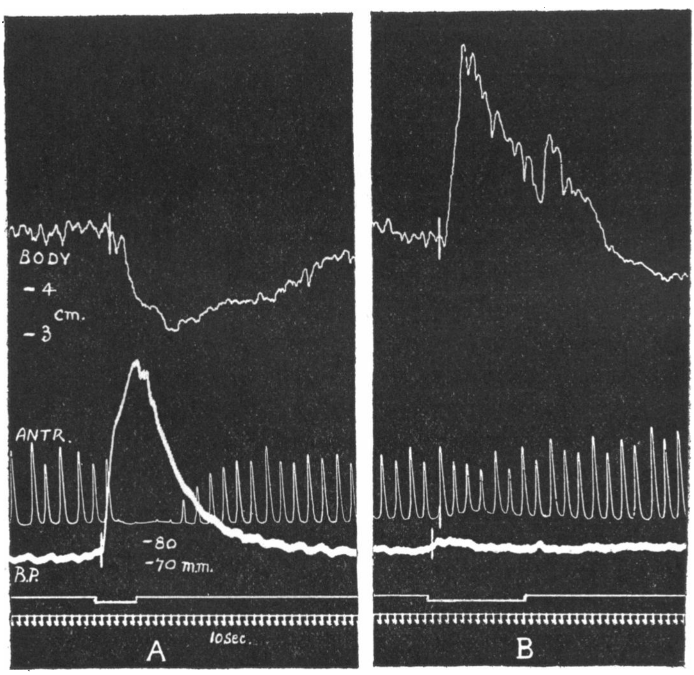

Fig. 2. Spinal cat. Consecutive stimulations of right sympathetic. (A) At 40 per sec. Coil 11 cm. (B) At 40 per sec. Coil 15 cm.

when the chain was stimulated at a frequency of 2 per second or less with stronger induction shocks (Fig. 1A). The motor response to this type of stimulation was observed in 75 p.c. of the animals. It is unusual for motor effects to occur in the presence of a rise of blood-pressure of more than 60 mm., and the most striking effects were observed when the blood-pressure was little affected. Occasionally contraction followed stimulation with very weak tetanizing currents which produced inhibition when they were increased in intensity (Fig. 2). Incidentally, it may be noted that traction on the nerve was one of the most effective means of producing a contraction of the stomach. Motor responses were, as a rule, more easily obtained towards the end of an experiment, when the excitability of the nerve was beginning to decrease.

The behaviour of the pyloric antrum was quite different from that of the body of the stomach. Stimulation at any frequency or strength brought about inhibition of rhythmic movements, the tonus remaining unchanged (Figs. 1 and 2). An augmentation or acceleration of movements was never observed. It is to be emphasized that the response of the antrum was independent of the response of the body, inhibition of the antrum occurring when the body showed either no effect, relaxation or contraction.

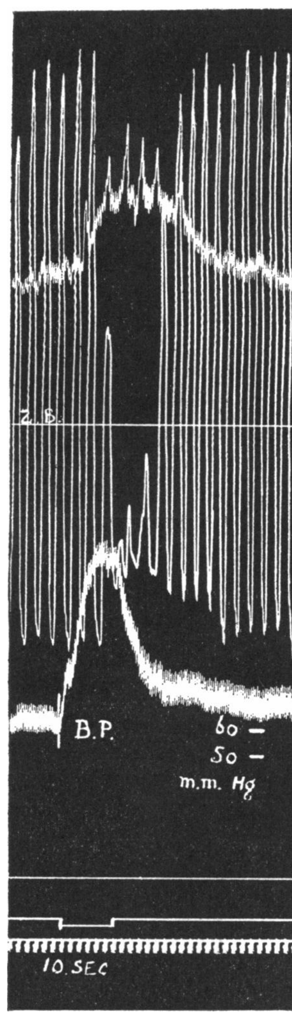

Fig. 3. Spinal dog. Stimulation of right sympathetic. At 45 per sec. Coil 0. No core.

(*b*) *Dogs*. The results from spinal dogs were definitely at variance with the results from cats. Sympathetic stimulation at any strength or frequency caused a rise of blood-pressure, inhibition of movement of the antrum and marked contraction of the body of the stomach (Fig. 3). The blood-pressure in these animals was low, and the body of the stomach inactive. Accordingly, it was decided to use decerebrate animals. The results with decerebrate dogs were in close accordance with those obtained from cats. Stimulation at a rate of 1 per second or weak faradization caused contraction of the body of the stomach, and stimulation at a greater frequency with a moderately strong current brought about inhibition (Fig. 4). In the majority of experiments the movements of the antrum were inhibited by all forms of

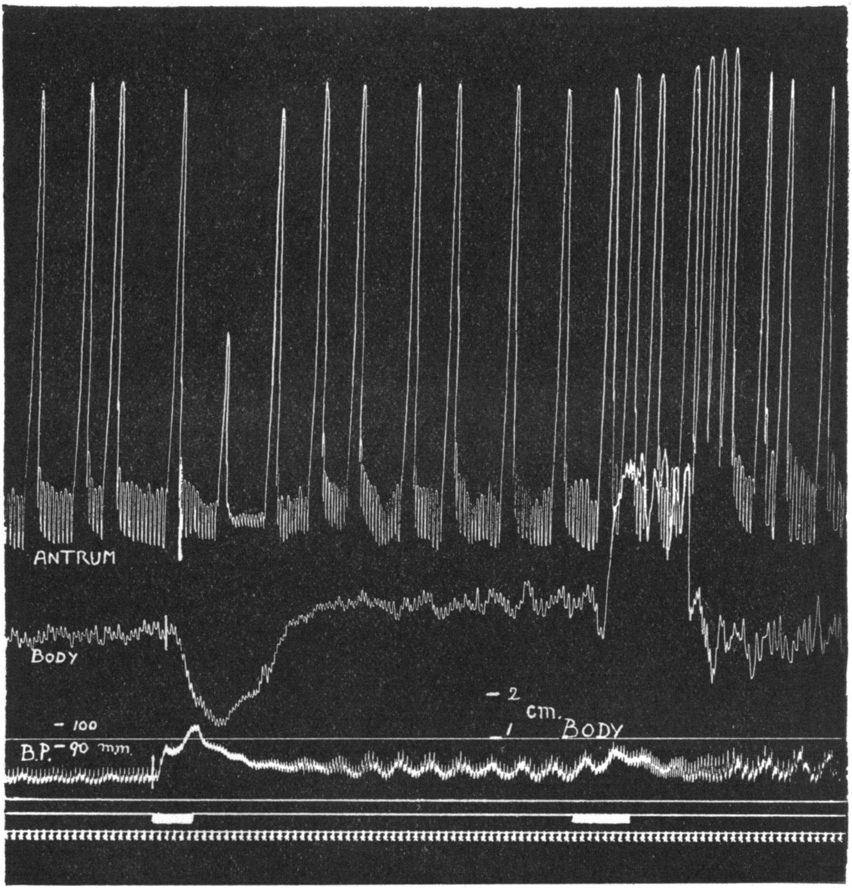

Fig. 4. Decerebrate dog. Stimulation of right sympathetic. At 45 per sec. Coil 10 cm. Followed by stimulation at 1 per sec. Coil 5 cm.

stimulation, but occasionally with the low frequency stimulation there occurred a definite augmentation and acceleration of its movements (Fig. 4). It must be emphasized that motor effects in the dog were greater and were produced much more readily than in the cat, and that the inhibitory effect on the dog's antrum was much less than in the cat. Section of the vagi in the decerebrate dogs did not alter the type of response obtained.

Action of ergotoxine.

The motor effects of sympathetic stimulation were largely abolished by injection of ergotoxine in doses of 0·03 mg. per kg. body weight, relaxation or a very weak contraction taking place with all types of stimulation.

Action of adrenaline.

Injection of adrenaline (P. D. and Co.) into the femoral vein in doses varying from 0·0001 mg. to 0·1 mg. always produced in the cat and dog inhibition of both body and antrum. Motor effects were not obtained.

Removal of the adrenals.

In a number of animals the adrenals were removed by a lumbar approach after decapitation. This procedure did not in any way affect the response of the stomach, inhibition being elicited as readily as usual. Adrenalectomy, on the other hand, did not appear to facilitate the occurrence of motor responses.

In both cats and dogs a number of experiments was performed with the stomach undivided. The responses to stimulation were identical with those of the body of the stomach, any different behaviour of the antrum being masked.

Discussion.

These experiments appear to us to show:

(*a*) that the pyloric antrum retains its sympathetic innervation after complete severance from the rest of the stomach;

(*b*) that there exist in the sympathetic chain fibres conveying inhibitory impulses to the stomach as a whole;

(*c*) that motor fibres to the body of the stomach are also present. No sympathetic motor fibres supply the pyloric antrum of the cat, but there is some evidence of motor fibres to the antrum of the dog.

The results we obtained from the cat are in close accordance with those obtained by Veach [1925], but his contention that inhibition of the stomach is only the result of vaso-constriction does not appear to us to be valid. There is in the cat a close correspondence between the degree of rise of blood-pressure and the degree of relaxation of the stomach. This does not, however, hold good with the dog: powerful motor effects can occur when the rise of blood-pressure is almost as great as when inhibitor effects occurred (Fig. 3). After ergotoxine, inhibitor responses are observed when there is little or no vaso-constriction. Inhibition of movement of the pyloric antrum is independent of a rise of blood-pressure, and takes place when motor responses are observed in the body of the stomach. Moreover, McCrea and MacDonald [1928] point out that the inhibitory effect of adrenaline on the stomach is well shown in doses which produce a fall in blood-pressure, whereas the motor effect is most frequently obtained with large doses when there is a very great rise of blood-pressure. McCrea and McSwiney [1928] have shown that splanchnic stimulation can cause contraction of the stomach during compression of the thoracic aorta. In our opinion, the different forms of stimulation pick out fibres of different excitability, and the correspondence between vaso-constriction and inhibition of the stomach is due to the vaso-constrictor and gastro-inhibitor fibres possessing approximately the same excitability.

The question of the relationship between the state of activity of the stomach and its response to sympathetic stimulation is difficult. McCrea and McSwiney [1928] found that motor effects predominated in both cat and dog when the stomach was inactive, and especially after the use of ether as an anæsthetic. Veach [1925] obtained motor effects with adrenaline in cats only after urethane anæsthesia, when the stomach was atonic, and on splanchnic stimulation after sodium carbonate had entered the circulation. In the present experiments motor effects were sometimes small and difficult to obtain in the cat even when the stomach was inactive, and it seems probable that the predominance of motor effects observed by McCrea and McSwiney was due to the effect of the anæsthetic upon the peripheral neuro-muscular mechanism. The results we have obtained from the dog point clearly to the existence of a relation between the condition of activity of the stomach and the direction of its response to sympathetic stimulation. In the spinal dogs, in which the circulation was impaired and the stomach flaccid, only motor reactions were elicited from the body of the stomach, whereas in the decerebrate preparations in which circulatory conditions were better and the stomach more active, both motor and inhibitor responses were obtained readily. It would appear that the stomach which responds to sympathetic stimulation of any form with contraction only cannot be regarded as normal.

It would appear, therefore, that the body of the stomach receives motor and inhibitor fibres from the sympathetic chain which can be influenced to a greater or lesser degree by the varying types of stimulation. The tonic condition of the stomach influences the results, inasmuch as a flaccid organ whose function is impaired responds only by contracting to any form of stimulation of its sympathetic supply. It must be made clear that there seems to be no relationship between the state of activity controlling the response to vagal stimulation and the direction of response to sympathetic stimulation. In a stomach which contracts with the vagus, both motor and inhibitor sympathetic responses can be elicited by suitable stimulation.

We would hesitate to attribute the results of these experiments to anything in the nature of a Wedensky inhibition phenomenon. Inhibition can be obtained with relatively low frequencies of nerve stimulation, and contraction can result from intense high frequency stimulation. No attempt has been made to work out the exact strengths and frequencies required to produce each effect, since the excitability of the nerves differs so much from animal to animal and in the same animal during one experiment.

The sympathetic innervation of the cat's pyloric antrum appears to be purely inhibitory. Motor responses are observed in the dog's antrum, but they are not frequent. It is possible that motor fibres running to the antrum are severed by the transverse section of the stomach.

SUMMARY.

In spinal and decerebrate cats and dogs the stomach was divided at the incisura, and records were made of the effects of stimulation of the thoracic sympathetic trunk upon the movements of the stomach. The effects on the stomach depended on the type of stimulation employed. Stimulation at a frequency of 1 per second caused contraction of the body of the stomach, while stimulation with a tetanizing current brought about relaxation. The movements of the cat's pyloric antrum were inhibited by all forms of stimulation. The antrum of the dog, although usually inhibited, occasionally showed an augmentor response to sympathetic stimulation. The motor responses were abolished by ergotoxine. Adrenaline did not reproduce the effects of sympathetic stimulation, an inhibition of both parts of the stomach being the invariable result of injection of the drug.

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