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Presented by
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ON THE
INFLUENCE OF SECTION
OF THE
CERVICAL PNEUMOGASTRICS
UPON THE
ACTION OF EMETICS AND CATHARTICS.

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LAST summer, whilst making the investigations upon the veratrum alkaloids, which were reported in the January number of this Journal, I had occasion to kill animals with veratria, after division of the pneumogastries in the neck, and was surprised to find that neither vomiting nor purging were induced. At first the simple explanation of idiosyncrasies suggested itself, but when several experiments coincided, it was obvious that individual peculiarities could not account for habitual results—that there must be some connection between the pneumogastric nerves and gastro-intestinal secretion; especially was this the case when the use of veratroidia was followed by similar absence of symptoms.

The experiments performed last summer were too few in number to lead to any conclusion whatever, but acted simply as an incentive to the present research, which was undertaken the more freely as tending to throw light upon the causes which, in various diseases, prevent purgatives from acting except in an increased dose.

The first question that arose in my mind in entering upon this investigation was as to the anatomical relations of the pneumogastries and the intestines.

A prolonged search through English and French anatomical works resulted only in the confirmation of my previous idea, that the pneumogastric nerves do not descend in the abdomen below the upper end of the duodenum.

Finally, however, my attention was directed to a beautifully illustrated prize essay published in the *Zeitschrift für Wissenschaftliche Zoologie*,

Band X., by Dr. J. Rollman. In this the author claims to have demonstrated that, whilst the anterior or left pneumogastric is distributed in the abdomen to the stomach and liver only, the posterior or right nerve, giving off but few filaments to the former viscus, passes to the liver, the spleen, the kidneys, supra-renal capsules, and the whole of the small intestines.

There consequently seemed ground for believing that such anatomical relation exists between the par vagum and the intestinal canal as might account for a connection of function between them. In order to discover the opinions of other observers as to the effect of section of the pneumogastrics upon secretion in the stomach and bowels, a search through all accessible French, English, and German authorities was instituted.

I believe it is now generally admitted that division of these nerves in the neck arrests secretion in the stomach, but I have not found more than two allusions to a similar influence upon intestinal secretion, one in a paper by Sir Benjamin Brodie, and the other in Dr. Reid's essays. These will be considered hereafter. As to the immediate cause of arrest of secretion in the stomach, there appears to be great diversity of opinion. This will also be commented on subsequently.

The series of experiments which will be first detailed was instituted to determine how far section of the par vagum interferes with vomiting. The latest published experiments bearing upon this point, as well as the fullest that I have met with, are those contained in the elaborate work of M. Schiff on digestion.

One set of his experiments would seem to prove that under certain circumstances vomiting can occur after the pneumogastrics have been cut in the neck. In these experiments, after such division of the nerves, M. Schiff introduced a stomach tube through an artificial opening into the cervical œsophagus, and passed it into the stomach. He then pushed through this tube, by means of a flexible piston, semi-solid food, of such a character as to be easily recognized. Out of 12 dogs subjected to this procedure, 7, after prolonged efforts, threw up a portion of the matters injected into the stomach.

M. Schiff does not appear to have tried whether, after section of the cervical pneumogastrics, it were possible to produce emesis by the action of ordinary emetics. He states, however, that when the nerves are cut below the diaphragm, tartar emetic causes efforts at vomiting as quickly as in healthy dogs, but that these efforts are rarely successful, or, if they be so, it is only after they have been very frequently repeated and long continued. His explanation of this is, that the division of the nerves prevents the co-ordination of the dilating fibres of the cardia and the associated actions of vomiting. The cardiac sphincter occasionally relaxes, but it does so, apparently, spontaneously, and without relation to the contractions of the stomach. So that if the opening of the cardiac orifice occurs at the same time as the expulsive efforts it is simply by chance. Successful vomiting is, therefore, dependent upon the fortuitous consentaneousness of complicated acts—which can happen but rarely. The function of the

par vagum in this regard, then, according to this authority, is simply to harmonize the numerous acts necessary to successful vomiting.

First Series of Experiments.

Expt. 1.—Youngish mongrel hound. One hour after section of the pneumogastrics in the neck, the dog being strongly under the influence of sulphate of viridia, $\frac{1}{2}$ gr. of the sulphate of veratria was given internally. Dog died in 30 minutes without vomiting or purging.

Expt. 2.—A good-sized Scotch terrier. One hour after section of the pneumogastrics in the neck, I gave hypodermically about $\frac{1}{4}$ th grain of sulphate of veratria. Thirty minutes afterwards I administered $\frac{1}{2}$ grain in similar manner. The animal died one hour and twenty-five minutes afterwards without being purged or having made any efforts at vomiting.

Expt. 3.—I cut the pneumogastrics in the neck of a stout poodle dog, and some time after administered hypodermically one half of a grain of sulphate of veratria. Animal died in fifteen minutes without any vomiting or purging.

Expt. 4.—I cut the pneumogastrics in the neck of a small Scotch terrier, and a few minutes afterwards gave hypodermically one-half of a grain of sulphate of veratroidia. Thirty minutes after this there had been no vomiting or purging. I gave $\frac{1}{4}$ grain additional after twenty minutes. No efforts at vomiting; no purging. Injected another quarter of a grain. Dog died about two hours after this without having purged or made any effort at vomiting.

I have used tartar emetic once, after section of the cervical pneumogastrics, without causing vomiting, but I do not attach any value to this experiment,¹ as I have failed to cause vomiting in the only two animals with uninjured nerves to which I have given it. The experiments differ somewhat in their results from what is generally stated as to the action of antimonials, and I therefore insert them. They are, of course, too few to lead to any positive conclusion.

Expt. 5.—Full-grown English rabbit. Cut pneumogastrics 12.40 P. M. Gave $1\frac{1}{2}$ grain tartar emetic in solution in both thighs— $2\frac{1}{4}$ grains in all. 5.30 P. M. No vomiting or purging; no other symptoms except those of general prostration. Gave gr. ij elaterium in alcohol hypodermically. 6 P. M. Rabbit dying in a convulsion; for five minutes previously has had convulsive movements. In five minutes afterwards the animal was dead. No vomiting or purging.

Expt. 6.—Full-grown English rabbit suffering from injury to throat; has not eaten anything for two days, but running about pretty lively. Gave gr. ijss of tartar emetic at 4 P. M. hypodermically. 6 P. M. No vomiting or purging; rabbit weak. Gave gr. jss additional. Animal died between this and half past seven without vomiting or purging.

Expt. 7.—Nov. 9. Large female cat. 10 A. M. Injected into cellular tissue of thigh gr. j antimonii et potassæ tartras, dissolved in ℥j of water. No apparent symptoms were induced up to 5 P. M., except unusual quietness. Cat not under observation after 5, until 9 o'clock, when she was found in the agonies of death. There had been apparently some slight purging, but no signs of vomiting could be discovered.

Besides the already detailed experiments, ten others will be subsequently related, having a direct bearing upon this point. In eight of these, lethal doses of veratria failed to provoke vomiting after section of the nerves; in the other two, arsenic was used with similar results. These experiments,

¹ This experiment is further vitiated by having been made with a rabbit, which vomits with great difficulty, if at all. M. Bernard says, I believe, not at all.

therefore, in every way confirm those of the first series. With the latter they are to my mind sufficient to prove that emetics will not act after division of the cervical pneumogastrics. In my experience arsenic has never failed to cause violent emesis when introduced into the circulation of an uninjured animal, and all authorities agree as to the constancy of its purging and vomiting, without regard to the method of its administration. As to veratria, it also always, in uninjured animals, produces violent, distressing, repeated vomiting; doing so in small doses even with more certainty, if possible, than arsenic.

That the non-occurrence of emesis is caused by the arrest of gastric secretion is, I think, demonstrated by the absence of watery fluid in the stomach on post-mortem examination, and by the absence during life of any attempts at vomiting, such as Prof. Schiff has shown to occur in animals with similar lesions, when food is injected in some quantity into the stomach.

It will be observed that nearly all the experiments which have been detailed to demonstrate the failure of emetics to act after section of the cervical par vagum, have direct bearing upon the question of the action of purgatives, since the most powerful emetics are at the same time purgative. In order to determine positively the relation between the nerves and purgation, the following experiments were instituted:—

Second Series of Experiments.

Expt. 8.—I cut the pneumogastrics of a large sized English rabbit at 4.30. Gave gtt. j of croton oil in emulsion in thigh. 4.45. Rabbit lively. 5.30. Rabbit quiet; moaning in breathing; no purging; passed some dry feces. Gave gr. ijss of gamboge dissolved in alcohol, injected in four or five different places in cellular tissue. 6.20 P. M. No purging or vomiting. Injected gr. ij resinæ podophylli dissolved in fʒss alcohol into peritoneal cavity. 7 P. M. Very weak, breathing quietly, not moving at all when touched. 7.30. Lying on side; breathing quietly, seemingly more conscious than at 7 o'clock; no purging; passed urine. 8. Tries occasionally to get on side but cannot. 9. Rabbit seems a little livelier. 10.45 P. M. Dying; only breathing three or four times a minute. Neither purging nor vomiting has occurred.

Remarks.—Not much importance can be attached to this experiment, as it is uncertain whether the same drugs would have purged the animal had the nerves been entire.

Expt. 9.—12.45. I cut pneumogastrics of a full-grown cat. Injected into peritoneal cavity gr. ijss podophyllin in alcoholic solution; into cellular tissue gr. j gamboge. 2.40 P. M. No purging. Injected into peritoneal cavity fʒij extr. sennæ fluid. 4 P. M. No purging. 6.10. Cat still alive, able to mew faintly; no purging or vomiting. 9 P. M. Still alive; no purging. Died during night without purging.

Remarks.—This experiment is open to the same objections as the preceding. I find podophyllin a somewhat uncertain purgative in cats.

Expt. 10.—3 P. M. Cut pneumogastrics of a dog and injected gr. iij podophyllin in fʒss alcohol into peritoneal cavity; also gr. j gamboge dissolved in alcohol. 4 P. M. No purging, dog quiet. 6.10. Alive, heart acting pretty regularly though feebly; no purging or vomiting. 8 P. M. Dog just dead. No purging or vomiting.

Remarks.—It may be very well objected to this experiment that the dog did not live long enough for the medicine to act. I thought, however, on the whole, best to detail it. It certainly does not weaken the proof.

Expt. 11.—Nov. 14. Gave gtt. ij *ol. tiglini* to a moderate sized cat at 2 P.M. by mouth. 4 P.M. Cat has been vomiting pretty freely. 6 P.M. No purging. Nov. 15. Has been some purging during night, apparently two passages, one partially formed, and one not so—perhaps all one passage. Cat seems all right.

Expt. 12.—Nov. 10, 10½ A.M. I gave to a large female cat gtt. ij of *ol. tiglini* by the mouth. 12 noon. No effect yet visible. 1.30 P.M. Cat has been purging several times; very weak; trembling all over and perfectly quiet in corner; apparently suffering. 2.30. No purging since. 4 P.M. Has been free from purgation since; cat mews livelier. Nov. 11. There has been more purging in the night, but cat seems quite lively. Nov. 12, 9½ A.M. Gave cat gtt. ij *ol. tiglini* by the mouth. 12 noon. No vomiting. Cut pneumogastriacs. 1.30. No purging; cat seems strong, but quiet. Nov. 13. Has been no purging. 12 A.M. Gave hypodermically gr. ss of *veratrica sulph.*; cat previously was weak but pretty lively. 1 A.M. Cat dead; do not know exactly how long after injection; had urinated freely; no purging.

Expt. 13.—Nov. 14. Gave between gtt. vi and x *ol. tiglini* by the mouth to a large cat at 10½ A.M. 12 noon. Has been profuse vomiting but no purging. 2½ P.M. Has been more vomiting, but no purging. 6 P.M. No purging, but very profuse vomiting. Nov. 15. Cat seems recovered. Gave 10½ A.M. ℥j castor oil, of which she probably got about half. Cat vomited directly; no effect on bowel. Nov. 16, 10 A.M. Gave same cat a bolus containing gr. x extr. jalapæ. 1 P.M. No vomiting or purging. 4½ P.M. No purging. No purging during night.

Remarks.—I think the excessive vomiting will account for the croton oil not purging in this case. It was constant, immediate, very much more prolonged—more violent, with more effusion of liquid than in either of the other instances. It was probably dependent upon the very large dose.

Expt. 14.—Nov. 13. Gave to a male and female cat each five drops of *ol. tiglini* by mouth, at 9.30 A.M. 11.30. Both cats have vomited freely; tom cat purged once. Attempting to cut pneumogastriacs on latter, he died from effects of ether. 12 A.M. Cut the pneumogastriacs of female cat successfully. 1.30 P.M. No purging. 4 P.M. No purging; cat seems very weak. 9 P.M. Cat still alive; no purging. Nov. 14. Cat died some time during night without purging. There had been urination.

Expt. 15.—Nov. 19. Kitten apparently about three months old, gave, 10.30 A.M., ℥ss *liq. potassæ arsenitis*, hypodermically. 2 P.M. Has been freely purging and vomiting. 2.45 P.M. Cut the pneumogastriacs, and injected into cellular tissue ℥jss *liq. potassæ arsenitis*. 3 P.M. Kitten seems suffering a good deal; very uneasy and restless. 3.10. Kitten very weak. 3.15 P.M. Kitten dead, without vomiting or purging.

Expt. 16.—Nov. 19, 3.5. Cut pneumogastriacs of a large cat, and injected into cellular tissue ℥ij *liq. potassæ arsenitis*. 3.15. No symptoms. Injected ℥j additional into abdominal cavity. 3.30. No especial symptoms; cat quite lively; no vomiting or purging. 4 P.M. Injected gr. j *acid. arsenios.* in water into peritoneal cavity. 5 P.M. Cat dead. No purging or vomiting.

Expt. 17.—Nov. 16. Gave a small spaniel by the mouth a bolus containing extr. jalapæ gr. x, *ol. tiglini* gtt. j at 2 P.M. Dog vomited the bolus twice in twenty minutes; each time it was given to him again; in about ten minutes more he vomited again, but this time no bolus could be found in the matters rejected. Nov. 17. Has been pretty freely purged during the night.

Expt. 18.—Nov. 17. Gave a moderate size cur a bolus containing *extr. jalap.* gr. x, *ol. tiglii* gtt. iss at 10 A. M. 11. No effects manifested. 12 noon. Has been free purgation; dog vomited directly after exhibition of dose, but did not throw up bolus. At 3.30 gave same dog *another similar bolus.* 4 P. M. Dog has not vomited since last dose. 4.30 P. M. Have just cut the pneumogastrics; dog came up from ether with great difficulty, but at 5 was able to walk. Nov. 18. Dog had no passage since operation. Nov. 19, 2.30 P. M. Injected by means of hypodermic syringe $1\frac{1}{2}$ fluidrachms of *liq. potassæ arsenitis* into cellular tissue. 3.10. The dog has had a firm passage since 10 o'clock; it possibly had been in the rectum ever since the nerves were cut; possibly was the result of secretion in the large intestines; no symptoms save general uneasiness. Gave in similar manner *f3ijss* additional. 4.15. No marked change in symptoms. 4.30. Gave gr. iss *acid. arsenios.*, injected into cellular tissue dissolved in water. 5 P. M. Dog still alive; no purging or vomiting. 9 P. M. Dog still alive; no purging. Nov. 18. Dog died during night without purging or vomiting.

Expt. 19.—Nov. 21. I gave by mouth to a large female cat a bolus containing 15 grains of *calomel*, at 4 P. M. Nov. 24. Cat has been purged, and vomited freely during the night. 10 A. M. Gave a bolus containing 15 grains of *calomel.* 2 P. M. Gave a bolus containing 10 grains of *extract of jalap.* and one and a half drops of *croton oil.* 3 P. M. Cut the pneumogastric nerves just one hour after last dose, five hours after the *calomel.* Neither bolus was vomited. Nov. 23. There has been no purging during the night, but apparently urination. 2.45 P. M. Injected by means of Wood's syringe gr. ijss of *arsenious acid* into cavity of the peritoneum. 3.20 P. M. Cat in pretty much the same condition as before the injection. 4.40. Cat still alive; no purging or vomiting. It being about two hours since injection of *arsenious acid*, time sufficient to purge if it had the power, and wanting the carcass for dissection, I cut the carotids.

Expt. 20.—Nov. 25, 4 P. M. Gave 10 grains of *calomel* to a large male cat. Nov. 26. Has been purged pretty freely during the night. 9.30 A. M. Gave 15 grains of *calomel.* 12 P. M. The cat has vomited a small portion of the mercurial. Gave a bolus containing 2 grains of *podophyllin*, 1 drop of *croton oil*, and 10 grains of *extract of jalap.* 2.30 P. M. The cat has been purged very freely since last dose, once or twice. Cut the pneumogastrics. 6 P. M. Cat pretty lively; no purging or vomiting. 9 A. M. Still alive; no vomiting or purging. Nov. 26, 9 A. M. Cat died during the night without purging or vomiting.

Autopsy.—Small bowels strongly contracted, not much larger than a large goose-quill; almost semitranslucent; waxy; almost as white as white wax; bloodless, with a small amount of very thick mucus in their interior; mucous membrane very pale and white, with here and there reddish flecks.

Expt. 21.—Dec. 10, 4 P. M. I gave 10 grains of *calomel* to a kitten apparently six months old. 4 $\frac{1}{2}$ P. M. Vomiting. 5 P. M. Seems better. Dec. 11. Vomited and purged freely once or more during the night. 10 A. M. Gave gr. x of *calomel.* 3.15 P. M. Has been purged once since last visit. Gave gtt. j *ol. tiglii* in a bolus. 3.30 P. M. Cut the pneumogastrics. 4 P. M. Cat seems pretty lively; no vomiting or purging. 6 P. M. About same; no vomiting or purging. 10 P. M. Still alive; no vomiting or purging. Dec. 11. Cat died some time during the night without any vomiting or purging.

Expt. 22.—Dec. 13. I gave 10 grains of *calomel* at 4 A. M. to a tortoise-shell kitten apparently six months old, perhaps older. Dec. 14. Kitten was purged very freely during the night. 10 A. M. Gave 10 grains of *calomel* in addition. 2.30 P. M. Kitten was purged since morning. Gave two pills containing each one drop of *croton oil* and two grains of *rhubarb.* Cat fought against taking them violently, chewed them up in her mouth, spit them out. We replaced the fragments several times, and she certainly swallowed equivalent to one pill. 2.45 P. M. Cut her pneumogastrics in the middle cervical region. 3.30. Cat seems pretty lively, walking about, fighting heroically upon

attempting to seize her. 4.30. There has been no purging or vomiting since pneumogastrics were cut. Cat is weak, very quiet, when it walks staggering. Injected into the cellular tissue of the back a solution of *arsenious acid* supposed to contain one-sixth of a grain, may have contained more, certainly not less. 5. Seems about the same, still able to walk, although staggering and uneasy. There is no apparent disturbance of the respiratory function. 5.30. Cat able to walk; lies still most of the time; no vomiting or purging. 6. Seems better. 6.30. Attempted to inject $\frac{1}{2}$ grain of *arsenious acid* into cellular tissue of back; cat flew into a violent passion thereat, bit, scratched, and behaved otherwise unseemly, so I was glad to let her go, with not more than a third the dose. 6.35. Cat running round the room wildly and stiffly, with head down; limbs and neck stiff; no vacillation in her gait; seems as it were convulsed. 6.45. Cat still in "tantrums." 6.55. Cat collapsed, nearly motionless; dying. Respiration for fifteen minutes has been markedly that of section of the pneumogastrics. No purging or vomiting.

Autopsy some time after death.—*Stomach* containing a quantity of thick, somewhat gelatinous, semitransparent, mucoid fluid. Small intestine contracted; nearly bloodless; empty; mucous membrane very pale.

Expt. 23.—Dec. 13. Gave 10 grains of *calomel* by the mouth at 4 P. M. to a black kitten, stout, vigorous, apparently nine months old. Dec. 14. Was purged freely during the night. 10 A. M. Gave an additional 10 grains. 2.40 P. M. Has been purging since morning. Gave a pill containing one drop of *croton oil* and two grains of *rhubarb*; swallowed without much difficulty. 3 P. M. Cat pneumogastrics. 3.30. Cat seems pretty well and strong, simply showing general signs of section of the par vagum. 4.30. Seems very lively; the marked evidences of respiratory disturbance have passed off. No vomiting or purging as yet since section of the nerves. Dec. 14, 10 A. M. Seems very bright, running about as if nothing was the matter. During the night she has passed water freely, and I found a few shreds of fecal mucoid matter, not half a teaspoonful, at her tail, which is covered with the remains of previous purging. This probably was from the wet, moistening the dirty, matted mass. Gave hypodermically gr. ss *acidum arseniosum*. 10.33 A. M. Cat seems sick, but running about and drinking. Gave gr. $\frac{1}{3}$ of the arsenic additional. 2.30 P. M. Cat about the same, seems hardly so ill as at 11 A. M.; no vomiting or purging. Gave gr. $\frac{1}{3}$ *acidum arseniosum* hypodermically. 3 P. M. Not much change. 3.25. No vomiting or purging; cat very quiet. Gave gr. $\frac{2}{3}$ of *arsenious acid* hypodermically. 3.35. Cat dead, without vomiting or purging.

Autopsy five minutes after death.—*Stomach* empty; much of its mucous membrane swollen, and intensely dark red. *Small intestine*. Peristaltic action evident upon opening abdomen; excited very readily by pricking the gut; intestine empty; mucous membrane mostly pale, a little reddish in spots; everywhere very dry.

Expt. 24.—Dec. 15, 3.30 P. M. Gave to a stout cat a bolus containing one drop of *croton oil*, and directly after cut the pneumogastrics. 4.30. No purging; cat pretty well. Dec. 16. Has been no purging during the night; cat in good state. 2.30. Injected by means of Wood's syringe into cellular tissue, in four or five different places, 2 grains of *arsenious acid* diffused in water. 3.30. No new symptoms developed, save cat seems very quiet and weak. Injected 2 grains additional of the acid. 4 P. M. Cat very weak and sick, making some motions as though she would vomit, but really no vomiting or purging. 5 P. M. No change; no vomiting or purging. 9 P. M. Cat still alive; no vomiting or purging. Dec. 17. Cat died some time during the night. After 9 she had a single firm passage; this had apparently been formed, and then flattened by being laid on.

Autopsy.—*Stomach* containing considerable liquid; its mucous membrane excessively red and congested. Small intestine, containing in places some thick mucus, in others dry and empty; its mucous membrane in places somewhat reddened, in others normal.

Expt. 25.—Dec. 16, 3.10 P. M. Gave to a kitten apparently six months old, a bolus containing 10 grains of *calomel*, and ten minutes after cut the pneumo-

gastries. 3.30. Disturbance of respiration excessive, almost convulsive. Injected into cellular tissue gr. j *arsenious acid* in water. 3.45. Put 3 grains of *arsenious acid* on the cat's tongue, and washed it down with 8 grains of *gamboge* imperfectly suspended in an ounce of water; probably half of this was spilled. 5 P. M. Cat apparently much better, symptoms of disturbed respiration have subsided; no vomiting or purging. 9 P. M. Cat dead. No vomiting or purging.

Autopsy.—Stomach containing a considerable amount of watery fluid. Small intestines, in many places dryish, in others containing some thick mucus.

The experiments just detailed, taken in conjunction with those of the first series, seem sufficient to prove that purgation is impossible after division of the cervical pneumogastries. As previously stated, the first two experiments of the series do not carry much weight, but experiments 10 and 12 are very conclusive. In 12, a cat, after free purgation has been produced by two drops of croton oil, the nerves being intact, receives again the same dose and in the same manner; two hours and a half are then allowed for absorption, and the nerves are divided; twenty-four hours afterwards, the medicines not having produced any effect, the animal is killed with veratria, dying without the stomach and bowels being excited to action. In experiment 13, two hours after the exhibition of a large dose of croton oil, when purgation had commenced in another animal to whom the same dose had been given at the same time, the nerves were cut, and the animal died without purging. Experiments 15 and 16 were made with arsenic, which, according to all observers, vomits and purges always when given in lethal doses, without reference to its mode of exhibition. In experiment 15 a non-fatal dose of the poison had previously freely purged the animal. Experiment 17 was merely tentative, and proved that croton oil and jalap act as purgatives to the dog. Experiment 18 is a very decisive one. A dog receives a bolus of croton oil and extract of jalap, and five and a half hours afterwards, this having freely operated, receives a second similar one. An hour after this the nerves are divided, and nearly two days afterwards the animal is slowly poisoned by arsenic, and yet is not purged or vomited. Experiment 19 is apparently an *experimentum crucis*. A cat, previously purged with fifteen grains of calomel, receives the same dose, and four hours after this ten grains of extract of jalap and a drop of croton oil. An hour after this the nerves are divided. Purgation is not induced, although the animal the next day is killed by two and a half grains of arsenious acid. Experiment 20 is very similar to this, except that the second mercurial was aided by ten grains of the jalap extract, a drop of croton oil, and two grains of podophyllin, and purgation allowed to commence before division of the nerves, ceasing immediately upon this. No arsenic was used. At the autopsy the small bowels were found contracted, with simply a slight amount of mucus in their interior. Experiment 21 is similar, except that the mercurial was aided by croton oil alone. Experiment 22 differs chiefly in the use of about a third of a grain of arseniate of potash. In experiment 23 the results were not quite so positive,

although I believe there was no purging during the night, and it is certain that there was none when the animal was killed the next day with arsenic. In experiment 24 croton oil was alone used at the time the nerves were divided, but the animal died of arsenical poisoning nearly thirty-six hours after this without purging. In experiment 25 calomel, gamboge, and arsenious acid failed to induce purgation after division of the cervical pneumogastrics, the kitten living some six hours after the exhibition of the mercurial.

The results of these experiments were pretty plainly shadowed forth, although not definitively proven, by the late Sir Benjamin Brodie, in a paper published in the *Philosophical Transactions*, 1814, p. 102. His experiments were only four in number, and were all made with arsenious acid.

In the first, ten grains of the acid were inserted into the thigh of a dog after section of the pneumogastrics in the neck, the animal dying in three hours and a half. The stomach and mucous membranes on post-mortem examination were found to contain no mucus or watery secretions—only food and feces. The mucous membrane of the stomach and intestines was found inflamed. The second experiment was in all respects similar to the first, except that the dog lived nine hours. In the third experiment two ounces of a saturated solution of the white oxide of arsenic were given by the stomach, after section of the pneumogastrics, the dog dying three hours afterwards. The stomach and intestines are said to have been slightly inflamed, but to have contained no mucus or watery fluid. Sir Benjamin Brodie, in the fourth instance, divided the nerves just above the cardiac orifice of the stomach, and consequently below the origin of the pulmonary and cardiac branches. After the operation the respiration was perfectly normal. The dog was now inoculated in the thigh with arsenious acid. He died in a few hours with the ordinary symptoms of arsenic poisoning, except vomiting or purging. No watery or mucous fluid was found in the stomach or small intestine. A small quantity of mucus in the colon.

There are two sides to every question, and so far, in this study, we have seen but the one; there is, however, another.

Dr. John Reid, in his investigation of the pneumogastrics, repeated the experiments of Brodie, with, as he believed, opposite results.

His manner of experimentation seems to me to be somewhat faulty, although he claims that it is the only true method. He took two dogs in each experiment, one with the vagi entire, the other with them cut, killed them with arsenic, and then examined the intestines to see whether there was any difference in the amount of fluid contained, and on finding equal quantities, reasoned that there had been no arrest of secretion produced by the cutting of the nerves. Now, it is evident that if the uninjured dog had been purging freely, and the other not, the intestines of the latter might contain more fluid than those of the former, although secretion had been far less active. Especially is a doubt thrown over this method of experimen-

tation, when it is remembered, in addition to the above, that it is wholly uncertain how much mucus was in the bowel of the dog before the section of the nerves and the subsequent poisoning. The experiments were five in number, and in only one (Expt. 40, Essay on the Pneumogastric Nerves) is it noted that diarrhœa was present after division of the nerves. Even in this it is barely possible there was some misapprehension, as the nerves were not examined at the autopsy to prove that they were actually cut. Still, it is most probable that this experiment gave an opposite result to those already detailed in this paper. All my experiments coincided, until over twenty had been made, when one occurred in which there was free purgation, and another in which there was some slight muco-fœcal discharges after division of the nerves.

These experiments were as follows:—

Third Series of Experiments.

Expt. 26.—Dec. 15, 10 A. M. I gave by the mouth to a very large and powerful mongrel pointer 20 grains of calomel. 3 P. M. Has been vomiting and purging freely. Cut the pneumogastriacs in the middle cervical region. The usual symptoms developed themselves. 5 P. M. Has recovered pretty well from the operation; no vomiting or purging since. Dec. 16. Dog quiet, although in pretty good condition. There has been no purging during the night. 10 A. M. Gave two boluses, containing together ten grains of *compound extract of colocynth*, two drops of *croton oil*, and five grains of *extract of jalap*. The dog swallowed them; of course they did not go fully down into the stomach, but, as they were soft, I conceive they must have melted and gradually been absorbed in the œsophagus, or found their way into the stomach. 2.25 P. M. There has been no purging or vomiting since 10 A. M. Have just given the dog 7 grains of arsenious acid, suspended and partially dissolved in about six drachms of water, injected into as many places in the cellular tissue of back and thighs. 3.30 P. M. Purged several times freely since 2.25; some very watery, some thick mucoid matter; some blood. I now gave 3 grains additional of arsenious acid in the same way as before. 4.30 P. M. Dog has purged once or twice since. Gave a solution hypodermically which had contained over two grains of veratria; some of the alkaloid, however, had probably been decomposed by a fungus growing in it. 4.45. Dog has exhibited most of the usual symptoms of veratria poisoning; had a single, very small passage from his bowels; profuse salivation; no vomiting; now lying on side, unable to stand on his feet. Dec. 16. Dog has purged freely during the night; is now dead.

Autopsy.—Stomach containing considerable fluid; its mucous membrane normal. Small intestine; its mucous membrane intensely congested; often markedly injected; the gut containing considerable fluid. Large intestine normal, except that it contains considerable liquid feces.

Expt. 27.—Dec. 15, 3 P. M. Gave by the mouth to a not very large, but very powerful and vicious male cat, 10 grains of *calomel*, and fifteen minutes afterwards cut the pneumogastriacs. 5 P. M. Cat seems in good condition; no purging or vomiting. Dec. 16. There has been some purging during the night, consisting of very thick, gelatinous mucus, with a faint fecal tinge. 3.45 P. M. Poured into the mouth 6 grains of arsenious acid in dry powder, nearly all of which was swallowed. I also gave a bolus containing 1 grain of *podophyllin*, 5 grains *compound extract of colocynth* 2½ grains *extract of jalap*, and 1 drop of *croton oil*. How much of this actually found its way into the stomach it is impossible to state. A quantity of thick saliva and mucus came from the mouth, much of it very deeply coloured by the extracts. 5 P. M. Cat seems lively; no purging. Dec. 17, 10½ A. M. Cat still alive, but weak; there has not been any purging. Injected into cellular tissue a little over two drachms of

Fowler's solution. 12½ P. M. In about the same condition as two hours ago; no purging. 4 P. M. Just alive. There has been some mucoid discharge from the anus, just enough to wet the surrounding parts.

Autopsy.—Dec. 18. Stomach containing considerable watery fluid; mucous membrane normal. Small intestine, containing in considerable quantity a thickish, yellowish, mucous liquid; mucous membrane in places intensely injected and inflamed.

Speaking of the different results obtained by himself and Sir Benjamin Brodie, Dr. Reid says:—

“We cannot pretend to account for the discrepancy between the results obtained in the experiments detailed above and those related by Sir B. Brodie. It is possible, however, that Sir B. had not taken the precaution of securing a free ingress of air into the lungs in the three experiments in which the nerves were cut in the neck, for it is stated in the first experiment the breathing of the animal was laboured and it died after three hours and a half. . . . Whatever be the cause of this discrepancy, it is obvious that the *negative* evidence obtained by Sir B. Brodie cannot affect the value of the *positive* experiments we have detailed.”

Probably no words have been more misused in physiological reasoning, or, indeed, in scientific reasoning generally, than *negative* and *positive*. Negative in one sense, the results of Sir Benjamin Brodie, are in fact, but in a higher and truer sense, they are positive, just as much positive as those obtained by Dr. Reid. If a poison be introduced into the system, possessing the power of invariably producing a fixed train of symptoms, and by any means such symptoms are prevented, the result is absolutely a *positive* one. Opposite results certainly were obtained by the different observers, but it is of no use to brand one as negative and pass it by. The true scientific sense will be awakened by such circumstances, not to ignore facts, but, if possible, to reconcile that which is apparently flatly contradictory. My experiments conclusively show that both observers were right, some of them agreeing with the one, some with the other. I think they are sufficient in number to prove absolutely that, after division of the cervical pneumogastrics, it is, in the majority of instances, impossible to purge, but in a few cases the normal action of the purgatives seems to be scarcely interfered with. The question is, Why is this? and the answer to this is evidently wrapped up in that of the question, How does the division of the nerves cause arrest of intestinal secretion?

It is, I believe, now generally conceded that section of the cervical par vagum arrests secretion in the stomach, and that, generally, the power of digestion is permanently destroyed. In certain instances, however, there is no such arrest of secretion in the stomach. This is precisely what I have found to be the case in the bowels, and it needs no elaborate argument to convince one that both depend upon a common cause, whatever that may be.

What then is this cause? To my mind but three plausible explanations presented themselves:—

First. The par vagum is possibly the direct antagonist of the contracting vaso-motor nerve of the alimentary canal, or, in other words, it is the dilating vaso-motor nerve of Bernard. This being true, it is evident that the cause in question is contraction of the capillaries after the section of the pneumogastrics by the unresisted contracting vaso-motor nerve, so as to prevent secretion.

Second. Shock.

Third. Accumulation of carbonic acid in the blood owing to the impeded respiration.

The former of these supposed causes is the one which first presented itself to my mind as very probably correct. The experiment of Bernard in which he cut the pneumogastrics of a dog, after having established a gastric fistula, has apparently direct bearing upon this point, for he found that the mucous membrane of the stomach instantly became pale and colourless when the nerves were divided.

The subject of the relation of the par vagum to digestion has attracted a great deal of attention, and in order to elucidate it, Magendie, Schultz, Bernard, Schiff, and others, have made numerous experiments. Several of these observers have many times cut the pneumogastric nerves just as they emerge into the abdomen from the diaphragm, and, therefore, after their cardiac and pulmonary branches have been given off. The results obtained have been somewhat various, digestion sometimes continuing, sometimes ceasing; the best observers, however, agreeing that secretion generally continues. The discovery of Brachet, that many branches of the pneumogastrics pass through the walls of the œsophagus and were consequently unharmed by the various experimenters, apparently accounted for this. Especially did this seem plausible, when it was found that if the œsophagus with the contained nerves was divided gastric secretion ceased. The facts brought forward in this paper to show that there is an arrest of secretion in the intestine as well as stomach after cervical section of the pneumogastrics, seem in themselves, however, enough to invalidate the explanation of Brachet, for the small intra-œsophageal branches, which by increased activity were supposed to do the work of the whole nerve in the stomach, certainly do not reach the intestine. There is not wanting, however, more positive experimental proof of the falsity of this theory. Prof. Schiff has shown (*Leçon sur la Physiologie de la Digestion*, vol. ii.) that section of the œsophagus close to the cardia, the nerves being carefully dissected off and left uninjured, is in itself sufficient to cause the instant and permanent arrest of digestion; and has also modified the experiment of Magendie, Bernard, etc., so as completely to meet the objections of Brachet, and at the same time avoid the disordering effects of section of the œsophagus. His operation consists in cutting down upon the cardia in the usual way, exposing and dividing the anterior and posterior branches of the pneumogastric, and then seizing the œsophagus between the finger

and thumb as close to the diaphragm as possible, rotating it, and at the same time carefully dividing it down to the muscular coat, which is left intact. In this way the nerves are all divided, and at the same time the œsophagus left practically unhurt. Prof. Schiff has repeated this experiment a number of times, always with the one result. He has assured himself, in the most positive manner, that there is no suspension whatever of digestion, even during the first twenty-four hours. Founding his opinion upon these experiments, he concludes that the arrest of secretion in the stomach is due simply to the disturbance of the circulation and respiration. At first this conclusion was not satisfactory to my mind, especially as I was slow to conceive how such disturbances could modify the action of the glands of the bowels. In order to satisfy myself whether the par vagum was a vaso-motor nerve or not, the following direct experiments were instituted. As a local stagnation in the circulation from capillary contraction would of necessity modify the rapidity of absorption, the first experiment was directed to discover whether section of the par vagum has any influence upon intestinal absorption.

Fourth Series of Experiments.

Expt. 28.—Very large powerful male cat, and much smaller female cat. Dec. 13, 11 A. M. Cut the pneumogastries of the large cat. 2.54 P. M. Seems pretty well, but breathing noisily, and with slow, laboured effort. Without giving an anæsthetic I opened abdomen in linea alba, and, exposing small intestine, placed in it a pill containing $\frac{1}{4}$ grain of strychnia. 2 minutes. No perceptible effect. 4 minutes. Cat apparently feeling the poison; standing erect with some stiffness. 7 minutes. Just seized with violent tetanic convulsions, in which he died. 3.5 P. M. Put smaller cat under the influence of ether; opened abdomen in linea alba, and placed a pill, in all respects similar to last, in small intestine. 2 minutes. No effect visible. 4 minutes. Perhaps some stiffness. 6 minutes. Marked tetanic stiffness of all the muscles. 8 minutes. Stiffness persisting, with constant convulsive shudders. 10 minutes. Same condition. 12 minutes. Cat dead, without any wild convulsions.

Remarks.—This experiment shows that it makes very little difference in the rate of intestinal absorption whether the pneumogastries be entire or divided. The reason the injured animal died in the shorter period of time is probably not that absorption was more rapid, but that the breathing was already so much interfered with that death occurred from suffocation in the first convulsive paroxysm. The length of time from the administration of the poison to the appearance of the first symptom was as nearly identical as possible in the two cases.

Expt. 29.—Dec. 1st, 4 P. M. Cut pneumogastries in the middle cervical region of a full-grown female cat. Exposed the small intestine; inserted a suture through it, and at the spot injected two and a half fluidrachms of the linimentum cantharidis into the gut, which instantly became deep red. I now replaced the intestine, and sewed up the wound. 5 P. M. Cat still living. Dec. 2d. Died some time during the night, without purging or vomiting.

Autopsy.—The small bowel was remarkably red, especially near point of injection. The colour was darkish rather than bright, but still marked. On opening gut it was found to contain a considerable amount of thick whitish

mucoid substance. On washing the mucous membrane it was found not so red as the outside of the bowel, often pale, grayish ashy. In no place was there any injection of the mucous membrane.

Expt. 30.—A full-grown cat. Abdomen opened, suture inserted into the intestine, and fʒijss of linimentum cantharidis U. S. P. injected. During the night the cat got out of the box in which she was placed, and in the morning was found dead with bowels protruding. Small intestine a very deep red, both externally and internally; the epithelium of the inside had the same grayish ashy appearance noted in previous experiments. Bowels more intensely red than in Experiment 29.

Expt. 31.—Jan. 26. Under ether exposed and cut the pneumogastriacs in the neck of an adult female cat. At 4 P. M. opened the abdomen and injected into the small intestine about two fluidrachms of linimentum cantharidis, in which two Chilian peppers had been soaked. At another place two Chilian peppers were introduced into the small intestine through a slit, which was then sewed up, and the bowels were replaced. 6 P. M. Cat seems pretty lively; no purging. Jan. 27. Died during the night.

Autopsy.—Small bowels nowhere very intensely reddened; in some places injected, containing a considerable quantity of a semi-fluid mucoid substance smelling strongly of turpentine, which probably was largely the injected material. There was no injection of the mucous membrane at the position of the peppers, although considerable blood, which almost certainly had oozed into the bowel from the cut.

Expt. 32.—Large female cat. Present Dr. McQuillen, Professor of Physiology, Philadelphia College of Dentistry, and Messrs. Dixon and Chaninell, office students. Etherized the animal and, after cutting the pneumogastriacs in the neck, slit open the small bowel opposite to its attachment to the mesentery, and applied a galvanic current of moderate intensity to the distal ends of the severed nerves. The colour of the mucous membrane of intestine changed from a pale whitish hue to a very decided reddish tint. The current was intermitted, and a fresh portion of the bowel on being exposed was found of the original pale colour. The current was then passed through the nerve again, and the mucous membrane again reddened. The current was again broken, a fresh portion of the bowel exposed, and again an increased redness followed a completion of the current. After this, however, the bowel failed to change colour, upon electrical stimulation. Dr. McQuillen, after the experiment was over, stated that he was thoroughly satisfied as to the change of colour in the mucous membrane of the intestine following the earlier application of the galvanism.

Expt. 33.—A large and old English rabbit. Under ether, cut down to the pneumogastriacs and placed a string loosely around each, so that it could be drawn out of the wound at pleasure; at the same time the trachea was exposed and a tube inserted therein, for purposes of artificial respiration if required. Operation complete at 3.30 P. M., and the ether withdrawn. 4 P. M. The intestines were exposed by a median incision in the abdomen, through which the large bowel immediately protruded. It was laid open, the contained fecal matter removed, and the mucous membrane carefully washed with a soft sponge. After some minutes' exposure, the mucous membrane was decidedly red. The pneumogastriacs were now pulled out of the wound and cut. In less than half a minute the bowel had become very decidedly pale; the change was marked, and persisted for fifteen minutes, when the animal was given what was supposed to be woorara, which produced in a short time violent tetanoid convulsions, and put an end to the experiment. No medical gentleman but myself was present. I asked my assistant—a very intelligent man—if there was any change in the bowel. He instantly replied, "It is of very much lighter colour." He knew nothing as to my expectations, whether there was to be any change, or, if so, of what nature.

Expt. 34.—Attempted to etherize a large cat, but had great difficulty in accomplishing it, and remarked to my assistant that I had never seen a cat resist

an anæsthetic so long. However, she finally became thoroughly anæsthetized, and I cut down on the left nerve. At this time it was discovered we had been using *alcohol* for ether, so that complete anæsthesia had been produced by vapour of cold alcohol. The abdomen was now opened. Peristaltic action was completely suspended in the bowels, reappearing, however, readily when the galvanic current was applied to them. When left to themselves they were always relaxed, perfectly passive. The small bowel was laid open, and the pneumogastriacs cut. No change was perceptible in the colour of the mucous membrane on division of the nerves. The distal ends of the divided nerve were now galvanized, at first with a very weak, afterwards with a much stronger current. Respiration was very sensibly affected, but no change whatever was perceptible at any time in the colour of the mucous membrane of the bowels.

Expt. 35.—Full-grown English rabbit. Under ether the pneumogastriacs were exposed without cutting them. The abdomen was now opened and a portion of the small intestines drawn out. The animal was then allowed to lie for half an hour, the intestines being covered with a wet sponge, until the effects of the ether had passed off. The intestine was now laid open, and after four or five minutes a very mild induced current was passed through the uninjured pneumogastriacs. At first no change; in two or three minutes darker points became apparent, and in five to ten minutes the whole intestine became markedly darker. After ten minutes the pneumogastriacs were cut; the bowel, however, scarcely changed. My assistant said he could see no change whatever. I thought it became a shade lighter, but was not positive. Galvanizing of the distal ends of the cut nerves for some five minutes produced no change whatever in the bowel. The proximal end of one nerve was also galvanized for a couple of minutes without effect. The currents used were very weak, but sufficiently powerful to influence respiration in a marked manner. No interference with the heart's action was apparent.

Expt. 36.—Full-grown English rabbit. Under ether cut down and exposed pneumogastriacs in the neck without injuring them; then opened the abdomen and dragged out the intestines. I now waited half an hour until the effects of the ether had thoroughly passed off, and then slit open the small intestine opposite its attachment to the mesentery. There was some bleeding, but it stopped on the application of a little cold water. Five minutes after this a tight ligature was placed around each pneumogastric. This apparently caused great pain, and the animal struggled violently. In two or three minutes the nerve was cut. Owing possibly to struggles the bowel *reddened* very decidedly after section of the nerve, and it *continued* so after the animal became quiet. Five minutes after this we galvanized the proximal ends of the nerves with a mild induced current. For some time no change was perceptible, but afterwards the bowel became somewhat lighter coloured, and persisted so until experiment closed. The peristaltic action of the bowels was apparently not affected by section of the nerves being about equally active after as before. There was apparently some increase in its activity upon galvanizing the nerve, but this seemed more of a coincidence than an effect.

A careful study of these experiments will, I think, convince any one that there is no direct connection between the pneumogastric nerve and the abdominal circulation. Experiment 28 shows, as already stated, that intestinal absorption is not affected by division of the cervical par vagum. The 29th demonstrates that important changes can be produced in the intestinal circulation by local influences after division of the nerves. In the 31st experiment the reddening was not so marked but still was quite apparent. Experiments 32, 33, 34, 35, and 36, taken together, I think prove that neither division of the nerve, nor galvanization of either of the cut ends, has any fixed effect upon the intestinal circulation. In some cases

there was some effect, but results were so often wanting, and when obtained were so often contradictory, that I have no doubt the changes in the colour of the mucous membranes were always either mere coincidences or were brought about indirectly, by the transmission of currents to other nerves, as has been shown to occur (Bernard, *Med. Times*, 1865, vol. ii.), or by effects upon the respiratory function, or upon the heart, or perhaps by exposure of the intestine, or in some other way, not readily discoverable.

Exactly how "shock" could cause a loss of power in the intestinal glands I do not understand, but it has suggested itself as an efficient cause. In order to test it the following experiments were instituted. They are not numerous, nor are they very decisive, but I think are sufficient to show that the intestinal effects of the division of the nerves cannot be accounted for by "shock" alone, although it very probably enters as one of the factors in the problem, and the sudden blanching of the mucous membrane of the stomach observed by Bernard was probably due to it. The experiments of Schiff upon division of the œsophagus corroborate the idea that "shock" has influence in the matter. As already stated, that observer found that cutting the œsophagus across low down was in itself sufficient to abolish gastric secretion.

Fifth Series of Experiments.

Expt. 37.—Etherized stout female cat, and by blows with the thick end of a heavy axe broke the thigh-bones of both hind legs completely, also the bones of the forelegs; in the latter there was a good deal of crushing, and from one considerable hemorrhage. 3.20. Cat has recovered from the ether; seems in good condition; administered hypodermically about gr. ss veratriæ sulphas dissolved in alcohol. 3.30. Making violent efforts at vomiting. 3.35. Vomiting violently. As the design of the experiment had been fully carried out, I now put an end to the animal's sufferings by a blow on the head with the axe.

Expt. 38.—March 1. At 3.50. P. M. tied the right carotid of a moderate sized cur. At 4 passed a ligature around the left carotid, without tying. 4.05. Dog has come out from under the ether to a considerable extent; tied the ligature tightly. 4.10. Dog sensible; perfectly quiet; immediately after the occlusion of the artery there was some stiffening of the muscles, and some apparently involuntary raising of the head; no convulsions. 4.12. Dog perfectly quiet; saliva dripping from mouth. Injected into cellular tissue of side about $\frac{1}{8}$ grain of commercial veratria in alcoholic solution. 4.20. Dog very restless, with a constant suppressed howl or moan. 4.30. Dog shows some indications of sick stomach. 4.35. Quiet. Repeated the dose. 4.40. Howling violently, and continued to do so for fifteen minutes. No vomiting, or purging, or convulsions. 5. Wild; biting; trying to get loose. Gave hypodermically, gr. $\frac{1}{8}$ commercial veratria. 5.15. Perfectly quiet; injected $\frac{1}{8}$ grain of the alkaloid. 5.30. Quiet; considerable salivation: heart beats 75 per minute. Injected into peritoneal cavity gr. $\frac{1}{4}$ of the veratria; immediately vomiting occurred without effort or straining a large quantity of partially digested food—a "puddeny" mass. Injected into cellular tissue of thighs gr. $\frac{1}{8}$ of the alkaloid. 5.40. Dog rigid all over; body bent forward very much; emprosthotonos; limbs stiff. 5.43. Dog relaxed; no convulsion; making constant violent efforts at vomiting; retching; straining; vomiting "dry;" no mucus or fluid rejected. 5.47. Retching still continues; very violent; mostly without any results; occasionally a little thick stuff rejected similar to that first thrown up. Heart beat 36. 6.10. Still alive, but no more; no vomiting or no convulsions since last entry;

sometimes an apparent tendency to convulsions; he appears to be below the convulsion state; at times apparently dead.

Expt. 39.—March 9. 2.30 P. M. Gave a large male cat a bolus containing arsenic 3 grs., compound extract of colocynth 7 grs., gamboge 2 and a half grains, croton oil one drop. 2.40. Administered ether, and 2.45 tied left carotid. 2.55. Put a ligature loosely around right carotid. 3.10. Cat pretty well recovered from effect of the anæsthetic; tightened ligature; respirations immediately became panting, exceedingly rapid, 150 per minute; expression of face wild, anxious; a constant low, suppressed moaning; head constantly moving from side to side with a sort of slow, rolling vibration. 3.15. Untied the cat. He made no effort to walk, but laid on his side, with the same constant motion of his head. 3.20. Breathing much more natural, not strikingly abnormal; when approached, cat shows desire to fight by spitting and growling, but makes no effort to get away or actually fight. Smart whipping has no effect on him; he will not attempt to rise or move forefeet save to alter their position slightly; when pushed forward with the foot he finally, however, rose and ran three or four steps and then fell, with limbs bent under him. There is some power in limbs, but great weakness as well as indisposition to move them. 3.35. Cat lying still, head erect; is roused with difficulty, but when finally pushed into getting up, can run quite well. 3.40. Cat pretty well, running about room some; no vomiting or purging. 4.30. Cat seems pretty well, but quiet, liking to creep into corners and cower there; has just vomited a considerable quantity of dark watery fluid, apparently discoloured by the compound extract of colocynth given some hours before. 5.30. No change; no more vomiting or purging. March 10. Still alive, and in pretty good condition. I am uncertain whether there has or has not been any purging during the night; certainly, if so, not more than a single passage; I think none. 10 A. M. Repeated the bolus. 12 M. Still alive; no vomiting or purging. 1½. Died some time after last visit; there has been no purging or vomiting.

Expt. 40.—March 9. 3.35. Administered to a young cat, apparently some nine months old, a bolus containing 3 grains of arsenic, 7 grains of compound extract of colocynth, 2½ grains of gamboge, and one drop of croton oil. 3.40. Tied the external jugulars; produced no very marked symptoms. 3.50. Seems in good condition; howling loudly, and trying to get away. 5.33. No change; no vomiting or purging; cat howling. 10. Still alive. March 10. Cat died during the night; there was evidently free purging.

The question which next suggested itself for investigation was, Is the arrest of intestinal secretion after division of the pneumogastrics in the neck dependent upon disturbances in the respiratory function? That it cannot be owing solely or chiefly to the lessening of the heart's power, is evinced by the fact that purgation frequently does take place when by other means the heart's action is lessened much more than it is by the operation alluded to. That the latter does profoundly interfere with the lung functions and that after it there is during life a gradual accumulation of carbonic acid in the blood, admits of no dispute. Now, if it can be shown that such an accumulation is in itself sufficient to check secretion, a great advance will have been made towards the solution of the problem. The following experiments were therefore instituted. They are in two series. In the first, measures were adopted to more or less completely suspend the action of one lung, and then purgatives were administered. In the second, the action of the medicines upon animals exposed to an atmosphere loaded with carbonic acid gas was studied. It is evident that in the first set of

cases "shock" entered as a possible factor, whilst in the latter it was altogether excluded.

In exposing cats to the gas an apparatus was used which commended itself by its cheapness, portability, and efficiency. An ordinary candle-box, with a sliding lid, was knocked to pieces, and its joints made tight by nailing them very closely and forcibly, with a strip of flannel between the boards. A pane of glass was set into the lid and a hole bored into the side of the box near the bottom. Into this a cork was placed which was fitted with a luted glass tube, such as the chemist frequently uses. Another hole was bored in the side near the top of the box at the opposite end to the first hole. A cork fitted this upper opening so that it could be opened or stopped at pleasure. The box was now connected by an India-rubber tube with a bottle or flask in which some carbonate of soda had been placed, and the apparatus only needed the addition of an acid to the latter to be in action.

Sixth Series of Experiments.

Expt. 41.—2 $\frac{3}{4}$ P. M. Pregnant cat. Made an incision on left side and forced a silver grooved director into and through right pleural cavity until it rested upon the vertebral column. Then inserted a tube in its place and pumped in air until cat was swollen like a drum. No bleeding of any moment. 3 P. M. Gave hypodermically about 2 grains of arseniate of potash. 4 P. M. No vomiting or purging; repeated operation; gave gr. j additional. 4.15 P. M. Gave gr. j additional. 4.30 P. M. Gave 2 grains more of the arseniate. 5 P. M. Cat just purged once with some effort; very loose; not very large discharge. 6.15 P. M. Cat dead.

Autopsy 15 minutes after death.—Cellular tissue almost everywhere infiltrated with air. Stomach filled with frothy liquid. Right lung not cut; congested; in places very darkly and looking as though bruised; heavier than the other lung and less crepitant; not collapsed.

Expt. 42.—Feb. 4. 4.10. Made a free incision in a large male cat on the right side near the sternum down to the ribs, and cut obliquely through one of these, making an opening into pleural cavity sufficiently large to introduce the finger. 4.15. Right lung pretty well collapsed, ascertained by introducing finger. Breathing laborious. Passed a cord very tightly around the chest in two places, so as to completely prevent thoracic breathing. 4.20. Cat well recovered from effects of the ether. Injected in four places into the cellular tissue two grains of arseniate of potash in half fluidounce of water, and half a grain into peritoneal cavity. 4.30. No change in condition of the animal. Breathing laboured, deep, abdominal. No vomiting or purging. 5. No change. Cat has been able to howl some. No purging or vomiting. Gave hypodermically gr. $\frac{1}{4}$ of commercial sulphate of veratria in solution. 5.15. Cat apparently dying of suffocation. Cut the string binding the chest. 5.17 Revived, got up and walked some steps, tottering considerably in so doing. 5.25. Had a convulsion, leaping some six or eight inches backwards, three or four inches from the ground. 5.30. Gave hypodermically gr. $\frac{1}{4}$ commercial sulphate of veratria in alcoholic solution. 5.35. Just dead.

Autopsy immediate.—Heart still beating. Stomach filled with a little frothy liquid. Small intestines very dry, almost no mucus in them. Arteries and left ventricle full of black blood.

Expt. 43.—Feb. 11. 3.40. Put a kitten apparently eight months old, under the influence of ether, and divided the cord between the third and fourth lumbar vertebræ. Collapse of respiration came on immediately; the heart kept beat-

ing rapidly, but breathing ceased almost entirely, and the kitten was at one time apparently dead. Cold water was dashed against her face and she began to breathe again. 3.50. Kitten showing signs of consciousness; paralysis perfect in posterior portion of her body. 4. Able to pull herself with her forefeet, going round and round and round, with her hinder end for a pivot. Administered hypodermically one-sixth of a grain of commercial veratria. 4.10. Pulling herself forward; seems well and strong. Gave gr. $\frac{1}{4}$ as before. 4.20. No change; no vomiting. 4.25. Saliva running freely from mouth and some gagging; breathing excessively hurried, very shallow, thoracic. No vomiting. 4.30. No decided change; mewing feebly; good deal of salivation. 4.35. Breathing as before, exceedingly rapid, irregular, shallow, 160 per minute. No change; no vomiting. I was now forced to leave the animal to my assistant, who informs me she was seized at 4.40 with violent convulsions, which recurred frequently until her death, which took place at 5.30. No vomiting or purging occurred.

Expt. 44.—3.20. P. M. I made an oblique incision an inch long over the right lung near the sternum, cutting through the cartilages of two ribs, of an impure black and tan terrier. Immediately dyspnoea was very marked. There was considerable arterial hemorrhage, but not enough to seriously affect the animal. 3.25. By means of a Wood's syringe threw into the peritoneal cavity one grain of arseniate of potash, dissolved in a fluidrachm of water, and directly after 3 grains in six different places, in the cellular tissue of thigh, flanks, sides, and back. 3.25. I bound a cord tightly around the chest so as to totally suspend thoracic breathing. Very great distress and laboured respiration was the result. In about five minutes the symptoms of suffocation were so urgent that I thought I would have to take off the string, but they abated somewhat, and the string was not removed until just before death. The breathing was always exceedingly laboured and almost completely diaphragmatic. 3.34. Administered two grains additional of the arseniate of potash, dissolved in water, injected into the cellular tissue in four different places. No vomiting or purging as yet. 4.10. No vomiting or purging as yet. Efforts at breathing very laboured. Dog evidently very ill. 4.30. No especial change in symptoms except dog apparently weaker. No vomiting or purging. 4.45. No vomiting or purging. Dog dying.

Autopsy immediate.—4.46. Right lung thoroughly collapsed. Heart still beating feebly and irregularly; distinctly two auricular to one ventricular systole. Left ventricle, aorta, and other arteries containing very dark blood. No bright aerated blood in the arteries. Intestines with the mucous membrane sometimes reddened; containing considerable mucus, but not enough to drop from them when cut, except perhaps in one or two spots; in some places dryish. Peritoneum contains considerable fluid.

Expt. 45.—Feb. 7. 4 P. M. Etherized a large male cat and exposed the ribs freely on left side; then made a long transverse incision into the pleural cavity, cutting through two ribs. 4.10. Cat having well recovered from the ether, gave him hypodermically one-sixth of a grain of commercial veratria dissolved in alcohol. 4.18. Bound a cord tightly once around the chest so as partially to suspend thoracic breathing. 4.25. Quiet. No vomiting or convulsions. Breathing very laboured. 4.30. Gave one-sixth of a grain of commercial veratria hypodermically. 4.35. Cat has had a formed passage from bowels, and appears to be making efforts at vomiting. 4.37. Vomiting. 4.40. Vomiting again. In this vomiting there has been little or no discharge from the stomach. No forcible pouring out of greenish fluid, such as is seen ordinarily in veratria vomiting. 4.48. String removed. 4.50. One-sixth of a grain additional given and cat placed in the carbonic acid box and the gas allowed to flow in freely. 5.20. No vomiting since being put in box. Still alive but unconscious. I now took him out and killed him with a blow on the head.

Seventh Series of Experiments.

Expt. 46.—Feb. 6. 3.15 P. M. Injected into the subcutaneous cellular tissue of a powerful male cat, one-half grain of commercial sulphate of veratria, dissolved in alcohol. The cat was then put into the box. 3.18. Struggling and fighting. 3.20. Lying on side perfectly quiet, with deep laboured breathing, 30 per minute. Taper goes out immediately when plunged in the box. 3.30. No change; no vomiting or purging. 3.35. Injected subcutaneously one-third of a grain of commercial sulphate of veratria. No vomiting or purging as yet. Salivation considerable but not nearly so profuse as generally under the influence of veratria. 3.40. Quiet; breathing deeply; somewhat rigid. Nothing at all like convulsions. 3.50. Cat died without vomiting or purging. Somewhat rigid. Died in an atmosphere in which taper was instantly extinguished.

Autopsy five minutes after death.—Stomach empty. Bowels containing a moderate amount of mucus. Peristaltic motion exceedingly active, more so than I remember ever to have seen it before; constant and active without stimulus; when intestine was cut across expelling the little contained mucus with violence through the cut.

Expt. 47.—Feb. 5. 12.35. Injected into cellular tissue of a powerful female cat, a little more than the eighth of a grain of commercial sulphate of veratria, dissolved in alcohol. Put the beast immediately into the box. 12.30. Taper goes out immediately in box, but cat struggling yet. 12.45. Has been lying perfectly passive on side for some time; breathing deep, laboured, 28 per minute; mouth open, tongue hanging out; pupils widely dilated; taper plunged in box instantly goes out. 12.50. No change. Salivation profuse, wetting every part of the box near the head; no vomiting. 12.55. Breath rate 26. No change; cat perfectly motionless save breathing. 1.15. No new symptoms or change. Atmosphere of box all the time containing sufficient carbonic acid to extinguish taper when brought into it. 1.20. No change. 1.25. No vomiting or purging as yet. No new symptoms. 1.30. No change. 2. No change. No vomiting. Salivation excessively profuse. Taper goes out. Injected into cellular tissue one-sixth of a grain of commercial sulphate of veratria, in alcoholic solution. 2.15. No change in cat or air of box. 2.50. Gave hypodermically one-sixth of a grain of commercial sulphate of veratria. 3.10. Took the cat out of the box, where she had lain perfectly passive. 3.15. Cat in convulsions, unable to stand, but lying on her side. 3.20. Almost constantly convulsive, or at least constantly and paroxysmally, kicking into air; occasionally some opisthotonos, still a good deal of salivation. Pupils still widely dilated. 4.00 Constant convulsive movements. Still considerable salivation. No vomiting or purging. Pupils widely dilated. 4.30. Knocked the cat in the head.

Autopsy.—Stomach empty. Intestines empty. Arteries and left ventricle containing dark blood.

Expt. 48.—Feb. 7. Injected into the cellular tissue of a powerful male cat, by means of a Wood's syringe, $\frac{1}{2}$ of a grain of commercial veratria dissolved in alcohol, and immediately placed animal in the carbonic acid box 5 minutes before 4 o'clock. 4.15. Restless; paper burns feebly in the box. 4.20. Quiet; breathing labored. 4.25. Exceedingly restless, apparently in a convulsion. Carbonic acid gas now passing in more freely. 4.28. Quiet; breathing laborious, feeble; no vomiting, but a moderate amount of salivation. 4.30. Nearly dead; perfectly unconscious and relaxed. Dragged her head out of the box; mouth open, tongue hanging out, lips pale; pupils alternately dilating and expanding without any reference to the intensity of the light. 4.34. Revived, able to raise his head up, look about, and apparently make an attempt to bite; suddenly seized with a violent vomiting fit. Returned him immediately to the box, and allowed carbonic acid gas to flow in freely. 4.40. Quiet; breathing laborious. 4.45. lying on side, breathing slowly and laboriously, apparently perfectly unconscious; tongue out; a moderate amount of salivation. No vomiting since return to box. 4.48. Dead, without vomiting since return.

Autopsy, within five minutes after death.—Peristaltic movements of intestines exceedingly active; they being constantly vermicularly moving on exposure to the air, and a touch of the knife throwing them into all sorts of contortions and writhings. Intestines dry, containing no mucus. Stomach with a small amount of watery fluid.

Expt. 49.—Feb. 5, 11.15. Gave hypodermically to a large female cat $\frac{1}{8}$ of a grain of commercial veratria dissolved in alcohol, and put the animal immediately in box. 11.20. Breathing exceedingly laboured, deep. 11.30. Struggling violently, it was impossible to say with certainty whether convulsively or voluntarily; she kicked, doubled on herself, etc., violently in the narrow box. 11.35. Some violent struggles. 11.45.* Opened box; cat appeared very much under influence, but still kept her head up. 11.48. Box lid has been entirely off for five minutes, and cat shows evident signs of coming up from her semi-asphyxiated state; taper burns freely at bottom of box. Cat just seized with sudden violent vomiting of greenish mucus. 11.50. Vomiting again violently. Took the cat out of the box and undid the cords that bound feet together; cat was able to walk pretty well. 12.30. In last half hour has vomited freely several times. 1.10. Injected into cellular tissue 3 grains of arseniate of potash dissolved in water, and put cat back in the box. 2 P. M. have been away; box wet all round head, cannot say certainly whether merely from saliva or from vomiting; has had a formed passage. 3. Convulsive seizures; has been quiet before, since 2 o'clock, in convulsions; muscles work disjointedly, often more twitchings than convulsions—often without movement of the limb. 3.10. Dead; no purging save a little fecal mucus, say a teaspoonful.

Autopsy.—3.20. Intestines deep red, containing a large quantity of mucus. Stomach full of frothy liquid. Heart not beating, not irritable to knife; left ventricle with dark blood, not absolutely black. Lungs pinkish, congested. Peristaltic motion of bowels marked 15 minutes after death, 10 after exposure to air; constant twitchings of muscles right behind thigh and leg, with occasionally jerking of the paw, continuing 25 minutes after death, 20 after opening thorax and abdomen.

In series No. 6, there are five experiments. In the first of these a lethal dose of arsenic produced some slight purging, consisting of but a single loose passage. It is evident that this was not nearly so great as should normally be produced by the drug. There can be little doubt but that I failed in this case to open freely the pleural cavity. The air which was pumped into the animal located itself in the cellular tissue and not in the pleural cavity, and the autopsy showed that the lung did not collapse. There was, it is true, a good deal of embarrassment of the respiratory function, just enough apparently to check, but not entirely to suspend the action of the intestinal glands.

In Experiment 42, suffocation was certainly a very efficient agent in producing the death of the cat. The blood after death was everywhere highly carbonized. During life there was no purging or vomiting, although both veratria and arsenic were freely administered. Experiment 44 is very similar, and in every way confirmed the preceding. It differs only in the circumstance that arsenic only was used.

Experiment 43 is chiefly interesting in confirming, as far as it goes, the others, and in showing that veratria may produce convulsions even when it is prevented from vomiting. The shock caused by a section of the cord manifestly, however, prevents much reliance being placed on the ex-

periment as proving that an interference with respiration is an interference with intestinal secretion.

In Experiment 45 an apparent contradictory result was obtained, yet the vomiting was by no means so severe as it normally is, after the use of such doses of veratria. There is no certain gauge in such experimentation as to how far the lung function is interfered with, and it seems to me that as there was an actual diminution of the gastric action of the poison, the results obtained really strengthen rather than weaken the testimony of the other experiments. The amount of respiratory disturbance was certainly not so great as in some other cases, and the vomiting was entirely checked by a carbonic acid atmosphere.

The experiments of series No. 7 are even more decisive and reliable in their testimony on the influence of an excess of carbonic acid in the blood upon gastro-intestinal secretion, since the equation is reduced to its simplest form.

In Experiment 46, a cat, kept in an atmosphere loaded with carbonic acid gas, receives hypodermically nearly a grain of commercial veratria, and dies 35 minutes after receiving the first $\frac{1}{2}$ grain without vomiting, and on opening the stomach and bowels, they are found in about a normal condition.

In Experiment 47, two doses of veratria, $\frac{1}{8}$ of grain each, are administered, and the cat is kept profoundly under the influence of the gas; no vomiting whatever occurs. Twenty minutes after the last dose and about two hours and a half after the first $\frac{1}{8}$ of a grain, the cat is taken out of the box, but never sufficiently recovers to be able to stand, or for her pupils to become natural. After severe convulsions she is killed, and the stomach and bowels are found empty.

In Experiment 48, a cat, into whom $\frac{1}{6}$ of a grain of veratria has been injected, is kept in an atmosphere loaded with carbonic acid, and shows no signs of vomiting. He then is allowed to breathe fresh air, and as soon as he comes pretty well out from under the gas, vomits violently. On his being thrust back into the box, the vomiting ceases and does not recur. At the autopsy the stomach contains but a small amount of liquid.

Experiment 49 is very similar to the last. So long as the animal is strongly under the influence of the gas the veratria fails to provoke secretion and vomiting, which, on the other hand, appear just so soon as the effects of the carbonic acid pass off. A lethal dose of arsenic failed to produce any purging, although at the autopsy a considerable amount of mucus was found in the intestine, showing that secretion had to a certain extent been excited. The explanation of this, I think, is to be found in the imperfect narcosis produced.

The experiment, although placed near the last in this series, was in reality the first made, and I had not learned the best way of managing the apparatus, and did not keep up the necessary steady flow of the gas.

That the narcosis was not complete was shown by the pinkish colour of the lungs and the partially arterialized blood found after death in the left ventricle.

The experiments of these series seem to me, when studied one with the other, to prove conclusively that an excess of carbonic acid in the blood is capable of lessening, and when carried beyond a certain point of altogether preventing, in most instances, emesis and purgation. In doing this, the poison does not merely arrest the muscular movement necessary to the performance of those acts, but actually arrests secretion. This is proven by the results of post-mortem examination, for if secretion continued and peristalsis was checked, there would be an accumulation of fluid in the stomach and bowels such as is said to be seen in certain cases of cholera.

Moreover, I think the experiments already detailed afford proof that the peristaltic action, although in some cases apparently checked by the anæsthetic, is not necessarily so. To aid in elucidating this point the following experiments were instituted:—

Eighth Series of Experiments.

Expt. 50.—Feb. 7, 3 P. M. Placed in the box a large female cat, pregnant, and let carbonic acid flow in freely. Died in about twenty minutes.

Autopsy within five minutes after death.—Opened her abdomen first. Peristaltic action of the bowels absolutely wanting; bowels relaxed, perfectly motionless. When pricked with a knife a local persistent contraction took place, forming a depressed constricted ring around the bowel. Pricking gave rise to no true peristaltic motion whatever. The constrictions spoken of sometimes lasted full two minutes, perhaps more. After between five and ten minutes' exposure to the air, peristaltic action commenced to appear. The cat was then thrown out doors, where the temperature was probably about fifty. Fifteen minutes afterwards the peristaltic movement was exceedingly active, the bowels worming and writhing spontaneously.

Expt. 51.—Feb. 5. Without in any way injuring it, I placed a young cat, apparently about a year old, in the carbonic acid box. After it had lain there about half an hour perfectly unconscious, I threw into the box a very rapid stream of carbonic acid gas. Kitten died in about 20 minutes.

Autopsy five to ten minutes after death.—Heart not beating but starting and beating a few strokes when vessels were cut across, and the blood choking it was allowed to escape. Blood everywhere very black. Peristaltic action of the intestines very evident, but rather sluggish. Some spontaneous movements on exposure to the air, and a certain, but rather slow and feeble response to pricking with the knife.

The experiments which have bearing upon the question of the influence of carbonic acid gas upon the peristaltic action of the intestine are then Nos. 46, 48, 50, 51. In the first of these the cat had been for half an hour in an atmosphere so loaded with carbonic acid that a taper, when brought near the box, was extinguished before it entered it from above, and dying in such an atmosphere, was examined immediately. In spite, however, of the everywhere present black blood, the intestines exhibited the most active peristaltic motion I have ever witnessed, constantly and rapidly writhing and twisting over one another. In Experiment

48 the exposure to the gas was not so prolonged, but it was, if possible, more intense, and the cat died, I believe, chiefly of suffocation, and here again peristaltic action was very active. On the other hand, in Experiments 50 and 51, the cats were undoubtedly killed solely by the gas, and in the former there was absolute abolition of the vermicular movements until after the exposure of the bowels to the air for fifteen minutes, and in the other the peristalsis was sluggish, although evident.

Putting these results together, I do not see how any other conclusion can be arrived at than that already mentioned, namely, that lethal poisoning with carbonic acid gas does not in all, or even the majority of cases, completely suspend intestinal movements.

The whole of the experiments, therefore, prove that carbonic acid gas in excess in the blood has the power of arresting intestinal secretion.

It seems well established by the facts and arguments previously adduced, that the failure of purgatives after cervical section of the par vagum, is not owing to any direct influence which the nerve exerts upon the intestine. That section of the nerve is followed by accumulation of carbonic acid in the blood is also well known. Taking these facts with the influence of the gas upon intestinal secretion just proven, it appears to be a logical inference that the impossibility of vomiting or purging after division of the nerves, is due to the accumulation of carbonic acid in the blood. My experiments with the gas, however, showed that in order for it to produce absolute arrest of secretion it must be in sufficient quantity to manifest very plainly its presence by other than gastro-intestinal symptoms, such as more or less complete unconsciousness.

Now after division of the pneumogastrics in the neck, the gas does not accumulate, at least until near death, sufficiently to do this. It is therefore evident that there must be some other cause or causes aiding it in controlling secretion.

"Shock" has already been shown to be a probable adjuvant, but is apparently not the only one. For its influence would scarcely endure, or, if it did, would diminish rather than increase, while the resistance to the action of emeto-cathartics mostly steadily persists until death takes place, mayhap several days after division of the nerves.

In those experiments in which the pleura was opened there was a similar arrest of secretion without profound carbonic acid narcosis.

It therefore being probable that there is some cause for the symptoms besides those enumerated, the question naturally arises—Is there any lesion to be found which, existing in a marked degree both among the results of cervical section of the pneumogastrics, in collapse of the lung from wounds, and in profound carbonic acid narcosis, is capable of acting efficiently in restraining intestinal secretion? Such lesion I conceive is the great interference with the circulation in the lungs, which occurs in each case, and, of course, backs the blood upon the right heart, then upon the portal

circulation, and hence tends to prevent intestinal gland-action by producing a more or less complete local capillary stasis. This, then, I believe to be a third agency in aiding the arrest of secretion in the bowels after division of the cervical pneumogastrics. That it is not the sole cause is evinced by the previously detailed experiments upon intestinal absorption, which prove conclusively that there is no absolute cessation of circulation in the intestines after the operation.

In conclusion, the results of this protracted study of the subject may be summed up as follows :—

First. The division of the cervical pneumogastric does, in the majority of instances, but not always, absolutely arrest free gastro-intestinal secretion, emetics and cathartics being absolutely powerless to produce it.

Second. That this arrest is not due to any direct influence which the nerve has upon the intestine or its circulation, but is owing to two or three causes : accumulation of carbonic acid in the blood, interference with the circulation of the lungs backing up the blood upon the portal circulation, and perhaps shock.

These things being granted, the opposite results obtained by Brodie and Reid are readily explainable.

It is well known that in a small proportion of cases division of the nerves does not induce the changes in the lungs ordinarily so fatal. In such instances there is no great accumulation of carbonic acid in the blood, nor is there any backing up of the blood in the pulmonary artery, and consequently upon the right heart, and finally portal circulation.

The secondary results of section of the par vagum—the actual causes of the arrest of gastro-intestinal secretion—are therefore wanting in these cases ; and I believe it to be in such that emetics and cathartics act freely after division of the nerves. The rarity of such cases is the reason why those experiments are proportionately so few, in which such drugs act in their ordinary manner after the operation.



