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The Relation of the Autonomic Nervous System to the Motility

and Secretion of the Stomach in Elasmobranch Fishes.

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Motility of the Stomach.

For the study of the stomach we used large specimens of Raja diaphanes

and adult Raja stabuliforuis (120 cm. length and 20 to 25 kgm. weight). In these

the various nerve branches can be easily found. The animals were immobilized by

section of the spinal cord below the medulla. Artificial respiration was employed

by having a cannula through which sea water ran, pass through one or both spiro[?]s.

In some experiments two balloons were inserted into the stomach,

one in the cardiac portion and the other in the pyloric portion; these connect-

ed with Marey's capsules and the contractions were recorded on smoked

paper.

Vagus. Our method consisted of stimulating different branches of the

vagus at the oesophagus. The upper branches of the vagus bear relations to the

oesophagus only; stimulation with a faradic current produces an almost im-

mediate contraction of the oesophagus. The other branches of the vagus have

relations to both the oesophagus and the stomach. Stimulation of the vagus

shows two remarkable features:

(1)It gives an immediate contraction of the oesophagus and a contract-

ion of the stomach which begins 25 to 45 seconds after the cessation of stimulation.

(2)Different branches of the vagus initiate contractions in different parts of the stomach but if the current applied to a vagal branch is strong enough, contractions spread all over the organ.

A typical course of events when one of the vagal branches (in this case on the right side of the oesophagus) was stimulated for 30 secs. with a moderately strong induction current (Harvard inductorium, coil 8 cm.) was as follows:

Expt. 2, Aug 9. Almost immediate contraction of the lower end of the oesophagus. 5 to 10 secs. after the beginning of stimulation contraction of the pyloric sphincter which lasted for 5 to 10 secs. Next there was a period which very few, if any, contractions, both during the rest of the stimulation period and the period immediately following cessation of stimulation. But 20 to 25 secs. after the end of the stimulation there began forward and backward movements of the lesser curvature and slight contractions of the pyloric canal. A pulsating ring appeared in the cardiac part; the parts in which such rings occurred were not quite definite. At times the body of the stomach would perform rotating movements.

Anterior Splanchnic Nerves. Stimulation of the anterior splanchnic nerves give a much stronger and more prolonged effect than does the vagus. During the first 5 to 10 secs. of stimulation contractions of the pyloric sphincter occur but last only 5 to 10 secs. For the remainder of the stimulating period (from 30 to 60 secs.) there are no movements whatsoever. The 25 to 30 secs. immediately following stimulation is also a period of quiescence, after which there begins at the distal end of the pyloric canal a very strong contraction, which spreads oralward. This contraction passes through the antrum pylori and constricts the whole stomach; as the organ becomes narrower it moves bodily posteriorly. About 1 min. 30 secs. after the end of stimulation the whole stomach has constricted and relaxed and then the same phenomenon begins to occur again; indeed, the picture may be

repeated several times.

After several stimulations of the vagus and anterior splanchnic nerve, in some experiments there set in spontaneous contractions which were in the form of travelling rings. These started at the cardiac end of the stomach and descended to about the middle of the fundic part.

Müller and Liljestrand have seen that vagus stimulation inhibits movements which had previously been provoked by splanchnic stimulation. In our experiments we found that stimulation of both nerves, either simultaneously or in rapid succession, produced no dimunition in effect. In one case (Expt. Aug. 15) we observed that preliminary stimulation of the vagus even increased the effect and shortened the latent period of splanchnic stimulation.

To repeat, we have not observed any inhibitory effects of vagus or splanchnic stimulation. Nicholls (1933) showed that the spontaneous contractions of an isolated strip of antral muscle of the skate are inhibited by adrenaline in concentrations of 1:1,000,000 or greater but that more dilute solutions (1:2,000,000) cause stimulation. Tissue from this region kept 3 to 4 days in saline at 0°C. was found to be stimulated by all effective doses of adrenaline. No special experiments (e.g. stimulation of the splanchnics during spontaneous contractions) were tried by us.

Effect of Atropine. Atropine in large doses (6 to 10 mg.) did not prevent the positive effects of either vagus or splanchnic stimulation. It stimulated somewhat the stomach muscle itself and, as a matter of fact, it even increased the effect of vagus stimulation. Nicholls recently demonstrated that the effect of vagus stimulation on a strip of gastric muscles of the skate is not affected by atropine, whereas the positive influence of acetylcholine is abolished by atropine.

Therefore it is to be concluded that the effect of the parasympathetic nervous system on the smooth muscles of the stomach of the skate is quite different from that in warm-blooded animals. Analogous relations were found to exist in the blood vessels of these animals with respect to

adrenaline and acetylcholine as both these drugs cause their contraction.

Another interesting point is the phenomenon of spread of contraction over the whole organ. According to Muller, the gastric plexus (Auerbach's plexus)in the skate stomach is in the form of a true "nerve net" because the neuro-fibrillae pass from one cell to another. Both vagus and splanchnic extrinsic nerves are connected with the cells of Auerbach's plexus.

Gastric Secretion.

For testing the gastric reaction a glass tube of suff-
icient width was passed through the mouth into the stomach of a
skate. If the stomach contained fluid, by lifting the posterior part
of the body of the animal and slightly moving the tube back and
forth, the contents were drained from the stomach. If the contents
of the stomach were scanty a wire with red and blue litmus and
congo red papers attached to it was passed through the glass
tube and the reaction of the gastric juice tested.

In certain cases the spinal cord from just below the
medulla to the tail was destroyed by means of a probe which was
introduced into the spinal cord through a cut in the ligament
between the first vertebra and the skull. Such animals could be
kept alive from ten to sixteen days.

A fasting skate (fasted for 14 to 15 days) never has
much fluid in the stomach. It is with great difficulty that even
¼cc can be aspirated from such animals. But the reaction of the
mucous membrane is very acid to litmus and congo red.

Section of vagi or injection of large doses of atr-
opine did not stop this secretion, hence it does not depend on the in
tegrity of the parasympathetic nervous system. This may be seen
from the following examples:

Expt. 34, Aug.17, Section of Vagi. Oesophagus and pylor-
us tied 4.20 P.M. Reaction in the stomach acid. The wound sewn
water-tight. 24 hours later (Aug. 18, 4.25 P.M.) animal in very
good condition. Stomach contained 2.0 cc of very acid mucus,pH 3.8.

Effect of Atropine. Expt. 39. 2.20 P.M. stomach
acid and empty. 4 mg of atropine sulphate subcutaneously and

intramuscularly. Stomach empty for next 5 hours. Reaction of
the mucosa strongly acid. 7.35 P.M. 0.55 cc of thick mucus
pH 2.8 to 3.2. Nineteen hours later (9.30 A.M.) stomach empty and acid.
It must be added that pilocarpine (up to 20 mg) and acetylcholine
(25 to 100 mg) do not activate gastric secretion. Adrenaline (sub-
cutaneously or intramuscularly) inhibited this spontaneous secretion
for a period of several hours, the time varying according to the size
of the dose.

In acute experiments (spinal cord cut below medulla, Dial)
stimulation of the sympathetic nervous supply to the stomach for
several hours as well as injection of massive doses of adrenaline
did not activate the gastric secretion. In case of adrenaline
there was even a definite inhibition of gastric secretion.when
food was present in the stomach.

Expt. Aug. 31. 1:5,000 adrenaline, 8 cc of which were
injected over 8 hours. At the end of this period, a little neutral
fluid and food could be aspirated from the stomach. Reaction of
the mucosa neutral.

Expt. Sept. 5. This expt, extended for more than 21
hours. 2 cc of 1:10,000 adrenaline were injected every 1½ hours
(total of 22 cc adrenaline per animal). 3 animals were employed.
No. 1. Stomach contained food. Reaction acid.

No. 2. Stomach empty. Reaction neutral.

No. 3. Stomach Empty. Reaction neutral.

Therefore neither the parasympathetic nor the sympathetic nervous
systems convey secretory impulses to the gastric glands. By
means of drugs, analogous relations were found to exist in the

pancreatic gland of the skate. (Babkin)

The elimination of vagus influence on gastric muc=
osa did not produce any marked effect, as was reported above.

Quite different results were obtained when the
influence of the sympathetic nervous system was eliminated by
the destruction of the spinal cord from the cervical region do
down to the tail. This resulted in a "paralytic secretion" of
the gastric juice. This secretion appeared from several hours
to 3 to 4 days after destruction of the cord and continued
to the end of the experiment (longest duration of experiment
being 16 days). The amount of fluid aspirated from the sto-
mach varied in different animals from a few ccs to 10 and
25 cc in 24 hours. The admixture of the sea water to the
gastric secretion can not be excluded, especially the first
time after the destruction of the spinal cord. The stomach,
usually empty, could lose its tonus or else the tone of the
sphincters could be diminished and the water would thus be
passed into the stomach cavity.

Sea water is a quite alkaline fluid with a pH
8.2 (approx.) If poured on the acid mucosa of the stomach and
kept there for one to two minutes, it turns it neutral or
alkaline (Expt.39). However, there are facts in favour of
actual secretion of gastric juice.

(1) The acidity of the gastric contents were
high (reaching pH 2.0). Hence not very much sea water could
enter the stomach.

(2) The osmotic pressure of the gastric con-

tents was lower than that of the sea water.

(3)Cl concentration of the gastric contents was lower than that of the sea water.

(4) The secretion possessed a moderate peptic power (from 40 to 150 Mett's units).

(5) During the paralytic secretion, the secretion itself and the blood became depleted of some electrolytes.

(6) There was no loss of Cl from the blood, possibly urea which, according to Baskin + Komarov is present to 1% in gastric secretion, was gradually lost by the animal.

(7) Injection of adrenaline stops this acid secretion. On several occasions the stomach contained a neutral or slightly alkaline fluid, presumably sea water because the Cl concentration approached the Cl concentration of the sea water. Thus in Expt. 33 in a skate with spinal cord destroyed on Aug.18, the stomach was found empty and acid on Aug.22. Injection of 2cc of 1:10,000 adrenaline at 10 A.M.

In L hour   (11.05) 0.5 cc fluid, pH7.2
In 2 hours (12.05) 23.0 cc fluid, pH7.6 ⎫
In 3 hours (2.05)   4.5 cc fluid, pH7.6 ⎬ Cl 1.79%
Next morning(8.15A.M.)3.0cc fluid,p pH3.0 ⎭

Conclusions: The conclusion we draw from these experiments is that the mechanism of gastric secretion in Elasmobranch fishes is different from that in other vertebrates.

In the higher mammalian forms (cat, dog, man)

gastric secretion is regulated by the two nervous systems
and by a humoral mechanism as well.

In amphibia, e.g.frog, the sympathetic nerve
seems to be the secretory nerve of the gastric glands
(Friedman).

In Elasmobranchs the gastric glands are al-
ways in a certain state of activity. This activity does not
depend on the influence of secretory nerves (vagus or sympathetic)
but it is highly influenced by changes in circulation. It
is highly probable that the origin of the "paralytic secretion"
is vascular and depends on the lowered tonus and presumably
increased permeability of the blood vessels.

In this connection it is worthy of mention that
histamine is practically without effect on the circulatory
system of the skate, even when injected in massive doses
(2 mg every two hours during ten hours, i.e.total of 10 mg)
and that it neither activated nor stopped the spontaneous
gastric secretion in normal animals(Expt.Aug. 26).

The phenomenon of "paralytic secretion" of gastric
juice in the Elasmobranch is reminiscent of the effect of section
of the splanchnic nerves on kidney secretion.

How the mechanism of secretion is set into activity in
normal conditions we do not know. However, it is a well-est-
ablished fact that after the introduction of food into the
stomach the secretion starts and reaches its maximum on the
third day (V. Herwerden).