Innervation especially Sensory Innervation of Stomach in White Rat

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Many histological studies on the innervation of stomach have been conducted from olden times, among which the study on the vegetative nerves made by Stöhr1) during the years of 1931 through 1937, with reference to human normal and diseased stomachs, especially stomachs with ulcer ventriculi, and the recent study of sensory nerves in human stomachs of adults and tenth month embryos by Sato2) may be especially mentioned as achieving excellent results and contributing honorable pages to the study of the innervation of stomach.

As a humble successor to the illustrious forerunners, I presume to announce my individual views on the subject as stated hereunder, gained after a minute observation of a multitude of ideal preparations of stomachs of white rats, stained with Seto's silver impregnation.

Individual Views

Vegetative nerves in stomach

By the successive announcement of epochal novel views on the peripheral vegetative nerves as the results of devoted studies by many rising investigators succeeding the renowned studies by Stöhr1) and Reiser3) in 1932, an almost entirely new page has been turned in their histology. For example, the end-apparatus of vegetative nerve fibres is no more represented by free terminations, but as the vegetative terminalreticulum (Stöhr), while nothing could be observed to endorse Langley's neuron theory. Also my observations on the distribution of the vegetative nerves and their histological pictures in the stomach in white rat revealed nothing essentially different from those in human stomach. Let me give some detailed views thereon.

The providing nerves for the stomach originate in n. vagus and sympathetic nerves, and upon reaching the curvatura minor, distribute both
ventrally and dorsally with many branches. Then, they run through
the outer muscular layer and come in close relation with the Auerbach's
plexus formed between the outer and inner muscle layers. In the tela
submucosa is found the Meissner's plexus which anastomoses with the
minute branches from Auerbach's plexus at many points.

Though in the cross sections of stomach, the Auerbach's pleuxs shows
only a nervous disirubtion limited over a very small sphere, in the plane
sections it is noticed as a remarkably conspicuous nerve net with rhomboid
meshes and containing nerve cell groups. The Meissner's pleuxs which
is composed of nerve elements distributed in the tela submucosa is de
veloped best in the outermost layer of the tela and has a little amount
of nerve cells in places, as described below.

To go into details of the nerve cells, in the cross sections of the stomach
wall are found many nerve cell groups in the Auerbach's as well as the
Meissner's pleuxus. By the latter, the nerve cells are located chiefly in
the deeper layer of the tela submucosa, decreasing more and more as
the superficial layer is reached, where they are sparsely found in solitary
existence.

The nerve cells in these two plexuses are in a stage of development
in comparably lower than those in human stomach, as shown in Figs.
1 and 2. For example, the number of their short processes is so far

Fig. 1. Nerve cells in Auerbach's plexus showing low stage of develop-
ment. Stomach of white rat. Seto's impregnation., X700, reduced to 1/2.

smaller than that in human stomach, that it is impossible to classify these
nerve cells into the Dogiel's two types of cells divided by the distribution
of the short processes. But there is no doubt about their being sym-
pathetic, because they have been confirmed to be multipolar. In human
stomach and intestinal walls, there are also found such extremely lowly
differentiated nerve cells on many occasions, and it is very interesting to
collate this fact to the data observed by the white rats described above.
The nerve cells are provided with many mantle cells around them, but no connective tissue capsules can be found around the latter, so that many nerve cells are surrounded by the mantle cells syncytially, as do those in human stomach. These mantle cells are embryologically Kohn’s accessory cells and it is surmised they are of endocrine nature.

The vegetative nerve fibres distributed in the stomach are composed of parasympathetic fibres of n. vagus, sympathetic fibres from the sympathetic nerves and long processes from the intramural multipolar nerve cells of sympathetic nature in the stomach. Now the incoming parasympathetic and sympathetic fibres anastomose nervously many times before entering the stomach, so that it is impossible to distinguish these both fibres histologically. The long processes of the nerve cells in the stomach gradually turn into minute fibres as they run farther from the mother cells and become indistinguishable from the incoming nerve fibres.

The providing vegetative nerve fibres first pass into the Auerbach’s plexus, wherefrom ramifications of various sizes branch out into both the outer and inner muscle layer, which again send out more minute branches and diffuse into the muscle layers. The branches which run into the tela submucosa pass into the Meissner’s plexus. The nerve bundles forming this plexus grow gradually minute as they approach the mucous membrane and passing through the lamina muscularis mucosae finally run into the lamina propria.

The terminal mode of the vegetative nerve fibres consist in forming the terminalreticulum (Stöhr). This terminalreticulum is not represented as free termination as deduced from Langley’s neuron theory, but is always connected with each other in endless anastomosis. This terminalreticulum shows a net-like formation of indivisibly fine neurofibrils running cord-wise, accompanying neuroplasm-mass interspersed with Schwann’s nuclei. The manner of the innervation of the terminalreticulum for all the tissue cells is effected in most cases by contact, in no case entering the protoplasm of the cells.
On the ground mentioned above the terminalreticulum is of sympathetic as well as of parasympathetic nature and furthermore includes the nerve elements of long processes from the nerve cells in the stomach wall, which are probably of sympathetic nature. In consequence, the mechanism of stimuli transmission is deduced to be as follows. In the case when the centrum is excited sympathetically, in the periphery the Schwann’s cells in the terminalreticulum are stimulated sympathetically and adrenalin is secreted, while if the central stimulus is parasympathetic, they are stimulated parasympathetically and acetylcholine is produced, these secretions deciding the functions of the innervated cells.

It is understood that, in the terminalreticulum formed to the nerve cells in the stomach wall, the stimuli actuate endocrine secretion in the mantle cells around the nerve cells, the endocrine substances stimulate in turn the nerve cells secondarily and the stimuli are thence transmitted to the periphery by way of the long processes.

*Sensory nerves in stomach*

Even in the stomach wall of such a comparatively low class mammal as a white rat I could ascertain the existence of sensory nerve elements, i.e. sensory nerve fibres and their terminations. So it would seem too natural that Sato\(^2\) has recently found that such is the case in adult men and tenth month human embryos. He made it clear that the pain in stomach by gastritis, gastric ulcer and presence of parasites is caused by the existence of cerebrospinal sensory nerve elements in the stomach, not by the sensory transmission by autonomic nerves, as advocated by Müller\(^4\) (1924), Kure and Okinaka,\(^5\) for explanation of apains in stomach by postulating existence of nerve fibres to transmit sensory stimuli belonging to vegetative nerve system, to account for their failure to find typical sensory nerve terminations in the stomach. I support Sato’s sensory nerve theory on the strength of my discovery of such terminations in the stomach in white rat.

The sensory nerve fibres running in the stomach of the white rat are also provided with conspicuous medullary sheaths as in the human stomach, and represented by axons thicker many times than those of the non-medullated vegetative fibres. Therefore it is very easy to distinguish both of them histologically. These sensory nerve fibres are assumed to originate in n. vagus, as clarified also by the fact that lately Russel\(^6\) succeeded in removing the pain in human stomach caused by gastric ulcer by cutting the vagal nerve.

Now, the sensory nerve fibres which run forward in the providing vegetative nerve bundles advance into the stomach wall from the curvatura
minor and come to the inner muscular layer and other peripheries after passing through the Auerbach’s plexus, as shown in Fig. 3. Their terminations are mainly found in the inner muscular layer as well as in the submucosa, and in rarer cases between the submucosa and the lamina muscularis mucosae. But the sensory terminations in the mucous muscular layer were not found by man, and by white rat they are very inferior in number.

These sensory terminations are never present in large number, but seemed to be a little more abundant in comparison with those in human stomach. Besides, also in white rat as well as in man the sensory nerve elements are more sparsely found in the corpus ventriculi than in the pars pylorica and pars cardiaca.

Sada\textsuperscript{7}) found extremely peculiar sensory terminations existing in the Auerbach’s and Meissner’s plexus in the human oesophagus. So, Sato\textsuperscript{2}) expected to find similar terminations in human stomach, but he found only sensory fibres passing through the Auerbach’s plexus and no terminations therein. I also could find no sensory nerve terminations in the plexuses in the stomach of white rat.

The ending mode of sensory nerve fibres in the stomach in white rat seems to be divided into the three types of simple branched termination, snake-like termination and unbranched termination. The simple branched terminations are chiefly found in the muscular layers especially in the inner one. This fact is in agreement with the Sato’s views in human stomach. As shown in Fig. 4, a thick medullated fibre running through the connective tissue between the muscle bundles in the muscular layer first loses the medullary sheath, then bifurcates two or three times, each branch showing change in size and a contorted course peculiar to the
sensory terminal fibres, finally to terminate sharply or bluntly. But I could not find nodular formations in the tip of the terminal fibres as seen in man. Besides, these fibres also accompany peculiar nuclei, corresponding to Schwann’s nuclei, in their course.

Sato\(^2\) has found, in a very small number, simple and complicated glomerular terminations in the human stomach, but I found none of them in the muscular layer of the stomach in white rat. It may be said that the terminal mode of sensory fibres is in the rat more primitive than in man.

The snake-like terminations are found in the tela submucosa and resemble strongly the “Schlingenendigungen” found by Sada\(^7\) in the submucosa of human oesophagus. They are represented by sensory terminal fibres which are comparatively thinner fibres showing little change in size and run in snake-like windings (Fig. 5). They differ from Sada’s “Schlingenendigungen” only in having no side branches. These snake-like terminations were not found in the tela submucosa of human stomach (Sato).\(^2\)

The unbranched terminations exist in general in the submucosa and lamina muscularis mucosae. Sato\(^2\) fails to report such terminations of simplest type in the human stomach, but it is probable that they exist also there. At any rate, these terminations consist in that the terminal fibres end sharply or bluntly after a weak winding course, without branching, as shown in Fig. 6.

As stated above, I have ascertained the existence of cerebrospinal sensory fibres and their terminations in the stomach in white rat, though.
in a small quantity, as in the human stomach, and on this discovery I base my assertion that the transmission of sensory stimuli in the stomach relies on the sensory fibres of cerebrospinal nature in agreement with Sato\(^2\) and not on the vegetative nerve fibres.

**SUMMARY**

The nerve cells in the stomach in white rat show a stage of development so low that they cannot be divided into any of Dogiel's two types of cells. But, as they are multipolar, they are probably of sympathetic nature.

It is impossible to distinguish histologically sympathetic and parasympathetic nerve fibres as well as long processes of the nerve cells in stomach wall especially at their peripheral parts, because they are in mutual anastomosis at many points. The termination of these vegetative fibres is represented by the terminalreticulum (Stöhr). So the terminalreticulum must be sympathetic and parasympathetic at the same time. The manner of its nerve supply of the tissue cells is effected mostly by contact.

Sensory nerve fibres and their terminations were found also in the stomach in white rat as in the human stomach (Sato). This fact shows evidently that the transmission of sensory stimuli is done also in the stomach through the cerebrospinal sensory nerve fibres.

The sensory fibres are very easily distinguishable histologically from vegetative fibres. Their number is very small, as is the case in human stomach (Sto).

The sensory terminations may be divided into simple branched,
snake-like and unbranched terminations. There were found no simple glomerular terminations as seen in man. It shows that the differentiation of the sensory terminations is in white rat inferior to that in man.

The simple branched terminations are mainly found in the inner muscular layer and are characterized by bifurcated branches of the stem fibre which show change of thickness, run a winding course and terminate sharply or bluntly. The snake-like termination is generally found in tela submucosa and is represented by a comparatively thin, scarcely branched fibre terminating freely after running a specific snake-like course. Unbranched terminations are the simplest of sensory terminations, where fine fibres terminate sharply or bluntly after light meandering, and are mainly found between the tela submucosa and the lamina muscularis mucosae.

References

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