Thesis

On the Structural Relations of the Peripheral Nervous System.
The Structural Relations of the Peripheral Nervous System.

The subject to which we propose directing attention in the present paper is one, the interest and importance of which have been very much increased by researches of a comparatively recent date. The many difficulties which it presents as a subject of investigation, from the reminiscences of the structures involved, and their proneness to rapid decomposition by which their histological characters are so much altered, have opposed the progress of successful observation, and indeed it is only lately that the peripheral nerve-terminations, with their relative structure, have obtained more than incidental reference in works professing to treat of the structure of the nervous system.
It will be seen also, from the numerous references made in the following pages to the somewhat prolific literature of our German neighbours, that this subject has attracted the especial attention of their physiologists.

From the variety, as regards form, situation and structural character of the different parts of the peripheral nervous system, the labours in this field of inquiry, although numerous, have limited their researches exclusively to particular portions of it, and accordingly we find the literature of the subject very unconnected, being widely scattered and disconnected; few or no attempts having yet been made to collect and arrange in a systematic form the numerous researches and their results, which have been announced, more recently by individual observers from time to time, with regard to the structural characters and relations of the periphery of the nervous system. Reference made to any of the latest systematic works in Anatomy and Physiology, such as the last edition of "Brain and Brain-stem," will show how very slow they have been to take advantage of the important results derived from recent investigation into this subject.

Before entering on the more particular...
In these introductory remarks I have followed chiefly the opinions of Prof. Godwin, as delivered in his preliminary observations on the Nervous System, which were communicated to his class in the sessions 1835-36, and also in his paper on the "Present state of Organic Electricity," in the Edinburgh New Phil. Journal, 1835, vol. ii. p. 327. The following works however have also been consulted with special reference to the views here expressed, viz.: Magendie's Physiologie; Thriller's Physiology by Dr. Daley; Mr. Carpenter's Works on Physiology; and the last of Sir H. Holland's "Chapters on Mental Physiology." Wagner's Handbuch by Ferneke part ii. § 163, and under the heads of the different senses.
consideration of our subject, and propose to devote a few pages to its more general relations, anatomical and physiological, to the other portion of the nervous system in order to understand the important share it has in the production and development of the various phenomena resulting from the operations of that system in the animal economy.

Among the different phenomena occurring in living bodies, we recognize some which cannot be referred to the action of any of those forces which preside over the changes taking place in the inorganic world. These accordingly have been ascribed to certain powers or properties called into action under certain conditions, in obedience to various stimuli, mental and physical, objective and subjective, appropriate to each, and which in consequence of their manifestations being confined to living bodies, have been termed "Vital properties". Of the Vital properties characterizing the animal there is more more indicative of the presence of the living principle than Sensibility. In virtue of this property the various parts and texture of the body, internal and external, are rendered more or less "sensible" or capable of receiving impressions
which we become conscious of through the faculty of sensation. This property is localized in a special tissue, the nerves, just as contractibility, another vital property, is localized in the muscular. On the general distribution and presence of this nervous tissue through-out the body, this property of sensibility is communicated to all the tissues and organs, in a degree proportionate apparently to the amount of the nervous element possessed by them.

The nervous system, in which this function of sensibility is thus specially developed, is an arrangement of structure, by means of which, all the other structures and parts of the body are united and co-ordinated into one individual organism, and that harmony of action and function produced, so essential to the maintenance of life. This is the organic function of the nervous system, but it subserves a still higher purpose—its harmonies, and controls the medium of the actions and reactions of the corporeal or physical, and the mental or psychical elements on each other— it affords the appropriate seal of the psychical phenomena and term "mind," not that their existence in the presence of the nervous element
but merely that it is necessary for their manifestation.
Mental or psychical acts are invariably accom-
pained or preceded by certain parallel processes occurring
in the nervous system. But mind is not a part of
the brain, nor is it a secretion or product of the
nervous system, as bile is secreted by the liver, or gastric
juice by the stomach, which is the view taken of it
by some German physiologists, but it is a co-ordination
of emotions and feelings produced by sensations and
arising in obedience to certain mental laws, and pro-
ceeding under certain conditions to which they are
subjected by the consciousness. The psychical element
of the human mental Constitution, which man pos-
sesses in common with the brute Creation, is to be
distinguished from that higher principle or essence, the
reason or soul, which he alone possesses as a special
endowment from the Creator, and on this his moral nature
depends. In the lower animals it is represented by the
instinct.

The ultimate structural elements of the
nervous system consist of nerve-cells, nerve-filaments,
and certain structures attached to the distal extremities
of the latter and which only partake of the nervous char-
acter.
actor in virtue of that connection.

We find the following primary functions performed by this system in the animal economy:

I. It connects in one harmonious whole all the different parts of the entire organism, by means of nerve-filaments which in their passage from one organ or structure to another have very recently been ascertained by Ostejanitchin, a Russian Anatomist, to be always intersected by nerve-cells in the nervous centres. He determined in the spinal cord of the lamprey and some of the higher fishes that there was a continuity of tissue between the ganglionic or nerve-cells and the intercommunicating nerve-filaments. Each cell giving off an efferent or motor filament while another pole of the cell is connected with an afferent or sensory filament, while a third pole is continued into a commissural filament connecting it to the brain.

It is near, therefore, all but certain that no nervous filament passes from one organic system to another without passing through a nerve-cell. This is the nervous arrangement upon which the process of "REFLEX ACTION" depends. The mind may or may not be conscious of the action, that depends on the
commisural filaments. It is purely a physical or physiological action, not a mental. The movements
propagated along the nerve fibres are, connected with or derived from their polar condition; it seems to
partake of the nature of an electrical current, though perhaps not identical, it is at least analogous for
the electrical current detected in the filament when in a state of functional repose, disappears when it is
traversed by a [defly] nervous movement or act.

II. This may be termed the sensory function
for excellence of the nervous system. The distal extremity
ities of the sensory filaments are so organized and connected
as to render them capable of being impressed by certain
appropriate stimuli. A nervous filament transmits
or propagates an impression or force originated or received
at the periphery (so induced), which force when it
reaches the ganglionic cells in which the conducting
filaments terminate in the nervous centre, produces
a physiological change in them accompanied by, but
not creating a mental act termed sensation, percep-
tion of the sensation being next effected by the
consciousness; for we may have sensation without
perception. The original excitement, the polar action
or force transmitted, and the action instituted in the ganglionic centre, are purely physical or physiological; the sensation accompanying the latter is a psychical act or mental condition. In main the rest of the process occurs under the influence of the spiritual principle, the soul or pneuma with which he is endowed, in virtue of which he possesses self-consciousness to enable him to interpret his sensations and reduce them to perceptions. "We must receive these phenomena as ultimate facts—how they occur we cannot explain." (Ps. 144).

III. By a series of commissural filaments the different ganglionic cells or groups of cells are united to one another; a sensation being set up in the manner above described, the physical nervous act, which precedes or accompanies it, does not remain in the ganglion in which it was originally produced, but is capable of being transmitted by the commissural filaments to the other ganglia, and thus, sensations and the perceptions interpreted from them, are co-ordinated, and to allow of the occurrence of those mental actions and reactions necessary for the evolution of thought or intellect—intellect or reason being the free exercise
of thought. Certain movements in the brain always occur along with such operations of the intellect, but the latter are conducted entirely independent of any physical or even psychical laws or conditions controlling the other dynamical and mental processes preceding the operation of the consciousness, which we have already considered.

IV. The nervous system affords the medium necessary for bringing the various movements of the body under the influence of the will, which is also, like the self-consciousness, an attribute of the pneuma. Then an act of the will, resulting from a process of the intellect, is instituted, a parallel action of a physical nature is set up in certain nerve cells in the brain. The movement is transmitted by a nerve-filament passing down to another set of nerve cells in the cord, from which a motor filament conveys the influence to the muscle. The latter part of the process from the intersecting cells to the muscle is entirely out of the control of the will, and purely physical in its nature.
Divisions of the Nervous System

Systematic Writers, in treating of the nervous system, have recognised a division of their subject into "Central" and "Peripheral" portions; the former comprehending the cerebral ganglia and the centra-spinal axis—the latter extending from the roots of the Spinal nerves to the Periphery.

The latter division however must necessarily include various highly important structures found in connection with the distal extremities of the nerve fibres, not strictly of a nervous character, and differing so much in their general structure and functions from the other nervous elements, as to entitle them to be separately considered as a distinct division of the nervous system, more especially as every addition made to our knowledge, which is far from being complete, of the peripheral nervous structures displays a differentiation of organisation so marked and elaborate, and functions so peculiar, as fully to warrant their being thus regarded.

Professor Goodenough's division of the nervous system is now in accordance with this view of the subject. He recognises:

1. Central Organs.
2. Intercommunicating nerve-filaments.

3. Peripheral Organs.

1. The central organs, consisting of the cerebral and sympathetic ganglia, and the cerebrospinal axis, are composed of nerve-cells and ultimate commissural nerve-fibres, arranged in masses or ganglia, with areolar or connective tissue, and very richly supplied with blood-vessels.

2. The intercommunicating structures are the afferent and efferent nerve-fibres; along the former are propagated those movements which end in sensation; and along the latter the impulses of the will. There is no anatomical difference as regards structure existing between them; and it seems that the nervous force or current may be transmitted either way along the nerve-filament. This force is the same in both cases— the result of the force depends entirely on the central and peripheral connections of the fibre. Thus, a motor nerve may convey a current in either direction but with effect only when it reaches a muscle—a sensory nerve may also transmit an impression either way, but only with effect when it reaches the sensomotor. The nervous force is purely physical, probably polar or electrical.
merely an act of matter, but under the control of the
physiological principle or mind.)

The recent observations of Rudolph Wagner, Schroeder
Van der Holt, and especially those of Overjannikow
render it more than probable that in every case the prox-
nal or central extremity of the nerve filament either
terminates or originates in a nerve-cell. How their dis-

tal or peripheral extremities are disposed or terminate
we shall consider under the next head.

3. The peripheral nerve organs include those
special structures, which we find in certain situations
attached to the distal extremities of the fibres of particular nerves,
but as Professor Goodwin, by a beautiful generalization
shown, perfectly in accordance with our knowledge of
this subject, shows—all organs and tissues to which
nerve are distributed must be regarded as peripheral
nerve organs, in as much as they are capable of in-
fluencing or influencing, or of being impressed or in-
fluenced by them. All efferent or sensory nerves are
connected by the peripheral extremities of their fibres,
with peculiar structures of various degrees of complexity,
as regards form and arrangement, in virtue of which
structure, the impressions which they transmit to
The nervous centres are initiated. These efferent fibres as we have already said, are in no way different from the afferent fibres; the former or incident nerves only receive and convey impressions the nature of their peripheral connections, in which those said impressions originate, or the application of the various stimuli. It is the distal extremity of the nerve fibre alone which is capable of being thus impressed for all stimuli or irritations applied to the nerve in any part of its course are invariably referred to its peripheral terminations. This is not only true as regards the nerves of special sensibility, as the optic, the auditory, and by partial observations also the gustatory and olfactory and those of the skin for touch—but it is also true with respect to the connection of the distal extremities of the incident nerve filaments with muscles, in glands, and other parts; for they can only convey information as it were to the sensorium with respect to the state of these structures, in virtue of a certain mode of connection of the ultimate elements of the nerves, and those of the part or organ in which they are distributed. Every texture and every organ has the power of transmitting through the incident nerves an account of its condition to the brain, in addition to the which the latter possesses of influencing the peripheral organ.
through its efferent nerve fibres. In this way every muscle and every gland, and indeed every tissue whatever, must be regarded as a peripheral nerve organ, quoad the nerves terminating in it. But it also stands in this relation to the efferent or motor nerve fibres, for they can only communicate to the muscle the force or impulse initiated at the Centre by the will, in virtue of its connection with the muscular tissue. In as much as every peripheral structure of the body to a greater or less degree has the power of influencing or being influenced by the nerves distributed in them, we must consider them as holding the position of peripheral nerve organs.

From the preceding observations, for which we are mainly indebted to the lectures of Professor Gooden on the Nervous System, delivered to his class in the session 1853-54, it is evident that a more intimate and accurate acquaintance with the peripheral connections and relations of the nerve filaments will add greatly to our knowledge of the different phenomena and laws of sensory action, subjects of which our acquaintance at present is still limited, though progressive.
We have found it more convenient for the purposes of description to consider the fact as here laid down, viz.: that, adorning the arrangement of the different parts of the apparatus, we have produced the arrangement of the different parts of the apparatus.
An inquiry into the peripheral nervous system, of an anatomical nature will involve:

I. A consideration of the various structural modifications which the extremities of the primary nerve-fibres themselves undergo, before finally terminating.

II. A description of the peculiar series of structural elements met with, in close relation, or attached to the peripheral terminations of the nerve-fibres, in which (the appropriate impressions) which it is the particular function of the latter to propagate or convey, are initiated. We shall find a peculiar differentiation prevailing among these peripheral nervous appendages, according to the nature of the impressions for the appreciation of which they are designed, and to transmit which to the sensorium, is the special function of the particular set of nerve-fibres to which they are attached. These impressions for real the sensations which produce them, vary much, both in kind and degree, from the sensibility possessed more or less by nearly all parts of the body in common, to certain special combinations of it localized in particular peripheral organs termed "head of sense," thus we have portions of the
1. Dr. Müller's Archives 1838, p. 249.

3. Müller's Physiology, by Dr. Bailey, 1840.

I Peripheral Modifications of the Nerve Fibres themselves.

(a) Divisions of the Primitive Nerve Fibres.

It is within a comparatively recent period, it was held as determined that the so-called primitive nerve fibres or trabecula, with double contours and varying from 1/200 to 1/500 of an inch in diameter, were the ultimate elements into which the nerve bundles were resolved at the periphery, in man at least. All investigation into the actual terminations of the nerve filaments at the periphery rested at this stage; and when apparent exceptions to this opinion were announced in the discoveries of Schwann, Haeckel and other observers, they were received with suspicion and their correctness doubted.

The resolution however of these primitive fibres into elements still more minute, as afterwards ascertained by numerous observations, was presented by Müller in 1835, who remarked, "It is not very probable that the so-called "primitive fibres, which are of considerable size, from the "actual terminations of the nerves in parts, the ultimate ele- "ments of which are more minute than these."

Subsequently we find the correctness of this opinion established by the researches of Schwann, Remak, and other
1. Neue Untersuchungen über den Bau, und die Erregung der Nerven 1847.

2. Volkmann in Mühlen's Archiv 1838, p. 74.

3. Stereotypische Anatomie vol. I. p. 241-3, in which also reference is made to folk observations.

anatomists who were led to consider, principally from observations in the lower animals, these primitive nerve fibres to be composed of extremely fine filaments into which they were resolved previous to their ultimate terminations.

Independent observations of the frequent occurrence, in the human subject, of distinct divisions of the primitive tubules of the motor nerves into minute fibres, were announced by R. Wagner in his monograph on "The Structure and Terminations of Nerves" published in 1847; by Volkmann about the same time, and their observations were subsequently confirmed by Holliker's researches, with respect to the muscular nerve-fibres, of which he figures a very beautiful instance which he saw in the omohyoid muscle. He also describes the occurrence of these divisions in the form generally of bifurcations in the nerves of various other tissues, such as the periosteum, intersosseus membrane of leg, in the mucous membranes in the mucous lining of the pharynx and vagina, and in the conjunctiva where very beautiful ramifications of the nerve fibres are found. We find Valentin also declaring the existence of this branching of the primitive tubules towards their distal terminations, and figures an instance of a dichotomous division of this nature.

Still later, bifurcations more or less complete
Pappenheim, in Comptes Rendus 1846 - vol. xxi, p. 968.


of the terminal extremities of the fibres of the sensory nerves, were observed by Hlute and Kolliker; Krohne and Pappenheim in connection with their terminations in the Pacinian Bodies to be afterwards more particularly described. Kolliker also observed divisions of the cutaneous nerve fibres occurring, according to him, generally at a right angle. These were especially apparent in the superficial fibres destined for the skin. The occurrence also of this branching of the distal extremities of the cutaneous nerve fibres and their relation to certain minute peripherally appendages in connection with the sense of touch, have still more recently been ascertained by P. Wagner and his pupil Meissner, and subsequently borne out by the results of subsequent investigations of Kolliker and others. Wagner has also seen in man, and in the calf, subdivisions in the form of tufts, to such an extent as to render it difficult to trace the fibres to their termination in the tongue. Similar appearances have been observed also by him in glands, such as the parotid and lacrimal, and he states they occur though rarely in the pulp of the teeth. Ecker also describes the nerve fibres breaking up in the medullary, after piercing the cortical substance of the suprarenal capsules, and Kolliker


has found them in the spleen of the calf.

Later investigations have also determined the existence of subdivisions in the primitive fibres, in the terminal expansions of the nerves of special sense, but we shall allude to this when we come to describe them at length in another part of this paper.

Finally R. Wagner states as the result of the examination of numerous preparations that, not only the autonomic fibres, but also the sensory, and those called primitive sympathetic fibres (trophiques) subdivide at several intervals towards the periphery.

These observations in man were anticipated by frequent investigations, and of wide range, in the field of com- parative anatomy. The credit of the original discovery of divisions of the primitive nerve fibres is due to Schwann, who first observed in the secretery of the frog a double system of divisions of the primitive bundles, which has also been seen by D. Sharpey. In 1840 Savi described a double bifurcation, or a doubly dichotomous division, rarely dichotomous, of the nerve fibres, in order to form the hexagonal meshes of a network on the diaphragm of the prisms in the electrical organ of the Torpedo. Marcone, Wagner successive observers have also remarked the occurrence


Kolliker's Human Histology vol. I, p. 266. (Cited in Loc. Worr.)

4. Müller's Arch. 1852, p. 61.


of these repeated subdivisions in that structure. Hott jerke likewise describes a dichotomous subdivision, sometimes tri-
dichotomous, to the extent of from 12 to 25 branches. Prf
for Dr. Secr. Judd has also found a nearly similar disposition
of the nervous element in the electrical appa ratus of
the Rain or Skate, (also observed by Berr.) Chr. Rubin has
remarked in the tail of fishes of the same genus, the prim-
itive tubules with double contours bifurcating and tri-
furcating several times. This has been also seen by Hilly,
in the Bethic Malacosternes. These subdivisions have been
recognized by Müller, Briice, and Hottjerke, in the orbital mus-
cles of the pike; by Wagner, Ecker, and Reichert, in the hyalophy-
nerous and the cutaneous muscles of the thorax in frogs; and
by Wagner and Kepner, in the muscles of the second.
These subdivisions for the most part have been repeatedly
confirmed by Hottjerke, Geiger, and Ogermann in various
animals and particularly by M. Duyvère and Dartege
in the invertebrates.

The purpose served by this breaking up of
the primitive nerve tubules at the periphery into num-
erous fibrils, is very evident. A greater extent of surface
is thus more readily supplied by one single primitive
fibre, than could possibly be effected by any other
arrangement. In connection with this view E. H. Weber conceived the sensory periphery as mapped out into tactile districts isolated to a certain extent, and each corresponding to a primitive fibre being supplied by the branches resulting from its subdivision. All impressions, consequently, initiated within such a district being referred by the sensorium to one point only, answering to the tactile district within which the impression was made, and accordingly producing only one sensation, since the independence of these additional filaments is not provided for with the original primitive tube, by their medullary sheaths being continued into it. But according to this theory of Weber, if we apply the points of the compasses as in his own experiment, when we get one point in one tactile district and the second point in another we should have two distinct sensations produced by a proximity of the points of contact far more close and delicate than in any part in the immediate vicinity, where we would have both points of the compasses in one tactile district, but this test has been frequently applied and always fails. The terminal divisions of the cutaneous filaments must therefore interradiate with each other—Thus...
met by this plan, for in this way the great bulk is avoided which would result from the isolation and independence of the minute fibrils, being maintained by the continuation of their medullary sheath from the periphery to the nervous centres. The extremely limited extent of the tactile districts which would arise from the isolation of the divisional filaments, would cause an unnecessary delicate power of distinguishing sensations derived from exceedingly close and minute points of contact. There must also be to some extent, at least, an increase of the true nervous matter gained as the sum of the branches exceed in diameter the primitive fibre whence they are derived.

6. Attenuation of the Nerve Filaments towards the Periphery.

Valentin and Miller and other anatomists have remarked the occurrence of a characteristic change which frequently takes place in the primitive nerve tubes at their peripheral terminations, independently of the subdivisions into minute filaments which we have just described. 

E.g. a gradual at...
loc. cit.

Annul. des. de l'Aut. 1846, 228.
termination of the fibre or diminution in diameter. In one instance mentioned by Motthier, primitive fibres of from 0.004-0.0083" became rapidly reduced in size within a short distance to 0.001". This attenuation may even be continued to such an extent as frequently to prevent the possibility of tracing the fibre farther towards its termination. The change of size is accompanied by their assuming the appearance of the so-called sympathetic fibres as described by Remak—becoming pale, presenting only a single contour line, and also an occasional wormiform or beaded appearance. W. Wagner describes the division of the nerve fibres as assuming an embryonic character and disappearing in the sheaths of the vibrissae ("Tasthaar") of rabbits.

Robin has described the primitive fibres in the Ray in some cases without subdividing, becoming smaller by degrees, and gradually lost themselves in the muscular tissue.

This decrease in diameter depends probably on the attenuation of their medullary sheath, which serves to isolate, perhaps, more than to protect the nervous filaments, and the circumstance of their being deprived of this isolating or conduction investment, partially or even entirely, toward their peripheral termination, must increase their susceptibility to the action of stimuli. This may probably
afford the explanation of the fact of the greater sensibility of the distal extremities as compared with that of the nerve fibres in their course, pointed out by C. H. Weber, and it may also throw light on the mechanism of sensibility when considered in connection with the conditions afforded by the type or part in which the nerve filaments, thus modified, ultimately terminate. This deprivation of the medullary sheath we shall find takes place to a great extent in the fibres of the nerves of special sense, as in auditory and optic, where it is essential that the nervous matter should be exposed under the most favourable conditions of functional activity. This has also been seen by Waker and Wagner, more recently, in the primitive fibres of the papillae of the tongue, and by Wagner, Hollitzer and others in the nerve filaments in the electrical organ of the Torpedo.

(c) Terminal Plexuses of the Peripheral Nervous System.

Tracing the nerves towards the periphery, we find them previous to the final distribution of their primitive


fibres, breaking up into numerous small bundles which interlace with each other in every direction, so as to form pleats of varying degrees of delicacy and extending close to the peripheral extremities of the nervous filaments. Valentine, whose description for the most part we follow here, and who first described this planiform arrangement of the minute nerve bundles at the periphery, and remarked the regularity of its occurrence more or less in all nerves, termed it "The Terminal Pleats of the Peripheral System." Gerlach states that Terminal Pleats occur of various degrees of complexity in the entire periphery of the nervous system. The terminal pleats formed by the cutaneous and muscular nerves of the frog were early recognized by Bardach, and very recently by Wagner in the papillae of the tongue, especially in the calf. The existence of this disposition of the nervous fasciculi into a peripheral pleural in all tissues has been sustained by all subsequent investigations into this subject.

Bardach and Valentine also observe that this terminal nervous pleura corresponds to the capillary network of the vascular system, and that, in the same manner as the capillaries of every tissue and organ assume a characteristic arrangement, so also the terminal pleura always exhibits distinctive features, according to the nature of the
part or texture in which it is distributed, and in both cases vascular and nervous, the mode of arrangement probably will have special reference to the function of the parts in which they are respectively situated. Ranstach also endeavored to show that distinctions prevailing in the character of the terminal pleurisy of the different classes of nerves. He believed that the nerves of special responsibility resolved themselves into their ultimate elements in their terminal pleurisy. In the case of the common sensory nerves the terminal pleurisy was generally formed, not by the primitive cord fibers but by the smaller sensory bundles, and the terminal pleurisy of the nerves in general was always composed of nerves particular of considerable size, and that even in their subsequent and final termination, they resolve combined themselves into the finer nerve filaments, but it is unnecessary to observe that these characters are now known to have no existence whatsoever.

The object gained by this pleurysm arrangement of the nerve bundles at the periphery are not well understood. Waldey supposed that it effects a greater interchange of the primitive packets, accompanied by increase in the actual amount of nervous matter, and a multiplication of the points of contact. But what influence or use it can have...
in this last particular does not clearly appear, for there are not
the ultimate peripheral terminations of the nerve fibres, and
Naber shows it is only the distal extremities of the filaments
that are endowed with sensibility, as previously stated. That
it has some direct influence on connection with the innervation
of the part in which it is placed is at least very probable.

(d.) History of Researches into the Peripheral
Nerve-Endings.

I. The earliest opinion that was held with respect to this
subject in question was exceedingly simple in its nature. The
nerve fibres were considered as ultimately becoming continuous
by a direct fusion of structural elements, with the tissues to
which they were distributed, and although this was neces-
sarily little more than a sound supposition in the absence
of the scientific appliances sufficient to determine such a
point, yet there is a very strong tendency among
physiologists at the present time to return to this view of the
matter, both as the result of actual observation, and from
the simplicity and harmony with which such a mode of
structural continuity could be regarded in connection
' Luc. cit. an. Se. nat. 

with the phenomena of certain vital processes.

In the invertebrata, an insertion (département) of the branches of the primitive nerve tubules into the muscular fibrils have been seen by several observers, as in the Sardi
grade (Miliomium Sardigrade) by Doyère, and in this instance the insertion was accompanied by a change at the extremity of the nerve-filament, from the previously crystalline to an opaque granular appearance. In the Sardi
grade, loricula, and Notifera (Eolidina and amplificus) M. Quatrefages has observed the digital extremity of the nerve filament enlarge into the form of a cone, the base of which being towards the periiphery, and embracing the muscular fibril; the structural continuity of the two tissues, nervous and muscular, now being established as Quatrefages expresses it by "une penetration reciproque, par une véritable fusion de substances": the same granular appearance was also here assumed. Goduvir Wagner
Huxley and others have set beyond doubt, by repeated observation, the occurrence of this mode of termination by continuity of tissue of the muscular nerves in the human subject. Both Wagner and Huxley indeed strongly maintain even a more extensive occurrence of the mode of termination in other struc
tures. W. James, with reference to the nerves of the kidney, remarks "The filaments end by becoming
continuous with the parenchyma of the organ, precisely in the
same way as I have observed those in the tail of a fatpole.

Second, directly continuous with the radiating fibres of the
vessels, corpuscles, and the filaments from the Corpuscles to
communicate each other. We can almost warrant in
supposing, at least with some degree of probability, that
when the extremities of the nervous fibres have not been
traced in consequence of their sudden disappearance, they
have in such cases become continuous with the tissue of
the part.

It is more than probable that
the further investigations of histologists into this subject, will
determine the more general occurrence of the ultimate dis-
position of the nervous element in other tissues in the human
body. This mode of termination of the nerve fibres
when accurately observed, is probably the only one in which
there can be no fallacy derived from the possibility of
a still further terminal disposition of the nervous element.

II. The preceding opinion was originally abandoned
in consequence of observations made in the muscular nerves
in man and in the arrangement of the nerve fibres in the
skin of the frog, tongue, and other textures, by Schwann
and van Beneden; especially which originated a general belief
in the termination of the nerve filaments at the periphery.
* Kokman also in a paper in Müller Arch. 1840, supported this doctrine.

"Researches incredible, but the dept. Rev. 1874."
by "loops" (Anse, Schlingo) in all tissues and organs in dis- 
erminated, in the same manner in which they were till 
saidly supposed to terminate in ganglione centres.

Valentin, among others, announced as a general doctrine 
that "Nerves have, properly speaking, no peripheral termi-
nation, but that in the peripheral organs the centrifugal part passes 
without any definite change into the Centripetal." He also 
added that this looped arrangement of the fibres assumed 
special characters in every tissue and organ. Gerber, an original 
observer, with equal confidence, declared that "_loops are 
the terminal endings of nerves" and he considered that the 
susceptibility of the part, varied according to the closeness or 
convolutions of the loopings of the nerve fibres in relation to 
their number supplying it.

So the correctness of this view of the ultimate nerve 
endings in loops, in addition to physiological objections which 
might be urged, we may oppose the possibility of fallacy 
in the actual histological examination as stated by Valentin 
himself: "that we are perhaps only looking at a simple 
branch of a nerve fibre, which subsequently continues onward 
to its true termination"; while Haurowitz remarks with 
equal truth, "une fibre qui a formé une courbe pourrait 
trouver sa marche et terminer dans une autre courbe."
loc. cit.

* Muller's Archives 1865 - p.36.

* Reuss. Untersuch. 1837.
Valentin further confesses that "the physiological study of these looped terminations presents numerous difficulties which render it absolutely impossible to establish a clear theory, not purely hypothetic, of the mechanism of perception in the peripheral parts of the body.

The subsequent progress of investigation transformed these possibilities into facts. Miller very early took exception to the general occurrence of looped terminations more particularly in the case of the nerves of special sensibility, and repeated exceptions were added to the general occurrence of the mode of nerve termination in question. Indeed, it may now be asserted with confidence that in no part of the body is a true ultimate looped termination of the nerve filaments at the periphery met with—except perhaps in the iris and ciliary ligament, where, in confirmation of the original observations of Valentin, Miller has very recently described loopings of the nerve filaments in connection with a plexiform arrangement. In the case of the nerves in the tooth pulp, as described by Valentin, Ehrlich, and which were always regarded as furnishing a typical example of the loop endings, recent observations show that their invariable occurrence everywhere admits of doubt, for K. Wagner has lately succeeded, sometimes
1. Muller's Arch. p. 56. 1853.
in tracing the primitive filaments, generally without division, through several loopings, the convergences of which generally, though not invariably being turned towards, the peripheral terminations, and prolonged beyond the loops to terminate by free extremities, though Hertel has since declared his adher to his original opinion. Niethner also describes the nerves of the tail of the tadpole as occasionally dividing and ending in the skin by free pointed extremities. It seems probable then that the nerve loops and hand just spoken of, though not forming the ultimate terminations of the nerves, are at least a further modification of their distal extremities, before they are finally disposed of. The doctrine of the general ending of the nerve fibres in loops is most positively denied to occur in any case what ever by R. Wagner. 2

III. The successive discoveries of the alteration of the peripheral extremities of the primitive nerve tributaries by subdivision and otherwise, their actual structural continuity in certain parts, with the tissues in which they are distributed; the frequent occurrence of abrupt terminations and along all the connection of their free extremities, in particular situations with certain minute appendages to all which we have already attended and into the

2. loc. cit.
details of which we must subsequently enter, declared that our knowledge of our subject was still progressing.

IV. The primitive nerve fibres, after subdividing into the minute fibres already described, have in some cases been traced into an exceedingly delicate network formed by them assuming a plexiform arrangement. This has been regarded by observers apparently as their final termination, as beyond this it was not possible to follow them.

With regard to the distribution of the nervous elements in the transverse clefts of the electrical apparatus of the Torpedo, the exceedingly minute nerve filaments resulting from repeated distributions of the primitive fibres have been lately traced by Kolliker, beyond the system of ramifications described by Remak, as prolonged from the extremities of terminal fields extremities of Wagner, which in his turn he had traced from what Lavi originally announced as the terminal loops. These we may have been ultimately traced by Kolliker into the extremely delicate pleats, supported on a fine homogeneous membrane.

M. Ch. Robin in the last of studies of the genus Raia found the primitive nerve tubes, with double continuities after bifurcating and trifurcating several times, finally to winding not in loops, but in a network with large meshes.
Annal. des De. Kat. 1877. p1070.
This mode of nerve termination by a plexiform arrangement of their ultimate elements has been described as occurring in various glandular organs. Thus the nerve filaments are described by Eber, breaking up into a serrated network in the medullary parenchyma of the submaximal capsule, after piercing the cortical substance of the gland. Wagnar also in the Lacrymal and Fertile glands in man, and in some of the lower animals, found the nerve filaments after leaving some loops always ultimately resolving themselves into a floculent structure, never terminating in loops.

With respect however to those ultimate terminal filaments especially in glandular organs it is certain that probably there is an ultimate terminal disposition of the nerve fibrils yet to be traced beyond this plexiform arrangement.

Dr. Carpenter in his Principles of Human Physiology advances a theory with regard to the peripheral connections of the extremities of the incident or sensory nerve fibers according to which he believes the existence of bodies of the nature of ganglionic vesicles at their distal ends to be as necessary for the reception of impressions, other than that of a mechanical kind, as their connection with an origin from ganglionic cells in the nervous centre, is for the initiation of motor or different impulses. He seems to have
laid his theory on the fact of certain ganglionic relations of
this nature existing in the case of the fibres of the optic, auditory,
and olfactory nerves. But as we shall subsequently see, the
fibres of the nerves in question do not terminate finally in
those ganglionic cells found in the course of their peripheral
distribution. However plausible this theory of Dr. Carpenter
may appear it is quite destitute of foundation as far as
active observation is concerned. The only approach, indeed,
to such an occurrence, is the supposition of Parini that
the expanded extremity of the nerve filament sometimes seen
within the canal of the corpuscles discovered by him, or of the
nature of a ganglionic globule. *Mr. Instepage also
describes the fibres of the cutaneous nerves of Amphibiares or
Branchiostoma as terminating simply in a little oval cell
like body.

It is not without difficulty that we can come
to any conclusion in the present stage of our knowledge, as
to the mode or modes in which the elements of the nervous
tissues are ultimately disposed of at the periphery. From
a careful consideration however of the extensive though
often apparently irreconcilable observations recorded in the
preceding pages, we are driven from the supposition of
the prevalence of any universal law in the mode of
the ultimate peripheral nerve terminations.

In addition to the actual results of microscopic research, physiological considerations oppose the existence of any such law, for it is to say the least, very improbable that there is any one type in which the distal terminations of the nerve fibres could be remodelled, which would permit of their adapting themselves to their share in the physiological actions of the textures or parts in which they are finally distributed.

II Simple Terminations of the Nerve Fibres at the Periphery.

(a) Ultimate Terminations of the nerves in muscle.

The earliest and most complete investigations into the subject of the peripheral terminations of the nerves were made in the muscular tissue in consequence of the facilities it afforded for histological examination, and indeed, our knowledge at present is perhaps more satisfactory and conclusive with regard to the nerve endings in muscle than in any other of the tissues.

Rudolphii appears to have instituted the first researches as to the muscular nerves, and although they seem to have been conducted with the naked eye, many subsequent observers...

2. Müller's Arch. 1858.
who employed the microscope did not improve much on his original discovery as was supposed of the looptite termination of the muscular nerves. But this must necessarily have referred to the arrangement of the larger nerves fasciculi.

Revest and Dumas also directed their attention to this subject, using instruments of low power to aid them in their examination. They described as the result of their observations, a tendency of the nerve fibres to descend perpendicularly to the muscular they then form curves or loops proceeding from one nervous branch to another, and finally re-ascending in the direction of the brain. Valentin and Hennert also made parallel observations of a more minute description, which were afterwards confirmed by those of C. Hufeland, and they seem to have agreed in regarding the ultimate arrangement of the nerve fibres to have been as follows: After entering the muscle the nerve assumes a course for a distance somewhat parallel to the muscular fibres; it then breaks up among the fibres into numerous anastomosing branches of different sizes, running obliquely from the main stem. These ramifications are continued till they are reduced to fasciculi composed of two or three primitive tributaries, which then by frequent intercommunication with each other, and two of other fasciculi, resolved themselves everywhere throughout the muscle into the terminal
plexus of Valentin, formed of oval or rounded meshes generally parallel to the course of the muscular fasciculi. Finally, from this nervous network, the so-called terminal loops are formed by twigs of one or more primitive nerve fibres passing in an arched manner from one branch to another, and returning centrifugally after the same fashion, the concavity of the arches being directed towards the terminations of the nerve, the cavity towards the stem.

This account of the final distribution of the muscular nerves, as given by the above mentioned authors, assumes the primitive fibres to constitute the ultimate element of the nerve bundles, and that even it is not always necessary for the latter to avail themselves of their power of resolving themselves into their primary constituents, and it would also lead to the supposition that the nerve fibres only came, at intervals in their course, in contact with the muscular, and consequently that the nervous currents whatever their nature may be was capable of being transmitted through the sarcolemma.

The discovery subsequently of the divisions of the primary nerve trabeculae into minute fibres in the muscular and other tissues by R. Wagner and others, formerly alluded to, declare that we had only reached a farther, not the farthest step in our acquaintance with the ultimate nerve ending.
I see. Eis. (Mie. Amab.)
Wölfler met with and figured a very distinct double dichotomous division in the omohyoid muscle in the human subject, but he was unable to trace them to their termination. Though he believed he had seen in the rabbit a termination of the divisions of the primitive nerve tributary in the pointed extremities of a facial muscle. H. Wagner describes the primary fibres dividing sometimes into as many as five minute fibres which appear actually to perforate the sarcomyoe, and then to subdivide into still finer filaments, not more than 1/10,000″ of an inch in diameter, that run between the muscular fibrillae when they elude further security. In other researches in the amphibia he also discovered divisions of the nerve-fibres varying in number from two to as many as eight, he was not however able to trace them into the muscular fasciculi but after running a short distance appeared to be either applied obliquely or transversely or to proceed for some distance parallel and in close contiguity to it—in either case becoming attenuated to a sharp point frequently as fine as a fibre of connective tissue. Their ultimate filaments becoming pale and presenting a simple contour line. Wölfler in the larvae of the Chironomus, a dipterus insect, observed the bifurcations of a primitive tributary implanted by slightly expanded extremities into the two muscular fasciculi of the
tissue. We have already sufficiently referred to the description of Royerl and Quehejga as to the division of the nerve filaments into the muscular fibres in certain of the lower animal forms, and to the positive assertions of the latter as to the occurrence of actual continuity between the two tissues. Professor Goodric, in the human subject, as also in the lower animals, has determined from his own repeated examinations of the tissues in question, that the nervous filaments, resulting from subdivision of the primitive bundles, pierce the sarcolemma, and that a continuity of kind is established within that membrane, between the primary elements of the nervous and muscular tissues.

From the preceding statements we conclude that the primitive nerve-fibres after leaving the terminal filaments form loops or curves from which they are continued onwards, and after subdividing into minute filaments, pierce the sarcolemma, and terminate in continuity with the muscular fibrils. The discovery of this ultimate connection between the two tissues may account for the veryimportant influence exercised by the nervous element over muscular contraction.
Annals of Nat. 1884, part II.
[b.] Peripheral Disposition of the Cutaneous Nerves.

We shall here study the nerve terminations in the thin
and a tissue highly endowed with ordinary sensibility, which
it possesses in common though greater in degree with all
other tissues and organs of the body, leaving the Consideration
of it as the seat of that special evaporation of sensibility,
we term the sense of touch, till we come to discuss
the nervous element in connection with the organs of
special sensibility. Our descriptions of the general cutaneous
nerve terminations will also include those of the tongue
for it is invested by a modification of the true skin.

Valentin, in accordance with his general theory on
the subject of the nerve endings believed the cutaneous
nerves to form no exception to his laws of termina-
tions. Pérevoz and Ducane also here as in nerves
entertained the same view. Brocchi also formed this con-
clusion from his own investigations. Bendaek took
another view however and declared from what he had
observed in the Chorion of the frog, that the primitive
fibres after leaving their respective nerve-trunks formed
an exceedingly delicate plexus or net work, and then again
collecting into bundles assumed a centrifugal course without
any further arrangement. Oppenheim however described several tubes coming off from the pleura described by Brandeis, repeatedly dividing dichotomously, and then forming a more superficial network of the finer elements. He did not succeed in tracing them any further. We must now however from our at present more advanced acquaintance with the subject, consider the above described arrangement as the "Terminal pleura" which extends throughout the entire thickness of the Cactus Vera, becoming finer and closer the nearer it approaches the surface. The prismatic fibres given off from the pleura and described by Gersh as terminating in distinct loops and in the sensitive papilae, assuming a highly convoluted knot-like arrangement (Fervenkänel) or sometimes in the form of a rosette (Ektroseiten) and he appears to have been supported in his opinion by Krause and Purtzinger. Kölliker and Wagner have both observed divisions of the prismatic nerve-fibres, as also Cermath and Geer, but they have not been able to decide whether this takes place in every instance. Kölliker is of opinion that these divisional filaments terminate in loops although he admits that occasionally free ends do occur. Gerslach has repeatedly described looped terminations in the pleura.
of the skin and in the tongue of frogs, in which Wagner declares him to have been deceived and insists on every insisted on the existence of free terminations. The formation of loops he holds to be only apparent not real, and as the true, resulting merely from the superimposition of two primitive fibres upon each other. And he holds that in the papillae in many other instances vascular loops have been mistaken for nerve filaments. Todt & Bowman, in the opinion of Wagner, as they declare having seen nerve fibres pursuing a superficial course from the fibres and then suddenly ending or losing their characteristic medullary substance. Westall finds also that in connection with certain minute structures, in the tactile papillae, to be hereafter described, the existence of free terminations is unquestionable. Moreover, while he describes a general termination of the cutaneous nerved bundles in loops, remarks that many fibres terminate instantly, the fibres sometimes continuing of the same size throughout, and sometimes becoming finer, and either pointed or rounded at the extremity, concluding his description with the observation that "Les division des fibres en fils plus fins, ci-dessous libres (mais non branlés) servent peut-être à regarder comme la mode de
"Terminaison des nerfs cutanes."

Giving due weight to the several opinions and observations cited above, we are probably justified in coming to the following conclusions: 1st. That although in some few instances apparently the cutaneous nerve filaments have been observed to form loops at the periphery, yet this is to be regarded as an exceptional occurrence. Indeed it is more than probable as Wagner seems to regard them, that these loops are merely an arrangement assumed by the fibres beyond the terminal phases and that their ultimate terminations are to be sought for still farther on.

2nd. That the general, if not universal, ultimate mode of termination is in free ends, by which is meant not an abrupt isolated unaltered extremity, but that the nerve-end is found holding certain structural relations which are probably of two kinds: (a) We find them terminating in connection with certain special minute peripheral structures viz., the Pacinian corpuscles, and the corpuscles tactile, which we shall shortly describe in connection with the skin as a sense peripheral nerve organ of the sense of touch; and (b) that where these said structures are not found the
Three introductory observations are derived from the same sources, as well with which we introduced this paper.
otal extremities of the filaments pass into and become continuous with theJessurral elements of the skin, which opinion is supported not only by analogy with what is observed elsewhere in the muscular tissue, but also by direct observation. We find them described as losing their structural characters and becoming alread as to prevent their being followed further, even by good observers who maintain the doctrine of coiled terminations. The fusion of structural elements would also be most consistent in a physiological point of view with the extreme delicacy of the sensibility of the skin.

III Special Peripheral Nerve Appendages.

Under this head we shall consider the Peripheral Structure and connection of the Nerves of Special Sensibility in relation to which alone we find developed these special structures.
sensations that all tissues and organs in which nerves are distributed possess the vital property of sensibility; and that every tissue and organ in the body in virtue of its capability of influencing or being influenced by the nerves distributed in it, is to be regarded, great these nerves, as a peripheral nerve organ. All parts of the body have a certain amount of this faculty though we may not be conscious of it as a physical reality; condition in some organs, but when more vividly excited the sensibilities produced are said to be that of pain. We have found also that while all tissues were endowed with this property to a greater or less degree, it was developed more especially in the skin or integument. From the general sensibility peripherally thus constituted, there are certain portions of it in which special developments of the nervous elements are segregated and adapted for the reception of specific stimuli appropriated to each—these are the nerves of special sensibility. They are distinguished by having formed in intimate relation to the peripheral extremities of their fibres certain minute and delicate structures evidently from their disposition and connections subserving such important
Many of the earlier writers, more especially Valentin, have described the occurrence of ganglionic or nerve cells in connection with or among the nerves of special sense, as a characteristic element, without having correct notion as to the relations subsisting between them. Recent and subsequently found have been determined to hold special relations in the nerves.
functional design; and they are further distinguished by being situated in each case in the centre of a special modification and arrangement of the surrounding tissue which afford in the highest perfection certain physical conditions requisite for exposing the nervous matter to the operation of its particular stimulus. Thus is constituted the apparatus of special in contradistinction to that of general or common sensibility.

We find five such special developments of the sensory periphery destined for the "appreciation" of a corresponding receptor of specific stimuli: The skin, constituting the seat of the sense of "touch;" The "tongue" of "taste;" the "nose" of "smell;" The "ear" of "hearing;" and lastly, The "eye" of "seeing."

The organs of special sensibility form a regularly ascending series, each excelling the one preceding it in the elaborateness of its structure, and in delicacy of function.

In all of them we recognize: (1st) a mechanical apparatus at the periphery surrounding other elements, (2nd) certain minute structures appended to the distal extremities of the nerve fibres and (3rd) we have the peripheral terminations of the nerve itself.
The first element can apparently be less considerable at least disposed with under certain circumstances, but the second element is entirely essential for the initiation of impressions and their communication to the nerve fibres, for the latter are perfectly incapable of being acted on directly by the stimulus, thus there is no sensation of light produced by exposing the distal ends of the optic nerve filaments to the operation of the normal stimulus of that sense.

Before proceeding to examine these structural depictions of their nervous elements we shall consider as briefly as possible, certain conditions and laws which are well known regarding the special functions of the organs of special sensibility and the operation of their appropriate stimuli:

1. The varieties in the sensations produced at the cornea by impressions excited at the periphery of the nerves are not derived from the properties of the stimuli exciting them, but are affections of the Psyche. Thus light is not a property of the fluid medium surrounding us but merely the peculiar form in which its waves or vibrations impinge the fibres of the optic nerve through the minute and delicate peripheral structures appended to them, and being conducted to the brain are there interpreted as ten...
sations of light. So also with respect to sound, for it does not exist except when the means necessary for receiving and conducting the Vibrations of the Atmosphere to the sensory nerve-present. This also holds with respect to the other senses.

II. No amount of Chemical or mechanical stimuli applied to a special sensory nerve-fibre will result in sensations of pain, as is the case with nerves of common sensibility, but all stimuli applied to them produce sensations at the various centres which are interpreted only as those derived from its own specific stimuli. But such sensations are to be distinguished from those derived from the normal stimuli, for the latter are said to be followed by objective sensations, the former by subjective sensations. Thus, if the optic nerve be irritated by any abnormal stimulus, a sensation of light results in the brain, but it is subjective light, and so also with the other senses.

III. The special senses can only be excited through the medium of their characteristic peripheral appendage or organ. The connection between which and the central nerve organs is maintained by the intercommunicating nerve-fibres. The nervous current or movement initiates
by the specific stimulus and the peripheral nerve structures of a sense of special sense, and propagated along its fibres is a purely physical act till it reaches the nervous centre when its nature is changed and it becomes a psychical
process or a special sensation interpreted by the conscious
ness into its corresponding perception.

IV. These special senses from their relation to the
consciousness as regards the nature of the sensations com-
municated through their agency, arrange themselves
into two types - a higher and lower. In the latter we
have touch, taste, and smell - and the character of
the appreciation of sensations derived from them is
more dependent relatively on conditions of the conscious-
ness than those from light and sound, which are always
absolute and fixed, not contingent and changing. To
explain - the sensations derived from the exercise of the
organs of taste and also of touch with respect to
the pleasure they afford, are ever varying with states
of the mind whereas those of light, giving varieties of
colour, &c. and those of sound, music &c. are
fixed in their mental appreciations. Agreeable sights
and sounds being always so disagreeable ones
the reverse, although they become less so by habit.
v. The organs of special sense act quite independently of each other, if we except those of taste and smell, for it seems that the latter exercises some influence over the former, or at least some correlation exists between them. For, if the current of air through the nostrils be arrested, the sensation of taste will be for the time interfered with or impaired, to an extent proportioned apparently to the completeness of the arrest of the atmospheric current.

(a) The Tactile apparatus of the skin!

The skin performs three important functions in the animal economy: (a) It serves as an envelope or covering for the body, protecting adjacent structures; (b) It acts as a great secretory apparatus; (c) It must also be viewed as a most important peripheral nerve-organ, for it contains the distal terminations of nerves both of common and also of special sensibility, and as much as it affords the mechanical or physical conditions necessary for the manifestations of the special sense of touch, it must be regarded as the special organ of that sense.
We have already described the general terminations of the nerves in the skin as a peripheral structure endowed with ordinary sensibility. We now proceed to consider the more particular disposition and relations of the nervous element with respect to certain structures in and modifications of that texture, in virtue of which it is constituted the organ of Touch. We must also recall that the integument of the tongue, being of the nature of true skin, in which we find tactile sensibility developed in the highest degree of perfection, must be considered as a part of that texture.

The special sense of Touch, in contra-distinction to common sensibility, as in all the special senses, depends upon the co-operation of these conditions: 1st. A special arrangement of the integumentary elements, 2nd. Special structures or organs of minute size appertaining to the extremities of the nerve-fibres and 3rd. The nerve-supplied to minister to the special sense.

The first of these conditions is answered by the elevations or 'papillae' of the Cutis Vera, which we find projecting from the surface through the cuticle. They do not extend over the whole of the skin—some portions being quite destitute of them—but they appear always...
To be developed in proportion to the degree of tactile sensibility possessed by the part. Thus on the palmar surface of the fingers and hand, on the plantar surface of the foot, the tongue, and the lips they are very abundant. In the first two of these localities they are arranged in a series of elliptical ridges. These papillae have always been recognized by physiologists as touch-organs but in virtue of what structural arrangements they subserved that function, no correct opinions prevailed. Brechet thus expresses himself with regard to them: 

"L'appareil de la sensibilité se compose à la peau des papillés ou éminences courbées formées essentiellement par les extrémités nerveuses, enveloppées par des couche épithéliales et les fillets nerveux parvenant sous ses grâces trouvées, se déplacent de leur méritisme, et finissent en s'anastomosant entre eux pour former des arcades." These papillae are for the most part extremely vascular. Some of them are very richly supplied with minute bloodvessels, but are destitute apparently of nerves, while others are comparatively unvascular, but have nerve filaments passing into them, and in these, in connection with the extremities of the nervous fibres, the second element of this
special sense organ with, the so-called corpuscular tactus, which are special structures possessing great interest both from their comparatively recent discovery, as well as the discussions which they have occasioned, we purpose describing at some length.

Corpuscular Tactus: These are a system of minute structures whose existence has only been recently demonstrated by the microscope, and the connections of which have been correctly referred to the nerves of touch (properly so-called).

C. H. Weber, whose inquiries into the physiology of the nerves of touch are so well known long before the actual discovery of these bodies, had already presumed in theory the existence of a special apparatus in the skin in connection with that sense. He argued from the circumstance that while the whole nerve fibre is the conductor of impressions it is only the distal extremity which has the power of receiving them; and he held it to be altogether improbable that the simple unmodified terminations of the nerve filaments could be the medium of producing impressions to various and

delicate as those of touch. In order to feel heat or cold it is indispensable," said he, "that the expansion or contraction produced by them should act in the first place on the microscopic organs of touch situated in the derma (that which are not yet discovered), and by the aid of these organs on the terminations of the nerves of touch."

Such suggestions seem to have directed the attention of Rudolph Wagner to the investigation, and according to when the discovery was announced by him and his pupil G. Meissner of Hanover, from point of view, of peculiarly organized bodies in the papillae of the Skin intimately connected with the nerves entering them, it was believed that Welcker's anticipation had been realized, and the actual existence of a special sensory apparatus of Touch in the Skin determined.

We shall now proceed to see with what degree of truth—

Wagner and Meissner examined portions of the skin prepared with a diluted solution of soda and acetic acid, and as the result of their joint investigations asserted that these so-called tactile papillae were from the nature of their contents to be distinguished as vascular,
R. Wagner has recently accounted for the fact that the vascular centres in length the corpuscularized papillae, and he does so by advancing the hypothesis of an abundant supply of warm blood in the immediate neighborhood of the sensitive papillae, being necessary to prevent the sense of touch being impaired by the temperature of the nervous structures within them being suddenly lowered by contact with bodies of a less elevated temperature. He points to a parallelism in this respect apparent in the position of the retina which is externally bounded by the vascular choroid; similar provision being also made in the peripheral expansion of the auditory nerve, and other special sensory structures— a certain elevation of temperature being necessary to be maintained according to him in order to the sustained exercise of the functions of the sensory nerves.
and nervous; the former more numerous and containing capillary vessels 1/200th of a French line in diameter, the latter conical in form, and in addition to the terminations of the nerves having a peculiar minute bodily corresponding sheath, situated in the axis of the papilla. Some of the larger papillae seem to contain two of these bodies enclosed. These nervous papillae are most numerous on the tips of the fingers gradually diminishing in frequency towards the hand. Considering that they had found the expected touch organ, their discovery named them “Corpuscles tactiles.” They were described as being formed of discs or laminæ super-imposed horizontally with elongated dark-outlined nuclei situated between them, made apparent by the addition of the acetic acid, and with their long axis parallel to the transverse axis of the Corpuscles tactiles and to the discs, the whole corpuscle being invested with a transversely striated fibro-cellular membrane of extreme delicacy derived from the second layer of the dermis. In a child four years of age they measured from 1/50 to 1/50” in length to 0.01 - 0.02” in breadth; in an adult woman their length was 1/15” and their breadth about 1/40”. They
Muller's Arch. 1855. Princess Human Anthology translated by Durlay and Fruck in Lyd. Soc. Works.
also described the epidermis surrounding the Corpuscula tactus as possessing a basement membrane.

With respect to the nervuous relations of these struc-
tures it was averred that the divisions and subdivisions
of the nerve fibres still preserving their dark outlines
forming a bush-like expansion to the mucous from
one to three enter the base of the papilla perpendicular
to the surface and are applied to or terminate in the
base or side of the Corpuscle, never proceeding so
far however as the Capillary loops do in the Vascular
papilla. Each primitive nerve fibre by means of
its ramifications being thus connected to a system
consisting of several Corpuscula tactus.

The correctness of certain of Millites recently pub-
lished observations being in a manner called in qestion
by these statements of Naquet, the former shortly after-
wards announced as the conclusions at which he had
arrived from a careful reinvestigation of the nerve
terminations in the skin, the following: THAT the
called corpuscula tactus of Rudolph Naquet and
Naquet do not possess the elaborate structure originally
assigned them— that they are not special structures
but merely the somewhat developed axis of the papilla.
made up of a mass of fibro-cellular or connective tissue, becoming homogeneous externally, so as to present the appearance of a distinct investing membrane; and slightly distinguished from the cortical portion of the papilla by being surrounded with transversely arranged spindle-shaped or fusiform elastic fibres with elongated nuclei, giving it a striated appearance, the fibres in the cortex being arranged somewhat longitudinally, and the whole body thus constituted very much resembling certain bundles of connective tissue surrounded by spiral elastic fibres found in the Corium. They were also distinguished from the whole texture of the papilla as compared with those of the Corium being in a more embryonic stage of development. No assured that the arrangement of elements he had described are particular by liable to become altered in appearance under the action of the Chemical re-agents employed by Wagner-Meissner in their investigations, and believed that this was the cause of the deceptive appearances which he overruled had misled them. From this view of their morphological characters be derived them the title of Corporcula Sackus as involving an
an unfounded theory as to their function, applied the term of "Aise Corporcles" to them. He also states that papillae were found containing both arcs, fibres, and Capillaries joining Compound papillae. That this papillae dejectum of Corporcles contain nerves, that the aise body in some papillae exhibited constricitions and other irregularities of form, and further that the fibres never terminate in the aise corpuscles but wind spirally round round them. Also he admits the possibility of their ultimately being free terminations, yet he has convinced himself in some six instances of the occurrence of distinct terminal loops in the papillae. He confesses that he experienced considerable difficulty in tracing distinctly the terminations of the filaments—indeed in most cases, this could not be done. He also found these bodies in the red margins of the lips, point of the tongue, but they could not be dis covered however in the toe, breast, back, glans penis or the scrotum. Indistinct traces of them were found in the sole of the foot and back of the hand. On the ground of their absence in many parts highly endowed with tactile sensibility, he refused to allow them the
1. Muller's Arch. 1856. 4. Neurol. Untersuch. p 120.

2. Muller's Arch. 1856.
High function as organs of touch assigned them by their original discoverers.

R. Wagner has, in his immediate reply to these remarks of Kölliker, and in a subsequent work, reiterated for the most part his original statements regarding the Corporesecula Tactus. He however seems to have somewhat modified his opinions as to the histological characters of these structures—admitting that they are yet probably undecided. He also seems to think that Kölliker has never succeeded in isolating and recognizing the true Corporesecula Tactus. He as especially asserts the correctness of his descriptions of the nerve terminations and refuses to admit that in any case, the nerve filaments terminate in loops as described by Kölliker. These supposed nerve-loops he holds to be vascular loops which have been mistaken for them. He explains away the occurrence of capillary loops in nervous papilled by assuming that a fusion of the two different kinds of papillae may occasionally happen. He also allows the Corporesecula Tactus to be more widely distributed than he originally held.

Nabrun of Heidelberg also published observations which seem somewhat to confirm those of Kölliker. He frequently remarked constrictions of the Corporesecula Tactus, as if there were two or more of these bodies superimposed upon one another.
Müller's Arch. 1855. p 71.
and he believed that he had seen a looped termination of the nerve fibres without ramification in the papillae, with a varying relation to the corpuscles, the loops being applied to the outside in some cases, while in others they were within the corpuscles. He also observed the nerve filaments forming spirals round the corpusculum; but he did not always succeed in tracing them to their termination but to clear out. Wajner's opinion, he remarks, that he had never detected a vascular loop in a simple corpusculated papilla; nor could he ever discover transversely disposed elastic elements or nerve fibres in papillae distinct of Corpuscula Satche.

J. Gerlach however, after careful inspections concludes that all papillae have vascular loops, but that they do not extend in the nervous papillae beyond the base of the Corpuscula; and in compound papillae, they occupy the axis while the corpuscles lie in the diverticula. He also particularly notes the distinctly spiral arrangement of the nerve filaments in the nervous papillae. He also states that the papillae are more pointed and conical on the tips of the fingers than on the fingers or on the face. Lateral diverticula from the conical papilla give them an irregular and convoluted outline, and constitute them compound papillae. He also holds an original view as to the morphology of the Corpuscula Satche, viz., that the divisions of the primitive
1. Müller Arch. 1855. 

Tabulae having dark contours, and a diameter of about 0.0005" are the transverse striae described by Köllicher and others running across the corpuscule factors, and by surrounding a part of the axis-substance of the papilla with numerous spiral coils that they form the Corpuscule Factors of Wagner and Weizsäcker, and after this course, he thinks it probable that they send ramifications at the apex of the papilla. This view of the structure of the corpuscule factors is opposed by Reichert from the fact of these transverse striae not having been altered after treatment with a solution of soda for twenty-four hours, as they would have been had they been nervous structures. This account as given by Gerlach reconciles in some measure the conflicting statements of Wagner and Kölliker, and he is also disposed to take a view of their function also intermediate with that of the above-mentioned physiologists. However, subsequently he entered the field of discussion, and he broached some very original views with respect to the subject in question. He considers the Corpuscule Factors to be enveloped by a distinct membrane of the nature of a capsule, and filled apparently with an opaque granular substance of different consistence, and in this it is not improbable that he has mistaken for Corpuscule Factors those peculiar bodies described by Reichert, as the remains of the Malpighian layer, and
“Müller’s Arch. 1853.

* Microscopical Journal 1853, October.

Sarti describes in a recent paper corpuscles Sachs in the point of the tongue and the nerves terminating in them by 'blunted extremities.' (Müller’s Archiv 1853, p. 63)

Dalyell describes the corpuscles Sachs very much after the manner of Keilholz in a paper in the Etruria Monthly Medical Journal, March 1853, p. 275.
which Wagner alluded to as likely to be confounded with them.

He also insists that the transverse striæ are the spiral cords of the divisions of the primitive nerve-fibres round the corpuscles. He instanced two cases of Paralysis of the sensory nerves in support of his views as to their intimate connection with the nerves; in these he observed the corpuscles showing in the characteristic degeneration of the nervous tissue into fat globules, as described by Waldeyer. He desires the extensive distribution of these bodies as affirmed by former authors, in the tongue, margins of the lips, etc. He describes, contrary to preceding observers, the fibrils as single continued, but he seems to agree with Gerlach as to their being the transverse striæ.

Wagner still more recently, seems inclined to entertain a more simple view of their structure. He regards them as the convolutions of the nerve fibres in the form of a ball and embedded in an elastic substance of some consistence, thus apparently resembling very much Gerlach's 'perivenenial' lo which we have previously referred. He also describes them as possessing no basement-membrane.

The subject of this discussion has been entered into with great ability by Prof. Howley, who has investigated its points very minutely. The results in some instances agreed with those of second party, sometimes with those of
the other, and while agreeing in the main with Kölliker, he advances some very original opinions. He has met rarely with capillary vessels in corporaculata papilleas and he has seen no papilleas containing nerve fibres without corporaculata. With regard to the structure he has reason to believe that the corporaculatae formed by the continuation and termination of the delicate neurilemma (described by Kölliker) which enters the papilleas with the nerve filaments. In fact I believe he says that the 'corpuscles' is simply the modified extremity of the neurilemma of the nerves tubes which enter the papilla; differing from the Pacinia corpuscles which we shall soon describe, in that the neurilemma in the latter is developed on both sides of the fibre while in the former it is only developed on one side.

He thinks there is the clearest possible reason to believe that the nerve fibres have free terminations in the 'corpuscles' or in other words become continuous with the connective tissue of the papilla through the 'corpuscles' in a similar manner to which he has seen them terminate in the papilleas of the tongue of the frog which was first noticed by Dr. Walter although he has not succeeded in actually demonstating this in man. His opinion of the connection between the 'corpuscles' and neurilemma is consistent with
what we know takes place elsewhere. Having considered their structural characters sufficiently we shall now enquire into their function as reputed organs of touch, but on this subject little is known of a positive character.

In accordance with the elaborately laminated structure which Wagner and Hufnagel originally described these bodies possessing they asserted their action to be like that of elastic cushions which intensified the impressions received by them and conducted to the nerve fibrils lying in their substance as well as coiled round them, thus enabling them to communicate sensations of pressure, while as Weber supported by their expansion and contraction produced by changes of temperature they were thus enabled to appreciate degree of heat and cold. On the other hand Kolliker, judging from his own observations as to the simplicity of their structure and the fact of all the essential sensory functions of the brain existing where they were not to be found, regards these structures as "resemble" consequence of their being composed of dense imperfectly formed elastic tissue, confer a certain amount of solidity upon the points of the papillae and serve as a firm support for the sense in consequence of which a pressure which in other
"sensations is not sufficient to affect, were taken effect," and he believes them to have no more special influence on the sense of touch than the phalanges and nails are known to possess. Gerlach, without ranking them so high in the functional scale, yet considers them to be special structures developed in connection with the sense of touch.

Dr. Franz Leydig in a recent memoir, classes the Pacinian Corpuscles, the Savian bodies of the Torpedo and the so-called "nucleoporous canals" of the osseous and cartilaginous fishes as homologous organs. Prof. Huxley, following up this idea, and viewing the corpuscles in the ichthys as an elaboration of the *neurilemma* as he also views the Pacinian Corpuscles, places the former at the bottom of the above series, and tracing a similarity between the "nucleoporous canals" of fishes and the follicles in which the "Vibrissae" which are found about the lips and eyebrows in nearly all mammals are produced, places them at the top of the same series of cutaneous organs in relation to the nerves of sensitivity, the lowest member of which series he regards the *corpusculo-lacinius* to form. While admitting the probability of such a graduated connection existing between the above-named organs we must confess that
The present evidence adduced in support of this view does not entitle us to come to such a direct conclusion.

I fear that there is more beauty than truth in this theory. The identity of all these organs with the sense of touch so far from being at present admitted is more generally denied, so that while agreeing with Mr. Huxley also perhaps a more than general resemblance between the members of his group, we cannot view them otherwise from their anatomical relations and apparent function than as organs developed in particular situations on nerves not all cutaneous at the periphery, to subserve some special aid it may so far as we can speak positively of some member of the series, be some very opposite function. But that the so-called corpora sacta have a definite connection with the nerves of the sense of touch, in fact that they are structures developed on the distal extremities of those nerve fibres for the purpose of placing them under the most favourable conditions for determining the finest varieties of impression we think there can be no doubt.

To conclude, we consider there is every ground for believing that the corpora sacta is a special de...
... on Bowman, Kölliker, Micros. Anat. + Human Histology; Sharp in
Gray's Anatomy; Bowman in Cyclop. Anat. + Physiol. Heubé + Kölliker
Pappenheim in Comptes Rendus vol. xxiii; and Hurley in Micros. Journ.
retirement of the neurilemma in connection with the function of touch, and that the nerve-fibres after forming spiral coils round it, enter its substance, and dividing into branches become continuous with the tissue of which it is composed and thread it with the substance of the papilla. And that it subserves the function of touch by placing the nerve fibres under the most favourable conditions for receiving the most delicate impressions by means of their continuity with a highly elastic body.

"Pacinian corpuscles:—We shall here describe the Pacinian corpuscles, because they are met with chiefly in the periphery of the cutaneous nerves, although the special function which their anatomical relations and elaborate structure would lead me to infer, has not as yet been ascertained or even more than guessed at."

Attention was first directed in 1830 and by successive memoirs in 1835-40 by Professor Pacini of Tilia to the minute structure and intimate connection of certain small rod-like bodies with the terminal fibres of the nerves of the human palm and sole, and occasionally in nerve fibres in other situations. Little more than this..."
more evidence had been pointed out in 1741, by Vater, a German anatomist, but as the peripheral relations of the nerve-tubules had not at that time become a subject of so much interest, his observations did not excite much attention. Reference was made to the existence and nature of these bodies in 1833 by the French physiologist, André, Caenius Lacerna, and also by Cruvelhier. Subsequently to the appearance of Pacini's Essay, Hultz and Völlers made them the subject of an elaborate investigation, and induced them after the Italian anatomist last mentioned. In our own country we are particularly indebted to the careful observations of Mr. Bowman, who has accurately examined the statements of his predecessors in the same field and added much that is new to our knowledge of the subject.

The Pacinian corpuscles are found on nerves belonging both to the cerebro-spinal and sympathetic systems, but are never met with on sensor nerves. They are chiefly found clustered on the cutaneous nerves of the palmar surface of the hand, and plantar surface of the foot, more particularly on the sides of the toes and fingers, and are met with sparingly on the nerves undentulous communs on the glans penis, and bulb of the urethra—on the intercostal nerves—on branches of
The cutaneous nerves of the upper arm and forearm, arms of the foot and hand, and on the cutaneous nerves of the neck. They are very numerous in the sympathetic plexuses, especially on branches of the costo-ribul nerve, containing this with them on the “diaz development” of the leg. Two nerves from its entrance into the foramen, and also on the largest nerve of the metatarsal bone of the great toe, immediately before it enters the bone. Legelius’ later found them in the intersosseous spaces of the forearm, and leg of birds. They have also been seen on the nerves of the clitoris of the cow by Dr. Pflander of Helingford. These structures may be recognized with great facility in the osseous and muscular of the fat, where they can be examined with the greatest facility, being more regular in outline and more transparent than in man. They resemble, according to Hars, about 300 in the nerves of the fat, and are situated in the subcutaneous fat, previous to the nerves entering the ovals. They become more numerous as the nerve trunks advance to its distribution. They are generally attached by a pedicle sometimes as long as 1/10 of an inch, sometimes their axis is parallel to the nerve-fibres, in other instances their position to it varies from and
acute to an obtuse angle. Viewed with the naked eye they present the appearance of clear transparent bodies, like small seeds, having an irregularly oval outline, generally somewhat uniform, as if bent on itself. Their transparency is interrupted by an opaque white streak running in the line of the axis. Their size varies from $\frac{1}{25}$ to $\frac{1}{50}$ of an inch in length, and to about one half as broad.

The microscopic characters of the Pacinian Corpuscles are extremely interesting. They appear to be made up of a set of concentric capsules varying in number from 40 to 60 and enclosing a longitudinal cavity in the axis of the Corpuscles. These capsules present elongated Nuclei, and are separated from each other by spaces containing a clear, serous, albuminous fluid, said not to communicate with each other. A few of the internal capsules are generally so closely applied together as not apparently to enclose spaces, and consequently produce a darkened tract round the central cavity. The capsules are connected at irregular intervals round another by processes extending across the intercapsular spaces, and Pacini has described a regular ligament connecting them all together at the distal or free extremity of the Corpuscles which he has termed the intercapsular ligament, but Heintz and Kolliker
dying its existence altogether. The proximal end of the corpuscle is attached to the nerve by a pedicle which conducts the nerve-fibre along with a minute artery and vein, but there are different opinions held as to the manner in which the central cavity is gained. Pacini and Reckert affirm that the capsules are derived from the successive layers of the neurilemma, which become separated from each other by fluid to form intercapsular spaces. By others it is maintained that the capsules are perforated at the base of the corpuscles by a canal with a distinct wall, through which the nerve reaches the central cavity, accompanied by its neurilemma as far as the innermost capsule. When this space is reached the nerve-fibre becomes flattened, and somewhat diminished in size, and presents the appearance of a pale finely-granular band, or as a sharp narrow line, according to whether the surface or margin is presented to the observer. It is considered doubtful by Holzknecht whether this change of appearance results from the nerve flattening with decrease in size, or from the desquamation of the medullary sheath. After pursuing a course always directly in the axis of the corpuscles it ends either in a cuneate extremity, or by dividing into two or even three filaments, and this is accompanied by a corre
'Comptes rendus' 1768, vol. XXXI, 1846.
fording adaptation of the walls of the Cavity.

Shortly after the publication of Heute and Stolteker, they made some very curious observations. Heute states that he has frequently seen two nerve-filaments enter a corpuscle, one following a straight line, the other a circular course, and ultimately uniting at the extremity of the cavity to form a distinct arch, but sometimes also forming two or even three such loopings. He has also met with a Pacinian body having quite an opaque aspect, depending on a nerve fibre filling the canal with arches or convolutions and less than 20 in number, formed by the fibre twisting on itself in a more remarkable manner. He has also traced in a few instances two nerve-filaments prolonged beyond the edges of the corpuscle and meeting so as to form an arch or loop enclosing a space. His observations as to their histological characters otherwise bear out those of preceding writers. He remarks further with respect to their development, that the capsular structure becomes progressively coiled from the periphery to the centre of the corpuscle, the concentric striae becoming first apparent at the circumference. He also refers to their reputed resemblance to the
"Ganglionic Viscera" of Mr. Serres, which he points out is quite unfounded. The latter are always larger, present a cellular appearance, have no capillary structure, and the nerve-fibre passes through, and is continued directly beyond them. He is disposed to regard them as a mere hypertrophy of the nerve-fibre.

Pacini has traced a resemblance between the knobby end of the nerve fibre and a ganglionic cell, to which we have before alluded, but this view merely rests on a hypothesis. The small artery which accompanies the nerve-fibre as soon as it enters the corporacles sends off capillary loops between the Corporacles which are continued into the companion vein. Prof. Huxley has lately published a description of these bodies, according to which the appearances already described by so many eminent observers have been deceptive. While he adopts the view of Pacini as to the derivation of the Corporacles from the neurilemma, he denies the existence of inter-capsular spaces, with fluid contents, and asserts that the locular capsules are merely a mass of fibro-cellular, or connective-tissue with the nuclei arranged parallel with the nerve-fibre in lines, and that the central cavity, which was considered to be filled with fluid, or by Prof. Bowman,
with semifluid substance, has solid contents which Holêt, Köller, and Leydig have recently also admitted, and which Leydig believes to be the expanded nerve fibre. These views entertained by Holêt as to the simplicity of structure possessed by these bodies are probably too extreme; they have not been confirmed by any other observer so far as we are aware while he has a whole array of authorities against him. That the Pacinian corpuscles are a development of the snailencephalon can be no doubt, but that they have an organisation of a higher type than asserted by Holêt is more than probable. We have already referred in treating of the corpuscles Tactae to the position assigned the Pacinian corpuscles in the theoretical series of homologous cutaneous nerve-organs of Touch proposed by Dr. J. Leydig and Prof. Holêt.

The function of the Pacinian corpuscles is involved in considerable obscurity. Their regular occurrence, in certain situations at all periods of life, forbid us entertaining the supposition of bruxellesians and others that they are stimulative structures. Their existence in such parts as the knee-cap, bulb of the urethra, or interosseous spaces, and their being found only in the subcutaneous fat of the part where they could most effectually administer
To the function, tend to detract from the prima facie probability of their being subservient to the sense of Touch, or even of ordinary possibility. The original opinion of Pacini that they are electric organs, which arising from the peculiar resemblance which they present to the parts of those apparatuses in certain fishes in virtue of which they are known to possess the power of generating electrical currents, seems to be the most correct view yet taken of their functional relations.

Prof. Gooden describes the essential structural elements and their typical arrangement in the electrical apparatus in fish to be as follows: Nerve surface, cellular-vascular surface, fluid; nerve surface, cellular-vascular surface, fluid. Now if, in the Pacinian corpuscles we had the nerve substance distributed in the intercapicular spaces instead of being confined to one central cavity, we would have an almost precisely similar relation of parts as that described by Professor Gooden. Before leaving this subject let us refer to the observations of Dr. Weing, who prefers to have seen numerous corpuscles, with concentric laminae, separated by fluid, situated on the nerve fibres of the arachnoid membrane of the brain or spinal cord, in every subject he examined. He considers them to be either adventitious in origin, or resulting from
a diseased state of the ganglionic corpuscles which are so numerous in the minute pleurese formed by the nerve fibres, and which extends throughout the whole membrane. He also states that Vogel has met with similar bodies in the choroid pleurese, and Dr. E. Harless also in the Pia mater. But their frequent occurrence on the nerves in parts of the same structure, so widely apart, and not on the nerves in others, would rather suggest a different opinion as to their origin and nature, to that entertained by Mr. Neison. It may be as well here to state that nervous pleurese of extreme delicacy have also been described by Bourgeron and Papenheim in the peritoneum. It would seem indeed from the regular occurrence of this planiform arrangement of the terminal nerve fibres in nervous membranes so widely apart for distance as the arachnoid and peritoneum, that it is the manner in which their nerves terminate.

(6). Gustatory Apparatus in the Tongue.

We have already considered the dermal investment of the tongue being a modification of the skin or common
integument, as one of the seats of tactile sensibility. Although we may be obliged to refer again occasionally to its structural adaptations with respect to that function, we must in this place endeavour to treat of that particular portion of it which has been almost definitely ascertained to constitute the seat of the special sense of taste, containing the distal extremities of the gustatory nerve fibres, and offering the conditions necessary for exposing them to the operation of their specific stimuli. The tactile sense and that of taste also we must recollect are ministered to by distinct nerves, in the former case by the lingual branches of the fifth pair — in the latter by branches of the glossopharyngeal. Some physiologists, such as Valentin and Müller, have asserted that both these nerves subserve the function of taste, and consequently that all parts of the buccal cavity, and the adjacent surfaces supplied by those nerves, are the seat of that sense. If this, however, were true, it would certainly be the only instance of such an arrangement such as in the body, viz., one special sense being performed through the agency of two different nerves, and we would then require also to have the central origins
The same, in order to have single sensations from one stimulus, not two separate sensations as would otherwise happen. We have here then, no exception to the general law of each special sense having its own corresponding nerve. But in addition to such considerations the careful experiments of Wagner and of Biddel have refined the possession of the senses of touch and taste respectively to certain portions only of the domain of the tongue, corresponding in the one case to the peripheral distribution of the lingual branch of the fifth, and in the other to that of the glossopharyngeal nerve. The beauty and importance of this combination in the tongue of the two senses in question, are at once apparent. For in addition to the mechanical purposes thus effected by the possession of tactile power, we have it also acting as an auxiliary to the gustatory sense in the appreciation of such properties in the rapid substances presented, as hotness, pungency and astringency, which can only be appreciated by both senses—perhaps also with the aid of the sense of smell. — (Soc. N.).

The domain of the tongue is correspondingly
papillae presenting great variety in form and structure in these, the nerves terminate, and they seem for the most part to afford the necessary physical conditions for exposing the nerve fibres to the action of their peculiar stimuli, and are, therefore, one of the elements essential to the constitution of a special sensory organ. These papillae have also been distinguished into simple and compound. The latter are the Papillae Circumvallatae, the P. Fungiformes and the P. Filiformes, and all of them having numerous processes termed secondary papillae. The simple papillae were first described by Prof. Bowman, and seem to have no special relations. The nerves form a general plexus before entering the papillae according to Remak, and numerous divisions of the primitive fibres have been observed by Holste. These compound papillae observe a certain localization in their distribution, which serves to map out the dorson of the tongue into certain districts or zones. These according to Prof. Gordon, are, 1. The Tactile Zone which includes the tip, and the anterior portion of the surface and margin of the body of the tongue. In this region, we have filiform
or conical papillae and also fungiform or elevated papillae. The former are vascular, while in the secondary processes of the latter, Corpuscles Sancius are frequently met with, and there is probably therefore a similar ultimate nervous distribution to that of the tactile papillae of the skin, although considerable difficulty has been experienced in tracing out the actual terminations. This tactile zone corresponds to the distribution of the lingual branch of the fifth pair. (2nd) Proceeding farther backwards we come upon the gustatory zone formed by the Papillae Circumvallatae. It has an angular, well-defined outline in consequence of the V-shaped arrangement of the papillae. The circumvallate papillae are circular, disc-like processes embedded in corresponding depressions in the mucous membrane, so that there is a circular discoid-like furrow extending round each papilla. They are divided into simple papillae and covered with epithelium. Helkki also describes a circular wall-like papilla surrounding each of the circumvallate, and states that the latter are from six to twelve in number. The branches of the glossopharyngeal are distributed within this zone, after forming a very delicate plexus.
Kolliker's Human Hist. in Key to Stories vol II. p 23. + ballistic Arco. 1822.
The nerve filaments break up into fine punctuated tufts, which enter the papillae, and nearly fill up their interior, and these are probably the structures in the body so richly supplied with nervous filaments. Proceeding still farther back, we have the glandular zone, which extends from the limits of the preceding to the base of the tongue. This name indicates its structure and its relations to the sense of taste, are not evident, though Histoire holds this region also to possess this special sensibility. Indeed, the exact limits of the sense of taste in the mouth are still a question, but there is no doubt as to the tongue being its special seat.

With respect to the ultimate punctual disposition of the glossopharyngeal filaments in the gustatory zone of the tongue, very little is known, and that little of a very uncertain kind. Numerous investigations have been made, it is true, but their results have not been very successful, and besides they have been directed in most instances to the general nervous distributions in the organ in question, not to their special relations with respect to the functions of Taste or Touch respectively. We have already referred to the general platform arrangement of the nerve fibres before entering the papillae described by Remak, which must be regarded as the Terminal Plexus he has...
also pointed out the existence of minute ganglia on the ramifications of the gestatorial nerve, and also of the buccal branches of the fifth, more especially in the sheep and calf. According to him, they are either hemi-ganglia or holocereus—nervating a part or the entire fibres of the branch. The ganglionic cells are multipolar, and the fibres in and around the ganglia are somewhat adhered to the ganglionic condition. Not having succeeded in tracing fibres from these ganglia into the papillae and noting their frequency in the vicinity of the buccal glands, he holds them to have the same functional relation to the latter as the maxillary ganglia to the corresponding gland. Killiker has found these microscopic gestatorial ganglia on papillary branches. He has also seen them on nerves branches of parts of the tongue destined of glands, and besides the region of the glandular gland in which Remah describes them occurring in greatest numbers, Killiker holds to be also endowed with the sense of taste. Walker's observations seem still more decided. He has met with nervous filaments of a dark grey colour on the fibres of the gestatorial nerve, at the basis of the fungiform papillae only, in which he includes the papillae circumvallate.
1. de Rütte 1848, No. 102; and Phil. Trans. London 1849, part I p. 145.
he suppose to be of the nature of ganglia. He also refers to having found "vesicular granules" among the nerve-fibres before entering the fungiform papillae. These observations as to the occurrence of peripheral ganglia and ganglionic vesicles on, or among, the fibres of the gustatory, are quite characteristic of a nerve of special sense, as our subsequent descriptions of the latter will show how generally this has been remarked.

Tod and Bowman, although they found terminal nerve-loops apparently, both in the fungiform and filiform papillae, were unable to trace the nerves in the papillae circumvallate. Holliker has observed the nerve-tubules enter the latter, divide into numerous filaments, forming a very delicate plexus, and then pass into their secondary papillae where he could not determine their ultimate termination. He also found nerve-fibres ramifying in the walls of the papillae, in the other papillae, however, he has remarked both loops and free ends. Dr. Augustus Waller's recent investigations into the papillae and nerve terminations of the tongue of the frog, made with sections from the living animal and the most satisfactory that have yet been made, they are, however, in some respects so remarkable, as
to render it necessary to receive them with caution, till further confirmed by other observers. He arranges all the papillae under the classes of Conicul and fungiform. He former he states are mostly of a vascular nature, and their nerves could not be successfully traced. He was more fortunate with respect to the nervous system of the fungiform papillae: he describes the nerve tributaries terminating at a part of the whole or membranous wall of the papilla, where that membrane is so transparent as to render it somewhat doubtful, if it is present at all—this is what he terms the gustatory or neuro-vascular area of the papilla, and where he supposes the functional operations of the sense of taste are instituted. This area has no fixed relation in the wall of the papilla—it may either be at the side, or apex. He has observed every variety of free terminations of the nerve filaments: either in abrupt, or irregularly pointed extremities. Some of the fibres, when they have attained the membrane of the area, end in a simple point—others are club-shaped; a few assume the form of a spiral; some again by small funnel-shaped ends, but most of them expand into the membrane by what he terms a kind of open concentric crook.

2. D. Institut 1848, 3. 712.
- the end of the fibre appearing dilated, and presenting a dark point at the extremity corresponding to its axis. P. Wagner, who seems to have got somewhat enthusiastic on the subject, subsequently repeated these experiments of Waller, by examining minute sections of his own tongue. His observations were to a certain extent confirmatory of Waller's. He particularly noticed the dark point on the dilated end of the nerve fibre, which he refers to as "Cette tache enigmatique." He also found the fibres as Prof. Foerder describes them terminating in tufts within the papilla, the fibres becoming finer and finer by subdivision. He has likewise convinced himself that no looped terminations occur notwithstanding Gerlach's recent assertions to the contrary, and that here he has met with additional evidence of the correctness of the view of the continuity of the nerves with other tissues which he has latterly so strongly maintained.

2. Waller considers from the mode of the ultimate peripheral disposition of the nerves especially in the tongue of man that there are two groups of papilla: myo-conical and fungiform — the former for touch, the latter for taste alone, which is so far consistent
with the views of Prof. Gurdie which we have already cited. Walder refers to the following physical anatomical conditions as favouring the initiation of the impressions of taste in the peripheral organs of that sense: 

I. The extreme thinness and delicacy of the membranous (gustatory area) enveloping the distal extremities of the nerve filaments within the gustatory papillae.

II. The abundant nervous supply of the papillae, and

III. Their extreme vascularity, more especially towards their apices, a condition which as we have already stated was first pointed out by Wagner as always present in connection with the nervous element to maintain the appropriate temperature necessary apparently for the highest exercise of the sensory function.

From this brief review of the actual state of our knowledge as regards the ultimate disposition and relations of the nervous element in connection with the sense of Taste residing in the tongue, as the special peripheral nerve organ of that sense, it will be seen how very imperfectly the subject has been investigated, and to what an extent it is still open to research. No light has as yet been thrown on the modus operandi of the sense in question, or the manner in
which the nerves of taste become exposed to the action of their stimuli, nor has the existence of any intermediate nervous apparatus for this purpose, been determined—while, arguing from analogy with the structural arrangements prevailing in the other organs of special sense, we should certainly expect to find developed in connection with the peripheral expansion of the gustatory nerve in the Taste Papillae. The latter afford the necessary physical conditions but where are those minute elementary structures which we find associated to the digital extremities of the nerves of touch as Corpuscula Aderens, and under various modifications of form in the other nerves of special sense? Are we to agree with Huxley in considering the simple terminal expansions of the nerve fibres in the gustatory area of the papillae as supplying their place? or Are we to await the probability of subsequent research yet proclaiming their existence, or at least some definite structural arrangement representing them? Till such progress is attained all physiological inquiries with respect to the operations of the sense of Taste must resolve themselves more or less into mere speculations, or at least bounded extent, speculations of that
character.


We shall now proceed to consider the ultimate disposition of the fibers of the optic nerve, and their intimate connections with a peculiar series of minute elementary structures at the periphery [the second element of a special sensory organ] the whole constituting a beautiful membranous expansion of extreme delicacy within the eyeball, known under the name of the Retina.

This remarkable structure, spreading out at right angles to and around the axis of the optic nerve which enters close to its centre, is situated at the back or deeper part of the eye between the choroid or vascular tunic, and hyaloid membranes, and extends forward nearly to the serrated margin of the former structure where it terminates in the ora serrata retina. It diminishes somewhat in thickness (from 0.1" – 0.04" – 0.05") from the centre towards the circumference. On the anterior o
or as regards the eye itself, the internal aspect, which is
cornea, directly in the axis of the eyeball is observed
a circular area about a line in diameter, distinguishing
from the rest of this surface of the membrane by its
yellowish color, hence termed the macula lutea. In
the centre of the macula lutea is the fovea centralis or fornix
centralis a thin sunken round spot 0.08-0.1" in diameter. About
two lines to the inner or nasal side of this spot, a slight
elevation the arterialis nervi optici, marks the point of "en
brochure" of that nerve.

The retina with reference
its component parts may be described more generally
as consisting of the peripheral extremities of the optic nerve
filaments and their continuations advancing towards their
ultimate determination, in which course, they undergo at
certain intervals modifications of form, size and interstices
by the interposition of certain microscopic elements, which from
the parallelism observed in the order of their occurrence
admit of the entire membrane being viewed as consisting
of several layers or strata, each layer representing the
particular change exhibited by all the nervous projec-
tions at that point in their course. It can be readily
conceived from the extreme tenuity and narrow limits of
the membrane in question in which their structural, modify

Wagner's Physiol. by Willis 1844, p. 569.

Müller's Arch. 1835, p. 457. As above, p. 553.
cations just referred to occur, how very difficult it must be to
arrive at successful results, except with the utmost patience
and minute research. It has however apparently been an
engaging subject of investigation were it to judge from the
number whose attention it has attracted.

This description will suffice for the general appearance
and structure and relations of the Retina—we shall now
attend to its microscopic structure which displays a most
beautifully stratified arrangement of parts.

It will be unnecessary to do more than refer to the
partial and often incorrect researches of the earlier observers.

*Valentin Haidr and *Franze for instance believed that the optic
nerve fibres terminated in loops at the anterior margin of
the Retina, which was first pointed out to be erroneously.

Hannover, who was the first to determine with any degree
of accuracy the structural elements of the Retina and their
relations to each other. The first indication of a step toward
a reconstruction of the ultimate disposition of the optic nerve
fibres was the announcement originally made by Traviria,
now, and subsequently somewhat modified by *Müller, *Gothse,
that the optic nerve fibres terminated in staff-like or "fra:
illary" bodies, superimposed one to prevent the appearance
of a matched roof. From more complete and extended
3. Muller's Arch. 1865. p31; + earlier in 1859.

9. Kölliker's Human Histology vol. II. of Muller's Arch. 1855.
researches, more satisfactory results were obtained, and valuable additional experiments added to our knowledge of the various modifications of structure found in connection with the free epithelial expansion of Rammower, Wagner, Remak, etc. This subject has been investigated more recently by Bowman, Freini, Corti, and others with considerable success, but it was not until H. Müller undertook his investigations that the exact number and relations of the structural modifications were fully established. He was closely followed by Kolliker, who did little more than determine the correctness of his observations. Still more recently this subject, the morphology of the retina has undergone complete revision by Prof. Godein, who has also investigated with reference to its physiological relations and whose descriptions and reconstructions we shall avail ourselves of more especially, in the account of the matter here attempted.

In the writings of the several authors we have just named considerable variety is found in the nomenclature employed to denote the different elements and parts, but these are all closely agreed in their number and the order of their arrangement as regards the entire membrane, but they find some differences prevailing with respect to their relations to each other, as to whether they are to be conjoined or separated in
loc. cit. in Bibliothèque Universelle vol. XXII. p. 246 (4th series).
The recognition of the different retinal layers. Accordingly we first
H. v. Müller recognizing eight layers corresponding to the eight different elements met with in his membranous expansion, the
number of series of these essential layers being identical in all vertebrates. Going from without inwards, we have: 1. The layer
of rods and cones, 2. The external layer of granules, 3. The
intergranular layer, 4. The internal layer of granules, 5. The
grey granular layer "concha gris" of Kölliker, 6. The layer of
nerve cells, 7. The layer of the fibres of the optic nerve, 8. The
limiting membrane.
Kölliker, however, recognizing
all these, added yet another elementary stratum, between 8 + 9
of H. v. Müller’s system, viz., "The inner expansion layer of the
Müllerian or radiating filaments." But, for the purposes
of description, he reduced them to five strata, by considering
the outer, inner, and inner granular layers as one, and
taking the terminal expansion of the Müllerian filaments and
the limiting membrane together as another:—
1. The
Bacillary layer, 2. The granular layer, 3. The layer of Excro-
isions cerebrum: 4. Expansion of optic nerve, 5. The
Pituitary Membrane. Virchow’s system differs only from
this, in that he separates the outer and inner granular layers,
making seven, including the Limiting Membrane. All these layers
extend throughout the entire membranum, except at certain
*Measurements of the retina from Kölliker.
points to be afterwards noticed, where there is more or less deficiency of particular layers. They are all with the exception of the most external, of a slight yellow colour.

Professor Jodier in his classification distinguishes five strata under the following definite names viz, 1. Bacillary 2. White cellular 3. Grey cellular 4. Filamentary 5. Sero-cellular layers. Following this method we proceed to consider

1. The Bacillary is the most external or outer of the retinae layers. It increases in thickness from within outwards from "0.036-0.015" or rather more than one half, and is composed of two elements arranged with utmost regularity and disposed vertically to the surface of the retina. "Rods" and "Cones" which at first sight be mistaken for two separate layers, but more careful examination shows that the broad extremity of the latter corresponded to the tipped extremity, or rather continuation of the former. The rods are exceedingly delicate, transparent, hollow cylinders, with transversely truncated extremities, the outer of which are in relation to the choroid, while the internal terminate about the middle of the layer, by each staff becoming continuous with a filament, which we shall return to presently, or by swelling out into the form of a conical or size-shaped body with a nucleus, which is also prolonged into a filament similar to the preceding; these are the "Cones", but the rods which
end in these cones differ from the true rods, in that the former have not truncated extremities, and when this layer is viewed from without appear as slight depressions at equal distances among the true rods, which are also more numerous.

2. The White cellular Layer consists of outer, inner, and intermediate strata, through which the radiating filaments, first described by H. Müller, pass from the inner extremities of the Rods and Cones, to the deeper parts of the retina. In the outer stratum, or outer granular layer, according to Gaudin, there are three sets of structures appended to or continuous with the inner extremities of the secondary elements, namely, 1°., the nucleated pear-shaped bodies on the filaments of the "Cones" 2°., conical bodies on the filamentary prolongations of some of the "rods" and 3°. ovoidal bodies similarly attached to the other "rods". The second or intergranular stratum is composed of a fine soft granular substance, through which the Mullerian filaments, as they have been called, pass perpendicularly to the deeper structures of the Retina.

The third stratum, or inner granular layer has sets of bodies similar to those of the outer stratum and connected to the filaments of the rods and cones. Remind however re: yards them as smaller ganglion cells like those of the mesh layer. The minute structural relations thus recently detected...
mixed by Prof. Goodsir, in the first and second Retzius layers are very different from those of preceding observers.

Vintscheg affirms also in the intergranular layer minute delicate spherical cells filled with granules and a nucleus-like body. Hoffmeister refers to the outer and inner strata as being composed of round and oval opaque bodies filled with granules which he seems disposed to regard as minute cells with large nuclei; the outer stratum according to the same author is thicker than the inner one, which last mostly consists of oval cells. The Müllerian filaments also have different relations to the two strata; those of the rods being continuous with the cells of the outer, and thinned from the cones with the oval cells of the inner layer. The entire thickness of the white cell layer, at the era erata, according to Hofmeister is 0.015."

Branching of the filaments may be observed in this layer; and Goodsir states that towards the circumference of the retina, the filaments from the ovoidal appendages often unite, and are prolonged into the other layers as a single filament. These Müllerian filaments pass from their connections in the white cellular into the next layer.

3) The Grey Cellular which closely resembles the gray vermicular matter of the convolutions—indeed its identity with such structure may be considered as all but established.
Embedded into a fine granular and very muscular matrix, we find a layer of branched nucleated cells with nuclei. With respect to their nature there can be no doubt. Remak considered the process of these cells to produce the properties of nerve fibers, and the recent discoveries of Wagner and others of the continuity in the nervous centers of nerve fibers with nerve cells, and the resemblance of the latter to the cells of this layer warrant us concluding that they are ganglion vessels most probably connected by their processes on the one hand with the branches of the Müllerian filaments (from the Bacillary) in the white cellular layer, and on the other with the terminal filaments of the optic nerve from the next layer, while they intercommunicate by similar means.

We may therefore regard, with some degree of certainty, the grey cellular layer as the Retinal ganglion, as it was supposed to be by Kölliker.

4. The Filamentary Layer, or the layer of the expansion of the optic nerve is constituted mainly by the optic nerve filaments passing outwards to become connected with the processes of the ganglionic vessels of the grey cellular layer, as observed by Foerster, and of the continuations of the Müllerian filaments passing outwards to their ultimate termination in the next layer. Kölliker and Müller however do not seem to have clearly comprehended this true ultimate
Both thalalboth maintain the existence of divisions of the optic primitive nerve fibres. See Kölliker’s *Human Histology* vol. 2.
relations of the optic nerve fibres — for they describe them as radiating from the **coli**cles of the optic, and terminating for the most part in a manner unknown at the ora serrata retina. The nerve fibres in their course to the eye present the ordinary characters. They have double contours, and are said to have a tendency to become beaded. Valentin and Paschal have reported the occurrence of ganglionie globules among them. On piercing the sclerotic the neurilemma is laid aside.

In the filamentary layer the fibres, having lost their medullary sheath, present a clear greyish, and somewhat varicose appearance, although this last feature is not allowed by Bowman, for he states that they have lost this tendency along with their medulla, but Kolliker has not assured himself of the absence of the sheath without standing the alleged appearance of the fibres. They form a sort of radiating plexus with the point of entrance of the nerve for its centre. Valentin seems to have followed the nerve fibres correctly so far, as he has described his plexiform disposition of the nervous element with tolerable exactness. The fibres gradually separate from each other to enter the grey cellular layer or the retinal ganglion singly. Through the meshes of this plexus the Müllerian filaments, also radiating, pass inwards. The
Latter constitute what Kölliker proposes to call the "radiating fiber-system" (vertical) in contradistinction to the "horizontal radiation" of the optic nerve-fibres.

5. The Limital Membrane is the last and most internal retinal layer, and some slight difference of opinion exists as to its nature or derivation. It is an exceedingly delicate transparent membrane 0.005" in thickness, and so intimately associated with the other elementary structures of the retina, as to be capable of being separated entirely from them.

Vinkelsaw seems to hold that the Membrana liminalis is an independent structure, while most of the other authors view it as almost entirely constituted by the terminal brush-like expansion of the radial filaments of Müller. This is the view held by Prof. Goodier with respect to the nature of the structure in question. In addition to this termination by expanded extremities of the Müllerian filaments, Kölliker also describes them, as ending off horizontal processes in the plane of the expansion of the optic nerve filaments, but this seems opposed to the view of the ultimate disposition of relations, which we have just considered, and which is borne out by the latest and most accurate observation.

H. Müller has recently convinced himself that the system of rods & cones connected with a nerve filament and a single
serve, cellular diminution in size as one approach the regular axis. Certain of these strata which extend generally through the retina with such regularity and distinctness exhibit certain deficiencies at the scotter and the fovea centralis. Remark describes the optic and ganglionic layers as being the only ones found at the macula lutea, and the fovea centralis. Remark describes the optic and ganglionic layers as being the only ones found at the macula lutea, and so intimately associated as to be termed the lamina ganglionica. In the first place, all seem to agree as pointed out by Heath that the pectinate layer is here only represented by the cones. According to Goodier the white cellular layer is only deficient at the fovea, where the choroid veins run through, and the filaments of the cone present in the macula lutea, terminate in it. Various authors assert that it is persistent throughout. All agree to the permanence throughout of the grey cellular layer of Goodier, who describes a deficiency of the granular structure at the fovea. The filamentary layer however, cannot be recognized in this situation as a continuous layer. The membrane limitans however is present. The peculiar
yellow, which characterizes all the structures here described, except the Bacillary elements, and the fovea, is owing, according to Kölle, to the presence of pigmented matter, which Remak describes as an extremely crystalline substance situated between the 'Bacilli' and the choroid. With respect to the functional relations of the structures which we have just described, it is to be regretted that our space will prevent us doing more than merely alluding to a subject of so much interest.

Remak appears to have regarded the radial fibres and the Neuroglial laminae as a connective-tissue, elastic apparatus of support for the other retinal elements, all of which latter he considered as composed of true nervous tissue.

Hamovre regards the Bacillary layer as an optical apparatus for the purpose of reflecting the luminous rays on to the optic nerve fibres, which he thus considers as the seat of the special sensitiveness. Brücke also regards the rods and cones as a catoptric reflective apparatus. This view of the function of the filamentary layer is generally rejected as untenable. Among others, Müller considers it opposed by facts, such as the following: The Colliculo-nervi optic, where the filamentary layer is particularly developed, is quite insensitive to light, and the macula lutea where this sensitiveness attains its maximum, the optic nerve filaments,
Kise Goodwin's paper.
as a continuous layer, are very deficient. Besides, if it were so, from the superposition of the transparent fibre on each other, the same luminous impression would act on several of them at once, which would be irreconcilable with the formation of a distinct image in the sense organ. The same arguments go so far to support the opinion of Helmholtz, which is probably the correct one, that the sensibility to the luminous impressions resides in the grey cellular or ganglionic layer.

Nottier and Müller hold the several parts of the retina to be essentially nervous structures, and maintain that the rods and cones are the "true recipients" of light, and being continuous with the nerve filaments transfer the luminous impressions to them. Prof. Goodair likewise considers, that the rods, cones, and Müllerian filaments, with their appendages in the white cellular layer, are entirely destitute of the special character of nervous structure; but from their evident structural relations, can with much more consistency be referred to that class of special structure, to which we have so often referred, developed in connection with the peripheral extremities of the nerve fibers, where an elevation of ordinary sensibility is demanded, and as such, consequently an essential element in the constitution of a special sensory organ; therefore analogous to the Corpuscles.
Sacks and Pacinian Corporcles already described, and to parallel structures in the lamina spiralis of the cochlea, and probably also in the olfactory district of the nose. The nerve filament proceeding from the "Rehinal Ganglion," reaches the Müllerian fibre obliquely and probably is continued onwards, and ultimately attached to the proximal extremity of the rod or cone.

Respecting the part taken by the different structures above described in the production of vision, Prof. Goodier is of the following opinion: Assuming first, that a ray of light cannot produce an impression on an optic nerve fibre except if fall upon its free extremity and in the axis of the fibre, and secondly, that it is only by light reflected from the bottom of the eye that sight is effected, the process is as follows. A ray of light having become convergent after traversing the lenses in front of the retina, passes through the transparent membrane, and is brought to a focus on the choroid, and nothing entirely absorbed by that structure is reflected as a divergent pencil, of which those rays only that pass along the rods and cones will impinge in the necessary direction on the extremities of the nerve fibres and produce the requisite impression of light. Every ray of light therefore must pass along a rod or cone. By such an arrangement the isolation of the...
different luminous rays is maintained, and a perfect image, though made up of detached points, is impressed on the sensorium.

By some, the rods and cones are considered to influence the rays of light in the production of sensations of colour, and Professor Bennett has advanced a theory to explain colour-blindness on the supposition of some abnormal arrangement of the rods and cones.

(a) Peripheral Expansion of the Auditory Nerve.

The ear or organ of hearing in man, and the higher animals, is a very complex and elaborate apparatus, which, from the nature of its anatomical structures, furnishes in the highest degree those acoustic conditions necessary for receiving and propagating those vibrating movements, which are interpreted in the sensorium as sound. It consists of an apparatus for collecting and conducting the vibrations to the internal ear in which we find very remarkable structural arrangements in connection with the terminal expansion of the...
and also Valentin, Trauss, Lümmen, "Wagner's Phyziol. by Mills" p. 333.
Valentin, "Traité de Neuro" p. 238.

Recherch. sur l'organe de Lorré 1840.
and auditory nerve. The internal ear is situated in the petrous portion of the Temporal Bone, in which there are two cavities—
the Vestibule and Cochlea. It will not however be necessary
to describe their general anatomical structure and relations;
so that we shall limit ourselves therefore to those portions of
them in more immediate connection with the nervous elements.

In its course towards its peripheral termination, the
auditory nerve presents at frequent intervals, numerous
ganglionic cells among its fibres, as has been described by
Bezold, Hart, Kölliker, Hammoner. Divisions of the ultimate
branches of the fibres have also been observed by Kölliker, Harley
Byerramak in vestibular nerve of the Sturgeon & Frog.

Valentin, Brechet, Lindau, Krause, Hammoner, Wagner
have described looped terminations of the nerve fibres both in
the Cochlea, and membranous walls of the Labyrinth. It was
from his observations of the free terminations of the cochlear
fibres that Müller grounded his objection to the general doctrine of "Cortico".
Heirvanees described a papillary termination of the fibres not only in the Retina, but also in the
Auditory and Olfactory nerves, but through right in the median
it was in all probability not the terminations of the
nerve fibres they observed, but certain structures, which we
have been appealed to the ends of the fibres in the retina.
2. Muller's Arch. 1836.

1. Cawthall's Harris Herent, 1847, p. 64.
and other forms of which we shall presently find in connection 
with the nerve endings in the Cochlea. In studying the 
terminal relations of the auditory nerve, it will be neces 
sary to consider the Vestibular and Cochlear divisions of 
respectively.

The Vestibular Nerves. — After entering that cavity through 
certain minute apertures in its occiput walls (the Cristiforme 
plate), they are distributed to the semi-circular canals, and 
the Utricular and Sacculae. The ampullae of the 
semi-circular canals are the only parts of them to which 
nerve have been traced. According to Richerand, they enter the 
hollow side of the cavity in a fold or duplication of its 
wall, which appears as a transversely projection extending 
one third of its extent, when viewed from within. Wagner 
describes the fibers as ending in corpus, an arrangement. 
which he says with great distinctness in the Vagi, and 
other ocular nerves. Godfrey Bowman confirmed this opinion 
generally, although they had been free terminations distinctly 
as well as loops in the Cord. In the Utricular and 
Sacculae, the nerve fibres after penetrating the membran 
ous walls, diverge, some passing to the Calcareous particles. 
where they terminate in fine extremities without losing their 
medullary investment, (though from the latter circumstance)
it is probable that they have a further course, while the others after radiating for some distance in the interior of the cavity come in contact with a layer of dark nucleated cells, and then losing their medullary sheath, are supported by Tode & Newman and Sharpey, to form a fine expansion of nervous substance, which they are disposed to consider analogous to the retina, and Wagner also more recently alludes to the resemblance.

More recently Godeir has described the vestibular filaments both in the ampullae and ampulla, as forming a species of looped terminal filaments becoming continuous with bipolar nerve cells from which, in the utriculus and sacculus, one set of fibres were continued to the otoliths among which they end by free terminations, the calcareous particles appearing suspended among them, while other fibres passed away to and in unipolar ganglion cells, the latter being, as Wagner says, attached like hair on their stalks. Professor Godeir however is not so certain as to the correctness of this connection. Wagner has also observed a very similar arrangement. He describes also numerous divisions of the double contoured fibres, which become ultimately pale and very minute. He has also observed ganglionic cells inserted at intervals on the nerve fibres, before entering the vestibule.
Coti - "Recherches sur l'organe de l'urie chez les Mammiferes", 1847. premier partie.


* We have most unaccountably omitted to refer to the papers on the laminar epithelium, in the Monthly Med. Journal, Dec. 1865, by Prof. Goodwin whose description we have for the most part followed, and have also adopted his nomenclature.


Carini in "Zeitschrift" f. w. 1855, 9. part, p. 134.
The Lamina Spiralis. — Before following the cochlear nerves to their termination, we shall examine certain structures comprehended in the term Lamina Spiralis, with which they have a peculiar and intimate relation. For our present knowledge of this subject, we are entirely indebted to Corte, whose researches were made chiefly on the lower animals, and to Tinglau, who examined the same parts in man. This structure, contained in the cavity of the Cochlea, is invested with a slightly modified extension of the epithelium, covering the perissal lining of the scala. The Lamina Spiralis is partly osseous and partly membranous, stretches from the Modiolus to the wall of the cochlea, and is attached to these respectively by the margins of its osseous and membranous zones. The osseous zone is separated into two branches by a number of pleurotom canals, which end anteriorly in a groove of fissure, bounded superiorly and inferiorly by the free margins of the laminae. These canals contain the cochlear nerves, and also the Capillary Vessels, the latter of which are chiefly remarkable from their minute size, as compared with the long canals containing them. The membranous zone is a fine transparent membrane, which is attached by its external concave margin to the superior or vestibular edge of the osseous zone, and by the external and convex, it is
connected to the wall of the cochlea, by means of a process of semi-transparent fibril, which springs from a very minute osseous ridge, the lamina spiralis accessoria of Buschke. This connecting structure first noticed by Puechot, is described by Dr. Bowman as the cochlearius muscle, but is more probably fibrinous structure, in accordance with which view, Wolffius has named it the Ligamentum Spirale. It has a columnar appearance, with numerous foramina through which veins pass to the external portion of the lamina. Cottt describes the membranous lamina as commencing with the osseo-lamina in the Vestibule, where it is continuous with the periosseous lining the cavities of the labyrinth, of which type, therefore, he regards it as a modification, occurring however somewhat abruptly. The smooth surface of this membranous zone is interrupted by a central tract distinguished from the lateral belts, by presenting a series of well marked lines radiating from the Modiolus — hence this membrane has received the name of the zona pectinata, and is of a fibrinous nature. Cottt however describes the most external tract of the membranous lamina at its insertion into the cochlear wall, as the zona pectinata, the external being the zona dentrincata, including the Haversia osteon, and Haversia dentrincata to be presently described.
surface of the lamina spiralis thus constituted, are situated certain structures to which we shall now attend.

1. The Haliotis sulcata, first described by Tod and Bowman, is a lamina composed of wedge-like or conical branching columns and gradually increasing in thickness, from the inner to the outer margin, the former of which is set perpendicularly on the ecosse zone, while the latter having a regularly serrated conformation, projects for a short distance beyond the ecosse zone, so as to form the sulci or semi-circular spirals of the shell. It is cartilaginous in texture, and glistening in appearance. The few margin has, as already alluded to, a dentoidly structured, so as to constitute what are termed, "the "teeth" of the first ramp", and between the columns prolonged inwards from these "teeth" clear muscle are found arranged in rows. This is the "Bandellea tenuis" of Cotti, who describes it as a part of the membraneous lamina, but continuous with or derived from the periosteum of the ecosse zone, and separated from the zona pectinata by the next tract of the lamina spiralis.

2. The Haliotis denturculata, the "Bandellea excreta" or densellee of Cotti and placed according to him between the Haliotis sulcata and the zona pectinata, is situated on the membrae zone zone, and consists of a system of jointed rods or cylinders.
radianing from the axis of the cochlea. Coti and Duchek describe it as being derived from the Habenula Sutata, the free or external convex edge of which separates into two lips or laminae, the upper one of which forms the extremities of the "Teeth of the first range," the lower continued outwards to form the Habenula dentata. These cylinders are somewhat compressed in form, and are arranged in three parallel series of segments. The first series is situated in the sulcus spiralis; the rods composing it are very indistinctly cylindrical and are separated by minute spaces: they constitute the "Dents apparents" of both. Radiating outwards from or from between according to Prof. J. Fontein and Kölliker, the Dents apparents in equal number are the "teeth of the second series." They are attached by their internal extremities, which are somewhat expanded to the distal terminations of the cochlear nerve fibres, as first pointed out by Kölliker. Connected to these last by two small quadrilateral segments, the "Coin articulaires" of Coti, are the terminal series of rods. They are compressed and elongated and bear on their upper surface, attached by tendinices, three hypodermic nuclei of bodies with nuclei, which have an imbricated arrangement from within outwards. These bodies are termed by Kölliker "teeth of the third series" and by Coti are considered to be cells merely of cylindrical epithelium. They
both describe the terminal cylinders as having free bifurcated extremities externally, but Claudius has found them attached to the membranous zone by dilated extremities, and consequently incapable of the degree of motion Cuvier believed them to possess. Claudius also believes these roots for the most part of their course to be hollow tubes. Reviewing the parts above described, Prof. Gourdon considers from the position and relations of the ducts apparent, that they belong more to the typanicula sphenate than to the typanicula denticulata, and regards the latter as consisting only of two segments, viz., the "teeth of the second order" and the "terminal series of roots," connected by the cornic articulations. A delicate homogeneous membrane, covered with the epithelium of the labyrinth, was described by both as extending from the upper surface of the typanicula sphenate over the typanicula denticulata, and separating from the ducts apparent by large clear vessels filled with nuclei, which also occupy the sulcus spiralis. This membrane of Cuvier has been traced out to the wall of the cochlea by Claudius who also found the whole space between it and the deeper structures occupied by a complete stratum of these nucleated vessels from 0.005-0.007" in diameter. The entire membranous zone of the spiral lamina is not therefore, a simple partition in the cochlea, on the superiority
or vestibular aspect of which, the apparatus of Corti is placed; but it is a double structure enclosing a spiral cavity, running parallel like another scale between those of the Vestibule and Sympatrum, from which it is completely separated, and in this space the organ of Corti is found. Claudius terms this superior membrane the Membrane of Corti, and the original membrane the "Membrana Basilaris". The cochlear nerves, after perforating the periotic otic plate, cling to the Internal Auditory Meatus, ascend within the columella or Modiolus, and give off filaments in a spiral order, which there form a very close plaques, these fibres becoming continuous towards the free margin of the lamina reticularis bipolar ganglion cells. These occur with such regularity, that Corti styles them "La Rainette ganglionaire." After passing through these they assume a planiform arrangement. Tod and Bowman however deny the existence of this ganglion formation altogether. Beyond the marginal fissure of the osseous zone the nerve fibres gradually become individualized, and according perforate the inner attachment of the zona subtendica, somewhat obliquely, and finally become connected with the inner expanded extremities of the rods of the second series, which, as before described, lie between the inner ends of the Dents apparens. This important connection,
of the nerve fibres, and the rods was discovered by Kölliker. Jodt & Brown think the medullary sheath of the nerve fibres, as being persistent throughout, but both saw single contours. The latter could not observe any divisions of the fibres; but he remarked an alternation towards their distal extremity.

With respect to the function served by the rods of both, Kölliker, believing them to be like the rods and cones of the retina, true nervous structures, the terminations of the cochlear sensory fibres, supposed that they are able to distinguish varieties of sound. Both, Claudius and Gower, however, from their peculiarly compressed and articulated arrangement, the alternation of their extremities, and their elasticity, though slight, consider them not to be composed of nervous tissue, but to constitute an acoustic apparatus of a purely physical nature. They are members of the same class of special structures developed in connection with the peripheral expansion of the nerves of special sense, which we have described in the retina as the rods and cones and their appendages, and in the tactile papillae as Corporuscula Pachys. Both consider them as a development from the base of the membranous lamina, but is silent as to their particular function. Professor Goodei-

of opinion that while the Vestibule and semicircular canals, as shown by comparative anatomy, for they represent
the entire organ in the lower forms receive the vibrations of the air, whatever, irrespective of pitch or harmony, in the higher, by virtue of a certain adaptation and arrangement; each rod, or it may be a set of rods, is capable of receiving impulses from various vibrations of a particular value only, and so communicate impressions of a corresponding value, to the extremity of the nerve fibre with which they are in contact, but we must recollect that sound has not existed, nor is it produced as such in this acoustic apparatus, but it is merely the form in which the consciousness interprets the sensations resulting from the vibratory impulses conveyed along the nerve fibres to the nervous centres.

12. The Terminal Expansion of the Olfactory Nerve.

The peripheral expansion of the olfactory nerve is confined to a portion of the mucous membrane, known as the Schneiderian membrane, lining the nasal cavity. The olfactory tract (regio olfactoria) occupies only the uppermost part of the septum, and walls of the nasal fossa.
as far down as the middle turbinate bone. According to
Rohrke it extends from 9/4 - 1" downwards from the
cribriform plate of the ethmoid, and he says that a very
distinct curious line of demarcation may be observed.
The other cavities lined by the Schneiderian membrane being
subsequent to the respiratory portion. But unmolested.
as the sense of smell depends, among other conditions, on
the carrying the odorous particles up to the olfactory region, for the production of which
certain currents the whole nasal organ must be looked
cerns an apparatus of a mechanical or physical nature is necessary, therefore
upon as furnishing the third or mechanical element in this
sensory organ of special sense. The inferior Turbinate bone
in this action
has a most important share, may even essential, for on its
removal, the currents are changed so as to destroy the sense
of smell. Prof. Goodrich thinks it acts, by raising the
atmospheric currents passing through it, to the olfactory
region, for during inspiration it is elevated along with the
nose. The olfactory membrane is extremely delicate
and soft and can be distinguished from the adjacent ones
by its greater thickness, and glistening yellowish
appearance, and especially by the absence of the cilia which
over the rest of the membrane. Its structure on examination
is found to be traversed by mucous glands (Bowman's), of
the simple type, situated vertically to the surface, so numerous
as to give it, according to Goodrich, a columnar appearance.
to the membrane in section. The contiguous membrane on the other hand has very few of these glands. The epithelium of this tract, besides being non-ciliated, has peculiar characters. It is arranged in several layers, the superficial being distinctly cylindrical, according to Kölliker, although the other strata are more or less epithelial, as Jed and Bowmen, and Professor Goodrich hold the entire epithelial layer to be. These epithelial cells have remarkably delicate walls, for on the addition of water their walls immediately give way. The entire membrane in question is also extremely vascular, the capillaries according to Goodrich extend immediately under the epithelium — numerous plexuses are also very well marked in the sub-mucous tissue.

With respect to the ultimate nervous distribution our knowledge is very imperfect. Each olfactory nerve after traversing the cribiform lamella enters the nasal cavity in three divisions: one for the roof of the nasal fossa, another for the upper part of the septum, and a third for a cone corresponding part of the external wall of the cavity. Its fibers have double contours, and medullary sheaths, and do not run in the first part of their course, at least to present the great differences in external characters from the other nerves of special sense, described by Valentin. In their further course in the mucous membrane
*(From in) Müller's Arch. 1850, (reaches looped terminations of the olfactory fibres in the nose of the hog).

"Traité de Neurologie" p. 270.
they gradually become pale, lose their mucociliary sheaths, become flattened and present nuclei at intervals.

In consequence of the difficulty of following the fibres of this nerve in the glandular and deeply epithelinated lining of the nasal cavity on account of their presenting such peculiar external character, and also from their great tendency to retrogressive changes, the particular manner in which they terminate is still very obscure. A papillary termination of the olfactory fibres was described by Netseramus. Sclerotic bodies were proposed to have been discovered by Esrenburg in the olfactory mucosa, which he connected with the ends of the nerve fibres.

Dr. Horn declares having seen the olfactory fibres of the frog terminate in loose, Helleborn describes a gradual attenuation of the fibres, caused by their branching and also a system of arrangements from which he was unable to trace any of the fibres. He saw none of the ganglionic vesicles which Fontana affirmed accompanying, in great numbers in close connection with the delicate terminal filaments, though, arguing from analogy, something of this nature might be expected in the peripheral expansion of a nerve of special sense. Post & Bowman have not observed divisions of the fibres, nor have they succeeded in tracing any of the fibres to an end.
This description of the olfactory epithelium is quite opposed to the original observations of Kölliker. It is also opposed to the views of Goodricke and Pott of Bovarian, who describe the epithelium of this region as being sphennoidal and ducturate of Cilia.
But from such meagre and unsatisfactory accounts, we turn with much pleasure to the researches of Fehlhard of Gießen into the peripheral expansion of the olfactory nerve, as contained in a paper, with a perusal of which we have just been favored, and as his observations are so very remarkable and original, and his hypothesis into the nature of peripheral connections of the olfactory nerve fibers so very much borne out by them, as well as being, in every way consistent with all our present knowledge of the ultimate disposition relations of the nervous elements in a peripheral organ of special sense, we shall take the liberty of here inserting a brief abstract of his essay-

Fehlhard states that he has confirmed the recent observations of Hebbard, in man, as to the occurrence of ciliated epithelium in those portions of the cerebrospinal Membrane corresponding to the distribution of the olfactory nerve (Papie Olfactoria). These cilia differ from those of the surrounding membranes in that the individual cilia are very long, and so exceedingly delicate, as only to be visible with instruments of high power. The cilia are generally one or twice as long as the cell to which they are attached. He always found the extent of this ciliated
epithelium is correspond to limits of the expansion of the olfactory nerve fibres, so far as he could trace them.

On preparing the smear and property, two layers can be recognized—an under fibrous layer, and an upper epithelial. Between both and in the upper portions of the former are numerous vessels and the larger branches of the olfactory nerve.

I. In the fibrous or deeper layer are also numerous corpuscles with long and many very delicate processes, but their connection with the filaments of the olfactory nerve cannot be ascertained. He thinks however they are the ganglionic globules so particularly described by Valentin, though as he says, possibly other histologists may call them connective-tissue-corpuscles.

II. The epithelial layer consists of 1st an upper cell layer and a deeper layer of granules.  (2) The cells of the upper layer may be seen to have prolonged from their attached or proximal end, a long bending fibre of variable length—come from 0.07–0.09 mm in length—sometimes ending in two or more extremely fine points or connect with a nucleus or granular body. Between these were the fibre bearing cells.

6) In addition to these cell-fibres there are other fine fibres more distinctly connected towards one extremity with
nucleus; the other being merely attached to, not continuous with, the end of a fibre-bearing cell. From the density of the deeper layer it is not possible to discover whether there is not also few nuclei. (c) Other clump-shaped bodies with pedicles and also discovered but were (found) to be glands with their duct running to the surface.

The nerve fibres with cellular investment unlike the other primitive fibres form together a granulated grey striped mass with nuclei. They ramify in the mesentery, the branches forming tufts (believed by Dr. How to be terminal), the filaments ultimately breaking up into branched expansions as first observed by Hessling.

From these observations he formed the hypothesis: "The epithelial cells, or the evidently terminating fibres in relation with them are the true ramifications of the olfactory nerves." And this is rendered still further probable from analogy with what is seen in the eye and ear, and also from the fact that actually having traced the finer filaments of the olfactory nerves, in quite fresh transverse sections, according towards the epithelial layer, as well as in preparations treated with solution of Chromate of Potash. After teasing out the epithelium, he observed numerous instances fibres lying themselves in the processes of epithelial cells which bore the greatest resemblance to the ultimate
ramifications of the olfactory nerve. The spreading of the filaments towards the epithelium is particularly distinct in fine transverse sections treated with creosote. Again the trunk-like expansion of the filaments already described forms a terminal connection. And again it is remarkable that in all the observations made, no other form of final termination was presented, which if such really existed would surely have been observed, since there is such a rich ultimate distribution within limited a space as the region of the olfactory. Certain physiological and pathological conditions also support such a view - 1st. the increasing rapidity with which the impression of odour follows the application of the finest odorous particle to the epithelium, and 2nd. the great impairment which follows even a slight lesion of that structure.

In the descriptions here given by Eschhards of the ultimate connections of the olfactory nerve filaments, there is an approach at least towards determining the existence of those special structures, which Prof. Gooden remarked previous to the publication of Eschhards Essay would most probably be found as peripheral appendages to the olfactory fibres similar to those already isolated and recognised in the terminal expansions of the optic, auditory and tactile nerves, and only requiring to be demonstrated here, and in the tongue, in connection
with the terminal expansion of the gustatory nerve, to establish the general law of the occurrence of such apparatus, as special appendages to the nervous periphery, in all parts of it, where a particular evaluation of the sensory function is demanded— for one nerve fibre does not differ from another as to the nature of the impressions it is capable of conducting; they can merely propagate a force or movement along their fibres. The character of this force or current must therefore entirely depend on the peripheral apparatus attached to the fibres, in which it is initiated, and the central organ in which they end, and when the said force or current is interpreted.


Notwithstanding the many very elaborate and extensive investigations, which we have referred to under the several divisions of our subject, and the numerous important results which have attended them, yet both from its nature and extent, the stage at which we have arrived in our knowledge of it, though in some parts complete, is still in a few, so deficient, and in many so transitional, that it is not without difficulty, and not
with certainty that we can form, with any degree of satisfaction, even general conclusions as to the anatomical and physiological relations of the peripheral nervous system, which, while they are consistent with all the facts as research has hitherto been able to place at our disposal, will also stand the tests which may be applied to them by subsequent investigations.

We have however anticipated, to some extent, many general conclusions derived from a consideration of the subject in extenso, which might otherwise be appropriately stated here, in the few remarks we have ventured to append to the several chapters under which we have arranged the different parts of the subject treated of in this Essay.

We may however, as the results of the considerations which have occupied our attention, state the following as briefly as possible.

I. T.owards the periphery the primitive nerve fibres generally assume a plexiform arrangement extending throughout the organ or tissue in which they ultimately terminate, and it seems also that the delicacy extant of this "terminal plexus" has a relation to the degree of sensibility possessed by the part.
II. It seems more than probable that the fibres from loops or arches also, at a point still farther in their course, have apparently been often mistaken for their ultimate disposition.

III. The primitive nerve tubules, into which the various bundles have resolved themselves, ultimately break up in most cases, into elements still more minute. The extent of this subdivision seeming also to vary with the sensibility of the tissue in which it occurs.

IV. These primitive fibres also appear, in some instances, independently of subdivision, to become attenuated as they approach their final termination, seeming to depend on the gradual deprivation of the medullary sheath, which, being an isolating medium, its absence brings the axis cylinder of the nerve fibres in immediate contact with the elements of the adjacent structures.

V. We find also as a character of the nerves of special sense, with a very doubtful exception in the case of the olfactory, that towards their peripheral expansions they have ganglionic cells developed on their fibres—i.e. that these fibres become connected with bipolar cells.

VI. The doctrine of the looped terminations of the nerve filaments once so universally received, has been shown
by more recent observations to be quite untenable. It can only be admitted now, indeed, as a very rare form— we are not however warranted probably in discarding these terminal loops so rashly and entirely, as has been done by some physiologists, so long as their existence is still asserted by some eminent authorities.

VII. We have also found the distal extremities of the nerve fibres terminating finely, but in continuity of tissue with the elements of the peripheral structures. This mode of termination by free ends, which cannot be strictly regarded as of that nature, is one of very frequent occurrence, and is a view of the nerve endings which many histologists seem inclined to maintain.

VIII. The termination of the nerve filaments by free extremities, without any continuity with the tissue in which they end, although it seems in many instances to depend on the nerves of common sensibility, as the structural changes in their fibres, which prevents their being traced beyond a certain point, cannot be regarded as that prevailing in most of the nerves of special sense, and will probably yet come to be determined in them all.

IX. While the predominance of these general forms
nerve termination can usually be recognised, yet they exhibit
in different situations the most varied modifications, fre-
guently co-grate acts render it difficult, may impossible
to refer them to any of the above. This gives every proba-
bility to the correctness of the conclusion that there is
an individual type observed in the terminal re-
solution of the nerve fibers at the periphery. We find
a nature most independent in her choice of forms, only
recognising, in them, the teleological principle—seek-
ing in every instance to effect that ultimate co-rela-
tion of structure and function, which ever seems to
prevail in her designs.

It may be asserted at all but fully determinate, that
while the presence of the simple nerveous element, per-
haps with some slight adaptation, in the tissue of the
organ in which the nerve is distributed is sufficient
under ordinary functional exigencies, yet in the cases of
the nerves of special sense, where the fibres are required
in accordance to the nature of the particular
function demanded of them, to these minute peripheral
organs only, can the particular impressions be initiated which are conducted by the nerve fibres to the censorium. The character, therefore, of the impression traversing a nerve fibre, depends on the nature of its peripheral connection, i.e. with each organ, while the resulting sensation will similarly depend on the nature of its central connection.

XL. But in the same manner also we must view all tissues and parts in which nerves end, as corresponding lower forms of such peripheral nervous organs, with their nerves; for in them only can be determined the nature of the impressions conducted to the nervous centres by the latter.

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