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The Histology and Histopathology of the Dental Innervation

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ABSTRACT.—The presence of a perivascular neural plexus in the periodontal membrane suggests that the dental structures have both sensory and autonomic nerve supply. The fibres described by Mummery are unaffected by section of the inferior dental nerve although there is marked degeneration in all demonstrable nerves. Nerve-fibres have been observed describing simple and complex looping in the odontogenetic zone and others which, running tangentially between the odontoblast layer and the dentine, form a very definite nerve plexus. Attached to these nerve-fibres are numerous round or pear-shaped bodies which may be either nerve-cells or end-organs. Definite nerve-fibres have been traced into the dentine. The convoluted forms described by growing nerve-fibres approaching transplanted teeth did not resemble the nerve-loops previously reported in the periodontal membrane of monkey and man. Plexiform nerve-fibres have been seen in the gum of the cat and varicose nerve-fibres in the gum of the sheep. In man, intra-epithelial fibres have been observed which pass from the intra-papillary neural coils to terminate near the surface of the epithelium in knob-like endings. No abnormality of innervation has been found in supernumerary teeth and teeth from cleft palates, dentigerous and ovarian cysts, and in the pulps of denticles from compound odontomes. Since there is no difference in the innervation of heterogenous and autogenous tooth-germ transplants, whether of normal or abnormal form, it would seem that abnormalities of form are not due to abnormal innervation. The development and degeneration of the peripheral nerves and the changes produced in the dental innervation by local and general disease in man and experimental animals are described and discussed.

RÉSUMÉ.—L'existence d'un plexus neural périvasculaire dans la membrane parodontale suggère que les structures dentaires ont une innervation sensitive et autonome. Les fibres décrites par Mummery ne sont pas atteintes par la section du nerf dentaire inférieur, bien que tous les nerfs démontrables soient très considérablement dégénérés. On a observé des fibres nerveuses qui décrivent des boucles simples et complexes dans la zone odontogène, ainsi que d'autres, passant tangentiellement entre la couche odontoblastique et la dentine et formant un plexus nerveux bien défini. De nombreux corps ronds ou en forme de poire, qui représentent soit des cellules nerveuses soit des organes terminaux, sont attachés à ces fibres. Des fibres nerveuses nettes ont été tracées jusque dans la dentine. Les sinuosités formées par les nerfs croissant envers des dents transplantées ne ressemblent pas aux boucles dans la membrane parodontale de l'homme et du singe qui ont été décrites antérieurement. Des fibres nerveuses plexiformes ont été observées dans la gencive du chat, et des fibres variqueuses dans celle du mouton. Chez l'homme on a observé des fibres intra-épithéliales, venant des boucles intra-papillaires et passant presque jusqu'à la surface de l'épithèle, où elles se terminent en forme de bouton. Aucune anomalie de l'innervation n'a été observée dans les dents surnuméraires, ni dans les dents provenant de cas de palais fendu, ni dans les kystes dentifères ou ovariens, ni dans les pulpes des denticules provenant d'odontomes complexes. Puisqu'il n'y a aucune différence entre l'innervation des greffes autogènes et hétérogènes de germes de dents, il ne semble pas que les malformations soient causées par des anomalies de l'innervation. L'auteur décrit et discute le développement et la dégénération des nerfs périphériques, ainsi que leur altération par les maladies locales et généralisées chez l'homme et chez l'animal expérimental.

ZUSAMMENFASSUNG.—Das Vorhandensein eines perivasculären Nervenplexus in der paradentalen Membran weist darauf hin, dass die Zahngebilde sowohl eine sensorische als auch eine autonome Innervation besitzen. Nach Durchschneidung des N. dentalis zeigten die von Mummery beschriebenen Fasern keine Veränderungen, während alle nachweisbaren Nerven stark degeneriert waren. Es sind Nervenfasern beschrieben worden, die einfache und komplizierte Schlingen in der odontogenen Zone bilden, sowie auch andere, die tangential zwischen der Odontoblastenschicht

und dem Dentin verlaufen und einen einwandfrei nachweisbaren Plexus bilden. Mit diesen Fasern stehen zahlreiche runde oder birnenförmige Gebilde in Verbindung, die entweder Nervenzellen oder Endorgane darstellen. Nervenfasern konnten einwandfrei bis in das Dentin verfolgt werden. Die geschlängelten Gebilde, die bei den auf transplantierte Zähne hin wachsenden Nerven beschrieben wurden, gleichen nicht denjenigen Nervenschlingen, die früher in der paradentalen Membran bei Affen und Menschen beschrieben wurden. Plexiforme Nervenfasern sind im Kiefer der Katze, und variköse Nervenfasern im Kiefer des Schafes beobachtet worden. Beim Menschen sind intraepitheliale Fasern beobachtet worden, die von den intrapapillären Nervenschlingen bis in die Nähe der Oberfläche ziehen, wo sie knopfförmig enden. Bei überzähligen Zähnen, Zähnen bei Spaltgaumen oder in zahntragenden und Eierstockzysten und in der Dentikel-Pulpa bei gemischten Odontomen sind keine Anomalien der Innervation gefunden worden. Da kein Unterschied besteht zwischen der Innervation der heterogenen und autogenen Zahnkeim-Transplantate, gleichgültig ob sie normale oder abnorme Formen aufweisen, scheint es, dass Anomalien der Form nicht auf Anomalien der Innervation zurückzuführen sind. Verf. beschreibt und bespricht die Entwicklung und Degeneration der peripheren Nerven, sowie die Veränderungen, die durch lokale und allgemeine Erkrankungen beim Menschen und bei Versuchstieren herbeigeführt werden.

The Normal Histology of the Dental Innervation

THE teeth are such specialized structures that *a priori* deductions regarding their innervation are inadmissible. Since their function in man differs from that in lower animals, it is not surprising that there are many differences in the way in which they are innervated. Morphological conclusions may not be drawn, however, from a study of their present function and theories of innervation can be properly founded on histological and experimental observation alone.

Anatomy.—Although 22 % of the main peripheral branches of the trigeminal nerve are believed to be unmyelinated (Brashear, 1936), little is known of the autonomic innervation of the teeth and jaws. So far as we are aware, no sympathetic fibres join the trigeminal nerve during its intracranial course (Koch, 1916) and some writers doubt whether it contains autonomic fibres (Leist, 1927, Bremer, 1938). Sympathetic cells, however, have been found in the Gasserian ganglion of man (Kiss, 1932), and parasympathetic fibres are said to be present in the lingual nerve (Marda, 1931). Although there appears to be some difference as to the distribution of the unmyelinated fibres (Windle, 1928, Brashear, 1936), it seems probable that all the dental tissues possess both sensory and autonomic nerve supply and that the latter travel partly in the divisions of the trigeminal and partly as a perivascular neural plexus (Woolard, 1928).

The innervation of the pulpal vessels.—It has been long recognized that there is an intimate association between the blood-vessels and nerves of the pulp (Walkhoff, 1897, Fischer, 1909, *et al.*). A perivascular neural plexus has been demonstrated about the larger vessels (Wellings, 1926, van der Sprenkel, 1936, Mummery, 1912), and unmyelinated fibres accompanying the capillaries are said to communicate across the vessels by a series of oblique anastomoses (Wellings, 1926) or sometimes to describe spiral turns about them (Wellings, 1926, Gordon and Jorg, 1933). The manner in which these nerves terminate is controversial, some observers (Gordon and Jorg, 1933) being unable to find organized endings of any kind and others describing varicose endings in close contact with the endothelium (Ochoterena, 1933), end-plates (Montfort, 1923), and endings in Rouget cells (Wellings, 1926).

The fibres of Mummery.—Mummery (1912) described fibres in the odontogenetic zone that had a " wavy " course but which became straightened out should the pulp separate from the dentine. He considered that these fibres were the axon cylinders of nerve-cells placed at the base of the odontoblasts. As the fibres are unaffected by section of the main nerve (Stewart, 1927, Bradlaw, 1936) or blood-vessel (Stewart, 1928), although marked changes are produced in all demonstrable nerves, it is concluded that Mummery's fibres are not nerve-fibres. Although it might be argued that decortication of vessels does not invariably produce degeneration of perineural fibres distal to the site of operation (Blair and Bingham, 1928), and that there may be autonomic paths other than those sectioned, the differential staining reactions of Mummery's fibres (Stewart, 1927, Chase, 1929) confirm the conclusions drawn from experimental investigation.

The innervation of the dentine.—Myelinated nerve bundles enter the apical foramina and losing their myelin sheaths in the coronal pulp, break up into numerous filaments to form the so-called " plexus " of Raschkow, but whether the unmyelinated nerve-fibres are distributed in a similar manner is not established. From this zone, nerve fibrils pass towards the odontoblasts and the odontogenetic zone, and here the disposition of nervous elements has been the subject of controversy for nearly a hundred years. This is not due to differences of subjective interpretation only, for chance alone determines whether the plane of a section is to be coincident with the distribution of nerve-fibres in the odontogenetic zone and for this reason histological investigation and experimental methods are limited in their application. Demonstrable continuity with an undoubted nerve bundle is essential before the nervous origin of fibrils can be accepted for truncated nerve fragments and sometimes even a reconstruction by serial section, are open to misinterpretation. Many of the histological techniques used are uncertain in their action and stain connective fibres in the same way as nerve filaments, while post-mortem change, fixation, and decalcification may produce artefacts. As we have already seen, it is quite possible that the pulpal nerve-fibres are of sensory, sympathetic, and parasympathetic origin. We have no reason to assume that the autonomic fibres are distributed only to the blood-vessels, and it may well be that there is more than one method by which the pulpal nerves terminate. The presence of nerve-cells in the pulp (Mummery, Montfort, Calderon) has received very little support. Some writers (Salter, Kolliker, Chase, Munch, Riegele, *et al.*), describe nerve-fibres looping at the inner margin of the dentine, while others (Huber, Dependorf, Calderon, Lewinsky and Stewart, Tiegs, Gordon and Jorg, Riegele, Tojoda), have seen them running in the odontogenetic zone parallel with the edge of the dentine. Some (White, Walkhoff, Gysi, Hopewell-Smith, Noyes, Mummery, Papa, Calderon), believe that they form a network about the odontoblasts, and others that they terminate by free arborization (Walkhoff, Brashear), or by varicosities, or end-bulbs (Bodecker, Huber, Walkhoff, Retzius, Fischer, von Ebner, Hoehl, Woolard, Riegele, Papa, Calderon, Tiegs). Many (Bell, Romer, Dependorf, Mummery, Law, Montfort, Munch, Kani, Tojoda, van der Sprenkel) believe that nerve-fibres enter the dentinal tubules, and some (Morgernstern, Dependorf, van der Sprenkel), describe them winding about Tomes' process, giving off branches which run in the calcified matrix (Morgernstern, Dependorf, Fritsch, Munch, Tojoda, Riegele, van der Sprenkel), and ending in terminal bulbs and arborizations (Romer, Morgernstern, Mummery, Kani, Allen, Tojoda).

I have found nerve-fibres describing simple (fig. 1) and complex (fig. 2) loops in the odontogenetic zone, fibres which pass between the odontoblasts and running parallel with the dentine give off numerous fine filaments (fig. 3) and a very definite nerve plexus (fig. 4) situated between the odontoblasts and the dentine which I suggest may be termed the " marginal plexus ". Sometimes these tangential fibres seem to end as fine arborizations, while at other times they loop back between the odontoblasts. Attached to them may be seen (fig. 5) numerous round or pear shaped bodies. The latter are not unlike the bodies seen by Tiegs (1932) and considered by him to be end-organs in relation to Tomes' processes. They also resemble the varicosities found by Gordon and Jorg (1933), and that figured but not described by Tojoda (1934). While there is nothing to suggest dendritic processes, there is a certain similarity to the cells shown by Maximow and Bloom (1937) in the Gasserian ganglion of the embryonic guinea-pig, so that whether these bodies are to be regarded as end-organs or as nerve-cells, I am not prepared to say.

I have traced undoubted nerve-fibres into the dentine (figs. 1, 4, 5, and 6), but I am not able to make any contribution regarding the course of the nerve-fibres in the dentine except that in several experiments where I have sectioned the inferior dental nerve in animals for varying periods before the termination of the experiment, fibrils very much like those figured as intratubular nerves by various workers (Mummery, Dependorf, Allen) are still intact in the tubules although there has been complete degeneration of the pulpal and periodontal innervation.

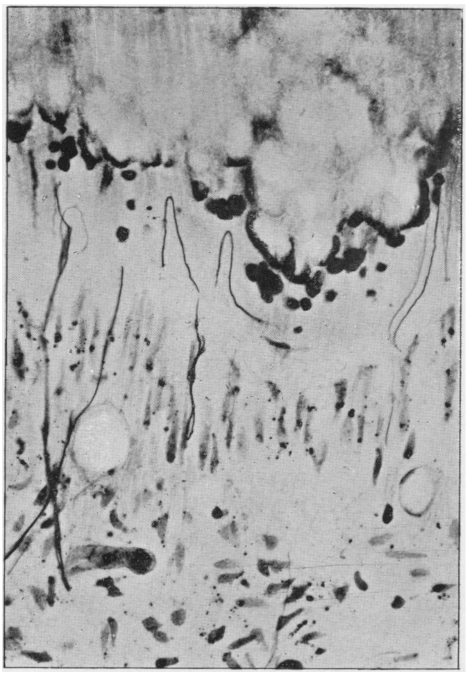


FIG. 1.

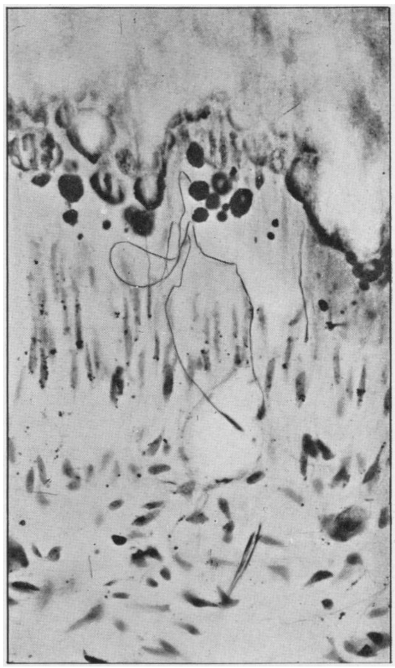


FIG. 2.

FIG. 1.—Simple looping of nerve-fibres in the odontogenetic zone and fibres entering the dentine of an adult human tooth. Stained Cajal. × 300.

FIG. 2.—Complex looping of nerve-fibres in the odontogenetic zone in the pulp of an adult human tooth. Stained Cajal. × 300.

The innervation of the periodontal membrane.—Both myelinated and non-myelinated fibrils are distributed to the periodontal membrane (Windle, 1928). While the main nerve enters from the apical region, accessory nerve bundles enter by perforating the alveolus at different levels (Dependorf, Wedl, Schumacher, Kadanoff, Lewinsky and Stewart). Some of these accessory nerves turn centrally, while others turn towards the gingival margin (Lewinsky and Stewart, 1937). The main bundle traverses the periodontal membrane close to the alveolar bone (Dependorf, van der Sprenkel, Bradlaw, Lewinsky and Stewart) and, passing through the circular ligament, arches over the alveolar crest to be distributed to the gum (Dependorf, 1913, Bradlaw, 1936).

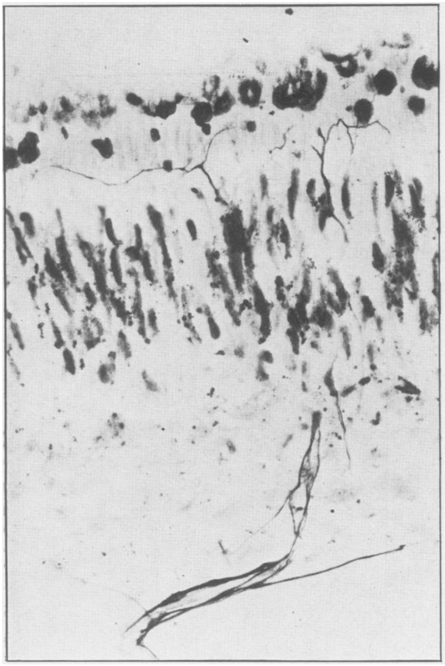


FIG. 3.

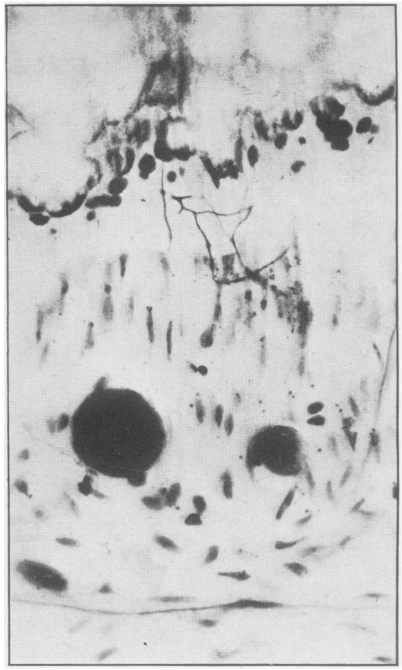


FIG. 4.

FIG. 3.—Nerve-fibres ramifying in the odontogenetic zone of the cervical pulp of an adult human tooth. Stained Cajal. × 300.

FIG. 4.—Plexiform nerve-fibres showing minute varicosities in the odontogenetic zone of an adult human tooth. A nerve-fibre is seen entering the dentine. Stained Cajal. × 300.

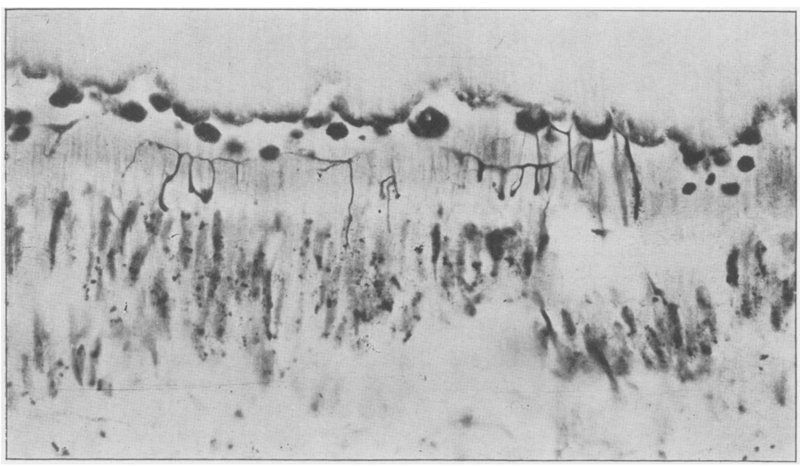


FIG. 5.—Plexiform nerve-fibres in the odontogenetic zone of an adult human tooth. Rounded bodies connected with these nerve-fibres and nerve-fibres entering the dentine are seen. Stained Cajal. × 300.

Anastomoses occur between the nerve-fibres of the periodontal membranes of adjacent teeth (Bradlaw, 1936) and between the nerves of the periodontal membrane, bone, and gum (Dependorf, 1913). It has been found that the periodontal innervation consists of coarse and fine fibres (Dependorf, Windle, Lewinsky and Stewart). The coarse fibres run in the outer part of the membrane and terminate in end-organs which vary in the different types of mammalia (Lewinsky and Stewart, 1937–9), while the fine fibres turn inwards towards the cementum ending in fine ramifications. In the cat the coarse fibres end in the outer part of the periodontal membrane in endings resembling the end-organs of Ruffini or in spindle-like end-organs formed by the nerve becoming twisted like a spiral spring with rounded thickenings on the

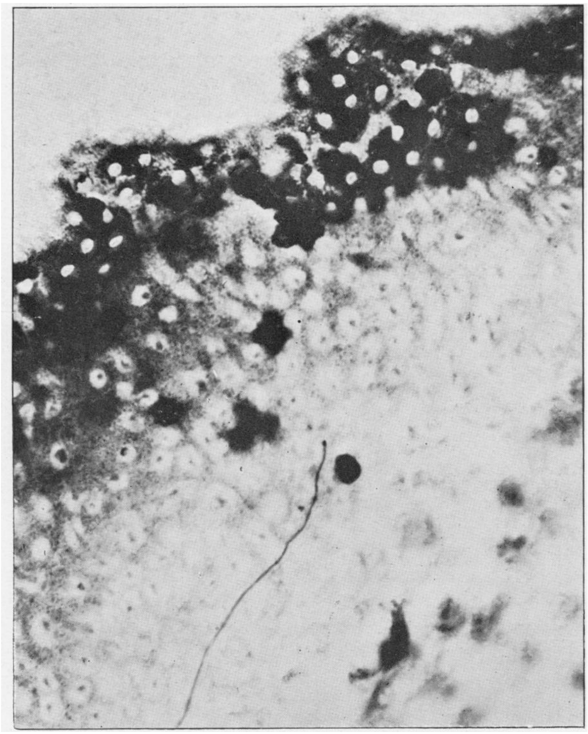


FIG. 6.—Nerve-fibre entering dentinal tubule which is seen in cross section. Stained Cajal. × 750.

convolutions (Lewinsky and Stewart, 1937). In the dog the termination of the thicker fibres closely resembles those of the cat, although their disposition is somewhat different (Lewinsky and Stewart, 1939). In the ferret the arrangement is similar but the end-organs are smaller and less complicated (Lewinsky and Stewart, 1937). The distribution is the same in the rabbit except that the end-organs, which show much variation, are of a coarse branching form with irregular swellings (Lewinsky and Stewart, 1937). In the mole and hedgehog no encapsulated end-organs have been found, but knob-like swellings and fine arborizations are present (Lewinsky and Stewart, 1937). In the mouse, in one investigation (Lewinsky and Stewart, 1937), much the same type of innervation has been reported as that described in other mammalia together with loop-like forms similar to those found in man (Kadanoff, 1929, Bradlaw, 1936, Lewinsky and Stewart, 1937), and in the monkey (Bradlaw, 1936). Another observer (van der Sprenkel, 1936), however, found periterminal networks lying on collagenous bundles, terminal networks around connective tissue nuclei, and a nervous network from which fibres pass to the dentine to end in very delicate rings inside the dentinal tubules. In the crocodile there are said to be tactile bulbs with connective sheaths of the Krause end-bulb type (Kolmer, 1925). In man the findings show some divergence. In addition to the loop forms in the inner part of the membrane, mentioned previously (Kadanoff, Bradlaw, Lewinsky and Stewart), one investigator (Black, 1887) found some encapsulated endings of the Paccini corpuscle type near the gingival margin, while others describe free terminations and fine arborizations (Dependorf, Black, Ochoterina, Stewart and Lewinsky), club forms (Dependorf), knob-like swellings (Dependorf, Black, Ochoterina, Lewinsky and Stewart), and terminal plexuses (Kadanoff).

As the growing neurofibrils in the tadpole's tail appear to form marked nerve loops, I have transplanted teeth in the path of severed sensory nerves to see if the fibrils growing to the cementum would present coiled or looping forms similar to those seen in monkey and man. Although several convoluted forms were found, they did not in the least resemble the endings to which reference has been made.

The innervation of the gum.—The main nerve supply of the gum has an extra-osseous course, comparatively few nerve-fibres entering from the periodontal membrane (Lewinsky and Stewart, 1938). Although the literature on the innervation of the gum is scanty compared with that on the innervation of the dentine, a bewildering array of terminal apparatus is alleged to be present. Thus, in the frog (Bethe, 1895) the intra-epithelial nerves end either as free arborizations, tripartite endings, or round discs. In the dog, pig, sheep (Merkel, Swerin), and cow (Merkel, Swerin, Jurjewa), tactile discs are said to be present. In the rabbit there is a " tree-like " nerve apparatus (Jurjewa, 1913) ; in the cat, Vater-Paccini corpuscles, tactile discs, varicose intra-epithelial fibres with button-like endings and leaf-like end-organs Jurjewa, 1913), and in the horse there are unencapsulated coils in the submucosa, varicose intra-epithelial neurofibrils terminating in arborizations, and encapsulated endings (Jurjewa, 1913). In man not only are there loose and close intrapapillary nerve coils (Jurjewa, Kadanoff, Kokubun, Hosaka, Lewinsky and Stewart) from which fibres pass into the epithelium to end in dichotomous division and arborizations (Hosaka, Jurjewa, Kadanoff) or in varicose terminations (Kadanoff, Hosaka, Kokubun, Lewinsky and Stewart), but in the subepithelial layers there are tactile corpuscles (Jurjewa, Kadanoff, Hosaka) Krause end-bulbs (Jurjewa, Kadanoff, Kokubun), cylindrical end-bulbs (Jurjewa, Kokubun, Hosaka), and sickle-shaped intra-epithelial nerve-endings (Kadanoff).

I have found plexiform nerve-fibres resembling the loose subepithelial coils described by Jurjewa (1913) in the cat, and varicose intra-epithelial nerve-fibres running as single fibres to their termination or branching dichotomously in the sheep (fig. 7). I have been able to confirm the presence in man of the loose and close intrapapillary nerve coils found by Kadanoff, Kokubun, Hosaka, and Lewinsky and Stewart (figs. 8 and 9), of intra-epithelial fibres running along the side of the papilla, and of fibres passing from the intrapapillary coils to terminate in knob-like endings (fig. 10) as described by Lewinsky and Stewart.

The innervation of ectopic and abnormal teeth.—For a long time there has been controversy as to whether the pulps of teeth formed in ovarian dermoid cysts (Liebert, Hoelscher, Harris, Wilms, Salter, White and Bland-Sutton, Klemm), and of other ectopic and abnormal teeth were normally innervated.

I have examined the pulps of supernumerary teeth, misplaced teeth from patients with cleft palates, teeth from dentigerous and ovarian cysts, and denticles from compound odontomes, and have found no abnormality of innervation whatsoever.

Autogenous and heterogenous transplant of tooth-germs and parts of tooth-germs (Legros and Magitot, 1874, Huggins, McCarroll and Dahlberg, 1934, Kostecka, 1937) have shown that growth and development may take place far from the jaw. This has been confirmed by the culture of tooth-germs *in vitro* (Glasstone, 1936–38). It has been found, however, that growth often ceased after a certain point had been reached, and the suggestion was made (Glasstone, 1936) that this might be due to the absence of normal innervation.

FIG. 7.—Branching intra-epithelial nerve-fibres with well-marked varicosities in gingival gum of sheep. Stained Cajal. × 450.

I have transplanted tooth-germs, both heterogenously and autogenously, into the crural region of kittens of various ages, but have found no difference in the innervation of the tooth-germs that survived, whether they were normal or abnormal in form. It may therefore be concluded that the abnormalities of development found in transplants (Kostecka, 1938) are not related to their innervation.

The Histopathology of the Dental Innervation

Comparatively little research has been devoted to the histopathology of the dental innervation. If we can recognize degeneration in the nerves supplying the teeth and jaws, it may well be that we will be able to contribute much to the knowledge

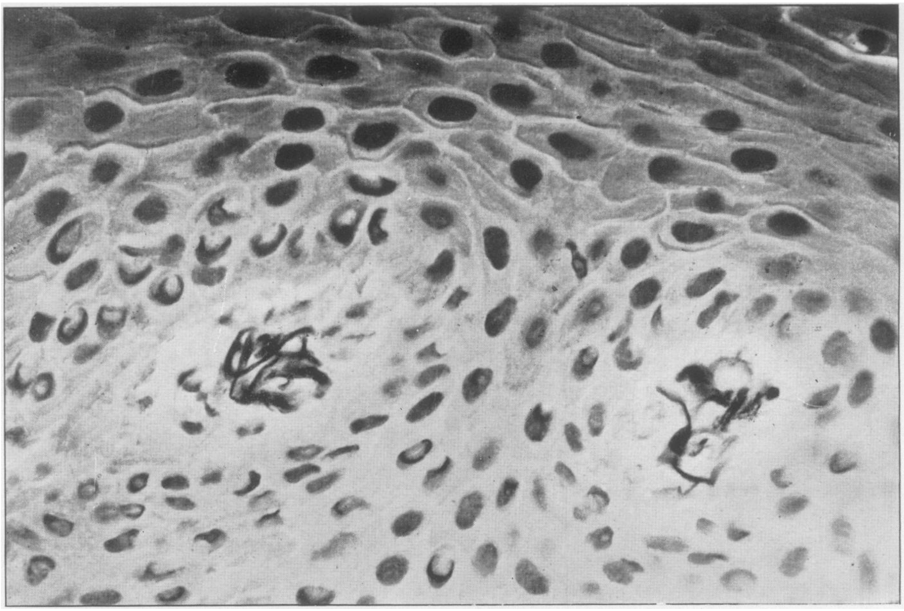
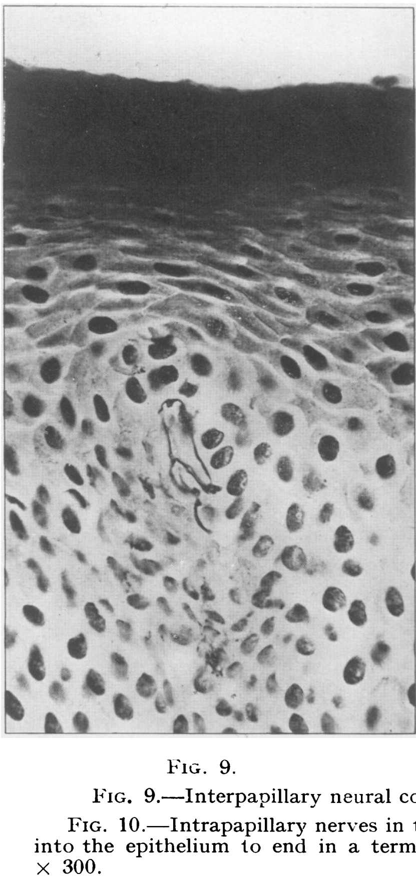


FIG. 8.—Cross section of intrapapillary neural coils in human gum. Stained Cajal. × 450.



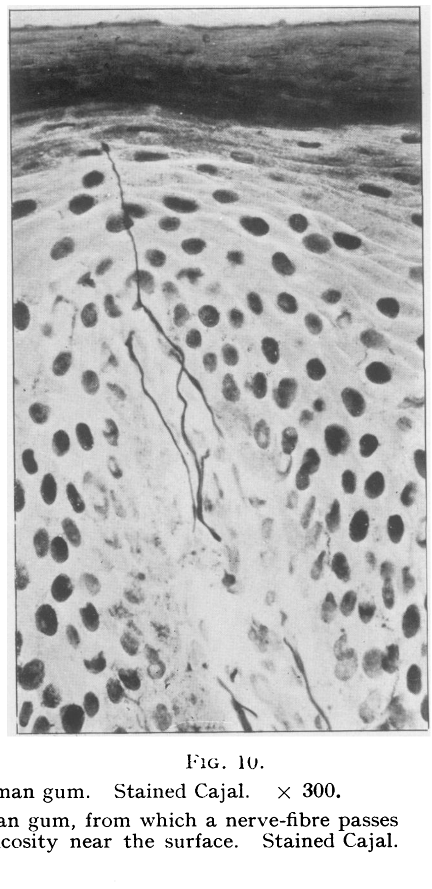


FIG. 9. FIG. 10.

FIG. 9.—Interpapillary neural coil in human gum. Stained Cajal. × 300.

FIG. 10.—Intrapapillary nerves in the human gum, from which a nerve-fibre passes into the epithelium to end in a terminal varicosity near the surface. Stained Cajal. × 300.

of local and systemic disease. Unfortunately there is no agreement as to what is fact and what is artefact, while the remarkable similarity between developmental and degenerative processes in nerves has been long recognized (Westphal, Semerling, Oppenheim, Sokolansky).

Development of myelinated nerves.—In a recently published work on the development of myelinated nerves (Sokolansky, 1931), it was stated that an early stage of myelinization is the formation of varicose bundles like " pearl chains ". Later the varicosities become longer and broader and are eventually transformed to the adult

FIG. 11.—Spindle-form enlargements of nerve-fibres of periodontal membrane of fœtal cat. Stained Cajal. × 750.

cylindrical form. Another observer (Speidel, 1935), however, regards these varicosities as an early evidence of irritation.

Degeneration of the peripheral innervation.—In order to decide the category into which abnormal appearances in the dental innervation should be placed, we may compare them with the appearances found in known degenerations produced either by the experimental method or by local and general disease. If a myelinated nerve is sectioned, the peripheral axon first shows some irregularity of contour and then some local thickening. After some days the myelin sheath becomes granular and the axon varicose or bead-like. Fusiform thickenings are then seen, followed by the formation of globular masses which become successively smaller by slow dissolution. During this time the myelin breaks up into ellipsoids which are phagocytosed. Eventually, a series of proliferated neurolemnal elements and some axonic spherules which have resisted destruction are all that are left (Cajal, 1928). Somewhat similar changes occur as a result of disease. They have been reported in avitaminosis (Eijkman, Hart, Kingery and Kingery, E. Mellanby, Hughes, Duncan, Seifried, Zimmerman, Sutton and Setterfield, *et al.*), in inanition, when the sympathetic fibres are said to be unaffected (Woolard, 1927), in poliomyelitis, where there is vacuolation, myelin destruction, swelling of nodes and the neurokeratin stands out prominently around the axon (Toomey and Weaver), in lead neuritis, where there is vacuolation (Doinikow, 1913), and in other conditions.

Abnormal appearances recorded in the dental innervation.—Many observers (Dependorf, Huber, Hopewell-Smith, Munch, Montfort, Riegele, *et al.*) have recorded varicosities occurring on the course of the pulpal nerves. In some papers they have been figured but not mentioned in the text, while in others they have been noted without comment. One author (Sealey, 1932) described nerve-fibres in the pulp splitting repeatedly to embrace oval structures at regular intervals, while another (Riegele, 1933) found expansions in the course of the pulpal nerves which he regarded as a normal histological appearance. Spindle-shaped or round swellings of different sizes which resembled a string of pearls and were sometimes vacuolated have also been described in the nerves of the dentine (Tojoda, 1934). It was suggested that these were due to post-mortem change, although the nature of other varicosities like short or long cucumbers which did not stain well and which gradually formed small granules and were lost, was undecided.

Degeneration of the dental innervation.—If the inferior dental nerve is cut, the changes that occur are similar to those found after nerve section elsewhere (Stewart, 1927–28, Bucy, 1928). After about two weeks, the myelin sheath is lost and the fibres become markedly irregular and filled with darkly staining ovoids (Bucy, 1928). One observer (Bremer, 1938) showed very definite vesicle formation in the pulpal nerves six days after section. Degenerative changes also occur in the inferior dental nerve if the accompanying artery is ligatured (Euler, 1922, Stewart, 1928). In acute or suppurative pulpitis the myelin of the nerve sheath is the first to be affected, the nuclei of the neurolemma at first staining well (Euler and Meyer, 1927). Following this, the axis cylinders swell and stain irregularly, later fragmenting into bizarre shapes and granular masses (Sigmund and Weber, 1926). Similar degeneration, with vacuolation, has been described in chronic pulpitis (Euler and Meyer, 1927), while marked changes in both axon and neurolemma, and the breaking up of the myelin sheath into fatty droplets are found in the pulpal nerves where arsenic has been applied (Witzel, 1898, Romer, 1909, Wassmuth, 1929) and in experimental animals given a diet deficient in vitamin A (M. Mellanby and King, 1934). In another investigation (Gordon and Jorg, 1933), two types of degenerative change—the " fuseau de retraction " and " spherule hypoargentophile " were found in the nerves of the pulp. As these appearances were seen in preparations where the pulp and the nuclei of the pulpal cells stained normally, they were thought to be degenerative changes, similar to those seen in certain diseases of the central nervous system and not artefacts.

I have not infrequently seen spindle-like enlargements of the nerve-fibres of the periodontal membrane (fig. 11) and pulps of fœtal and very young cats. Perhaps these are stages in the development of the nerves. In fracture of the mandible I have found marked fragmentation and sometimes vacuolation in the pulpal nerves of teeth anterior to the line of fracture (fig. 12). Thickening and varicose changes have been observed in the pulpal and periodontal innervation in pyorrhœa (figs.

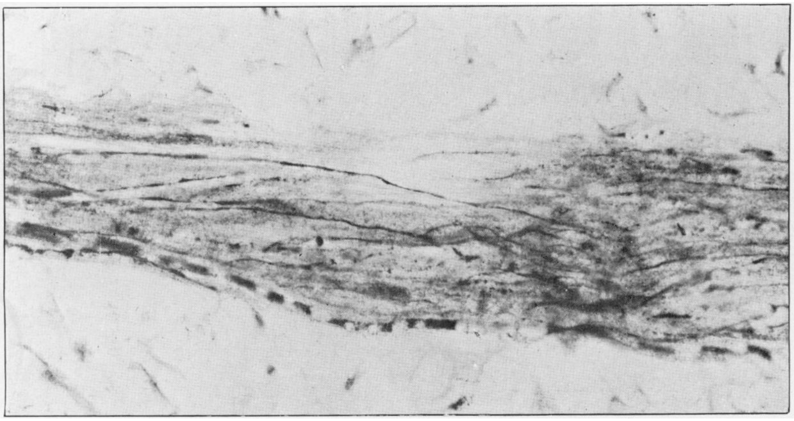


FIG. 12.—Fragmentation and vacuolation of nerve bundle in pulp of tooth anterior to a fracture of the mandible sustained sixty-eight hours previously. Stained Cajal. × 300.

FIG. 13.

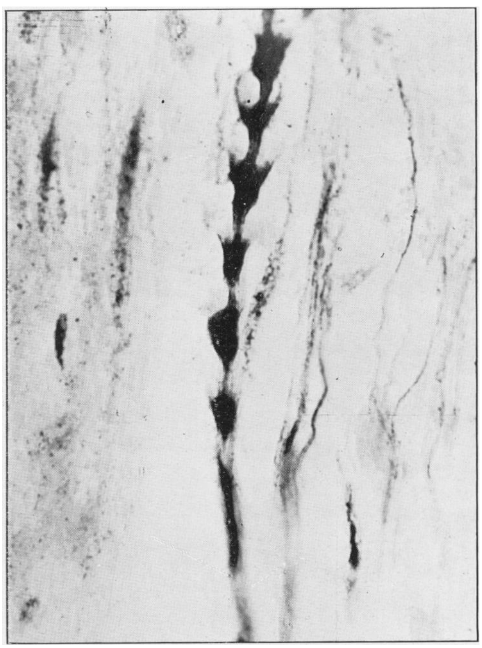


FIG. 14.

FIG. 13.—Irregular thickening of nerve-fibres of pulp in a case of pyorrhœa. Stained Cajal. × 750.

FIG. 14.—Abnormal appearance of nerve-fibres in the periodontal membrane in a case of pyorrhœa. Stained Cajal. × 750.

FIG. 15.—Vacuolation of pulpal nerve-fibres in a case of avitaminosis. Stained Cajal. × 300.

FIG. 16.—Abnormal appearance of pulpal nerves in a case of avitaminosis. Stained Cajal. × 300.

13 and 14), while other appearances resembling the degenerative changes shown by King, Lewinsky and Stewart (1938) in rats given a diet deficient in vitamin A and carotene have been seen in the nerves of the human pulp in avitaminosis (figs. 15 and 16). Fragmentation and varicosities have occurred in the apical and alveolar nerves as a result of extraction and the introduction of toxic material into the pulps of experimental animals has resulted first in a deeper staining with irregularity of

FIG. 17.—Irregular thickening and fragmentation of alveolar nerve bundles in monkey. Multiple extractions had been carried out and toxic material introduced into the sockets seven days before. Stained Cajal. × 75.

contour and then fragmentation with loss of myelin sheath, while similar degenerative changes (fig. 17) with occasional vacuolation of alveolar nerves has followed the introduction of toxic material into extraction sockets.

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