

# THE NERVUS TERMINALIS IN MAN AND MAMMALS<sup>1</sup>

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NINE FIGURES

It is over nineteen years since Pinkus ('94) first called attention to a 'new nerve' attached to the telencephalon of *Protopterus*, and thirty-five years since the first record of this nerve having been seen in a shark (Fritsch '78). The forms in which this nerve has now been recorded and its chief characters have been briefly summarized in the writer's previous communication ('13). In that paper the existence of a true *nervus terminalis* in human and certain mammalian embryos was clearly established. At the same time McCotter ('13) pointed out the existence of the nerve in the adult cat and dog. Huber and Guild ('13) have since studied the peripheral relations of the nerve in the rabbit in late foetal stages and during the first six days after birth.

The purpose of the present note is to call attention to the presence of the *nervus terminalis* in certain other adult mammals in the hope that a larger number of workers may undertake the study of its central and peripheral relations. At the present time it is clear that at least a part of the nerve is distributed to the mucosa of the nasal sac and in mammals accompanies the vomero-nasal nerve. A part of the nerve, however, in mammals clearly goes beyond the limits of the vomero-nasal organ. In the rabbit it spreads over a rather wide area of the nasal septum (Huber and Guild). The nerve is usually accompanied by ganglion cells, which Brookover ('10) believed to be sympathetic in character. Huber and Guild incline to the same conclusion. Although the central relations of the nerve have been studied by special methods by Herrick ('09), Sheldon ('09) and McKibben

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('11) it is still not known whether its fibers are all afferent, or whether some or all of the fibers arise from cells within the brain. In the latter case they might be considered preganglionic fibers of the sympathetic system. The present state of our knowledge suggests the probable presence of both afferent and efferent components in the series of vertebrates. The wide-spread presence of the nerve in adult mammals, including man, should add interest to the study of its relations.

*The pig.* In my previous communication it was stated that the nerve had not been seen in 73 and 90 mm. pigs. Since then it has been found by dissection in numerous pig fetuses ranging from 50 mm. to full term. The brain of the adult pig has not been examined.

*The horse.* Figure 1 shows the proximal portion of the right nervus terminalis in the brain of an adult. The figure shows a small portion of the basal surface of the brain between the olfactory trigon and the median fissure. A part of the anterior cerebral artery is seen in the right hand part of the figure. The plexus of small vessels lies immediately upon the brain substance, the nervus terminalis lies outside of them and is in turn covered by the pia. The nerve has about fourteen rootlets which enter the brain along the rostral and medial border of the medial olfactory tract. The rootlets unite by twos and threes and eventually form a common nerve trunk. Upon the largest one of three main roots into which the rootlets unite, as seen in the figure, there is an obvious ganglion. The nerve trunk extends forward nearly parallel with the olfactory peduncle to a point opposite the rostral border of the olfactory bulb, where it is lodged in the pial septum between the hemispheres. Here the nerve had been cut off in removing the brain from the skull.

The nerve of this side was removed after drawing and cut into three pieces for staining. The distal piece was treated with vom Rath's picro-osmo-palatino-acetic mixture, cleared in cedar oil and mounted in damar. It contains three fairly well medullated fibers and seven or eight fibers which were lightly and irregularly blackened. The middle piece was stained in a mixture of nigrosin and acid fuchsin but a differential staining of nerve fibers

and connective tissue was not obtained. The proximal piece included a part but not all of the ganglion seen in figure 1. The piece was stained in neutral red. A number of cells were found scattered along this piece and the portion of the ganglion consisted of about twenty closely packed cells varying in size. All



Fig. 1 Root of the nervus terminalis in the horse, right side. Description in text.

the cells had large nuclei with prominent nucleoli. Although the Nissl bodies were not clearly stained, owing to unsatisfactory fixation, there is no doubt that the cells are nerve cells. Two nerve cells were seen also in the piece stained by nigrosin.

The nerve on the left side of this brain is similar to this although it differs in the number and arrangement of rootlets.

*The sheep.* Three brains of the adult sheep have been examined. The nerve was not found in the first but was present in the other two. In one of these brains (fig. 2) there was a single strand on the right side and two strands on the left. One of the latter strands presented three conspicuous ganglion-like enlargements. Upon staining and mounting these proved to be true ganglia. The nerve of the right side contained single ganglion cells scattered along its course, two collections of six or eight cells each and a ganglion at its distal end larger than any one of the three on the left side. A piece of the left nerve, treated in vom Rath's fluid, showed a single lightly medullated fiber.

*The porpoise.* I am indebted to Mr. W. F. Allen of this laboratory for the brain of a porpoise (*Phocaena*) preserved in Bouin's fluid. The brain of the porpoise has a very broad, rounded frontal lobe (fig. 3), the optic tracts diverge very widely and the anterior perforated space is greatly elongated from side to side. In the absence of the olfactory bulb and peduncle the topographical relations in this part of the brain must be based chiefly on the extent of the anterior perforated space. Upon the basal aspect of the frontal lobe there are seen beneath the pia seven slender strands which converge forward to a point corresponding as nearly as may be judged to the point at which the *nervus terminalis* was cut off in the horse's brain. Here likewise the nerve had been cut in removing the brain. Proximally the strands enter the brain over a wide area. The most lateral one enters the lateral part of the anterior perforated space. The most medial strand runs along the median fissure and bends up on the medial surface to penetrate the brain in the *fissura prima* on this medial surface (fig. 4). Two strands follow the anterior cerebral artery in the median fissure and bend laterad with it almost in contact with the rostral surface of the optic chiasma and enter the brain in the depth of the *fissura prima* on the basal aspect. The nerves of the left side have been described and drawn; those of the right side have a similar arrangement. The nerves are relatively larger than in the horse and are more closely applied to the brain surface throughout their course. They differ also in that the rootlets are flattened strands which run for a longer distance before uniting.

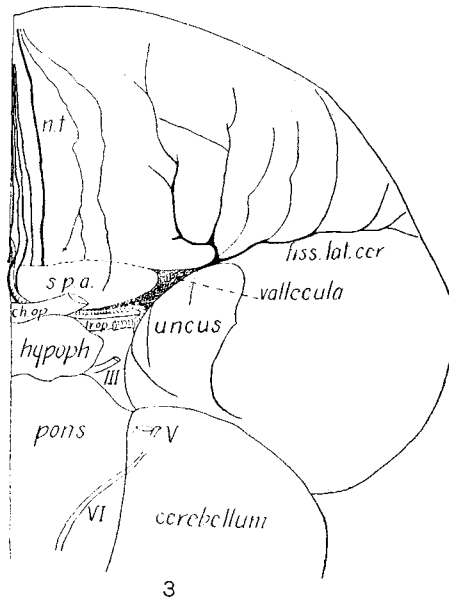
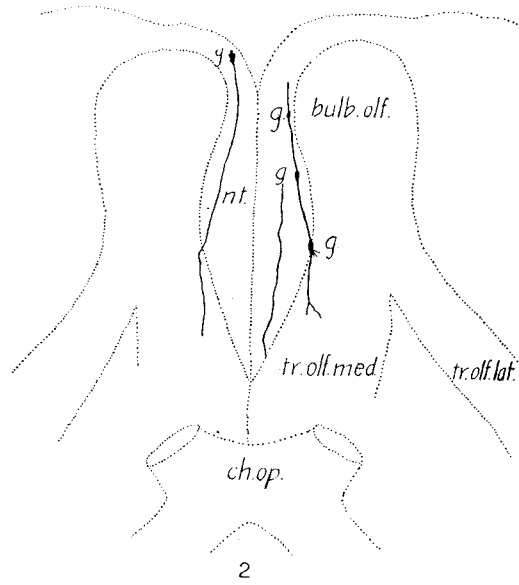


Fig. 2 Nervus terminalis in the sheep; *g*, ganglia; *ch.op.*, optic chiasma.

Fig. 3 Basal aspect of the brain of the porpoise; *s.p.a.*, substantia perforata anterior. The broken line bounding this rostrally marks a small sulcus occupied by a blood vessel. Three of the rootlets penetrate the brain beneath this vessel. *X* indicates point at which a root was broken in dissection.

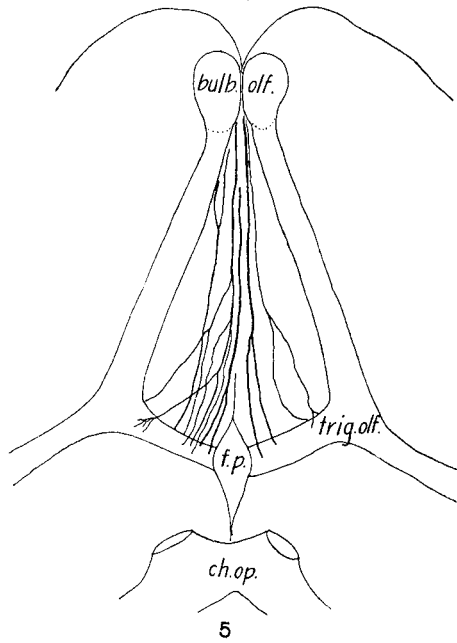
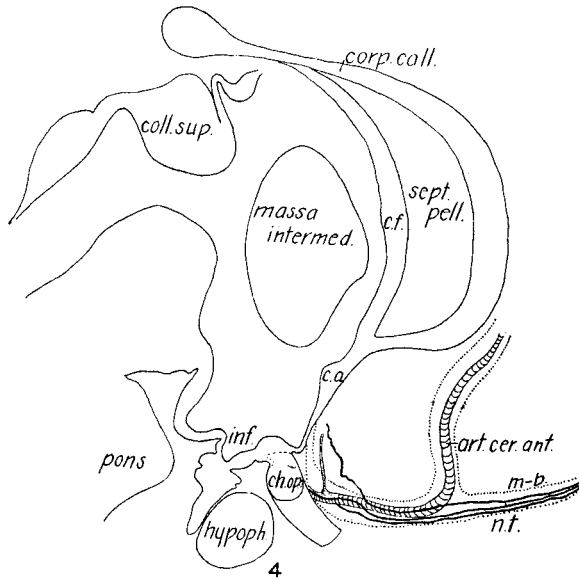
*The monkey.* The brain of *Macacus rhesus* and that of *M. cynomolgus* have been examined. Both show the nervus terminalis in characteristic form (fig. 5). Rostrally several nerve strands converge on the orbital surface of the frontal lobe (gyrus rectus) between the olfactory bulb and the median fissure and are cut off opposite the anterior end of the bulb. Traced proximally these strands diverge over the surface of the gyrus rectus and bend down into the fissura prima. The number of rootlets is greater in the rhesus, but otherwise the arrangement is essentially the same. The most mesial and thickest strand was removed from the rhesus brain, treated with vom Rath's fluid and stained with carmalum. The strand proved to be so compact that it could not be teased out with needles and only its proximal and distal portions could be examined satisfactorily. The rootlets contained no medullated fibers but in the distal one-fourth of the nerve medullated fibers began to appear and increased until there were fourteen to be seen at the distal end of the portion mounted. Near the distal end was seen a single large, typical ganglion cell. Several small cells in both the proximal and distal ends presented the appearance of nerve cells.

*Man.* I have examined a foetus of the fifth month, one of seven months, one at full term, a baby of four months and fourteen adult brains.

The five-months foetus had been long in Zenker's fluid or other bichromate solution and was very brittle when it came into my hands. On removing the right hemisphere the nerve of the left side was readily seen as a good-sized whitish strand extending from the fissura prima forward parallel with the olfactory peduncle toward the septum medial to the bulb. The condition of the material made it impossible to follow the nerve peripherally.

Fig. 4 Medial aspect of part of the left half of the brain of the porpoise. The dotted line *m-b* is the line of meeting of the medial and basal surfaces of the frontal lobe. The dotted line below is the profile of the rounded basal surface of the frontal lobe. The three more medial roots are shown. The most medial one enters the brain below the anterior commissure (*c.a.*); *c.f.*, fornix.

Fig. 5 Nervus terminalis in the monkey. The nerves of the right side of *Macacus rhesus* and those of the left side of *M. cynomolgus* are drawn; *f.p.*, fissura prima.



The seven-months foetus had been in formalin for at least six years and had not been fresh enough for histological study when preserved. The brain was rather soft and the tissues tough, so that the attempt to trace the nerve into the nose had to be given up. The brain was carefully removed and upon examination under the Greenough binocular, two transparent nerve strands were seen (fig. 6) upon the orbital surface of the gyrus rectus which were cut off opposite the anterior end of the olfactory bulb as in the forms above described. The apparent change in the position of the nerve since the five month stage is due to the

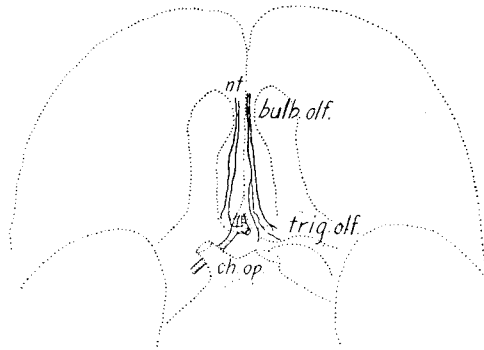


Fig. 6 Seven months human foetus, basal surface of the frontal lobes showing the nervus terminalis.

rapid development of the frontal lobe, which has expanded mesad producing a gyrus rectus medial to the olfactory peduncle. The pre-chiasmatic space is filled with a gossamer-like fibrous tissue which had to be removed patiently in order to follow the strands to their point of entering the brain. On the left side one of the strands pierced the rostral border of the medial olfactory tract near the trigon. The other strand divided into two rootlets which ran deeper into the fissura prima (fig. 6). On the right side the nerves were not fully dissected, the anterior cerebral artery being left in position to show the relations.

In the full-term foetus the attempt was made to trace the peripheral course of the nerve. The dissection was made from the face in order to expose the orbital surface of the frontal lobe. The



nerve of the left side was found on the gyrus rectus as in other cases. It was a single thick strand readily visible to the naked eye. Traced forward it entered the median fissure opposite the anterior end of the olfactory bulb. Curving somewhat dorsad in the fissure the nerve makes a gentle curve ventrad again and at the same time leaves the surface of the brain, with which it is in contact, and enters the pia mater. At the same time the nerve divides into several strands which flatten out like a fan. These thin flat strands pierce the pia and enter the tissue of the cribriform plate close to the median plane among the most anterior strands of the olfactory nerve. Here the connective tissue was so tough, owing to the formalin preservation, that the thin strands could not be followed far. Some of them were followed without doubt into the septum, and some appeared to go toward the lateral wall of the nasal chamber, but this was uncertain. The point at which these strands pierce the pia mater is the place where the nerve is cut off when a brain is removed from the skull. The fact that at this point the nerves in the adult brains dissected were either within or very near to the median fissure and imbedded in the pia, suggested the possibility that the nerves might be distributed to the meninges, but the dissection of this specimen was carried far enough to show conclusively that they go down into the septum, and to explain their position in the adult brain.

The brain of a baby of four months showed two strands on the left and three on the right. On both sides the roots entered the brain beneath the medial and rostral border of the medial olfactory tract. The nerve of the left side was stained and mounted, but no ganglion cells were found.

Fourteen adult human brains have been examined and the nervus terminalis found in all. In most cases the nerve is visible under the lowest power of the Greenough binocular without any dissection. It is only necessary that the pia mater shall be intact in the region between the olfactory peduncles and rostral to the optic chiasma. In only one of the fourteen brains was the nerve so small as to be at all difficult to follow. The nerve strands lie just beneath the pia and are visible through it because slightly

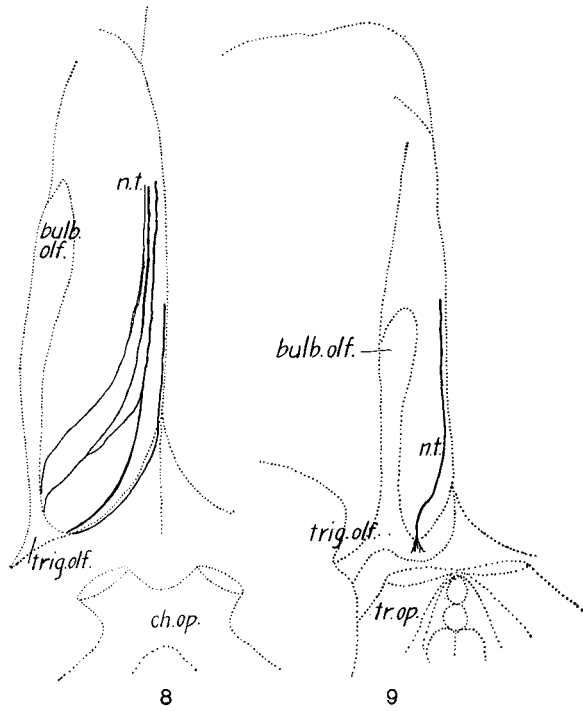
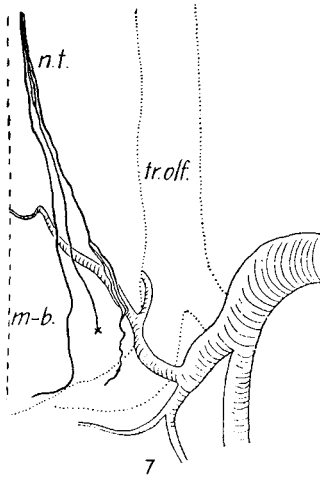
more whitish opaque than the pia. They are distinguished from small blood vessels because the vessels, even when apparently empty, have a slightly yellowish color. Moreover, small blood vessels are readily traced to the larger ones from which they arise. It is more difficult to distinguish the nervus terminalis from thin bands of connective tissue which lie in or beneath the pia. Most of the connective tissue strands in this region are inserted in the thick tissue surrounding the anterior cerebral artery or some of its branches in the median fissure, from which they stretch obliquely forward and laterad. The connective tissue strands can be detected by pulling this way and that upon the pia with fine forceps. The strands of connective tissue will be distorted and the appearance of strands will be produced parallel with the direction of tension, while the nerve strands, if present in the area pulled upon, will not be distorted, nor obscured. When the pia mater is pricked through, lifted up with forceps and dissected away it is found that the nerve strands lie beneath the pia but are attached to it more or less closely. The attachment is by means of slender connective tissue strands and in some instances by small bands which pass beneath the nerve in the form of loops or straps. In some cases the length of the nerve was drawn through one of these loops in order to free it from the pia. With a little care the nerve is separated from the pia and a few minutes suffice to expose the nerve through the greater part of its intracranial course. The dissection of the roots where they bend around the heel-like convexity of the gyrus rectus just in front of the optic chiasma requires more care, especially when the nerve divides into several slender rootlets.

Figures 7, 8 and 9 show the course of the nerve in three adult brains. It runs over the orbital surface of the gyrus rectus and

Fig. 7 Part of the basal aspect of the left frontal lobe in the adult human brain. The blood vessel is a small vein greatly distended with blood. X marks a root broken in dissecting.

Fig. 8 Basal aspect of the right frontal lobe in the adult human brain. Anastomosis of rootlets.

Fig. 9 Similar to figure 8. Nervus terminalis, a single strand with five rootlets on the surface of the medial olfactory tract.



enters the median fissure or lies near it at the level of the anterior end of the olfactory bulb, where the nerve is cut off in removing the brain. As seen in the figures, the nerve in these cases consisted of one, two, three or four strands. In one case (fig. 7) one of the strands divided into three strands which again united into one. In another case (fig. 8) a slender strand crossed obliquely from one of the main strands to another. It is entirely possible that slender strands would be overlooked or destroyed in dissecting and two or three minute strands were seen which are not included in the drawings. In the fourteen brains the type of nerve most frequently met with is that shown in figure 8. In one case the subdivision and reuniting of strands seen in figure 7 was present, together with a large number of very slender strands which ran along the medial border of the olfactory peduncle and bulb. When the nerve consists of a single strand, as in figure 9, it is large enough to be seen and dissected without the use of a lens. In one case it appeared larger than some of the rootlets of the IX and X nerves; but, being a broad thin band, it probably contains fewer fibers than those rootlets.

The point of attachment of the roots to the brain varies considerably. In all cases thus far examined it is in the region of the basal end of the fissura prima, either upon or in front of or behind the medial olfactory tract. In figure 8 the roots are seen converging toward the olfactory trigon, where they seemed to dip beneath the anterior and medial border of the olfactory tract. In figure 9 the single root divides into five rootlets which pierce the medial olfactory tract. The two roots of the other side of this brain had the same position. Two of the three roots in figure 7 have nearly the same position but one of them passes farther toward the median plane.

In position these strands correspond very closely to the *nervus terminalis* of lower animals and of human embryos previously described. Proof of the nervous character of the strands was sought, however, by removing and staining some of them. In one brain the nerve was found on only the right side. Its two rootlets entered the brain just at the rostral border of the medial olfactory tract where that bends from the orbital to the medial

surface. The roots were pulled out and the entire nerve was stained in neutral red and mounted in damar. It consists of some fifteen or sixteen small bundles of non-medullated fibers and has imbedded in its course about twelve ganglion cells. These cells occur singly or in twos. There is no larger collection. Each cell has a large nucleus and prominent nucleolus and stains deeply with neutral red. Unfortunately the material was not fresh enough to give a good stain of the Nissl substance.

The nerve on the right side of the brain from which figure 9 was taken was removed and stained as was also the left nerve of the four months baby brain, but no nerve cells were found in either. From the brain shown in figure 8 the nerve of the left side was stained in neutral red, while that of the right side was treated with vom Rath's fluid and afterward stained with carmalum. Neither medullated fibers nor nerve cells were found in this case. The largest nerve found was treated in the same way and teased out carefully. After clearing and mounting in damar there were found four ganglion cells surrounded by numerous sheath-cell nuclei. Two cells were in the middle part of the nerve, two at the distal extremity. No medullated fibers were found. Failure to find ganglion cells in some of the other cases may have been due to the fact that the nerves were not as well teased out.

From the above facts it appears that a nerve corresponding to the nervus terminalis of lower vertebrates exists in adult man and several other mammals. This nerve contains some medullated fibers at least in the sheep, horse and monkey, and in the monkey these fibers increase in number distally. In the sheep, horse, monkey and man the nerve contains ganglion cells in at least some individuals. In the sheep and horse there are distinct ganglionic enlargements of the nerve. The failure to find ganglion cells in the other cases here reported has little significance, since only the intra-pial course of the nerve could be examined. The probability that ganglion cells would be situated farther distally is suggested by the condition in the rabbit (Huber and Guild) and by the presence of a large ganglion in the sheep (fig. 2) just at the point where the nerve pierces the pia, rostral to the olfactory bulb. The presence and large size of the nervus termi-

nalis in the porpoise serves to emphasize its independence of the olfactory nerve, which has been abundantly established by previous work.

The nerve has usually been regarded as a vestigial structure, but it is an interesting fact that it is larger in man than in many fishes and amphibians. The question suggests itself, for how many million years has the nerve persisted in a vestigial condition? Further studies are desirable upon the central relations of the nervus terminalis and upon its structure and distribution in the nasal septum.

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