A historical note on the ascending reticular formation of the brain-stem

ALFRED MEYER

Professor Emeritus of Neuropathology, University of London

SUMMARY

Early work on the reticular formation has been largely overlooked, and this article traces back to the beginning of the 19th century the roots of modern developments in this field.

The concept of the ascending reticular formation has found an important place in psychological and psychiatric theory. Evidence is now convincing that it plays a vital part in the phenomena of consciousness, sleep, and alertness. Its role in the mechanism of conditioning and learning has been widely discussed. It may, therefore, be of interest to the psychiatric reader to be given, in the following pages, a brief account of its historical background.

When Jasper (1949) and Moruzzi and Magoun (1949) introduced this concept, they presented it as an alternative sensory system. Moruzzi and Magoun pointed out that, when Bremer discovered the so-called cerveau isolé, 'classical sensory paths were the only known connections ascending through the midbrain. . . . The present identification of a second, parallel system of ascending reticular relays . . . now raises a possible alternative interpretation of Bremer's observations.'

These electrophysiological pioneer publications contained little more of the historical background of the reticular formation. The new concept was a challenge to neuroanatomists who, with few exceptions, had at this mid-20th century period shown little interest in the reticular formation. Their chief aim, however, was to provide an anatomical substrate for a new physiological mechanism.

In the important monograph of Brodal (1957), historical information is comprehensive from about the turn of the century onwards. Brodal excluded the earlier history, since he was mainly concerned with the charting of individual reticular centres and their connections with the spinal cord, cerebellum, etc.—work which started in earnest with the publications of Held (1893), Kohnstamm (1899), Probst (1899), van Gehuchten (1903), and Cajal (1899–1904), among others. The almost simultaneous review of Rossi and Zanchetti (1957) on the anatomy and physiology of the reticular formation is equally informative on the historical background, though, again, it does not cover the early period. Other recent contributors, such as Meessen and Olszewski (1949), Droogleever Fortuyn and Stefens (1951), Nauta and Whitlock (1954), Olszewski (1954), Olszewski and Baxter (1954) Papez (1956), in their otherwise important investigations or atlases, are little concerned with historical aspects. Nauta and Kuypers (1958) are an exception, but again, they went little further than the publications of Kohnstamm and Quensel (1908, 1909) and Kohnstamm (1910).

Despite much progress, the anatomical pathways between brain-stem and cerebral cortex cannot be claimed to be indisputably established. The present writer accepts much of Kuhlenbeck's (1954) criticism, who also stressed the developmental difference between the reticular formation of the brain-stem, and the so-called reticular centres (reticular nucleus, intralaminary and midline nuclei) of the thalamus. In an interesting analysis of the direction of nerve cell processes within the reticular nucleus, the Scheibels (1966) consider the nucleus reticularis unlikely to be a final common pathway in the non-specific projection upon the cortex. The possibility that indirect pathways, for example, from centro-median nucleus via globus pallidus, nucleus ventralis anterior of the thalamus to the agranular frontal cortex, might be involved has been widely discussed. (See also the detailed discussion on this problem by Hassler, 1967.)
and of others of this time. The account they gave of the 'tractus fasciculorum Foreli' and of the 'centrum receptorium reticulatum' for sensations of pain and temperature is much like that found in these publications.

It should, therefore, be of some interest to give a more detailed account of the beginnings of knowledge of the reticular formation.

**EARLY 19TH CENTURY**

One must go back to the first decades of the 19th century when the search—chiefly associated with the names of Gall and Spurzheim, Reil, and Burdach—for ascending pathways, other than the pyramids, was particularly intense. Of the suggestions made at that time, two are of particular interest—namely, the so-called olivary columns and certain pathways on the floor of the 4th ventricle. Gall and Spurzheim (1809) had mentioned olivary pathways to the midbrain; Burdach (1822) was even more emphatic on the functional importance of the ascending olivary columns. These he believed to be the rostral continuation of the anterior spinal grey columns which he thought to be compounded of a chain of grey centres and fibrous pathways, connecting the olives with the region of the corpora quadrigemina. The *Olivenstrange* continued to occupy the attention of neuroanatomists—for example, Arnold (1838a, p. 18 et seq.) had noticed a network of fibres, and Stilling (1843, p. 66) described fibres of a 'substantia cinerea hic illic interposita', in the most medial part of the lateral spinal column and, more extensively, in the brain-stem upwards from the crossing of the pyramids. Both these authors regarded the fibres as derived from the pia mater, and consequently they spoke of a 'rete vasculosum'.

Lenhossek, the Elder (1855)², seems to have been the first to deal systematically with what he termed the 'processus reticulares', and to which he devoted nearly five pages of his paper. Like Stilling, he found this network of fibres and nerve cells in both the spinal cord and in the brain-stem. Although he did not free himself entirely from their connection with the pia mater, he tended to interpret the processus reticulares as fibres of the nerve cells of the grey columns—namely, the anterior and posterior horns of the spinal cord and their equivalents within the brain-stem. In 1859 (p. 91) Schroeder van der Kolk also referred to reticular fibres, but added little to the description of Stilling and Lenhossek. It was Deiters (1865) who coined the term 'formatio reticularis' for 'strands (Balken) of grey matter which encompass bundles of longitudinally directed nerve fibres' (p. 198). Unlike his predecessors, he found this network chiefly in the grey matter from the pyramids upwards, and this emphasis

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¹Bechterew traced the tract up to a region between the floor of the 3rd ventricle and the red nucleus, but believed that it continued into the cerebral hemisphere. He mentioned also that both Stilling and Wernicke had been aware of its existence, but had misinterpreted it.

²The names of Lenhossek, van der Kolk, and Deiters in relation to reticular fibres are mentioned in J. Dobson's (1962) *Anatomical Eponyms.*
on the brain-stem was maintained by Kölliker (1867), Meynert (1872), Flechsig (1876), and Forel (1877). Forel, however, compromised by suggesting the term 'formatio reticularis' for its appearance in the brain-stem only, while reserving 'processus reticulares' for the spinal cord.

FOREL

Thus, in 1877, Forel was already able to review much work on the subject, carried out by previous workers. In addition, he made extensive personal investigations, in the brains of man as well as of rodents and of carnivores, of which the following brief translated passages may give a general indication:

'It must be frankly admitted that almost nothing is known of origin and termination of these fibres. The general direction of these fibres is best studied in serial sagittal sections ... but no certain information is obtainable on the real course of individual fibre bundles ... since the direct connection with nerve cells can be traced for only short distances ...'

'The direction of the longitudinal reticular fibres, in general, is sagittal up to the level of the red nucleus and Meynert's bundle [that is, fasciculus retroflexus]; however, the bundles seem to join each other in acute angles, forming a network ... they appear to be mainly continuations of the anterior and lateral [spinal] tracts which become loosened through interposition of grey matter ... it is difficult to prove, however, whether they are direct or merely indirect continuations of the anterior and lateral tracts. ... In the medio-dorsal aspects, the longitudinal reticular fibres pass imperceptibly into fibres of the posterior longitudinal bundles; ventrolaterally they are not always separable from the Schleifenschicht¹ and the inferior [that is, our lateral] lemniscus. ...'

'Nevertheless, the general direction of the longitudinal reticular fibres is fairly clearly recognizable, up to the level of the red nucleus and Meynert's bundle [that is, fasc. retroflexus]. Here, however, ... the fibrous network—mainly owing to fibres of the red nucleus coursing in a dorsal and lateral direction—becomes so dense, that one loses one's thread entirely, and not before one arrives above the red nucleus is it possible to see an oval field [that is, Forel's field H], consisting of both finest fibres and grey matter. It is dorsally bordered by the thalamus and laterally connected with a medullary lamina which is very constant in mammalian brains and which, elsewhere,² I have previously called lamina medialis externa [of the thalamus]. ... In the brains of rodents in which the brachium conjunctivum is small and less disturbing, the longitudinal fibres of the reticular formation, though in much reduced numbers, can be observed—above the red nucleus and the root of the occulomotor nerve and between corpus mammillare and the thalamus ... to reach this field which corresponds to field H of man and is continuous with the lamina medialis externa' [p. 415].

This, in essence, is Forel's description—the basis of the term 'tractus fasciculi Foreli' of which Kohnstamm et al. spoke later.

THRESHOLD OF MODERN ERA

Forel's review and contribution crown and end the early phase of research into the reticular formation. Bechterew (1885b), on the other hand, stands on the threshold of a new phase—our modern era, as Brodal explains—when the general concept of a reticular formation is being progressively disentangled into its concrete individual components. Bechterew described the nucleus reticularis tegmenti pontis, included in the reticular formation a nucleus described by Roller,³ and also a more rostrally situated nucleus centralis superior. Fibres ascending from the anterior and lateral spinal tracts end in these and other nuclei. From a study of myelogenesis, he concludes that the most important rostral connections of the reticular formation ascend in the latero-dorsal segment, to reach the inferior corpora quadrigemina, the region of the 3rd ventricle, and, perhaps, the thalamus. Significantly, he tentatively suggested they may carry sensory impulses, transmitted from the spinal cord.

Subsequently (1889) Bechterew distinguished a nucleus medianus and medial and lateral nuclei reticulares both superior and inferior. He included Gudden's nuclei profundi and dorsales of the midbrain tegmentum (in which the mammillary tegmental bundle and part of the

¹The name is attributed to Reichert (1859-1861). According to Meynert (1872) the Schleifenschicht is more or less identical with the superior—that is, our medial—lemniscus.

²Forel (1872).

³This is the nucleus of Roller (1881), known also as sublingual nucleus, and situated ventrally of the hypoglossal nucleus. Some still consider it a condensation of reticular cells.
mammillary pedunculi terminate or originate) in the reticular formation which he considered an important reflex centre, although 'there is not yet any certain evidence about the nature of its reflexes'. He mentions, however, that his disciple Misslawski (1885) had experimentally been able to demonstrate a respiratory centre in the region of the nucleus funiculi anterior (of Obersteiner) and a vasomotor centre in nucleus centralis inferior, both in the reticular formation of the medulla.

CONCLUSIONS AND SUMMARY

I hope to have shown that the history of knowledge on the reticular formation can be traced back to the beginning of the 19th century. The 'round bundles' of Reil, and the olivary columns of Burdach and others were valid anticipations, albeit crude, since they were seen as chains of grey and white matter linking medulla with midbrain tegmentum, hypothalamus and thalamus. The word rete first appears in the writings of Stilling; Lenhossek spoke of 'processus reticulares' and in Deiters' posthumous book of 1865 we find the first mention of the term 'reticular formation'. Forel (1877) was able to review a considerable body of previous work; in his descriptions and concepts and in those of Bechterew, we find astonishing anticipations of modern developments.

This early work has been largely overlooked. It received no explicit mention when mid-20th century pioneers launched the electrophysiological concept of the ascending reticular formation, and even in the subsequent anatomical analysis, important as it is, it found no adequate place. When Moruzzi and Magoun claimed the 'classical sensory paths' as the only known connections ascending through the midbrain, they may have been correct for the recent past: the early workers, however, erred rather towards emphasis on the importance of the reticular pathways, at the expense of the 'classical sensory paths'—that is, the various lemnisci—of whose significance they were as yet only dimly aware.

Such can be the irony of history.

REFERENCES


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Although historical notes on the ascending reticular formation of the brainstem are available, the specific references and context are not directly transcribed from the image. However, some general historical notes can be inferred from the given text:


