Introduction.

Modern neurophysiological research has focussed with compelling concentration upon events — electrical, chemical and hormonal — occurring at the junction between neurones. This junction, the synapse as Foster and Sherrington called it in 1897, has entered inextricably into the physiology of the nervous system as carrying especial functional importance. The very word "synapse" contains within its meaning a physiological principle that has emerged from a long and penetrating investigation of the nervous system seen either as a protoplasmic continuity or as chains of contiguous neuronal units impinging one upon the other at discrete interfaces. Actually, the problem whether the central nervous system is built up of independent living units or whether it is in itself a structurally unified reticulum gives place to and is largely resolved by the unfolding truth of its unifying, integrating action. Bethe's work has indeed pointed the way and stands as an enduring contribution to this concept of central nervous function. From this point of view, Riese has assessed the difference between a syncitial and a neuronal central nervous system as essentially a difference in degree rather than in principle, asserting that neither of these two types alone represents a perfect model of true integrative action since neither of them reflects the absolute unity implied in integration. Inspection of the nervous system from a broad, comparative point of view reveals evidence for both the discontinuous and syncitial character of the central nervous system and the endeavor to penetrate into its true nature still goes forward.

It is not the object of the present paper to review the history of this endeavor in its details or even to deal comprehensively with the

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subject of synapse morphology. Rather we shall concern ourselves with certain aspects of the structure and pathological features of the central axone terminals of the mammalian spinal cord known variously in the literature as boutons terminaux, end-feet, end-bulbs or end-knobs. The word “bouton” has been applied extensively in the English language literature to designate these structures and although it is not an especially happy term the word has been choosed for this paper, “end-feet” and “end-bulb” being used synonymously.

The Structure of the Boutons.

The history of the boutons themselves comprises an extensive literature and observations and relatively recent reviews on their structural features may be sought in papers by CAJAL 21 (1934), HOFF 36, 37 (1932, 1937), HOFF and HOFF 39 (1934), GIBSON 26 (1937), PHALEN and DAVENPORT 42 (1937), BARR 7 (1939), BARNARD 8 (1940) and MINCKLER 38, 39 (1940, 1941). For considerations of the comparative structure of vertebrate boutons, the paper by PHALEN and DAVENPORT is useful and the reader is referred to papers by BODIAN 16-17 (1938, 1940) for descriptions of the axone endings on Mauthner’s cell in teleosts. For an entry into the more recent literature on nerve endings in sympathetic ganglia a starting point is Gibson’s paper published in 1940.

End-bulbs were described by ABONSON 2 in 1886 on sympathetic and dorsal root ganglion cells and by MEYER 37 in 1899 in the brainstem of the dog. Their description by HELD 29 (1897) and the confirmation of HELD’s observations by AVERBACH 3 in 1899 attracted particular attention to these structures which came to be known as the end-feet or boutons terminaux of HELD and AVERBACH. It was early seen that these loop- or knob-like organs occurred not only as terminal expansions upon cell bodies and dendrites but also as swellings of the fine pericellular fibrils, to which was assigned the name, “bouton en passant”. APÁTHY’S description in 1897 (see 20) of an internal fibrillary structure in nerve cells provided further source material for the divergence that developed as to the exact form of the structural matrix subserving nervous action. On the one hand, the conducting system was seen as a continuous reticulum, a view upheld by BETHE 10, HELD 29 and many others. Consistent with this view HELD 29 (1897) and more recently TIEGS 52 (1931) reported minute protoplasmic strands proceeding from the boutons into the cell to become continuous with the intracellular neurofibrils. Between the concept of protoplasmic fusion and the views of CAJAL 20 (1908) there was a sharp dichotomy and the latter and his followers continued to maintain that the boutons make only a simple contact with the cell and that there is no structural interneuronal continuity.

In our own experiments the boutons have been examined in particular detail in the cat and in the monkey (Macaca mulatta) in preparations fixed by perfusion with 10 per cent chloral hydrate and treated subsequently according to Cajal’s formula (6a, in Bolles LEB 35, 1928). In preparations of new-born kittens it has been impossible to demonstrate any boutons on any cells of the cord. In a series of kittens ranging in age from one day to two months, the first boutons were seen in the 21-day old animals.