ARTICULAR NEUROLOGY

ARTICULAR neurology is that branch of the neurological sciences that concerns itself with the study of the anatomical, physiological, and clinical features of the nerve supply of the joint systems in various parts of the body. As such, it is clearly of relevance not only to neurologists and neurosurgeons, but also to orthopaedic and physical medicine specialists and to physiotherapists; nevertheless, until recently it has never been the subject of specific and organised investigation.

Extrinsic Innervation of Synovial Joints

Each synovial joint in the body has a dual pattern of nerve supplyfirst, by primary articular nerves that reach the joint capsule and ligaments as independent branches of adjacent peripheral nerves, often (but not exclusively) in company with articular blood vessels; and second, by accessory articular nerves, which are branches of related muscle (and sometimes cutaneous) nerves. Many of these latter articular nerves arise within some of the muscles that are attached to each joint capsule as intra-muscular branches of various muscle nerves, and reach the joint by running (embedded in the interfascicular connective tissue) through the substance of the muscle, Neurohistological studies have shown that each articular nerve contains a mixture of myelinated and unmyelinated nerve fibres whose diameters range from less than 1 micron to 13,u (and up to 17,u in a few instances), When these data are considered in combination with the results of oscillographic analyses of the impulse traffic in the articular nerves, of electrical nerve stimulation procedures, and of other neurophysiological investigations, it emerges that the fibres in articular nerves generally may be subdivided into the three major size categories indicated in Table 1, each of which has specific functional correlates conferred upon it by the particular nerve endings in the joint tissues that its constituent fibres supply. A large proportion (at least 45%) of the total number of fibres in each articular nerve has diameters of less than 5 microns Most of these small myelinated and unmyelinated fibres are afferent in function and subserve articular pain sensation; but a small proportion of the unmyelinated fibres in this group consists of visceral efferent fibres of sympathetic origin that innervate the articular blood vessels-that is to say, these latter are articular vasomotor nerve fibres. There is no evidence of the existence in any articular nerve of secretomotor fibres, or indeed of any direct nervous influence on the production of synovial fluid other than that exerted indirectly by vasomotor nervous effects on the diameter of the articular blood vessels (and thus on joint blood-flow).

Another large proportion (some 45% to 55% of the total) of fibres in articular nerves consists of medium sized myelinated fibres between 6 and 12 microns in diameter, all of which are mechanoreceptor afferents. That is to say, these nerve fibres innervate small corpuscular endorgans of varying morphology (vid. inf.) located mainly in the fibrous capsules and fat pads of the joints, which respond to changing mechanical stresses in these tissues (see Table 11) and which subserve reflexogenic and kinaesthetic functions.

A third small proportion (some 10% or less) of fibres consists of very large myelinated fibres between 13 and 17/1 in diameter that are also mechanoreceptor afferents. However, these latter (as indicated in Table 11) innervate very large corpuscular endorgans (of relatively high threshold) that are confined to

the joint ligaments; and thus this third group of afferent fibres is absent from those articular nerves that do not contribute branches to extrinsic or intrinsic joint ligaments. Their function appears to be entirely reflexogenic.

Articular Receptor Nerve Endings

The use of specially modified neurohistological staining techniques, correlated with neurophysiological observations of receptor endorgan behaviour, has shown that the nerve endings distributed through the tissues of all synovial joints may be classified into four distinct varieties in terms of morphological and behavioural criteria, as follows.

1. **Type i:** The Type I receptors, a group of globular or ovoid corpuscles with a very thin capsule that are similar to those described originally by Ruffini in subcutaneous and fascial connective tissues. They are numerous in the capsular tissues of all the limb joints, the apophyseal joints of the vertebral column and the temporomandibular joints-although their population density differs in the individual joints. For example, in the limbs the Type I receptors appear to be more densely distributed in the proximal (for example, in the hip) joints than in more distal (for example, the ankle) joints; whilst in the spine they appear to be more numerous in relation to the apophyseal joints of the cervical region than elsewhere. In each joint in which they are present, the Type I receptors are located mainly in the superficial (that is, in the external) layers of the fibrous capsule, within which they are distributed tridimensionally in clusters of up to 6 corpuscles per cluster; and each such cluster is supplied by the fine terminal branches of a single myelinated afferent axon that is some 6 microns to 9,u in diameter. Within the capsule of each individual joint, the clusters of Type I receptors show regional differences in their distribution density, in general being more numerous on those aspects of the joint capsule that undergo the greater changes in stress during natural joint movement.
2. **Type ii:** The Type ii receptors, are elongated, conical corpuscles with a thick multi-laminated connective tissue capsule enclosing a single (or sometimes multi-stranded) unmyelinated nerve terminal that ends in a bulb or a Y-shaped bifurcation near the apex of the corpuscle. Some previous workers have regarded these nerve endings as a modified form of the VaterPacinian corpuscle, but for reasons discussed in detail elsewhere we do not agree with this homology. In fact, true Pacinian corpuscles are not found in the tissues of any joint anywhere, although they are numerous in peri-articular tissues (and in periosteum) in many parts of the body. The Type 11 corpuscles are present in the fibrous capsules of all joints in numbers that vary with the particular joint; but in the limbs they are relatively more numerous in distal (for example, the ankle) joints than in more proximal joints such as the hip. They are also particularly numerous in the temporomandibular joints, and in the intercartilaginous joints of the larynx. They are located mainly in the deeper layers of the fibrous capsules of the joints, particularly at the border between the fibrous capsule and the sub-synovial fibroadipose tissue where they often lie alongside or coil around the articular blood vessels. They are distributed in each joint capsule in clusters of 2-4 corpuscles per cluster, each such cluster being innervated by a branch of a parent myelinated afferent articular nerve fibre some 9 microns to 12 microns in diameter, as indicated in Table II It should also be noted that similar clusters of Type ii endings are present on the

surfaces of all the fat pads related to synovial joints, whether these be intra-articular or extra-articular.

3. **Type iii:** Type I and Type ii corpuscles are joint capsule receptors primarily, whereas the Type III corpuscles are confined to the joint ligaments, both extrinsic and intrinsic. They are the largest of the articular corpuscles and are identical structurally with the tendon organs of Golgi of which they appear to be the articular homologue. Type I corpuscle is a fusiform endorgan applied longitudinally to the superficial surfaces of the joint ligaments, usually near their bony attachments, and consists of a filmy connective tissue capsule enclosing a mass of densely arborising nerve filaments derived from a large myelinated parent afferent axon that may be up to 17 microns in diameter. A few of these corpuscles are found on all the extrinsic (that is, the collateral) ligaments of the limb and spinal apophyseal joints and on all intrinsic joint ligaments, such as the cruciate ligaments in the knee joint and the ligamenturn capitis femoris in the hip joint. A few are also present in relation to the lateral ligament of the temporomandibular joint; but they are absent from the longitudinal and interspinous ligaments of the vertebral column.
4. **Type iv:** The Type IV category of articular receptor nerve-endings embraces the non-corpuscular nerve-endings in the joint tissues, and is represented either by lattice-like plexuses of small unmyelinated nerve fibres or free nerve-endings. These terminations are derived from the smallest of the afferent fibres in the articular nerves, some of which (those between 2 and 5 microns in diameter) are thinly myelinated, whilst the remainder (those less than 2 ,u in diameter) are unmyelinated. The plexus or network system of terminals is prominent in the limb, spinal apophyseal and temporomandibular joints, in each of which it is distributed throughout the fibrous capsule and the adjacent periosteum, the articular fat pads (both external and internal) and the adventitial sheaths of the articular blood vessels. In the capsular tissue of these Joints free nerve-endings are relatively sparse, being confined largely to the extrinsic and intrinsic joint ligaments. In brief 'it seems that plexus system is the main variety of the Type IV receptor ending in fibrous capsules and joint fat pads, whereas the free nerve-ending variety is more characteristic of joint ligaments.