A PHYSIOLOGICAL APPROACH TO CLINICAL NEUROLOGY

SECOND EDITION

James W. Lance

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Butterworths

A Physiological Approach to Clinical Neurology

Second Edition

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London: 88 Kingsway, WC2B 6AB

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SOUTH AFRICA
Butterworth & Co. (South Africa) (Pty.) Ltd.
Durban: 152-154 Gale Street

USA
Butterworth
161 Ash Street
Reading, Mass. 01867

First published 1970

Second edition 1975

ISBN 0 407 00022 4

Suggested UDC Number 616·8: 612·8

Printed and bound in Great Britain by
R. J. Acford Ltd., Industrial Estate, Chichester, Sussex

To Professor P. O. Bishop
who must assume some responsibility for our
becoming neurologists

Preface to the Second Edition

Reviews of the first edition of this work suggested that it would be more useful if it were made more comprehensive by including sections on peripheral nerve on the one hand and the special senses and cranial nerves on the other. To mount this two-pronged attack on the neuraxis, I invited Professor J. G. McLeod to join me in the authorship of the second edition. New chapters have been added on the neuromuscular system and spasticity, and the chapter which was previously devoted to vertigo has been expanded to provide a summary of the relevant anatomy and physiology of special senses and cranial nerves. Recent research in experimental and clinical neurophysiology has been incorporated into all chapters. Chapter 12 remains rather detached as befits an essay on the mind–brain relationship and must remain so until philosophical speculation is braced by firmer data. The authors trust that the text now provides a physiological talisman to guard the bearer against confusion in his journey into clinical neurology.

Sydney JAMES W. LANCE

Preface to the First Edition

As a clinical neurologist and amateur physiologist, I have always sought to bridge the gap between the research laboratory and the hospital ward in teaching undergraduate and postgraduate students. A knowledge of neuroanatomy and neuropathology is generally accepted as a basis for the understanding of clinical neurology, while neurophysiology has become isolated in the student's mind by its technology, its emphasis on animal experimentation, and its apparent lack of relevance to clinical problems. The account given here attempts to overcome this unhappy state by explaining the mechanism of various neurological symptoms and signs in terms of disordered physiology wherever this is possible.

To present a simple version of complex and often controversial mechanisms and then to illustrate the concept by line diagrams is to invite criticism, but this has been done deliberately since the value of an interpretation lies in its clarity as well as its validity. The validity of the text will certainly change with the acquisition of new experimental evidence and re-examination of the old. Thus, no statement in the following pages can be regarded as immutable. The coverage is patchy, reflecting the interests and bias of the author, since there is no intention to compete with comprehensive textbooks of neurophysiology or clinical neurology.

The first two chapters are designed as an introduction to the clinical analysis of sensory and motor disorders. In the later chapters, appraisal of current neurophysiological thought is applied to common neurological syndromes. The author hopes that the presentation will be clear enough to hold the interest of the clinical reader, without being so artless as to offend the professional physiologist. The book is proffered to those who are proceeding into the clinical years of a

medical course, to those who are studying for senior qualifications in internal medicine or neurology, and to those who are merely curious about the cause of neurological phenomena which they observe daily in their patients. However brilliant the physiological advances made in the understanding of other species, they are profitless for man until applied to him.

J.W.L.

Acknowledgements

The authors are grateful to their colleagues who have contributed to knowledge in various aspects of clinical neurophysiology and have assisted by the constructive criticism of the preliminary drafts of this text, particularly Drs. J. D. Gillies, D. J. Burke, C. J. Andrews and P. D. Neilson of the University of New South Wales and Drs. J. W. Prineas and J. C. Walsh of the University of Sydney. Professor P. O. Bishop, Professor W. Burke, and Dr. W. R. Levick have given most helpful advice on the chapter on special senses. The text has been collated and prepared by Mrs. R. M. Kendall with her usual incomparable care and efficiency.

The line diagrams were drawn by Dr. Peter Ashby (*Figure 4.2*), Mrs. G. Lindley, Mrs. P. Zylstra and Mrs. R. Sicuro; photographs were prepared by the Departments of Medical Illustration of the Universities of New South Wales and Sydney.

We are indebted to the editors of *Brain*, *Journal of Neurology, Neurosurgery and Psychiatry*, *Journal of Neurological Sciences*, *Australian and New Zealand Journal of Surgery* and the *Medical Journal of Australia* for permission to use material and figures from earlier publications. We wish to thank those authors whose illustrations we have used as models, where acknowledged in the legends.

The research programme at The Prince Henry Hospital has been generously supported by Edwin and Daisy Street who provide an annual research fellowship, as well as by grants from the National Health and Medical Research Council of Australia, The Spastic Centre of New South Wales, Merck Sharp and Dohme (Australia) Pty. Ltd., Ciba-Geigy Australia Ltd., Roche Products Pty. Ltd. and Sandoz (Australia) Ltd.

Contents

1—Pain and other Sensations

The nervous system of a normal individual is constantly active in conveying information to the brain about the state of the body and of the world outside it. If all these neuronal messages were received in equal measure, consciousness would become a nightmare of confused and largely irrelevant stimuli, so that a selective response would become impossible. Fortunately, there are various physiological processes which speed the passage of pertinent stimuli and retard awareness of the background activity. We thus become oblivious to the touch of clothes, the pressure of a hard seat and the functioning of contented viscera. The processes involved in this selectivity of sensations are as follows.

(1) Adaptation of sensory end organs, which cease to respond after variable periods of stimulation.

(2) Presynaptic inhibition of adjacent nerve cells by collaterals from an active nerve cell, thus assuring priority for 'the stimulus of the moment'[9]. This process probably takes place at all levels of the nervous system, thus repeatedly 'refining' the impulses representing a particular sensation, or, in electronic jargon, ensuring 'a high signal-to-noise ratio'.

(3) Regulation of synaptic transmission in sensory nuclei by the motor cortex. Stimulation of the sensorimotor cortex of the cat may inhibit or excite nerve cells in the cuneate and gracile nuclei by means of collaterals from the pyramidal tract and, to a lesser extent, by an extrapyramidal system[20, 38]. This provides a mechanism for the voluntary suppression of sensory information or for involuntary suppression during movement.

(4) Alteration in the state of awareness at a cortical or subcortical level. A subject, while fully conscious, may so concentrate his

attention on a particular sensation, thought or response as to preclude perception of other sensations.

The perception of any sensation therefore depends not only on the appropriate receptor organ in skin, muscle, joint or viscus, and the integrity of the peripheral nerve and spinal cord pathways, but also on complex connexions within the cerebral cortex which may be influenced by the thoughts and emotions of the subject. Thus sensation is subjective and each individual has his own 'perceptual world' which is unique to him and can be known to others solely by his description of it. A certain stimulus may be registered by some as pleasant, by others as unpleasant but tolerable, and by others as so uncomfortable that they use the term 'pain' to describe it. Each person may therefore be regarded as having a 'pain threshold', and if the level of sensory stimulation exceeds this, pain is experienced.

When the normal functioning of the body is disturbed, sensory impulses of unusual quantity, quality or pattern are received by the brain, and the resulting 'sense data' are expressed by the subject as 'symptoms'.

Sensory symptoms

Symptoms bring the patient to the doctor. It is part of the art of medicine to record the patient's symptoms accurately and to interpret them in the light of the patient's intellectual and educational endowment, his personality and his emotional state.

Symptoms may be negative in that the patient complains of numbness or inability to feel touch, pain, temperature or position of the limbs. Symptoms may also be positive, providing curious abnormal sensory experiences (paraesthesiae).

Ischaemia or irritation of peripheral nerves or the central projection of touch pathways gives rise to pain or to the prickling sensation described as 'pins and needles' or the arm or leg 'going to sleep'. Compression of the lateral cutaneous nerve of the thigh in the inguinal ligament produces a curious creeping feeling in the outer aspect of the lower thigh which has been likened to the sensation of ants crawling under the skin (formication).

A disturbance within the posterior root entry zone or posterior columns of the spinal cord, or pressure upon them, may be responsible for a girdle sensation around the trunk, described as a tight band; or a feeling of pressure in the limbs as though they were being wrapped by a bandage. Sudden flexion of the neck may induce an electric shock sensation which shoots down the back when there is a cervical lesion irritating the posterior columns. This phenomenon (Lhermitte's sign) is found most commonly in cervical spondylosis

and multiple sclerosis. A lesion in the spinothalamic tracts or thalamus produces an unpleasant burning sensation or pain which spreads diffusely down the opposite side of the body.

Irritation or ischaemia of the sensory cortex evokes paraesthesiae, which may spread rapidly over the contralateral side in epilepsy and transient ischaemic attacks, or advance more slowly when caused by migrainous vasospasm. Disturbance of the sensory association areas in the parietal lobe may give rise to weird illusions of the body image so that parts of the body appear larger or smaller than normal.

Pain is the most consistently unpleasant symptom which the nervous system can provide and may signal a disorder in any part of the body through irritation or distortion of sensory endorgans, or may arise from disease of the sensory pathways at any level from endorgan to cortex.

Pain is often associated with an emotional change so that it may be hard to determine which is primary and which secondary. In spite of all the complexities of the individual reaction to pain, it is usually possible to analyse the description of the pain so as to determine its site of origin and often its cause.

THE PERCEPTION OF DIFFERENT KINDS OF SENSATION

Cutaneous nerves and sensory receptors

Human cutaneous nerves contain myelinated fibres which range in diameter from about 1 to 16 μm, and unmyelinated fibres which are less than 2μm in diameter. The myelinated fibres are designated A fibres and are subdivided into A α β (6–16 μm) and A$\gamma\delta$ (2–6 μm) groups. The unmyelinated fibres are C fibres. All the fibres have their cell bodies in the dorsal root ganglia, and they terminate peripherally in skin and subcutaneous structures. The sensory receptors in the skin may be encapsulated endings of nerves such as Pacinian corpuscles and Meissner's corpuscles; specialized free endings, such as Merkel's discs; and simple free endings. The encapsulated endings are concentrated in areas of the body which are particularly sensitive—the tips of the fingers, the lips, the areola of the breast and the genitalia. There now seems little doubt that many cutaneous receptors display stimulus specificity and include slowly and rapidly adapting mechano-receptors, warm and cold receptors and pain receptors[14, 16, 17].

Pacinian corpuscles are extremely sensitive to displacement and vibration. Some receptors respond to more than one stimulus; for example, some mechano-receptors are sensitive to change in

temperature[13]. Some free nerve endings have a high threshold and respond to painful stimuli only, while others have a low threshold and probably play an important role in sensory discrimination[1]. The cornea, for instance, has only free nerve endings but is sensitive to touch, heat and cold as well as to pain[26]. There is no absolute relationship between the sensory modality perceived and the diameter of sensory fibres excited although large diameter fibres are important for conveying sensations of light touch, position and vibration sense and small diameter fibres for conveying pain and temperature. Light touch of the skin and movement of hairs activates unmyelinated and small myelinated fibres as well as the large diameter myelinated fibres[8], [16], [40]. Evidence in primates indicates that warm and cold receptors are innervated by slowly conducting myelinated fibres of the A group or by unmyelinated C fibres[14]. It seems to be necessary to activate $A\gamma\delta$ and C fibres in order to arouse the sensation of pain[4], [5], [40], although these fibre groups play an important role also in the transmission of other sensory modalities. Recent work in our laboratories in the human has shown that the perception of warmth and of dull aching pain is mediated by C fibres. The perception of cold and of pricking pain is only observed when the larger A gamma fibres are activated.

Light touch

Clinically, light touch is usually tested with cotton wool. Large myelinated ($A\alpha\beta$) fibres are excited by this stimulus, but $A\gamma\delta$ and C fibres are also activated. Experiments on man indicate that tactile sensation may be induced by the excitation of only one or two large myelinated fibres[13]. Most of the fibres excited in the periphery by light touch pass centrally in the spinal cord by way of the dorsal columns to the gracile and cuneate nuclei, where they synapse[33] (*Figure 1.1*). Second order neurones arise in these posterior column nuclei and cross over to pass upwards as the medial lemniscus to the external component of the ventro-basal complex of the thalamus (nucleus ventralis posterolateralis, VPL). The comparable fibres from the main sensory nucleus of the trigeminal nerve cross to join the lemniscal system and end in the arcuate or medial component of the ventrobasal complex of the thalamus (nucleus ventralis posteromedialis VPM). Thalamocortical fibres project mainly to the postcentral gyrus in the cerebral cortex. Throughout the posterior columns, lemniscal system, thalamus and cerebral cortex there is a topographical distribution of the sensory fibres. The posterior column/lemniscal system is responsible for the finer forms of tactile sensibility in man which are tested by stereognosis, two-point

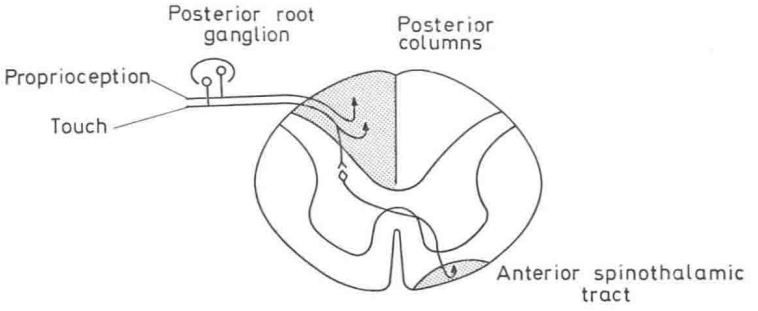

Figure 1.1 Spinal pathways for proprioception and touch (after Ranson, S. W. and Clark, S. L. (1959). 'Anatomy of the Nervous System'. Philadelphia and London; Saunders)

discrimination, and figure writing on the skin. These functions may be severely impaired by destruction of the dorsal columns although, with unilateral lesions, there may be no permanent sensory impairment which is clinically detectable[7]. The classical views of dorsal column function have been criticized recently by Wall[39], who suggests that their role is to initiate exploratory movements and to assist in the analysis of information conveyed through other sensory pathways.

Some tactile sensations must be mediated by the spinothalamic system because touch can still be perceived in man after damage to the posterior columns (*Figure 1.1*). This touch pathway of crossed second order neurones is known as the anterior or ventral spinothalamic tract, but its exact position in the anterolateral columns is unknown[33].

Joint position sense

It has been accepted for many years that joint position sense and kinaesthesia are signalled by means of afferent fibres which innervate receptors in the ligaments and capsules of joints[37]. Muscle receptors were considered to play no part in the conscious appreciation of the position of joints and limbs[33]. However, recent work by Goodwin McCloskey and Matthews[11] changes these classical views and indicates that muscle afferents do in fact contribute to kinaesthesia.

Destruction of dorsal columns causes impairment of joint position sense, and it may therefore be concluded that the afferent fibres responsible for proprioceptive sensation are situated mainly in this spinal pathway. There is also a disorder of posture and movement predominantly of the upper limbs, following destruction of the dorsal columns in the high cervical region[10]. Cortical evoked potentials, elicited from the scalp in man following stimulation of

peripheral nerve, travel in the posterior columns and are present in patients who have lost only pinprick and temperature sensation[12].

Vibration sense

The testing of vibration sense with a tuning fork is probably merely a specialized way of testing tactile and pressure receptors and their pathways. The peripheral pathway consists mainly of large afferent fibres which innervate one or two Pacinian corpuscles[15]. The central pathway is by way of the posterior columns/lemniscal system, but not exclusively so, since the lateral columns may also relay vibratory sense[3].

Temperature sense

Specific warm and cold receptors exist, and both $A\gamma\delta$ and C fibres respond to thermal stimulation. The central pathways are in the lateral spinothalamic tracts, in close association with the pain pathways (*Figure 1.2*).

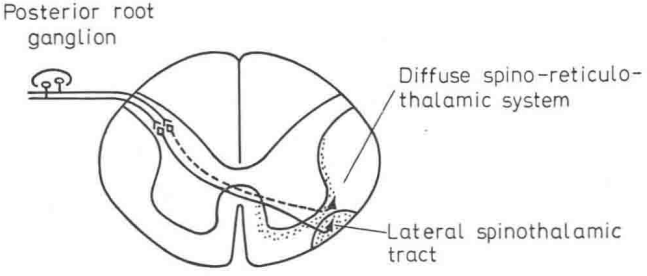

Figure 1.2. Spinal pathways for pain

Tickle and itch sensations

These sensations probably depend upon activity in $A\gamma\delta$ and C fibres, and are abolished by anterolateral cordotomy[41].

Pain

Fibres from free nerve endings run in peripheral nerves to the posterior root and posterior horn of the spinal cord. There are two groups of afferent fibres particularly associated with pain perception—unmyelinated C fibres conducting slowly at 1–2 metres/second, and the $A\gamma\delta$ group of myelinated fibres which conduct more rapidly at 10–20 metres/second. It is probable that the time interval in conduction between these two groups gives rise to the clinical phenomena of 'immediate' and 'delayed' pain[36].

Fibres involved in the transmission of pain sensation synapse in

the posterior horn of grey matter in the spinal cord within a few segments of their entry into the cord and the second-order neurones cross to the other side and then ascend in the lateral spinothalamic tract (*Figure 1.2*). It is now apparent that many pain fibres are scattered diffusely throughout the anterior and lateral white columns of the spinal cord, since it is necessary to destroy the greater part of this area before pain perception is abolished (*Figure 1.2*). These scattered 'extra-lemniscal fibres' relay in the reticular formation of the brain-stem, the intralaminar nuclei of the thalamus and the lateral reticular nucleus, and are distributed to both hemispheres by a diffuse thalamocortical projection[2], which is illustrated in *Figure 1.3*. The lateral spinothalamic tract is relayed by the nucleus ventralis posterolateralis (VPL) of the thalamus, and is probably projected to the sensory cortex in the post-central gyrus.

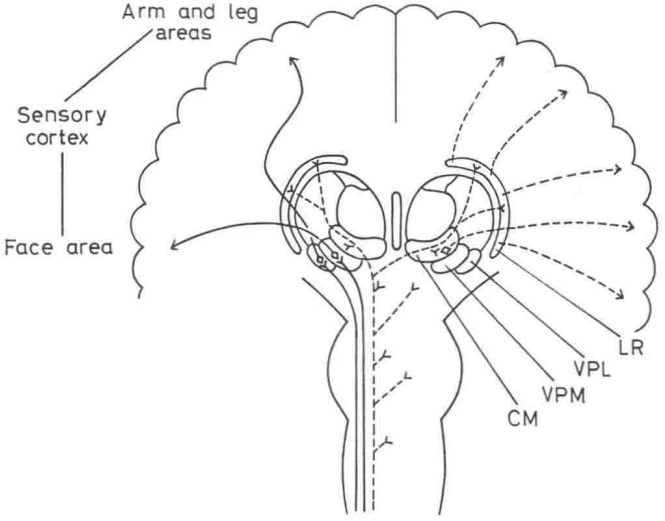

Figure 1.3. Cerebral termination of pain pathways. Specific afferent projections from body and face (spinothalamic and quintothalamic tracts) are indicated as solid lines on the left of the diagram, relaying in nuclei VPL and VPM, and projecting to the post-central sensory cortex. The diffuse spino-reticulo-thalamic pain pathway is displayed as interrupted lines, relaying in the midline thalamic nuclei, centrum medianum (CM) and lateral reticular nucleus (LR), and projecting diffusely to the cerebral cortex (after Bowsher[2], reproduced by courtesy of the editor of 'Brain')

Melzack and Wall[31] proposed a hypothesis concerning the mechanism of pain perception which they called the 'Gate Control Theory'. They suggested that activity in large diameter afferent