THE AUTONOMIC NERVOUS SYSTEM.

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PART I.

PHYSIOLOGY OF THE AUTONOMIC NERVOUS SYSTEM.

INTRODUCTION.

NOMENCLATURE.

Throughout the history of the development of our knowledge of what is now generally known as the autonomic nervous system many terms have been used. In 1732 Winslow (1) first used the term "sympathetic nerves". This was due to the theory that owing to their widespread connections they could affect a large area of the body and that it was through them that the "sympathies" of the body were brought about.

Johnstone (2) (1764) advanced the ganglion theory. This was that in the ganglia, both cerebro-spinal and sympathetic, voluntary movement was changed into involuntary movement. These nerves through which the involuntary movements were carried out were known as the "ganglion nerves".

Even/
Even when it was shown that cerebro-spinal ganglia were afferent nerves the term "ganglion nerves" was still applied to the autonomic nervous system.

BICHAT (3) (1800, 1801) conceiving the life of the organism to be divided into:

(1) an animal life controlled by voluntary nerves and

(2) a vegetative life controlled by what was known then as the sympathetics, renamed these nerves and their ganglia "the vegetative nervous system". This terminology is still current in French literature.

By the middle of the nineteenth century the terminology of Winslow had returned but it included certain unnamed branches of the fifth, seventh, ninth and tenth cranial nerves under the one term sympathetic nervous system.

LANGLEY (4) (1898 - 1903), though not unmindful of its dependence on the rest of the nervous system, was led, by his results, mainly derived by the use of nicotin, to propose a new term the autonomic nervous system. In 1905 he subdivided the autonomic nervous system into:

(1)/
(i) Sympathetic ganglia and nerves (i.e.) the thoraco-lumbar outflow.

(ii) Parasympathetic nerves.
   (a) cranial.
   (b) sacral.

(iii) Myenteric and submucous plexuses of the alimentary tract.

This division of autonomic nervous system into sympathetic and parasympathetic has never been questioned, but to put the plexuses of the alimentary tract into a separate group has been questioned. However as he states in 1921 (5) "The classification is, I think, still advisable, for the central connection of the enteric nerve cells is still uncertain and evidence has been obtained that they have autonomic and reflex functions which other peripheral nerve cells do not possess".

Throughout this paper Langley's classification will be used:

(i.e.) sympathetic refers to the thoraco-lumbar outflow.

(i.e.) parasympathetic either to the cranial or sacral outflow.

while the terms myenteric and submucous will be used to describe the nerve plexuses in the wall of the alimentary canal.

HISTORICAL/
HISTORICAL SURVEY.

(1) ANATOMICAL.

It is to WINSLOW in 1732 that the credit must be given for describing as a separate entity certain visceral nerves which he called the sympathetic nerves. He differentiated these from the cerebro-spinal nerves.

The next advance was in 1884 when DASTRE & MORAT (6) included in the description of the "sympathetic system" certain unnamed branches of the fifth, seventh, ninth and tenth cranial nerves.

Two years previous to this BREMER 1882 (7) described three types of nerve fibres supplying skeletal muscle:

(1) coarse myelinated.
(2) fine myelinated.
(3) unmyelinated.

HUBER & DeWITT considered the latter to be sympathetic in origin and vaso-motor in function.

The work of GASKELL (8) (1886-1889) contributed largely to a better understanding of the nerves in question. He pointed out that only certain/
certain cerebro-spinal nerves had visceral rami, and in addition showed that the efferent fibres in these visceral rami which he designated collectively as the visceral nerves, arise in the central nervous system in homologous columns of cells which are interrupted by the development of the nerves to the limbs. This was the first division of the nerves into a cranial-thoraco-lumbar and a sacral outflow. He also showed that the sympathetic system did not receive fibres from every spinal nerve. Another feature he discussed was the possibility of dilatory fibres to the blood vessels via the somatic nerves.

Finally LANGLEY and his co-workers (1898-1903-1921) by the use of nicotin poisoning added a vast amount of knowledge not only from an anatomical and physiological, but also from a phama- logical view-point.

(II) PHYSIOLOGICAL.

CLAUDE BERNARD (9) and BROWN SÉQUARD working independently showed in 1852 that stimulation of the cervical sympathetic nerve in the rabbit produced vaso-constriction while section of the nerve produced vaso-dilation. In 1871
OWSJANNIKOFF demonstrated by transecting the brain stem at various levels the presence of a vaso-motor centre in the medulla oblongata.

Since Gaskell's suggestion in 1886 much work has been done on the possibility of vaso-dilatory fibres and the bulk of the evidence seems to show that there are fibres present which when suitably stimulated produce vaso-dilation, but whether they are specific vaso-dilation fibres belonging to the parasympathetic system is another matter.

Since BAYLISS & STARLING'S work in 1900 concerning gut movement much controversy has been raised regarding the part played by the frankly sympathetic and parasympathetic nerves and that played by the enteric nervous system. This question will be gone into more fully in a discussion of the role of the autonomic nervous system in relation to the alimentary canal.

(III) EMBRYOLOGICAL.

The autonomic nervous system is related developmentally to the central nervous system. The early workers such as BALFOUR (1877) HIS (1890) MARSHALL (1893) all supported the theory that the cells which make up the primordia of the sympathetic trunks/
trunks and prevertebral plexus are derived exclusively from the spinal ganglia or neural crests. It was not until 1908 that CAJAL expressed the opinion from his findings that cells could be traced passing via the ventral roots from the neural tube to the sympathetic ganglia. The tendency at present is to believe that with regard to the sympathetic nervous system the cells are derived both from the neural crests and neural tube. With regard to the parasympathetic system especially the plexuses related to the vagus the position is not all clear. This conception that the sympathetic trunk is derived from the neural tube is a wide departure from the older teaching but "it is more logical to assume that the sympathetic neurons are derived from the ventral portion of the neural tube which is a source of efferent neurons, than from the spinal ganglia or neural crests which are essentially a source of afferent neurons". (KUNTZ) (18)
CHAPTER I.

ANATOMY.

The autonomic nervous system may be regarded as the division of the nervous system which includes all the neurones lying outside the central nervous system and cerebro-spinal ganglia, except those associated with the special sense organs, and the cells through which these outlying neurones are functionally connected with the central nervous system. Certain centres in the brain stem which are functionally superimposed on the aggregates of neurones in the central nervous system which send their axons out to the outlying neurones, are also regarded as autonomic centres. The outlying neurones are situated in the autonomic ganglia. The connecting neurones lie in the general visceral efferent nuclei in the brain stem and in the cord in the intermedio-lateral columns of the spinal cords. Their axons come into synaptic relation with the cells in the outlying ganglia. Thus we have the division pre-ganglionic and post-ganglionic fibres. The visceral afferent fibres which are closely/
closely related functionally to the visceral efferent fibres are not regarded as part of the autonomic nervous system. These fibres make up part of the posterior nerve root, have their cell bodies situated in the posterior spinal ganglia, send fibres into the spinal cord where they come in direct relationship to the cells of the visceral efferent neurones in the intermediolateral column. There are probably no intercalated neurones.

The autonomic nervous system can be anatomically at least, divided into three parts:-

(1) Sympathetic.

(2) Parasympathetic, which is further subdivided into,
   (a) cranial
   (b) sacral.

(3) Enteric plexuses.

It is impossible in a paper such as this to discuss all aspects of autonomic nervous system, thus I wish to confine myself to a description of the anatomy and physiology, where they are known, of only those portions which have a direct bearing on the six cases illustrating the surgical importance of this system. The sympathetic portion of the autonomic nervous system consists of ganglionic trunks/
Fig. 1. Diagram showing relation between preganglionic and postganglionic fibres. (From Essentials of Physiology, Bainbridge and Manners.)

FIG. 1.
trunks which lie along the ventro-lateral aspects of the vertebral column and extend from the base of the skull to the coccyx. Each trunk is made up of a series of ganglia (vertebral or sympathetic ganglia) connected by longitudinal fibres. They are arranged segmentally except in the cervical region. They are connected with the spinal nerves by the rami communicantes of which there are two types:

(1) white rami.
(2) grey rami.

The white rami are not so extensively distributed as the grey, as they arise from the spinal nerves Thoracic 2nd. (Th. 1) to Lumbar 2nd. (L 3). The white rami consist of the white medullated axons of the neurones in the intermediolateral columns which pass into the sympathetic ganglia. From the sympathetic ganglia grey rami arise which pass to every spinal nerve in the body (FIG. 1). They consist mainly of the fine non-medullated axons of the cells of the vertebral ganglia, but in certain areas there are also fasciculi of white medullated fibres present. These are the pre-ganglionic fibres of the sympathetic ganglia which lie outside the vertebral/
Fig. II. Diagram of spinal segment showing the somatic and visceral nerve tracts.

Fig. 2 (left). The paths of the reflexes: path of the ordinary spinal reflex, path of the sympathetic spinal reflex. (From "The Sympathetic Nervous System in Disease," London: Thomas.)

Fig. 3 (right). Pathways of spinal segments showing the smooth and efferent nerve tracts. (From Physiology, Life and Diseases.)
vertebral chain (i.e.) coeliac, splanchnic etc. In addition the rami communicantes contain sensory nerve fibres from the posterior nerve roots. These fibres pass into the ganglia but make no synaptic relationship with the cells within the ganglia, but pass on directly to the spinal cord.

The somatic spinal reflex consists of three elements:

1. The excitor element, the anterior horn neurone which sends its axon to a muscle
2. The receptor element with its cell in the spinal ganglion and a distal process sending in a peripheral sense organ and a central process ending in relation to the posterior horn.
3. A connector element consisting of an intercalated neurone lying wholly within the spinal cord.

The latter not only connects the efferent and afferent neurones at the same levels, but may pass up or down the cord bringing neurones at different levels into functional relationship.

In the autonomic system reflex the pre-ganglionic fibres play the role of the connector element; the post-ganglionic the excitor element.

Just as the connector elements in the somatic system may ascend or descend in the spinal cord, so may the pre-ganglionic fibres ascend or descend.
FIG. III. The Course of Preganglionic Sympathetic Fibres.
(a) Fibre passing to ganglion at a higher level.
(b) " " " " " same "
(c) " " " " " a lower "
(d) " " " " " a peripheral ganglion.

Fig. IV. A diagrammatic representation of the various ways in which the respective neurones may be arranged. While the preganglionic fiber must obviously be a single unit, the postganglionic neurone may be arranged through the medium of one or more substations. In the case of the involuntary nerve supply to the adrenals there are no postganglionic fibers, as the supply is directly through the preganglionic. (Modified from Physiology, de Sousa.)
descend in the sympathetic trunk. There is not however a definite receptor element in each autonomic nervous system reflex as in the somatic and this is probably the reason why somatic reflexes are localized and accurate, while visceral reflexes, in general, produce more diffuse effects.

THE COURSE OF PRE-GANGLIONIC SYMPATHETIC FIBRES.

The pre-ganglionic fibres in the sympathetic system arise in the intermediolateral column of the spinal cord. They pass to the ganglion corresponding to the segment from which they have arisen, and there they take one of four routes. (FIGS. III & IV)

(1) They may end in relation to the ganglionic cells. (FIG. IIIa)

(2) They may pass through the ganglion giving perhaps a branch off to it and end in a ganglion of a lower segment. (FIG. IIIc).

(3) They pass through the ganglion and end in a ganglion of a higher segment. (FIG. IIIa)

(4) They pass through the ganglion to terminate in one of the peripheral ganglia. (FIG IIIId)

The preganglionic fibres as they pass from the anterior nerve roots to the ganglia are known as the/
the white rami communicantes. Usually it is a distinct nerve bundle from the grey rami, but in many cases the two are intimately mixed.

It is obvious from a casual study of the autonomic system that the post-ganglionic fibres far exceed in number the pre-ganglionic fibres (i.e.) the neurones in the autonomic ganglia are greater than the number of pre-ganglionic fibres. Therefore, one is forced to conclude that pre-ganglionic fibres come into relation with more than one ganglionic cell. Not very much work has been done on the subject, however, but BILLINGSLEY & RANSON (10) (1918) by carefully executed actual counts of the preganglionic fibres in the upper internodal portion of cervical sympathetic nerve, and of the neurones in the superior cervical sympathetic ganglion showed that ratio of pre-ganglionic fibres to ganglionic neurones was 1:32. This cannot be taken as an actual number for all preganglionic fibres, but it gives definite proof that the pre-ganglionic fibre comes into relationship with more than one ganglionic cell. That, it gives off branches to ganglia through which it passes en route, but does not end, has not been definitely settled.

THE/
FIG. V.

Ganglion cell of Lumbar ganglion (Cajal silver nitrate)
THE AUTONOMIC GANGLION CELLS.

The neurones in the autonomic nervous system are, in general, aggregated in ganglia which are enclosed and more or less definitely delimited by a connective tissue capsule. The cell bodies of the neurones in all the larger ganglia are enclosed in delicate cell capsules which are made up of a layer of small endothelial cells and a non-cellular membrane with which the endothelial cells lie in close relationship. (FIG. V) Surrounding the cell capsules and separating them one from another is a varying amount of interstitial connective tissue. In the smaller mammals such as pig, dog, cat and rodents this is small in amount. In man it is almost negligible in the newborn, but increases in amount with age until at the age of forty to fifty and over, each cell is widely separated by a definite pericellular area of connective tissue. Embedded in the connective tissue are the intraganglionic blood and lymph vessels. Slit-like lymph spaces occur in close relationship to the cell capsule and their relationship to the endothelial cells of the cell capsule "suggests that those cells play an important part in the metabolic interchange of food material."
material and degenerative processes involving the ganglionic cell”. KUNTZE (11) (1929). The ganglion cells however of the terminal ganglia (e.g.) in the alimentary wall do not have these capsules but are merely surrounded by connective tissues.

The ganglion cells do not seem to be arranged in any special manner although here and there definite cell columns can be distinguished. This, however, is not common.

Similarly, the bundle of nerve fibres which enter the ganglia may run a more or less definite course, while again they interlace with one another in a most complex fashion. The terminal branches of fibres of extrinsic origin which terminate within a ganglion ramify among the ganglion cells and form an intercellular plexus of fine fibres.

The dendrites are of two types:

(1) long dendrites which penetrate the cell capsule and ramify widely in the interstitial connective tissue.

(2) short dendrites, the majority of which ramify intercellularly.

While an extrinsic fibre may come into functional relationship with more than one ganglion cell, yet it has never been shown definitely that one/
one ganglionic cell comes into relationship with another ganglionic cell (i.e.) the dendrites of the cell are only in relationship to the extrinsic fibres not to any intrinsic ganglionic fibres.

This has an important feature in that it means that the autonomic ganglia are only nerve cell centres, not centres wherein reflexes can occur. If the ganglion is deprived of its connection with the central nervous system it is functionless. This statement is not true for the ganglion cells in the wall of the alimentary canal and it was this and the resulting different physiology of these ganglia which led LANGLLEY to classify them in a different group from the sympathetic or parasympathetic.

In man, the ganglionic cells are multipolar, although bipolar and unipolar have also been described in the ciliary ganglion. In size and form they vary widely; they may be angular and not definitely elongated, again they may be both flattened and elongated. The position of the ganglia seem to determine the shape of the individual cells. According to SPIEGEL & ADOLF (12) (1922) their size varies from 20-65 microns.
THE INTERNAL STRUCTURE.

A short account of the internal structure of the ganglion cells seems to be relevant here, as a knowledge of the normal is essential before the pathological changes can be discussed. Unfortunately the methods for showing up the internal structure of cells are strictly limited and the pathology which has been carried out by research workers so far, appears to have been misdirected, as I can find no reference in the literature to histological studies carried out on ganglia removed from patients suffering from an obvious defect in the autonomic nervous system such as Raynaud's Disease, intermittent claudication etc. All the pathological studies have been on tissue from persons who have died from chronic wasting disease, acute febrile infections and traumatic lesions.

INTERNAL STRUCTURE.

(1) NEUROFIBRILS.

According to CAJAL (13) the neurofibrillar substance in the majority of the autonomic ganglion cells in mammals consist of a perinuclear network which is fairly compact and a peripheral network/
network which is less compact. Occasionally, but not usually, there can be seen interlacing fibres which connect the two. The peripheral network in some cells can be seen extending both into the axons and the dendrites. The arrangement of these networks is very variable as shown by Michaelson (14) who attempted to classify the ganglion cells of mammals by the different configurations of the neurofibrillar substance. He also showed that they are not of homogenous structure, but vary in size, configuration and probably composition. The present state of knowledge prevents any conclusions being drawn from these findings.

CROMIDIAL SUBSTANCE.

Chromidial substance is a common constituent of the autonomic ganglion cell. Like the neurofibrils it varies in amount, size of granules and position. In some cells it is perinuclear, in others peripheral and all stages of gradation between the two are met. It appears about the 7th - 8th month in foetal life; in the new-born it shows all the varieties of the adult cell, while as the cell grows older or degenerates the chromidial substance/
Substance is said to aggregate into larger granules. The changes are more likely due to cell activity than to age as it is believed that there is a close relation between the chromidial substance and the activity of the cells.

**NUCLEUS.**

The nucleus of the autonomic ganglion cell is not distinctive. It is large, oval or rounded in outline, relatively little stainable substance except a nucleolus. It exhibits a reticular structure in some specimens. The usual situation is more or less central, but peripheral nuclei are not uncommon. There is a definite nuclear membrane.

Bi-nucleated cells although common in the sympathetic ganglia of rodents are not common in adult sympathetic ganglia of mammals. According to SPIEGEL & ADOLF (1920) bi-nucleated cells are not uncommon in young children, uncommon in middle age and rare in old age. LAIGNEL - LAVAETISE (1906) regarded those as reserve cells capable of division without further nuclear changes. The occurrence of two cells within the one cellular capsule supports this view.

**AXONS.**/
The axon commonly arises from an implantation cone or axon hillock which is free from chromidial substance. Neurofibrils may be traced from the cell body, through the axon hillock and down the axon for a variable distance. The majority of axons arising from the autonomic ganglion cells are slender unmyelinated fibres though myelinated fibres are not uncommon. The ratio of myelinated to unmyelinated fibres vary in the different vertebrates, and in the different species in the same class. No data is available to indicate either the significance of myelinated fibres nor if they differ functionally from the more common unmyelinated fibres. They are relatively more common, however, in the grey rami passing to peripheral nerves than to the plexuses supplying the viscera.

Since the majority of autonomic ganglion cells are post-ganglionic neurones in visceral efferent chains their axons terminate in relation to the tissue elements innervated by them viz. muscle and gland cells.

The fibres supplying smooth muscle commonly form plexuses around the fasciculi. Fine fibres/
fibres arising from these plexuses pass into the fasiciuli run parallel to the muscle fibres, in relation to which they end by means of delicate terminal nodules.

The autonomic fibres supplying cardiac muscle also form plexuses around the fasiciuli and end in a similar manner to those in smooth muscle.

The node of termination of the fibres in skeletal muscle will be described under the innervation of skeletal muscle.

DENDRITES.

The autonomic ganglion cells vary widely with regard to the distribution and morphological characters of the dendrites. The dendrites represent extensions of the cell body. They are usually broad at the base and taper distally, branch frequently, are tortuous in their course, and exhibit varicosities throughout their length. Neurofibrils may be traced from the cells extending through the dendrites to their terminations. The character and distribution of the dendrites were used as a basis for classification of the autonomic neurones by DOGIEL in 1896. Although his conclusions are no longer upheld, his work is of interest historically as/
as it was the first attempt on a morphological basis to distinguish the cells physiologically. His first type included neurones with numerous small branching dendrites. Those he regarded as efferent in function. His second type included neurones with relatively few but long slender dendrites which branched sparingly and passed out of the boundaries of their respective ganglia and which he thought were sensory. Numerous other workers have attempted to classify the neurones with regard to their dendrites, (CAJAL, 1905; MICHAILON 1911; MULLER, 1924; PINES, 1927) but the results of all these attempts only emphasize the variability and add little to the knowledge of functional relationship of the cells.

As previously stated, although CAJAL, (1905) among others, states that they have found dendrites of one autonomic ganglion cell coming into relationship with another ganglion cell, the bulk of histological evidence shows that there is no relationship between the cells of the ganglion.
CHAPTER II.

GENERAL PHYSIOLOGY OF THE AUTONOMIC NERVOUS SYSTEM.

A. FUNCTIONAL CONNECTIONS of the AUTONOMIC NERVOUS SYSTEM with the CENTRAL NERVOUS SYSTEM.

Although the nervous control and regulation of the vital functions of the body are carried out through the autonomic nervous system, this system is in no way functionally independent of the central nervous system. The preganglionic fibres have been shown to be analogous to the intercalated neurones in the spinal cord, and without the presence of the ganglion neurones cannot function. LAGENDORFF (16) (1901) and LANBY & ANDERSON (17) (1904) demonstrated this when they excised the superior cervical sympathetic ganglion and anastomosed the preganglionic and post-ganglionic fibres at operation, but no functional regeneration occurred.
The autonomic ganglion cells are analogous to the anterior horn cells and just as these cannot function without the intercalated neurones so the ganglionic cells cannot function if the preganglionic fibres are divided. The exception to this is the independent action of the myenteric plexuses of the alimentary canal.

PHYSIOLOGICAL SIGNIFICANCE OF GANGLIONIC NEURONES.

The first fact to be considered in this respect is that a preganglionic fibre comes into functional relationship with more than one neurone. The exact number varies probably with each fibre, but that they are numerous was shown by BILLINGSBY & RANSON (10) who found the ratio of preganglionic and post-ganglionic fibres in the superior cervical sympathetic to be 1:32. This widespread synaptic relationship may be regarded as an adaptation to bring about a relatively diffuse effect to a single visceral efferent impulse and also to correlate the functions of the areas supplied by different fibres of the autonomic nervous system.

The autonomic ganglia are essentially
and only relay stations in the visceral efferent pathways for although SCHULTZ (1900) observed that effective stimulation of post-ganglionic fibres requires a stimulus of greater intensity than pre-ganglionic fibres and VEACH (1926) showed that post-ganglionic and preganglionic required different strengths of FARRADIC current to produce stimulation, no evidence can be obtained which seems to indicate that impulses are modified quantitatively by passing through a ganglion.

Impulses cannot arise in the ganglion itself for no afferent neurones make synapses there. Indeed there are no afferent neurones belonging to the autonomic nervous system. The afferent part of the autonomic reflex consists of both visceral and somatic afferent components of the cerebrospinal nerves.

Again the myenteric plexuses of the alimentary canal offer an exception to this general statement.

B. THE/
B. THE ANTAGONISTIC ACTION OF SYMPATHETIC AND PARASYMPATHETIC NERVES.

The antagonistic action of the sympathetic and parasympathetic fibres has been long known. It was on this more than on the different anatomical distribution that led LANCASTER to classify the autonomic nervous system into sympathetic and parasympathetic. The distribution of the sympathetic fibres throughout the body is fairly well established, but that cannot be said for the parasympathetic.

The action of the sympathetic nerves throughout the body are not the same. For while stimulation of them causes vaso-constriction it also causes inhibition of gut movement. On the other hand, stimulation of the parasympathetic causes vasodilation and increased peristalsis. The dual innervation of internal organs such as the heart, lungs and viscera lead to the hypothesis that every structure in the body which received sympathetic nerves also received parasympathetic. This almost seems essential to explain certain physiological phenomena, but no anatomical evidence has come forward to support it. Thus there is at present no known pathways whereby/
whereby all the blood vessels in the body receive parasympathetic fibres, and the sweat glands which receive a profuse supply of sympathetic fibres have never been shown to have a parasympathetic supply. Therefore it cannot be accepted as yet that every structure in the body receives both parasympathetic and sympathetic nerves.

In the alimentary canal the sympathetic and parasympathetic nerves contain both types of fibres, for stimulation of the sympathetic causes not only relaxation of the gut (inhibition), but also closure of the sphincters (excitation) while stimulation of the parasympathetic causes increased peristalsis (excitation) and relaxation of the sphincters (inhibition). This is probably the best example of the antagonistic action of the parasympathetic and sympathetic and the necessity of the maintenance of a perfect balance between the two sets of fibres.

The close analogy between this and the crossed innervation of somatic muscles is very striking. In the somatic muscles, for movements to be carried out perfectly not only have the actual muscles used in the movement to be excited but their antagonists/
antagonists have to be inhibited. So it is with the structures supplied by the autonomic nervous system. Increased tone in the sympathetic means a decreased tone in the parasympathetics and vice versa.

C. REGULATION OF AUTONOMIC FUNCTION THROUGH HIGHER CENTRES.

Although the nervous reactions mediated through the autonomic nervous system is essentially reflex, yet it is well known that there are higher centres mainly situated in the hypothalamus and wall of the 4th. ventricle.

It would appear that these centres are superimposed on the lower autonomic mechanisms over which they exercise a regulatory influence and thus play an important role in the general functioning of the visceral organs. As would be expected this control seems to be greater in the mammals and birds than in the lower vertebrates.

It does not seem relevant to discuss this aspect and I only intend to give a list of the functions which have been proved by experimental evidence to/
to be controlled by centres in the diencephalon.

(a) Control of the smooth musculature of the eye.
(b) Temperature regulation.
(c) Vasomotility.
(d) Secretory activity of the salivary, lacrimal, sweat, sebaceous and other glands.
(e) Water elimination.
(f) Carbohydrate and protein metabolism.
(g) Trophic regulation of the skin and subcutaneous fatty tissue.
CHAPTER III.

INNERVATION OF BLOOD VESSELS.

The nerve supply to the blood vessels contain both afferent and efferent fibres. The afferent fibres distributed to the blood vessels are components of the sensory cerebrospinal nerve roots. The efferent are mainly sympathetic with possibly parasympathetic fibres, the former being vaso-constrictors, the latter vaso-dilators. The large vessels of the trunk, (i.e.) the aorta and inferior vena cava are supplied directly by the autonomic fibres nearest them, in the thorax from the sympathetic ganglia and cardiac plexus, in the abdomen by rami from the plexuses along the aorta. The vessels in the head and neck are supplied mainly from the cervical sympathetic ganglion. The vertebral artery is supplied however, from the inferior cervical ganglion and rami from the 2nd thoracic ganglion.

It is with the supply to the peripheral vessels that we are most interested. The older anatomists/
anatomists were conversant with the fact that the peripheral arteries are joined by nerves along their route. GOERING in 1836 described the supply as vascular rami which arise from somatic nerve trunks at an acute angle, join the blood vessels, especially at points where the latter divide, and spread out in the superficial layers of the vessel walls. FREY (1874-1876) stated definitely that the blood vessels are supplied by the nerves nearest them. KRAMER & TODD (1914) corroborated these results and gave a very detailed account of the nerve supply to the upper extremity. Notwithstanding this evidence and arising from results obtained at operations especially by LERICHE and his co-workers it was maintained that the sympathetic nerve supply to the vessels passed by means of long fibres running the entire length of the vessel; (i.e.) fibres to the lower limb arose from the lumbar ganglia became included in the plexus around the common and external iliac arteries and passed via the femoral artery to a more peripheral distribution. HIRSCH (20) (1925) with careful dissection under moderate magnification of silver impregnated arteries showed that this assumption was entirely unwarranted, for not only were there no/
FIG. VI.
no long fibres, but even a plexus derived from the aorta running for any length along the common iliac artery could not be demonstrated. The external iliac is supplied by branches from the genito-femoral, the femoral by branches from the femoral, and saphenous nerves and the other arteries by their accompanying nerves. (FIG.VI) HIRSCH rightly maintains that, if there were any long fibres of any number, they would have been demonstrable by the technique he used. The findings of HIRSCH not only shows that the peripheral arteries are supplied by the nerves nearest them, but also that the supply is far greater than was thought and that this supply is maximal to the smaller unnamed arteries and arterioles. The branches of the nerves contain both myelinated and unmyelinated fibres and it is legitimate to suppose that they are sympathetic and sensory cerebro-spinal in origin.
DISTRIBUTION of NERVE FIBRES in the VESSEL WALLS.

The nerves of the arteries and veins are arranged in a more or less definite manner in the vessel wall. MICHAILOW (21) (1908) described three plexuses:

(i) "Adventitial" plexus situated in the adventitial coat.

(ii) "Border" plexus situated between the adventitia and the media.

(iii) "Muscular" plexus situated in the media.

Certain other investigators have not recognised a border plexus, nor do they think it correct to consider the nerve fibres in the media as forming a plexus. However, they all agree that both the adventitia and the media contain nerve fibres. No nerve supply to the intima has been described.

ADVENTITIA.

According to HIRST (22) (1926) slender rami arising from the somatic nerves pass towards the vessel. Having reached the surface of the vessel wall they run but for a short distance, if at all, along it before entering the adventitia. They are usually in close relationship to the vasa vasorum.
FIG. VII.  (By courtesy of Prof. Fraser)

The distribution of nerve fibres in the adventitial coat.
vasorum, but this is probably rather a convenient pathway of entrance than a functional relationship. Having penetrated the adventitia the rami break up into larger or smaller bundles which run longitudinally in the outer coat, the majority of fibres running distally and the others proximally. (FIG. VII)

The fibres are partly myelinated and partly unmyelinated. These fibres form a plexus in which the fibres are more profuse in the peripheral portion than towards the media. This increase is due to the larger myelinated fibres which are in greater abundance in the outer layer of the adventitia than in any other part of the vessel wall. Fibres arising from the plexus pass into the media.

MEDIA.

The fibres in the media are described as forming an encircling plexus around the vessel. They are derived from two sources:

1. Fibres from the plexus in the adventitia.
2. Extrinsic fibres which pass through the adventitia, without coming into relationship with the plexus there.

The fibres in the media are less numerous than in the adventitia, but there is a relatively larger proportion/
Flu. 311. - Drawing from a longitudinal section of the radial artery of a dog after degeneration of the spinal-nerve fibers following section of the dorsal and ventral nerve roots distal to the spinal ganglia, showing the distribution of sympathetic fibers in the adventitia and media. Nerve fibers indicated by black lines. (Kerner.)

FIG. VIIIa.

Flu. 311. - Drawing from a longitudinal section of the dorsal pedia artery of a dog after degeneration of the sympathetic fibers, showing the presence of dorsal-root fibers in the adventitia. Nerve fibers indicated by black lines. (Kerner.)

FIG. VIIIb.
proportion of fine unmyelinated fibres.

The differentiation of these fibres into sensory cerebro-spinal and sympathetic was carried out by KERPER in 1927. By cutting the dorsal nerve roots of the nerves supplying the limb and examining the arteries after an interval of 5 weeks or longer when degeneration of the peripheral cerebro-spinal afferent fibres would be complete he found that the number of fibres in the adventitia were reduced, but that the nerve supply to the media was approximately unchanged. (FIG. VIIla) The fibres which had disappeared from the adventitia were the larger myelinated fibres. On another set of animals he extirpated the sympathetic ganglia which supplied the hind limb. Examination of the arteries (pyridin silver impregnation method was used) after the appropriate interval showed that there were practically no nerve fibres in the media while the majority of unmyelinated fibres in the adventitia had disappeared. Furthermore the myelinated fibres were mainly found in the superficial layers of the adventitia, the unmyelinated in the deeper portions. (FIG. VIIIb).

From KERPER'S work it would appear that the blood vessels receive two sets of fibres myelinated/
myelinated and unmyelinated. The myelinated are mainly concerned with the innervation of the superficial layers of the adventitia and are components of the different sensory cerebro-spinal nerves. The unmyelinated innervate the deeper layers of the adventitia and the media and are derived from the sympathetic ganglia.

KERPER also records another extremely important observation in the same paper. In a third set of experiments he:

(1) ligated the femoral and brachial arteries,

(2) removed both the sympathetic ganglia and the appropriate nerve roots supplying the hind leg in animals.

Where he had ligated, the vessels were only devoid of nerve fibres for a very short distance below the ligature, but where he had removed both afferent cerebro-spinal nerves and sympathetic nerves no nerve fibres could be demonstrated at all. This work only needs to be corroborated to explode once and for all the theory of long efferent fibres arising from the paravertebral plexus as a means of supply of sympathetic fibres to the peripheral blood vessels.

With regard to the presence or not of ganglionic/
ganglionic cells within the vessel wall this question can be definitely answered. In arteries, other than the aorta and internal carotid, no ganglion cells exist either superficial to or embedded in the adventitia. None, of course, occur in the media.

Ganglionic cells have been described in the superficial layers of the adventitia of the aorta, but, if the aortic plexus ganglion cells are normal constituents and the cells which have been described as lying in the adventitia are probably cells which are related to the plexus which lies just superficial to it rather than to the nerve fibres supplying the actual vessel wall.

DISTRIBUTION OF NERVE FIBRES TO CAPILLARIES.

Capillary blood vessels are quite generally accompanied by unmyelinated nerve fibres which either run singly or in small bundles. These fibres run in close proximity to the vessels, but actual points of contact have been described by relatively few investigators. A functional innervation of capillaries has, in recent years been generally conceded, partly by reason of observed anatomical relationship of nerve fibres and capillaries, but more especially/
especially by reason of the normal physiological behaviour of capillaries and their responses to sympathetic stimulation.

STOHR Jr. (24) (1926) investigated anew the nerve supply to capillaries and he believes capillaries receive a supply of fine unmyelinated nerve fibres. These fibres run in fairly close relationship to the vessel though not in actual contact with it for any considerably distance. Here and there the fibres seem to come in direct contact and where that occurs they become more spread out and less closely aggregated forming a flattened area. In addition, nerve fibres can be demonstrated terminating in contact with the capillary endothelium. He still maintains however that the capillaries of the central nervous system have no nerve supply. The nerve fibres accompanying the capillaries are derived in part from the nerve plexus associated with the arterial branches from which the capillaries arise and in part from nerves which ramify in the adjacent tissue.

What are the functions of such fibres? The capillary wall contains no contractile tissue similar to arteries and veins. KROGH (25)(1922) showed/
showed that in amphibia the Rouget cells which were constant constituents of the capillary vessel wall could cause diminution in the lumen by their contractile power and stated that these cells were under the influence of vaso-constrictor substances such as adrenaline and also receive a sympathetic nerve supply. Several other later workers, however, have shown that the Rouget cells are not necessarily essential constituents of the capillaries in mammals and KROGH'S merely assumed that the fibres in relation to the capillaries were sympathetic without any anatomical proofs. That they are sympathetic is suggested by the fact that they are unmyelinated and are finer in calibre than the fibres considered afferent in the arteries in vein. Furthermore KUNTZ (1927) found that they were still present following resection of the ventral and dorsal nerve roots.
CHAPTER IV.

PHYSIOLOGY of the NERVES to the BLOOD VESSELS.

The functional control of blood vessels depends in part on nervous influences, and in part on the effects of hormones and other substances carried in the blood. The calibre of the blood vessel plays an important role in the functional state of the tissue or organ by reason of its effect on the rate of interchange of substances between the blood and tissue elements. When the activity of an organ is increased, vaso-dilation of the vessels occurs, when resting, the calibre of the vessels decreases. To what extent these changes depend on nervous influences and to what extent they "represent the direct effect on the blood vessels of products of metabolism arising by reason of the activity of the organ" is not known. The vascular dilatation effects the capillaries more than the arterioles in this "activity dilatation", and since the capillaries are less affected by nervous influences/
influences than the arterioles, the changes in calibre which they undergo under normal physiological conditions are probably quite independent of nervous origin.

This dilatation on the part of the blood vessels in an area of activity calls for a redistribution of blood throughout the body, should the active area be of any considerable size such as the limbs in movement or the splanchnic area during digestion. The redistribution is brought about by the constriction of vessels in the parts of the body at rest. The sympathetic system is the means whereby this constriction is brought about. It may be said that the nervous influence, on the blood vessels, of the autonomic nervous system is:-

i. Vaso-constriction via the sympathetics.

ii. Possible vaso-dilation in some areas by parasympathetics.

The chemical influence is:-

(1). Vaso-dilation by metabolites.

(2). Vaso-constriction by internal secretions.

The distribution of the blood in the body according to its needs is carried out by vaso-dilation by the metabolites & by vaso-constriction by the sympathetics/
sympathetics nervous system. The vaso-constrictor action of the sympathetic nervous system is potentiated by the presence of the vaso-constrictor hormonic substances, especially adrenaline, in the blood.

Another phenomenon which is directly traceable to the activity of the vaso-constrictor nerves is the reaction to the external environment with regard to the loss. If the body is placed in a temperature of 70°F there is a fall in skin temperature. The skin over the abdomen falls 2 - 4°F while that over the sole of the foot 9-10°F. This fall in temperature is due to a reflex constriction of the blood vessels to prevent loss of heat from the surface of the body. When the temperature of the external environment is raised to almost body heat, the temperature of the skin throughout the body rises similarly. If we discount for the present the possibility of vaso-dilator fibres, we may say the external cold produces an increased tonus of the sympathetic nervous system, heat a decreased tonus.

It is interesting to note the increased reaction in the skin of the limbs as compared with that/
that over the abdomen. The explanation of this is
that (1) The heat produced by the viscera in the
abdomen maintains the abdominal skin temperature at
a higher level. (2) There is a greater supply of
vaso-constrictor nerves to the vessels of the extre-
mities.

Whatever the explanation may be, these
facts show that the skin of the limbs play a much
more important part in regulating heat loss than
was previously supposed.

The sympathetic nervous system has always
a certain tonus and this is well illustrated in
relation to the blood vessels. If the appropriate
ganglia are removed (e.g. Lumbar 2nd. - 4th. for
the lower extremity) a vaso-dilation in the peri-
pheral blood vessels occurs. This control can be
affected, as has been shown, by intrinsic reflexes
e.g. activity in certain organs,extrinsic reflexes
in its reaction to heat loss, etc., but it can also
be affected by the emotions. Shame produces a
vaso-dilation which is local i.e. blushing, worry
produces a general peripheral vaso-constriction.

The vaso-constrictor fibres which arise from/
from the 2nd. Thoracic (1st. Thoracic) to the 2nd. Lumbar (3rd. Lumbar) are controlled by a vaso-motor centre situated in the medulla, and it is by means of this centre that the distribution of blood and the nervous regulation of the heart is controlled and co-ordinated with the other functions of the body.

As has been previously stated, resection of the sympathetic nerves leads to a vaso-dilatation of the peripheral blood vessels. After an interval which varies in different animals, these vessels regain a certain amount of tonus and diminish in calibre. The time interval is too short for this to be explained on regeneration of the cut nerves. Since there are no ganglion cells along the walls of peripheral arteries, it must be assumed that the musculature of the vessels develop a certain degree of tonus in the absence of nervous influence. This probably involves a reaction of the arterial musculature to vaso-constrictor substances in the blood. BOSSAMER (26) (1925) showed that if only the pre-ganglionic fibres are cut, leaving the ganglia and the afferent neurones intact, this tonus was more promptly/
promptly regained. This led Schiff (1926) to postulate a ganglionic influence in the absence of preganglionic fibres, but it must be remembered that adrenalin acts on the neuro-muscular junction of the sympathetics, and is therefore more likely to be effective in the case where the preganglionic fibres are cut, for then post-ganglionic fibres do not degenerate, than in the case where the post-ganglionic fibres and their terminations in the muscles have degenerated following removal of the ganglia.

The tonus regained after removing the sympathetic nerve supply is never so great as is present in the normal vessels.

Apart from the reversed action of the sympathetic nerves in the presence of certain dilutions of adrenalin and in excess of calcium, there are two exceptions to the "rule" that sympathetic nerves are vaso-constrictors. These are the coronary and pulmonary vessels. The old teaching regarding the nerve supply to the coronary vessels was that the amount of blood circulating through them was controlled by the pressure in the ascending aorta. Therefore, when the pressure was low and the activity of the heart was diminished a reduced amount of/
of blood flowed through the coronary arteries. The coronary flow was in direct proportion to the blood pressure in the aorta. From a physiological standpoint it was impossible for the increased sympathetic tonus that caused an increase in the cardiac activity to cause at the same time a constriction of the coronary vessels. For that would mean a diminution in blood supply as the activity of the organ increased. However, it was shown histologically that the coronary vessels obtained a very rich supply of sympathetic fibres from the cardiac plexus in addition to parasympathetic fibres from the vagus.

The functions of these nerves were unknown until ANREP in 1924, working with the 'heart-lung' preparation in dogs, showed that stimulation of the sympathetics caused an increased coronary flow which was independent of the aortic blood pressure, while vagal stimulation produced a diminution in the coronary flow. That is, the sympathetic nerves to the coronary vessels are vaso-dilators in function, while those of parasympathetic origin are vaso-constrictors. A similar result can be shown for the pulmonary vessels.

Taking/
Taking the organism as a whole, these results are what one would expect, for increased sympathetic tonus usually means increased activity on the part of the cardiac and respiratory systems, while decreased vagal tonus means a decrease in their activities. In addition, it adds interesting light to the theory promulgated by Gaskell in 1896, who stated that the autonomic nervous system really consisted of one part, and that it was the development of the nerves to the limbs' buds which divides it up into three anatomical entities, cranial, thoraco-lumbar, and sacral.

**VASO-DILATOR FIBRES.**

That vaso-dilator fibres are present both in the cranial and sacral parts of the autonomic nervous system has been definitely proved, but evidence that every vessel receives vaso-dilator fibres has not been forthcoming. That some vessels, apart from those supplied by the parasympathetic system have vaso-dilator fibres has been shown. If the sciatic nerve is cut and sufficient time given for the sympathetic fibres in it to degenerate, stimulation of the peripheral end produces vaso-dilation. This/
This has not been universally accepted as proof that there are specific vaso-dilator fibres. BAYLISS and STARLING among others, consider it to be more of an antidromic reflex coincident with the peripheral sensory distribution.

The only anatomical evidence lies in the work of KURE et al (27) (1928), who found that if the dorsal nerve roots of the 6th. and 7th. lumbar nerves in a dog were divided between the spinal ganglia and the spinal cord, certain fine myelinated fibres did not degenerate. These fibres seemed to have their origin in the intermediate cell tract of the spinal cord.

Our knowledge concerning the vaso-dilator nerve fibres is too scanty at the present for any definite statement to be made with regard to their physiological significance. That they have any pathological importance is extremely doubtful.
EXTRINSIC NERVES.

OESOPHAGUS.

The oesophagus receives a profuse parasympathetic supply, from the vagus via the recurrent laryngeal nerve to the cervical portion, and directly from the vagi to the thoracic portion, where the nerves come in close relationship to the oesophagus. In the lower portion, branches from the two vagi overlap.

That the oesophagus receives a sympathetic supply is more doubtful. POTTINGER (28) states that the oesophagus receives only vagal fibres, while KUNTZ (1929) states that it receives, in addition, sympathetic fibres, mainly from the inferior cervical ganglia, but also from the superior cervical and thoracic rami.
CARDIAC SPHINCTER.

The Cardiac Sphincter receives both vagal and sympathetic fibres.

STOMACH.

The stomach is also supplied by both the vagus and sympathetic nerves. The vagal supply is distributed generally over both surfaces, the left vagus supplying the anterior surface, the right mainly the posterior. In the pre-pyloric portion a very free anastomosis takes place between the two nerves.

The sympathetic distribution is more marked in the lower portion of the stomach than in the upper, the fibres being derived from the coeliac plexus.

THE SMALL INTESTINE.

The small intestine receives both vagal and sympathetic fibres.

The vagus fibres are mainly derived from the right vagus through the division of that nerve, which joins the coeliac plexus. The sympathetic fibres
fibres are derived from the coeliac and superior mesenteric plexuses. Both fibres enter the small intestine through the mesenteric nerves which, in general, accompany the mesenteric arteries. The vagus and sympathetic fibres can be distinguished by their calibre and by their distribution in the intestinal wall. The vagal fibres, after leaving the coeliac plexus, form branches, run either free in the mesentery or with the larger blood vessels, but have no essential connection with them, penetrate the subserosa and longitudinal muscle layer, and enter the myenteric plexus. The sympathetics are also in relationship to the vessels, but some of their fibres anastomose in the adventitial coat of the arteries, the others passing into the intestine. The distribution in the intestine is twofold. Firstly, in the subserous coat; these are probably visceral afferent fibres. Secondly, in the longitudinal and circular coats.
LARGE INTESTINE.

According to POTTINGER the caecum, ascending colon, transverse colon, descending colon and pelvic colon, receive only a sympathetic nerve supply, derived from the inferior mesenteric plexus. The rectum and anal canal receive both a parasympathetic and sympathetic; the sympathetic from the hylo gastric plexus, the parasympathetic from the nervi erigentes.

KUNTZ, however, states that the sympathetic nerve supply to the large intestine is by the superior and inferior mesenteric plexuses, the superior innervating as far as the transverse colon the inferior mesenteric in conjunction with the pre-sacral nerve the remainder.

The vagus innervates the large intestine as far as the descending colon, via fibres which pass in the superior mesenteric, and from fibres of the coeliac plexus via the inferior mesenteric.

The remaining portion of the large intestine receives parasympathetic fibres from the nervi erigentes.

INTRINSIC/
INTRINSIC NERVES.

The third division of the autonomic nervous system consists of the intrinsic nerves of the alimentary canal. It consists of two plexuses,

(1) the myenteric plexus, situated between the longitudinal and circular muscular layers, and,

(2) the submucous plexus, situated in the submucosa.

Both the myenteric and the submucous plexuses contain numerous ganglion cells which are intimately connected with each other by nerve fibres. These nerve fibres are mainly made up of fibres arising from the cells in the ganglia, but also contain extrinsic fibres. Vagus fibres (pre-ganglionic) terminate in relationship to the ganglion cells which are really the post-ganglionic neurones of the parasympathetic nerves. The sympathetic fibres on the other hand are post-ganglionic fibres. They make no synaptic connection with enteric nervous system, but terminate directly in relation to the tissue which they innervate.

The two plexuses are made up largely of unmyelinated fibres which vary in size. Anastomosing fibres pass freely between the two plexuses.
FIG. IX.

Fig. IX. - Intercellular junction and intercellular connexions between the epithelial cells of the intestinal wall of a rabbit (H. J.). Upper and lower limits of a narrow band of connective tissue of the submucous coat of the intestine. Between epithelial cells: 1. Intercellular cohesion. 2. Intercellular connexions.
The ganglia are located at nodal points in the meshwork of fibre bundles. They vary both in size and in the number of their constituent neurones, conforming, in general, to the intermuscular spaces which they occupy.

This enteric nervous system stretches from the oesophagus to the anal canal, and, while conforming generally to the above description, vary somewhat in their morphological features in the different situations.

Perhaps the most important difference lies in the oesophagus. Here the entire nervous system is not so well developed as elsewhere, consisting entirely of branching interlacing fibres. There are no ganglionic cells.

There is an ever-increasing volume of physiological data, the interpretation of which seems to require the existence of local reflex mechanisms, but anatomical studies have failed to produce any positive evidence for the presence of afferent enteric neurones.

Many workers, among whom are DOGIEL, (1896), MULLER, (1904) KUNTZ, (1922) and HILL, (1926) have described fine nerve (FIG. IX.) fibres terminating between the cells of the intestinal epithelium.
Many workers have claimed to have traced connections between these and the enteric plexuses, but on this point there has never been any definite evidence. There are three possible origins of these fibres:

(1) afferent fibres of extrinsic nerves, probably vagus.

(2) dendrites of the ganglion cells of the submucosa plexus.

(3) axons of afferent neurones which come into synaptic relation with the submucous and myenteric plexuses.

Which of the three, or combination of the three, is the true interpretation cannot be decided, and so the anatomical proof of a local enteric reflex arc must be left undecided.

A casual study of these plexuses gives a picture which is very similar to the nerve net which is present in the lower animals, and this, in part, lead to the nerve net theory. This was first described by BETHE in 1903 and supported by R. MULLER in 1908. C. MULLER in 1921, however, stated that in mammals the enteric nervous system was made up in part of neurones and in part of nerve nets. Further work, however, failed to confirm this, and the view generally held now is that in mammals, at least, the enteric nervous system consists entirely of neurones which come into synaptic relationship with each other, and that there is no evidence to show that there are any synctial nerve nets.
CHAPTER VI.

PHYSIOLOGY OF THE NERVES OF ALIMENTARY CANAL.

OESOPHAGUS.

The oesophagus is different from the remainder of the digestive tube for it consists of both voluntary and involuntary muscle. The act of swallowing and of passing the bolus of food to the stomach is first a voluntary and then an involuntary movement. After passing the posterior fauces the act becomes involuntary and the reflex concerned is carried out entirely by the vagus nerve. The afferent chain varies in different animals, but usually as in man it is the superior laryngeal. The efferent chain is the vagus. The enteric nervous system plays no part in this as was shown as far back as 1876 by MOSSO. He transected the oesophagus at various levels thus throwing out of action the intrinsic but retaining the extrinsic nerves. Stimulation of the central end of one vagus produced a reflex contraction of all the segments of the oesophagus, the impulse travelling by the intact vagus nerve/
nerve.

No result has ever been obtained by stimulat-
ing the extrinsic sympathetic nerves to the oeso-
phagus and functionally speaking one may say that
the oesophagus has only one nerve supply and that is
parasympathetic via the vagus.

CARDIAC SPHINCTER.

The cardiac sphincter has both a sympathe-
tic and a para-sympathetic nerve supply, but the ex-
perimental evidence as to their functions is not in
full accord. The first difficulty is that in dif-
ferent animals the relative amount of the two sets
of fibres varies and secondly the results of stimu-
lation vary according to the tonus of the nervous
system. The true physiological response would ap-
pear to be that sympathetic stimulation causes spasm
of the sphincter while vagal stimulation causes inhi-
bition. The presence of a bolus of food in the
oesophagus stimulates the vagus; this causes a wave
of peristalsis to pass down the oesophagus starting
above the bolus of food while the segment below it
is inhibited. When the bolus reaches the cardiac
sphincter the sphincter relaxes and the food passes
down/
down to the stomach. The sphincter closes again until the next peristaltic wave is set up in the oesophagus. The vagus, however, contains both motor and inhibitory fibres to the vagus as BARTSON (1922) showed. In high vagal or low sympathetic tone (i.e.,) when the cardiac sphincter is open, stimulation of the vagus causes contraction, in low vagal or high sympathetic tone, the cardiac sphincter is closed, vagal stimulation causes inhibition.

During the period when digestion is in progress in the stomach the cardiac sphincter is in high sympathetic tonus. The mechanism whereby this is maintained is unknown.

STOMACH.

The study of intestinal movement is beset by many difficulties for there are no less than four factors to be considered. These are:-

(1) the extrinsic nerves - parasympathetic and sympathetic,
(2) the intrinsic nerves,
(3) the different types of gut movement,
   (a) the segmentation movement,
   (b) true peristalsis (diastalsis),
   (c) the peristaltic wave,
(4) the depth of anaesthesia.

The/
The differentiation of just how much one factor influences another cannot be said. Each species of animal varies in its response to experiments and this further adds to the difficulty.

With regard to the stomach, stimulation of the vagal fibres usually results in peristaltic movement with inhibition of tone of the pyloric sphincter, while sympathetic stimulation produces inhibition of the gastric musculature and closure of the pyloric sphincter. Thus both the vagus and sympathetic nerves contain excitatory and inhibitory fibres. Paradoxical results have been obtained where vagal stimulation produces inhibition and sympathetic excitation. Furthermore, if all the extrinsic nerves to the stomach be excised the stomach will still continue to contract and relax with a co-ordinated opening and closing of the pyloric sphincter. Thus the stomach as regards its motor activity is an automatic organ; its automatic activity being carried out by reflexes arising within its own walls and depending upon the intrinsic nerves. These activities however, are normally regulated and controlled through the vagi and sympathetic nerves.

INTESTINE/
INTESTINE.

In general, vagus stimulation results in contraction of the intestinal musculature as far as the distribution of vagal fibres extends i.e. from the pyloric sphincter to the ileocaecal sphincter according to POTTINGER, but throughout the whole intestine, above the pelvic colon, according to KUNTZ. Stimulation of the nervi erigentes produces peristalsis in the rectum and anal canal. This contraction as was shown by BAYLISS & STARLING in 1913 is preceded by a wave of inhibition. On stimulation of the vagus the wave of inhibition followed by contracture passed down as far as the ileocaecal junction and then ceases.

Sympathetic stimulation causes relaxation of the intestinal musculature and closure of the sphincters.

On results following stimulation of and removal of extrinsic nerves it would seem that removal of extrinsic nerves upsets for a time being, the tonicity and movements of the intestine, but recovery to the normal condition sooner or later could be expected, therefore, as in the stomach we may/
may say that the intestine is an automatic organ depending upon its enteric nervous system for its co-ordinated movements, but that normally to obtain a proper functional co-ordination between the different parts the extrinsic nerves are necessary.
CHAPTER VII.

AUTONOMIC INNERVATION OF SKELETAL MUSCLE.

Perhaps of all the branches of the autonomic nervous system the innervation of skeletal muscle by autonomic fibres is the most difficult to assess, for throughout the literature there are two widely divergent schools of thought. There is the school which states that the fibres of skeletal muscle receive in addition to the motor fibre from somatic nerves an additional fibre from the sympathetic nervous system, while on the other hand, there is the school which maintains that the muscle fibres receive only a somatic nerve supply.

Before going on to discuss this question in greater detail let us dismiss the question of parasympathetic supply to muscle. For the present although one or two workers have reported the possibility of parasympathetic fibres in muscle there is only one paper of any significance and it is that of KURE et al. (27) (1928) referred to previously. Those workers found that on dividing the dorsal nerve roots central to the ganglia there remained fine myelinated/
myelinated fibres which did not degenerate. They considered these to be parasympathetic origin, but whether they are to be regarded as vasodilators or as a parasympathetic supply to the muscle fibres cannot be decided from their experiments. Indeed their work will have to be corroborated before the existence of these fibres have been proved.

In 1879 TSCHIRNEW (29) described the presence of fine unmyelinated nerve fibres which terminated in grape-like structures ("Terminaisons en grappe") in relation to the muscle fibres. HUBER & de WITT described the same, but decided they were of sympathetic origin and vasomotor in function. Further workers elaborated the study of these fibres without very much advance until BOEKE (30) (1909) recognised in skeletal muscle the existence of a system of fine unmyelinated fibres which he considered to be unrelated to myelinated fibres. He considered that each and every muscle fibre received an unmyelinated nerve fibre which terminated either embedded in the granular sole-plate of the ordinary motor nerve ending or occurred as an independent termination taking one of three forms end-rings, end-loops or end-nets. He considered that because of
FIG. Xa.

Fig. 58. — A, sympathetic nerve-fiber terminating on skeletal muscle fibers.
their frequent association with the motor nerve endings that they were efferent in character. (FIG. Xa.). He named this system the "accessory nervous system". In further papers (1911-1913) he discussed this system more fully and on the evidence of degenerative experiments definitely advanced the opinion that they were sympathetic in origin. Although BOEKE in his latest survey of the whole question in 1927 still supported his earlier findings other workers have not done so. Many have described these fine unmyelinated fibres ending in skeletal muscle, but none have been able to show that every muscle fibre receives such a termination. Indeed nearly every worker has been struck by the scarcity of these fibres in preparations suitably treated to demonstrate them. This, however, may be due to technical difficulties. Silver impregnation methods have been universally used, but in those an even impregnation is difficult to attain, and only a small portion of any one muscle fibre can be examined. But even in those specimens where the impregnation has been excellent and a relatively large fibre of muscle examined, few or no fibres have been demonstrated.
In 1930 I carried out some work on the intercostal and leg muscles of cat and rabbit in order to demonstrate if possible sympathetic innervation. The methods used were:

(a) Silver impregnation as used by BOEKE (1913).

(b) CAIRN'S modification of KULCHITSKY. As this later method is not well known and is the best of all the teasing methods for demonstrating nerve fibres in muscle a detailed account of it is not out of place.

(1) **Tease** the muscle with glass rods into small pieces. *(The muscle must be taken within ten minutes of death of animal)*

(2) Fix in three parts fresh filtered lemon juice, one part formic acid. S.G. 1.22.

(3) Place tissue on clean cloth and express fixing fluid by gentle pressure.

(4) Transfer to 1% Gold Chloride using just sufficient fluid to cover tissue. Keep in dark 10-15 minutes.

(5) Repeat (3).

(6) Transfer to 25% formic acid for 24 hours. In dark.

(7) Repeat (3)

(8) Transfer to Glycerine and store in stoppered bottles.

Although the tissue can be examined immediately within 24 hours of placing in glycerine, the impregnation of gold gradually increases up to two months. This is very satisfactory for mammalian tissue.
FIG. Xb.

Motor nerve endings in muscle (Cat intercostal, CAIRN'S method).
tissue, but is not so good for cold-blooded animals. The specific gravity of the formic acid must be 1.22 and the gold chloride of British make.

By the CAIRN'S method by gentle teasing of the muscle fibres a beautiful picture of deeply impregnated motor nerve-endings was invariably obtained. Unmyelinated fibres were extremely rare in over three hundred specimens examined. No trace of unmyelinated fibres ending on muscle could be found. (FIG. X b & c). Where unmyelinated fibres were seen they were in close relationship to capillary vessels and would follow the course of these vessels very closely, but rarely ended upon them. Although the amount of material examined was not sufficient to come to any definite conclusions it seems legitimate to assume that:

(1) Even although the impregnation was sufficient to stain the motor nerve endings deeply or lightly (according to the time in the gold bath) unmyelinated fibres could only be found with rarity.

(2) When present those fibres never terminated upon a muscle fibre, but were always in relation to a capillary.

This also bears out what other workers have found with/
FIG. Xc.  Sympathetic nerves in muscle (Rabbit).

(A) Nerve trunk.
(B) Small nerve bundle breaking up into individual nerve fibres.
(C) Sympathetic fibre to arteriole.
(D) Sympathetic "nerve ending" at branching of arteriole.
(E) Motor nerve ending on granular "sole plate".

In both FIGS. X(a) and X(b) there are no sympathetic nerves in relation to the muscle fibres.

(Camera Lucida drawings).
with regard to the innervation of capillaries (i.e.) it is the exception to find a sympathetic nerve supply to capillaries - true sympathetic fibres have been shown to end on them, but these are very few considering the number present.

Is there any explanation for these fine unmyelinated fibres which BOEKE and others describe? BOEKE carried out his experiments by dividing the ventral and dorsal nerve roots, and allowing sufficient time for the motor and sensory nerves to degenerate, but he took no steps to prevent regeneration occurring. HINSEY (31) in 1927 reporting the results of his own experiments makes an interesting suggestion "when precaution was used against regeneration, and at the same time sufficient time was given for degeneration of the somatic component, no sympathetic fibres ending hypolemmally in skeletal muscle were seen in the small muscles of the foot, we feel that regeneration may account for some of the observations made and recorded in published investigations by BOEKE and his followers where longer degeneration times have been used".

Anatomically speaking the presence of sympathetic fibres cannot be accepted as being proven/
proved. Is there any physiological data which would support or demand a sympathetic nerve supply to muscle?

MUSCLE TONUS.

Following the description of the presence of fine unmyelinated nerve fibres in muscle and the acceptance that they belonged to the sympathetic nervous system the earliest investigators who undertook to study their functional significance naturally surmised that their influence was exerted on muscle tonus. Thus MOSSO in 1904 advanced the opinion that they governed tonus and slow contraction. De BOER (32) (1915) on the basis of experimental studies carried out mainly on frogs, stated that the tonus of muscle was mediated solely through the sympathetic nervous system. Although this view was quite erroneous it focussed attention on muscle tonus as related to the sympathetic nervous system.

LANGELAAN (33) (1915) from the result of a series of experiments on frogs advanced the following theory. Tonus of muscle consists of two components/
components:

1. A "contractile" component concerned with movements and the assumption of posture.
2. A "plastic" component concerned with the maintenance of assumed posture.

The former is controlled by the cerebro-spinal nerves; the latter by the sympathetic.

Section of the rami communicantes to a limb caused loss of plasticity and lack of steadiness of movements. After section of the dorsal nerve roots posture is not so well maintained. When both rami communicantes and dorsal roots are cut, there is, in contrast to only a diminution of tonus, as in either of the first two experiments, a complete loss of tonus. The most important observation made by LangeLaan in his paper is that following operation there is a complete loss of tonus due to operative shock and the true results of the operation cannot be observed until this has passed off. This fact is probably the explanation for the previous workers stating that sympathetic denervation of a muscle lead to complete loss of tone. Further work has shown that the division into plastic and contractile components is not a correct interpretation of tonus and therefore LangeLaan's theory is untenable.

HUNTER/
The wing of a bird was inserted by the operator to remove sow muscle. Contractile tone was removed by the posterior somatic reflex. The wing was molded into a new position as the wing was still present. The wing was folded by the terminal adductor muscle. On account of the presence of plastic tone, the wing folded forward. A similar case is illustrated in Fig. XI. The same test was given in the previous two figures. With the wing closed, the bird was placed in a series position. No regular movement was noted in this position, whereas for the bird to take up the normal folded attitude.
HUNTER (34) in 1924, divided the sympathetic fibres arising from the upper thoracic nerves in a sea-gull and found that the adducted position of the wing was no longer maintained. Also if the dorsal roots of the lower four cervical nerves were divided, the limb exhibited a tendency to remain in any position in which it was placed. (FIG. XI). If the dorsal nerve root of the first thoracic was then cut, the tendency became less apparent.

From these observations HUNTER agreed that "plastic" tonus of skeletal muscle was mediated through the sympathetic nervous system for it was lost on division of the rami communicantes supplying muscle, but present when the dorsal nerve roots alone were divided. In the upper limb the bulk of the sympathetic fibres join the brachial plexus by means of the first thoracic nerve, therefore, the diminution of the tendency for the wing of the bird to remain in any passive position following section of the first thoracic nerve, was due to the loss of sympathetic nerve supply contained in this nerve.

KUNTZ & KERPER (1926) showed, however, that "section of the sympathetic trunk just below the brachial plexus does not result in appreciable drooping/
Fig. 8. Diagram to illustrate the various lines of section to produce decerebrate rigidity (A A') to remove the nucleus of Deiters (B B'); and to produce facial palsy (C C').

Fig. XII.
drooping of the wing, if the operation is carried out with a minimum amount of traumatic injury to the nerves of the brachial plexus. COATES & LEIGHS (36) (1928) have since corroborated this finding.

To explain the tendency for the deafferented wing to remain in whatever position it is passively placed, it is not necessary to postulate a "plastic" tonus mediated through the sympathetic nervous system, for, when the dorsal nerve roots are cut, there is a loss of the sense of position due to interruption of the proprioceptive fibres present in these nerves. This is the more probable explanation.

In a decerebrated mammal (FIG. XII) the hypertonus of the extensor muscles forms a characteristic posture of the limbs. It has been assumed by some that if muscle tonus is mediated entirely or in part by the sympathetic nervous system sympathetic denervation would either prevent the onset or bring about a diminution in the degree of rigidity exhibited by the extensor muscles.

ROYLE in 1924 reported diminished extensor tonus in the left lower limb in goats in decerebrate/
decerbrate rigidity where unilateral lumbar ganglionectomy had been previously performed. This he states is a fairly common result in goats. Nearly every other worker, before and since he published his paper, have found that sympathetic ganglionectomy has no obvious effect in diminishing the extensor rigidity in decerebrate animals.

SPIEGEL (37) (1923) and later KUNTZ & KERPHER (35) (1924-6) using a technique whereby quantitative measurements of tonus could be obtained have shown that sympathetic denervation does result in diminution of tonus. This diminution is, however, so slight that an elaborate method is required to record the change.

These results show the fallacy of the use of the method of decerebrate rigidity to judge whether the sympathetic nervous system has any functional relationship to tonus. For while the sympathetic nervous system may exert an influence in the tonus of the normal animal, to expect it to be demonstrable in the exaggerated extensor tonus of decerebrate rigidity is to consider that the sympathetic influence is equally exaggerated which of course is not the case. Therefore, any influence that/
that it might have, easily escapes detection unless accurate quantitative methods are employed.

Following his own experimental work on animals ROYLE applied sympathetic ganglionectomy and ramisection in the treatment of spastic paralysis. Since then (1924) a mass of literature concerning the efficiency of the treatment has arisen. Although ROYLE has had his supporters, the bulk of the evidence goes to show that his assumptions, as to the benefits derived from the operations, were too sanguine. As to the position at present concerning this operation and its results. FRASER (38) states "It is agreed that, if the method is "to be efficiently applied, the sympathectomy must "concern the ganglia or the associated rami related "to the affected limb; a periarterial sympathectomy "is not applicable".

THE RESULTS:

I believe it is now possible to offer measured criticism of the results. ROYLE'S reports of his early cases were most encouraging and in a paper which he published in 1927 (39) he estimated that the results were an improvement on any other/
other method yet suggested. Von Lackum said that in his opinion the method "offers the most effective method of relief in many cases of spastic paralysis in children". Kuré, though not so sanguine, was of the impression that certain cases were distinctly benefited, particularly those in which the paralysis resulted from a pyramidal lesion (in contrast to the Parkinsonian Type).

So much for the protagonists; there are numerous adverse criticisms, but the only one to which I shall refer is the report published in the Lancet on July 19th, 1930, subscribed by ten English orthopedists embodying the results of six cases on which Royle operated in Queen Mary's Hospital, Carshalton, while he was on a visit to this country.

The report says, "the operation appears to have no place of value in the treatment of spastic weakness".

PERSONAL CASES:

Our own cases in this series are six in number; all have been examples of spastic diplegia and all were children of ages varying from six to twelve years. The procedure carried out was lumbar sympathectomy/
sympathectomy. The observation of the results has left an impression which is frankly disappointing. For a few weeks succeeding the operation, there seemed as though there was a reduced degree of rigidity, but the phase was a passing one, and in a relatively short time the condition was very much as it was before operation. The phase of temporary improvement is ascribable in all likelihood to the enforced rest which follows the operation, to a reduction of nerve impulses subsequent to the anaesthesia, and shock of the operation and perhaps in part the vaso-dilation which undoubtedly follows interference with the sympathetics.

In two cases, for purposes of contrast, a ganglionectomy was carried out on one side, and at a subsequent date a Stoeffel's operation was performed on the other. I have no hesitation in saying that the results of the latter (Stoeffel's operation) were infinitely better than those resulting from sympathectomy.

From experimental and clinical evidence it would appear that tonus cannot be explained as being mediated through the sympathetic nervous system; therefore, as regards tonus we have no physiological evidence/
evidence that skeletal muscle receives a sympathetic nerve supply.

MUSCULAR FATIGUE.

HUNTER in 1925 reported that birds with one wing deprived of its sympathetic innervation showed the effect of this deficiency by fatigue increasing in degree during prolonged flights. Also birds who had both their wings deprived of sympathetic innervation were apparently exhausted after a few short flights. Further work mainly by TOWER in 1926 and KUNTZ & KERPER in 1929 have failed to substantiate this finding. They say that "the capacity for prolonged muscular work and the onset and severity of fatigue were in no way affected by sympathectomy" (TOWER) (40); and "the sympathetic innervation of the muscles in question did not appreciably influence their power or their capacity to fatigue".

KUNTZ (41), ORBELL (42) attacked the problem from another aspect; instead of denervating muscles of sympathetic fibres and then stimulating, he produced fatigue in avascular muscles and then stimulated the sympathetics. In his findings he states/
states that the sympathetic fibres retard the onset of fatigue for he found that when a muscle was fatigued by somatic stimulation, sympathetic and somatic stimulation caused the muscle once more to contract. Although some workers have corroborated this, there is so much negative evidence, that for the present, it cannot be accepted.

So again physiological evidence does not demand a sympathetic innervation of skeletal muscle.
PART II.

CHAPTER VIII.

SURGERY OF THE AUTONOMIC NERVOUS SYSTEM.

Up to the present it is only in the sympathetic division of the autonomic nervous system that surgical interference has been undertaken.

The first of the operations to be devised was that of peri-arterial sympathectomy. JOBULAY (43) in 1899 attempted denervation of certain arteries by cutting as many as possible of the nerves which approached them. HIGIER (1901) recommended tearing the nerve plexus around the femoral artery in cases of intermittent claudication. Following those early attempts no attention was paid to the sympathetic nervous system until LÉRICHE (44) in 1913 once more approached the subject of peri-arterial sympathectomy. It is to LÉRICHE and his co-workers that we owe the first real conception of the indications for such a procedure. Working first upon such conditions as causalgias and other painful/
painful manifestations in the extremities he showed that considerable benefit could be obtained by dem- 
nuding (for 3 to 5 cms.) the main artery to the 
limb, of its adventitial coat. Since that time he 
has produced several papers showing the benefits to 
be obtained from such an operation and the condi-
tions to which it could be applied.

Following upon HUNTER'S work on the 
genesis of spastic paralysis ROYLE (45) in 1924 
advocated division of the rami communicantes supply-
ing the ganglia to the lower limbs in order to re-
duce the spastic element and to allow better condi-
tions for re-educating the muscles. Although the 
physiological basis of this operation has yet to be 
proved sound, it opened a new field in surgery for, 
when ADSON & BROWN (46) in America repeated 
ROYLE'S work they noticed the thermal changes which 
took place in the legs and applied this operation of 
ramisectomy to certain diseases which were believed 
to have their origin in vascular spasm. Finding 
that the certainty of complete ramisectomy was dif-
ficult they introduced a third method of attacking 
the sympathetic system gangliectomy. 

Since 1924 the subject of the autonomic 
nervous/
nervous system has from a clinical stand-point undergone a radical change and is now being attacked from an anatomical and physiological basis completely different from the haphazard empirical methods previously employed.

In the literature of the surgery of the sympathetic nervous system one is amazed to find the wide variety of diseases into which sympathectomy has been tried as a therapeutic measure. Naturally a completely new field such as this passes through what FRASER calls a period of "experimental optimism" and one finds references to the effect of sympathectomies in cases of epilepsy (Jacksonian and idiopathic) non-union or delayed union in fractures, chronic varicose ulcers, arterio-sclerosis, thrombo-angiitis obliterans, erythromelalgia, Raynaud's disease, intermittent claudication, causalgia, severe pelvic pain, retinitis pigmentosa, Hirschsprung's disease, dysmenorrhoea, and many other conditions.

The sympathetic nervous system, however, has only two main functions:

(1) Vaso-constriction.

(2) Relaxation of plain muscle and closure of the sphincters in the alimentary canal and hollow viscera such as the bladder.
and the results following sympathectomy depends upon just how much those factors played in the production of the disease. Thus if vaso-constriction is the cause of the disease then sympathectomy will relieve the condition. If on the other hand no vaso-constrictor element is present then sympathectomy cannot be of any benefit. In making this general statement it must be remembered that sympathectomy is followed by an increased blood supply to the part and therefore if the disease is influenced by an increase of blood to the affected part then this influence will be manifested following sympathectomy.

Similarly in the alimentary canal and hollow viscera. If there is any sympathetic - parasympathetic imbalance, with a hyper-sympathetic tonus as the underlying factor then sympathectomy will produce a beneficial result.

In addition to these two fundamental factors a third indication for interference with sympathetic nerve supply to any part is pain arising from viscera. The sympathetic nerves have been shown to contain visceral afferent fibres which relay painful stimuli from the periphery to the central nervous system. If the cause of the pain cannot be removed then sympathectomy by breaking the reflex on/
on the sensory side is an extremely useful palliative measure. This has been found to be very effective in relieving the pain of inoperable tumours invading or arising in the bladder. This indication for sympathectomy has to be distinguished from the previous two for, whereas here it is only a palliative measure, in the previous cases it is curative in that it attacks the underlying cause of the diseases, hyper-sympathetic tonus.

With those physiological principles in mind it is possible to postulate those cases that will he helped by sympathectomy.

(A) CASES WHERE VASO-CONSTRICTION IS THE UNDERLYING CAUSE.

In this group are such conditions as:-

(1) Raynaud's disease.
(2) Acroparaesthesia.
(3) Angiospasm giving rise to the syndrome of "intermittent claudication".

(B) SYMPATHETIC - PARASYMPATHETIC IMBALANCE IN ALIMENTARY SYSTEM AND HOLLOW VISCERA.

(1) Hirschprung's disease.
(2) Retention of urine or "cord bladder".
(3) Chronic constipation or dyschezia.

(c)/
(C) RELIEF OF PAIN.

(1) Angina pectoris.

(2) In inoperably tumours of bladder and other pelvic organs which are giving rise to severe pain.

(3) Causalgia.

(D) CASES in which a DECREASED BLOOD SUPPLY to the PART is a SIGNIFICANT FEATURE in the PROGRESS of the DISEASE.

It is essential in this group to distinguish between the cause of the decrease in blood supply to the limbs. Thus if it is dependent entirely upon a vascular degeneration with a subsequent thrombosis of all the vessels then sympathectomy cannot produce any beneficial results. If on the other hand there is an element of spasm present then according to the degree of spasm so will sympathectomy be of value.

This group includes such diseases as:

(1) Thrombo-angeitis obliterans.

(2) Scleroderma.

(3) Incipient gangrene in middle age people without or with only slight arterial degeneration.
WHERE an INCREASE of BLOOD to the PART will be BENEFICIAL.

(1) Arthritis of joints.
(2) Chronic varicose ulcers.
(3) Trophic ulcers.

MISCELLANEOUS GROUP.

This includes a vast number of diseases in which sympathectomy has been carried out without sufficient physiological evidence that such a procedure would be of any value. The most important members of this group are:

(1) Spastic paralysis.
(2) Erythromelalgia.

but it also includes such diseases as epilepsy and dysmenorrhea in virgins for which there seems to be no cause.

The benefits arising out of surgical interference with the sympathetic nervous system are best illustrated by cases, but before passing on to the individual diseases I wish to refer to the pre-operative tests and to the technique employed in the three recognised operative procedures.
CHAPTER IX.

THE PRE-OPERATIVE TESTS.

(a) IN VASCULAR DISEASES.

From an appreciation of the physiology of the sympathetic nerves and the peripheral blood vessels it is apparent that sympathectomy will only procure relief in those diseases in which spasmodic contraction of the blood vessels is either the cause or an important factor in the development of the condition. The greater the degree of spasm the greater the benefit from sympathectomy.

Previous to the introduction of ganglionectomy in 1924 little attention had been paid to this factor, and the operation of peri-arterial sympathectomy was carried out on the purely clinical findings in cases of vascular ischaemia in the limbs. This was no doubt due to the fact that the pathology of the diseases attacked and the physiology of autonomic nervous system were only imperfectly understood and that the operation of/
of peri-arterial sympathectomy had such a small operation risk, being truly a minor operation, that it was justifiable to carry out the procedure in all cases of decreased blood supply to the limbs. On the introduction however of ramisectomy and ganglionectomy the operation could no longer be considered a minor operation thus, it was essential to differentiate between those vascular ischaemias which were due to a spasmodic contraction of the arterioles and those due to vascular degeneration. On clinical grounds alone it is not difficult to differentiate between the purely vascular spasms and the vascular degenerations. A typical Raynaud's disease with gangrene can be easily distinguished from a gangrene arising from arterio-sclerosis, but there are many cases, indeed the majority, in which it is difficult to say whether spasm or degeneration is the underlying cause and impossible, should both factors be present, to be able to decide how much is due to degeneration and how much to vascular spasm.

BROWN (47) in 1926 introduced the first method for distinguishing between vascular spasm and vascular degeneration.

During acute febrile conditions the toxing/
toxins act upon the heat-regulating centre of the body causing a general rise in temperature. In addition they also by acting upon the sympathetic nervous system produce, in a varying degree, loss of sympathetic tone. The peripheral blood vessels in addition to supplying blood to the parts also play an important part in regulating heat loss. Thus, if the temperature of the body should rise they dilate in order to allow more blood to the skin and underlying tissue so that heat loss by conduction and radiation may be increased. Working on this, BROWN promulgated the following test. By means of a thermocouple the temperature of the skin of the foot or hand is obtained.

A triple thyphoid (T.A.B.) vaccine in doses of 5,000,000 to 75,000,000 is used to produce a rigor.

The temperature of the mouth and skin of the foot are obtained. An injection (the amount regulated according to weight, age, and condition of patient) of T.A.B. vaccine is given intravenously. At the height of the rigor which lasts from twelve to forty-eight hours the oral and skin temperatures are once more taken. The rise in skin temperature depends/
depends upon two factors:

(1) the effect of the vaccine upon the heat regulating centre of the body.

(2) the vaso-dilation of the peripheral arterioles.

The rise in oral temperature can be taken as a measure of the first factor, and if the rise in oral temperature is subtracted from the rise in skin temperature, the "vascular index", as BROWN calls this figure, represents the rise due to vaso-dilatation. "The increase of skin temperature divided by the number of degrees increase in the temperature of the blood gives a figure which, in simple terms indicates that for every degree rise in temperature of the blood there is in the temperature of the skin a certain number of degrees rise which is largely of vaso-motor origin" (48).

Vascular indexes of 5 to 14 are obtained in conditions where spasm is the predominant feature. In cases of thromboangeitis obliterans in which spasm plays a part, figures from 2 to 6 may be obtained. In cases of arterio-sclerosis little or no rise in skin temperatures occur and the figure may be below unity. The following are three examples of what is found when carried out in these types of cases.

| TABLE I |
TABLE (I) Where Vaso-spasm is Predominant.

<table>
<thead>
<tr>
<th>TEMPERATURE OF</th>
<th>BEFORE INJECTION</th>
<th>AFTER INJECTION</th>
<th>DIFFER.</th>
<th>VASCUL. INDEX</th>
<th>RISE IN SK. RISE IN MOUTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temp. of foot</td>
<td>75</td>
<td>90</td>
<td>15</td>
<td>12</td>
<td>$15/3 = 5$</td>
</tr>
<tr>
<td>Temp. of mouth</td>
<td>98</td>
<td>101</td>
<td>3</td>
<td>12</td>
<td></td>
</tr>
</tbody>
</table>

TABLE (II) Where Vaso-Spasm is only one factor.

<table>
<thead>
<tr>
<th>PART</th>
<th>BEFORE INJECTION</th>
<th>AFTER INJECTION</th>
<th>DIFFER.</th>
<th>VASCUL. INDEX</th>
<th>RISE IN SK. RISE IN MOUTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temp. of foot</td>
<td>75</td>
<td>85</td>
<td>10</td>
<td>7</td>
<td>$10/3 = 3.3$</td>
</tr>
<tr>
<td>Temp. of mouth</td>
<td>98</td>
<td>101</td>
<td>3</td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>

TABLE (III)/
TABLE (III) Where Vaso-spasm is not a Factor and the condition is entirely one of Arterial Degeneration.

<table>
<thead>
<tr>
<th>PART</th>
<th>BEFORE INJEC-</th>
<th>AFTER INJEC-</th>
<th>DIFFER.</th>
<th>VASCUL. INDEX</th>
<th>RISE IN SKIN</th>
<th>RISE IN MOUTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temp. of foot</td>
<td>80</td>
<td>82</td>
<td>2</td>
<td>-1</td>
<td></td>
<td>$\frac{2}{3} = 0.66$</td>
</tr>
<tr>
<td>Temp. of mouth</td>
<td>98</td>
<td>101</td>
<td>3</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In examples (I) and (II) the vascular index being over 3 which BROWN considers the lowest limit that will be benefited by sympathectomy the pre-operative tests indicate that sympathectomy is justifiable. In example (III) no vaso dilation has occurred and therefore sympathectomy will not produce any beneficial results.

While this test was of the greatest importance in making the first effort at distinguishing between the vaso-degenerations and the vaso-spasms, it was found that the results could not be strictly adhered to. For reasons unknown some cases which gave a vascular index of over three were not benefited/
benefited by sympathectomy and others which had shown no rise in skin temperature following the injection of the vaccine, were benefited. The test does not give a clear indication of the amount of degeneration and spasm present, and the figure the "vascular index" is a too arbitrary one to be depended upon in all cases. In addition the rigor produced is very distressing to the patient and unless very carefully controlled is liable to be dangerous. It has been reported that in a series of 250 cases two deaths have resulted following upon severe reactions to the injections.

MORTON & SCOTT (49) in 1930 measuring skin temperatures under full surgical anaesthesia noted that the temperature of the foot in normal subjects rose to between 92-93°F. This rise in temperature was due to complete loss of peripheral vasoconstriction following upon loss of sympathetic tonus due to the anaesthetic. This level they called the "normal vaso-dilation level". If the temperature of the foot did not rise to this level, then there must be some degree of vaso-degeneration present, accounting for the decrease in the amount of blood in the peripheral vessels. In addition, they pointed out that all the vaso-constrictors going to the lower/
lower limb were paralysed following spinal anaesthesia and they advised, as a pre-operative test, the injection of 5-10 ccs. of novocaine intrathecally as in spinal anaesthesia.

Taking the figure of 92-93°F as the "normal vaso-dilation level" the rise of temperature following spinal anaesthesia they called the "vaso-constrictor gradient". If the limb failed to reach a temperature of 92-93°F then some organic occlusion was present in the vessels and the number of degrees below the "normal vaso-dilation level" was known as the "occlusion index". The following examples illustrate these points.

**TABLE IV.**

<table>
<thead>
<tr>
<th></th>
<th>TEMPERATURE OF FOOT.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before spinal anaesthetic</td>
<td>75°F</td>
</tr>
<tr>
<td>After spinal anaesthetic</td>
<td>93°F</td>
</tr>
<tr>
<td>Difference</td>
<td>18°F</td>
</tr>
<tr>
<td>Vaso-constrict. grad.</td>
<td>18</td>
</tr>
<tr>
<td>Occlusion index</td>
<td>0</td>
</tr>
</tbody>
</table>

In/
In this case there is no occlusion due to organic disease, therefore, the vascular ischaemia will be entirely relieved by sympathectomy.

**TABLE V.**

<table>
<thead>
<tr>
<th></th>
<th>TEMPERATURE OF FOOT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before spinal anaesthetic</td>
<td>75°F</td>
</tr>
<tr>
<td>After spinal anaesthetic</td>
<td>85°F</td>
</tr>
<tr>
<td>Difference</td>
<td>10°F</td>
</tr>
<tr>
<td>Vaso-constrictor grad.</td>
<td>10</td>
</tr>
<tr>
<td>Occlusion index.</td>
<td>93-85 = 8</td>
</tr>
</tbody>
</table>

In this case the ischaemia is due both to vascular degeneration and vascular spasm, therefore, sympathectomy cannot result in a complete cure with a return to normal circulation in the limb, but considerable relief will result, relief being indicated by the ratio of vaso-constrictor gradient to the occlusion index.

**TABLE VI.**
In this case the ischaemia is almost entirely due to organic vascular occlusion therefore, sympathectomy cannot be expected to relieve the condition.

By this test we have an absolute accurate measure of the amount of degeneration of the arterioles present and a means of differentiating between the parts played by organic disease and by spasm in the production of vascular ischaemia of the lower limbs.

While this is the most accurate test we have which has proved itself by results, it had two serious disadvantages. Firstly it can only be applied to cases in which the lower limbs are affected and secondly it has all the dangers associated with spinal/
spinal anaesthesia.

To overcome these objections MORTON & SCOTT in 1931 (50) introduced the method of infiltrating peripheral nerves with novocaine. If the test was carried out on the foot, the posterior tibial nerve was infiltrated. This they claimed paralysed the sympathetic fibres in the mixed nerve and dilatation of the peripheral vessels occurred. The rise in skin temperature was taken as an indication of increased blood to the parts. In this test the results of the pre-operative findings were substantiated by operation, but in some cases the test failed to indicate to the proper extent the benefit following sympathectomy. The fault probably lies in that complete anaesthesia of all the sympathetic nerves supplying the foot is difficult by infiltration anaesthesia, and this difficulty is increased when the test is performed on the hand.

COLLER & MADDOCK (51) in October, 1932, introduced a fourth method of testing - one which if it is reliable will replace all the others, for it is safe, applicable to all parts of the body, requires no special technique, and can be performed on the patient without necessitating their admission to hospital.
SKIN-TEMPERATURE INDICATIONS

FIG. XIII. (COLLER & MADDOCK).

FIG. XIV. (COLLER & MADDOCK).
hospital.

The autonomic nervous system regulates the internal temperature of the body to the external environment. That is if the external environment is high then the body must lose more heat and the method employed is by vaso-dilation of all the peripheral vessels bringing more blood to the subcutaneous tissues and by this means to increase heat loss by conduction and radiation. If the local external environment is at the same temperature of the body then complete vaso-dilation of the peripheral blood vessels will occur and the temperature of the limb will rise to the "normal vaso-dilation" level of MORTON & SCOTT.

The method employed in the test is as follows. The patient is placed in a warm room (Temperature 70-73°F.) and lies naked except for a perineal drape (and breast towel in the case of females) for one hour. At the end of this time by means of a thermacouple the skin temperatures of the hands and feet are obtained. (FIGS. XIII & XIV) The patient is then covered with:

(1)/
FIG. XV. (COLLER & MADDOCK)

CHART I

AVERAGE SKIN TEMPERATURE OF:
A = SIX NORMAL WOMEN EXPOSED TO AVE PM TEMP 24.5°C FOR ONE HOUR
B = ENVIRONMENTAL RESPONSE IN WOMEN
C = SIX NORMAL MEN EXPOSED TO AVE PM TEMP 25.0°C FOR ONE HOUR
D = ENVIRONMENTAL RESPONSE IN MEN.
(1) A mackintosh sheet to prevent evaporating, conduction, and radiation and by this means to raise the temperature between the skin and the mackintosh sheet to 96-98°F.

(2) three blankets. If it is desired hot water bags may be placed around the patient. At the end of one hour the skin temperature of the feet and hands is taken.

By this time the local external temperature is equal to the body heat, all the vessels have dilated as much as possible and the skin temperature depends upon the increased amount of blood following dilatation.

FIG. XV. shows the average results obtained from six normal people of ages between 20-60.

**TABLE VII. (Fig. XV.)**

<table>
<thead>
<tr>
<th></th>
<th>UNCOVERED</th>
<th>COVERED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature of Axilla</td>
<td>98°</td>
<td>98°</td>
</tr>
<tr>
<td>Temperature of Abdomen</td>
<td>96.8°</td>
<td>98°</td>
</tr>
<tr>
<td>Temperature of leg</td>
<td>85°</td>
<td>94.2°</td>
</tr>
<tr>
<td>Temperature of hand</td>
<td>86°</td>
<td>94.7°</td>
</tr>
</tbody>
</table>

The figures 94-94.7°F for the hands and feet when covered are slightly higher than the figure 92/
FIG. XVI. (COLLER & MADDOCK). Body points as in FIG. XIV.

The close correlation between the temperatures in B, C, and D indicates the reliability of the COLLER & MADDOCK test.

FIG. XVII. (COLLER & MADDOCK). Body points as in FIG. XIV.

Pre-operative test results compare with post-operative results.
92-93°F. the normal vaso-dilation level obtained by MORTON & SCOTT following spinal and general anaesthesia. Therefore the claim of COILER & MADDOCK that full dilatation of the peripheral vessels can be obtained by raising the local external environment is completely justified.

FIGS. XVI and XVII show that:

I. The Coller and Maddock technique is as reliable as either BROWN'S vaccine or MORTON & SCOTT'S spinal anaesthetic test.

II. The pre-operative results are in close agreement with the post operative results.

III. The amount of degeneration and the amount of spasm present in arterial vessels can be accurately estimated by this test.

Considering it has no disadvantages, is easy of application and has no risks, this test should be the method of choice for examining cases of vascular ischaemias.

A fifth test has been introduced in December, 1932 by JOHNSON (52). It is different from all the previous tests in that it is not dependent upon skin temperatures for differentiating between diseases arising from occlusion and spasm of/
THROMBO ANGITIS OBLITERANS
FINGER
SKIN

BEFORE

27.0

27.5

32.3

28.0

AFTER HEAT

1

2

3

4

34.5

34.3

34.0

33.2

Fig. 6. This figure shows records of the volume changes in the fingers of the right hand of a patient with thrombo-angitis obliterans. The third finger apparently has a good circulation but the vessels manifest no vasoconstrictor tone, or the entire capacity of the vessels to dilate is being constantly utilized which is evidenced by the absence of an increase in pulse volume change from local heat. This illustrates the utility of the instrument in differentiating between different degrees of organic as well as functional constriction of the smaller blood vessels.

FIG. XVIII.

DATE

12,8,31

VOLUME CHANGES

3RD FINGER RT. HAND

TIME

HT.

SYPATHECTOMY

10

15.5

102

11

15.5

110

12

23.7

99

19

32.5

98.6

84

28

33.3

98.6

81

Fig. 7. This figure illustrates the volume changes of the third finger of the right hand before and after removal of the right superior cervical and first and second thoracic sympathetic ganglia. It is to be noted that the pulse volume changes of the finger return to the control level in 21 days.

FIG. XIX.
of the arterioles.

His method is as follows. A plethysmograph is made which will fit either the patient's toe or finger according to the location of the disease. This plethysmograph is attached to a pipette in which a ball of fluid is present. The arterial pulse in the digit causes increase and decrease in the volume of the finger and this is indicated by a oscillating movement of the ball of fluid. The movements are photographed. The movements are not an indication of increased or decreased blood to the part, but are measurements of a change in the pulse volume. The arterial wall modifies the pulse volume in that a wall of high tension (spasm) or of arterio-sclerosis damps down the pulse volume. On the application of heat the vaso-constrictors are thrown out of action, the spasm of the arterioles is reduced and the pulse volume increases. In arterio-sclerosis heat has no effect on the vessel wall and the pulse volume does not change. By this means the two types of vascular ischaemias can be differentiated, but the degree of each present cannot be ascertained by such a method. (Figs. XVIII & XIX). Its value in the pre-operative tests of vascular/
vascular neurosis has yet to be ascertained but
JOHNSON, SIMPSON & GILBERT (53) have brought out
an interesting point. It is known in animals, as
KUNTZ has shown that the vaso-dilation following
ganglionectomy is not permanent. The above workers
reported a case of ganglionectomy for arthritis in
which they claim to have shown, by the plethysmo-
graph, that the peripheral arterioles reached a
state of tonus, equal to that before the operation,
within twenty-one days following the operation.
The temperature of the hand however remained 2-3°C
above the pre-operative level. They conclude "our
experiments in this case do not show a permanent
increase in peripheral circulation following gang-
lionectomy and ramisectomy and are in accord with
results of animal experiments. We feel that the in-
creased heat following ganglionectomy is due to loss
of sweating and evaporation and possibly other minor
unknown factors".

This statement although it cannot be sup-
ported except by animal experiments in cases where
the arterioles are not in a state of spasmodic con-
traction due to a hyperactivity of the vaso-constric-
tors/
vaso-constrictors, must be thoroughly examined. For if it were true it would mean a complete upheaval of the whole of the surgery of vascular neurosis.

By means of any of those tests, but especially by means of spinal anaesthesia and the technique employed by COLLER & MADDOCK an absolutely accurate picture of the post-operative results can be obtained and by these means it is possible to obviate operating on cases in which the benefits would be so negligible that to submit the patient to a ganglionectomy would be an unjustifiable risk.

(b) HIRSCHSPRUNG DISEASE.

MORTON & SCOTT (49) in 1930 showed that in cases of Hirschprung's Disease the following test should be carried out before operating. The lower bowel is cleared out as completely as possible. A barium enema is given. 5 c.c. of a percaïn solution injected intrathecally. As the anaesthesia develops the sympathetic nerves to the large intestine become paralysed, the inhibition is lost and the unopposed parasympathetic cause expulsion of the enema. As one would expect the whole enema is not/
not expelled completely in advanced or long standing cases, but if the intestine shows increased activity following the spinal anaesthetic lumbar gangliectomy will result in, if not complete cure, then considerable alleviation of the condition.
(1). PERI-ARTERIAL SYMPATHECTOMY.

This procedure first suggested by HIGIER in 1907 received its strongest exponent in LERICHE (44) who perfected the technique.

The following description is taken from YOUNG'S (54) paper on "The Place of Peri-Arterial Sympathectomy, of Ganglionectomy and Sympathetic Trunk Resection in the Treatment of certain Vascular Diseases and other conditions".

"The operation consists in the effective excision of the adventitial coat of an artery, for a distance of several centimetres. The avowed purpose is the elimination of the sympathetic nerve plexus distributed through this coat, particularly at its deepest part, and the making in this way of a definite and substantial breach between the central nervous system in the one hand and the plexuses distal to it. Any of the larger arteries may be dealt/
Pig. A. - Operative field, showing artery, showing artery, showing artery, with common ailments. Then bring gauze under the artery.

Fig. XX.
dealt with this way, the subclavian, the axillary, the brachial, the iliac, the femoral, the popliteal. In any of these it is generally capable of being easily carried out, except where the wall of the vessel is the seat of calcareous degeneration. In the case of the arteries of smaller calibre it is more difficult. I have myself carried it out, in one case, upon the anterior and posterior tibial vessels immediately above the ankle, but there is no doubt that in such small vessels the separation and removal of the outer coat is a much more difficult and delicate proceeding.

The technique of the operation is simple. The operation can be done under a general or local anaesthesia. The selected vessel is exposed at the most convenient site, with the least possible disturbance of surrounding tissues, and the least possible dislocation of relations. (FIG. XX.) Associated venous trunks and branches should be avoided as much as possible and the vessel itself is most easily dealt with if, in the region selected there are either no branches or a minimum of these. The femoral artery may be exposed in Scarpa's triangle or in Hunter's canal. The axillary artery may be
FIG. XXI.

FIG. XXII.
a little more difficult to expose for a sufficient length, because of the closely associated nerve trunks. The brachial artery at mid-arm should give no difficulty.

Once the vessel is exposed, and the common sheath, within which it is associated with veins and nerves, has been incised for a sufficient length, the adventitial coat is seized carefully with fine toothed forceps, and is raised a little. Thereupon with the point of a fine scalpel, the adventitia is incised and carefully separated with a fine blunt dissector, from the middle coat, for a distance of several centimetres. (FIG. XXI.) This separation must be systematically done, the artery being displaced gently outwards, inwards and forwards, and gently rolled round until it is clear that the adventitial coat has been completely separated. (FIG. XXII.) This is very necessary, because if the operation is to be thoroughly effective, i.e. if a complete breach is to be made in the sympathetic limb, no vestige of adventitial coat should be left behind. The segment of separated adventitia is cut across at both ends and removed. There is seldom much bleeding either from the vaso-vasorum or/
or from minute branches. and such bleeding as does occur is generally easily controlled. With ordinary care there is little risk of accident".

Such was the technique as devised by LERICHE. SAMPSON HANDLEY in 1922 described a method whereby the same results as denuding the adventitial coat was obtained by injecting into the adventitial coats absolute alcohol. "With the finest hypodermic needle obtainable, 2-3 minims of alcohol were injected as stated at four points equidistant from each other around the vessel. The needle was introduced obliquely and nearly parallel with the length of the artery. In doing this the artery might require to be partially rotated, to make the posterior injections. The alcohol in this way was introduced into the substance of the tunica adventitia and the effect of the alcohol upon the artery was to produce a whitish band about \( \frac{1}{4}\)" wide round the vessel. The band, however, did not cause any constriction to the vessel".

CAMERA in 1925 advised the injection of normal physiological saline into the adventitial coat. This raised the adventitial from the medial coat and greatly facilitated the stripping of the adventitia.

CRITICISMS./
CRITICISMS.

(1). Bleeding from the vaso-vasorum and small branches of the main artery lead to little difficulty. They can be easily controlled either by ligatures or pressure.

(2). In vessels where the walls are unduly soft and in those which are friable from atheromatous changes the stripping has to be done with great care. Perhaps SAMPSON HANDLEY'S method is best in such cases.

(3). The operation has been criticised on the grounds that aneurysmal dilatation would occur at the site of stripping, but this is entirely unfounded as JOHN HUNTER (57) showed as far back as 1835. He decorticated the carotid arteries in a dog, down as far as the intima. Three weeks later autopsy revealed that instead of the aneurysm which he expected, the walls of the vessels were surrounded by a strong band of fibrous tissue making them stronger than usual.

(4). The most serious criticism to the operation is that it does not denervate the peripheral blood vessels of the sympathetic fibres. As KRAMMER & TODD.(19) have shown the peripheral blood vessels receive their sympathetic fibres in/
in the "instalment form" and that no long fibres run from the lumbar chain down along the main vessel to the limb. All that peri-arterial sympathectomy does is to denervate only that part of the vascular system which is actually denuded of its adventitial coat. If such is the case, and it has been proved by later workers beyond all doubt, how can the beneficial results following peri-arterial sympathectomy be explained. Peri-arterial sympathectomy does produce beneficial results, for innumerable workers, since the days of LERICHE down to the present, have reported many cases showing improvement following the operation. LERICHE tried to defend the operation by saying that if no afferent fibres passed down, then sensory afferent fibres passed along the whole length of the arterioles, and in this way the reflex arc was broken. But, no anatomical proof could be found to support this. He then postulated that ganglion cells were present in the arterial walls, and that there were centripetal fibres in the adventitia of the arteries which correlated these peripheral intra-mural centres with the central nervous system. "The action of peri-arterial sympathectomy............. has not to/
to do with motor fibres, but with centripetal association fibres. In dividing them, one removes for some time the motor elements of the periphery from the regulating influence of the higher centres. This explains the hyperactivity of the peripheral ganglionic centres, which thus produce a régime of vaso-dilatation". (58).

Such a hypothesis receives not the slightest support from either physiological or anatomical studies. It is better to admit that, for the present, a physiological explanation of the benefits following peri-arterial sympathectomy cannot be given than to postulate hypotheses which however attractive in theory are not only unsupported by anatomical evidence, but definitely disproved by it.

From several cases reported it would appear that any interference with the sympathetic nervous system at any part produces a temporary diminution in tone of the system and perhaps this temporary diminution in tone breaks the vicious circle and allows a return to normal.

The tendency at present is to regard peri-arterial sympathectomy as an unphysiological operation, and only to be considered where the condition/
condition of the patient contra-indicates the more serious operation of ganglionectomy.

(2). RAMISECTOMY.

Ramisectomy, the last of the three operations to be devised was advocated by ROYLE in 1924 for the relief of spastic paralysis. The method of approach and the whole technique of the operation is similar to that of ganglionectomy. The only difference is that in the latter the ganglia are actually removed, while in the former only the rami communicantes are divided, thus isolating the ganglia. Therefore, the description of ganglionectomy holds as well for ramisectomy.

(3). GANGLIONECTOMY.

While it is true that ALEXANDER (59) in 1889 performed bilateral extirpation of the superior cervical sympathetic ganglia for epilepsy, and other workers perform similar operations for hyperthyroidism, glaucoma, and angina pectoris, it was not until ROYLE (45) & HUNTER (34) in 1924 published their work on ramisectomy in relief of spastic paralysis that the surgical possibilities/
Fig. 8. The relations between the thoracic and cervical ganglia, the subclavian artery, and the cardiac plexus are shown. The darkened portion illustrates that section of the sympathetic trunk and the ganglia, which are definitely removed. Occasionally the cervical portion also may be removed.

**FIG. XXIII.**

Fig. 15. The dark portion illustrates the section of the lumbar trunk and the ganglia that are removed in the treatment of Raynaud's disease of the lower extremities.

**FIG. XXIV.**
possibilities of such a field was realised.

There are two sites at which ganglionectomy are carried out.

1) Cervical-dorsal region, where to denervate the upper limb of sympathetic fibres, the inferior cervical and the first and second thoracic ganglia are removed. (FIG. XXIII.)

2) Lumbar region, where the second, third and fourth lumbar ganglia are removed in order to either denervate the lower limb of sympathetic fibres or to sympathectomise the lower part of the large intestine. (FIG. XXIV.)
FIG. XXV.
At first it was thought sufficient to remove the inferior cervical sympathetic ganglion to denervate the upper limb, and the anterior approach was used. As the distribution of the sympathetic fibres became known it was necessary that not only should the inferior cervical ganglion be removed, but also the 1st. and 2nd. thoracic. In order to obtain a freer access, ADSON & BROWN (48) introduced in 1929 the new method of "posterior approach". It is this method as quoted by YOUNG (34) which is given here.

"The patient is placed in the prone position with the upper part of the trunk raised on pillows and the neck flexed, the head hanging somewhat forwards. An incision 4 or 5 inches long is made, either in the mid-line, if both sides are to be done at the one sitting, or 1½ inches from the middle-line if only one side is to be done. (FIG. XXV.) In the former, once the skin and subcutaneous tissue have been divided, the edge of the wound must be strongly retracted towards the side on which the operation is being done, and then the deeper/
FIG. XXVI.
"deeper parts are incised further out. The incision extends from about the level of the sixth cervical spine as far down as the level of the fourth dorsal. The incision is deepened carefully and systematically, recognising the successive muscular layers as they are divided, trapezius, rhomboids and serratus posticus, erector spinal muscles and the lower end of splenius. The margins of the wound are separated by retractors and the bony relations confirmed.

"One considerable difficulty is the recognition of the actual level of the spinous processes. It is always somewhat difficult to be quite certain which is the seventh cervical and which is the first dorsal. The important one, in that its level should correspond with the centre of the incision, is the spinous process of the second dorsal; (FIG. XXVI.) for the actual exposure of the sympathetic trunk is supposed to be accomplished best after excision of the transverse process of that vertebra and of the innermost three or four centimetres of the corresponding rib. Having cleared the bony surfaces at the proper level, and having identified the proper vertebral processes, the periossteum over the rib is incised and cleared from the surface of/
Fig. 5. Subperiosteal exposure of the second rib and its articulation with the transverse process of the second thoracic vertebra. The lines indicate the places where resection was done.

Fig. 6. Exposure of the second thoracic and cervicothoracic ganglia, with only a small portion of the cervicothoracic ganglion in the field. The method by which the second thoracic ganglion is elevated by traction preliminary to resection of the thoracic trunk below the ganglion is illustrated. The procedure is shown by which the cervicothoracic ganglion is drawn downward to expose the various communicating branches. In this particular case, the lower cervical portion of the cervicothoracic ganglion is separated from the thoracic portion by a dense band.
of the bone; (FIGS. XXVII & XXVIII.) whereafter
the posterior and inner 3 cms. of the rib are ex-
cised, the corresponding transverse process of the
rib being simultaneously divided and removed. There
ought not to be any special bleeding. If the inter-
costal artery is injured, it is easily ligated. In-
jury to the first and second intercostal nerves
should be avoided. When the portion of the rib has
been excised, the chest cavity is opened, and the
surface of the pleura, which ought to escape injury
if ordinary care is taken, becomes at once apparent.
It is carefully separated from the side of the verte-
bral column and retracted outwards and forwards.
The sympathetic trunk then become visible, between
the 2nd. thoracic ganglion below and the cervico-
 thoracic ganglion above. (FIG. XXIX.) The latter
is not at first visible.

Following exposure of the sympathetic
trunk, the latter is divided well below the second
ganglion and is carefully lifted upwards; the rami
of communication with the second and third thoracic
nerves are divided, and by gentle traction on the
upper segment of the ganglionic trunk the lower
portion at least of the cervico-thoracic ganglion
is brought into view. Rami to the subclavion are
divided.
"divided and part or whole of the cervico-thoracic ganglion is taken away, after division of the ascending and other branches. The wound is closed with care, successive muscular layers being sutured in turn.

"Following the operation, it is probably best to keep the patient in the prone position during the first few days, whereafter the dorsal cubitus may be safely adopted.

"NOTE: ADSON ..... has now modified his method of approach ........ he find it more convenient to enter the thoracic cavity through the first rib rather than through the second. He believes in that way he is able to ensure a more complete removal of the lower cervical and first thoracic ganglia, and to carry out a more careful ramisection of any ascending fibres to the two lower roots of the brachial plexus."

(2). OPERATIVE/
(2). OPERATIVE TECHNIQUE FOR LUMBAR GANGLIONECTOMY.

There are two methods of approach:-

(1) extra-peritoneal.
(2) trans-peritoneal.

(1). The extra-peritoneal has only one advantage, and that is, it is unnecessary to open into the abdominal cavity, but this is heavily outweighed by the long incision that is necessary in order to obtain a sufficiently wide displacement of abdominal viscera to give effective and safe access to the side of the vertebral column.

(2). The trans-peritoneal route as advocated by ADSON (48) is the one now generally employed.

"A long vertical incision is made, either medial or paramedial, and it should extend from close to the pubis as far up as may be necessary to afford free access, and without limiting freedom of manipulation within the abdomen. It is desirable to have the patient in the Trendelenburg position before the peritoneum is opened, and this position is maintained throughout the special executive part of/"
Fig. 13. The incision on the right side, similar to that on the left side which is illustrated in Figure 8.

FIG. XXX.
of the operation. It allows of the intestine being packed upwards out of the way, and renders access to the special operative field to either side of the lumbar spine much easier.

RIGHT LUMBAR CHAIN.

"For exposure of the right lumbar chain, an incision is made close to the right lateral border of the vena cava, across the root of the mesentery of the small intestine and downwards into the pelvis, crossing the right common iliac vein and artery. This incision, which may be 15-20 cms. in length, and may be extended upwards if desired, divides the parietal peritoneum, and opens up the loose sub-peritoneal tissue. (FIG. XXX.) The caecum, small intestine and ureter are displaced outwards and the edge of the vena cava, which bulges sometimes to the right of the aorta, is carefully drawn inwards. In this way the surface of the psoas is uncovered, and several of the downward descending nerves become visible. Of these, the most important as a guide to the sympathetic chain is the genito-femoral, which is usually easily recognised, being the innermost of all. The/
Exposure and resection on the right side. Note the venous displacement slightly to the left, and the lumbar sympathetic trunk and lumbar vertebral veins firmly exposed. (By courtesy of Dr. Abbot and the Editors of Surgery, Gynecology and Obstetrics.)

FIG. XXXI.
The sympathetic trunk lies close behind and under
cover of the vena cava, and at its lower end passes
behind the right common iliac vessels. (FIG. XXXI)
The fourth lumbar ganglion is situated just about
the brim of the pelvis, and the trunk is divided
immediately below this ganglion. Rami of communi-
cation with successive spinal nerves, with the
hypogastric nerves are divided systematically from
below upwards, and the cord is raised from its bed
gradually until the second lumbar ganglion is
reached. Above this it is divided, and the whole
trunk removed between the two levels named. The
only difficulty of note that may be encountered is
in the avoidance of several small intervertebral
veins, which cross the trunk at several places.
With care, however, they can be avoided, and, even
if one or more are accidentally injured, the bleed-
ing can easily be checked, the small bleeding ves-
sel being at once picked up and ligated.

LEFT LUMBAR CHAIN.

The exposure of the trunk on the left
side ought to be even easier than on the right,
firstly because the vena cava is further out of the
way, being more to the right, and secondly because
The incision through the posterior parietal peritoneum on the left side, permitting elevation and retraction inwardly of the sigmoid and descending colon.

**FIG. XXXII.**

Further elevation of the parietal peritoneum, retroperitoneal layers, and large bowel on the left side, exposing the psoas muscle, the genitofemoral nerve, the abdominal aorta, and the common iliac artery previous to the exposure of the lumbar ganglia.

**FIG. XXXIII.**
the sympathetic trunk is slightly under cover of the left side of the aorta, which is readily and safely displaced a little to the right to expose it. On this side the parietal peritoneum is incised lateral to the root of the sigmoid and to the attachment of the lower part of the descending colon. (FIG. XXXII.) The sigmoid and the descending colon are displaced well to the right along with the ureter, until the psoas muscle, the aorta and its bifurcation, and the left common iliac vessels have been freely exposed. The genito-femoral nerve perforating the muscle is recognised, (FIG. XXXIII) and, internal to it, under cover of the aorta, the sympathetic trunk is exposed from the level of the fourth ganglion at the brim of the pelvis, up to the second ganglion, as on the other side. The segment of the trunk, including these three ganglia, is excised in the same way as on the other side, after systematic division of the various rami of communication. (FIG. XXXIV.) On this side there should be less risk of venous bleeding, as intervertebral venous branches of any consequence are generally absent.

It is well to keep in mind the chain of lymph nodes to either side of the vertebral column, which/
Fig. 11. Exposure and resection of the left lumbar sympathetic trunk, with the second, third, and fourth lumbar ganglia.

FIG. XXXIV.
which occupies a position very closely related to that of the sympathetic chain.

"The position of the second and third ganglia is liable to some variation. Sometimes the second ganglia is placed unusually high, and is only reached by extending the wounds upwards sufficiently to expose the lower border of the third part of the duodenum. This applies on either side, but more particularly on the right.

"The retroperitoneal incision is sutured, the abdominal viscera are replaced in their normal relations, and the abdominal wall is closed in layers in the ordinary manner".

(3) PRE-SACRAL/
FIG. XXXV.
(3). PRE-SACRAL NEURECTOMY and REMOVAL of the SYMPATHETIC FIBRES of the INFERIOR MESENTERIC PLEXUS.

These operations are carried out in cases of Hirschsprung's Disease where the dilatation reaches as far as the internal sphincter, for removal of the inferior mesenteric plexus derives the lower portion of the large intestine of sympathetic fibres, while the pre-sacral neurectomy removes the motor fibres of the internal sphincter. (FIG. XXXV.)

Pre-sacral neurectomy is performed in cases of "cord-bladder" and "pelvic causalgia". The method described is that of RANKIN & LEARMONTH, who introduced the operation in 1930. As before, the description is taken from YOUNG'S (54) article.

"The abdomen is opened through a long "para-medium incision centred on the umbilicus. A "self-retaining retractor is employed, and the "Trendelenburg position is adopted from the first. "The small bowel is packed upwards and to the right "in order to permit of free exposure, and to allow "the root of the mesentery to be drawn upwards. "The/
"The sigmoid colon is displaced to the left and slightly downwards, to expose the bifurcation of the aorta. The promontory of the sacrum is identified, and in most cases the strands of the pre-sacral nerve can be seen through the posterior parietal peritoneum, as they descend in the middle line. The peritoneum is picked up in the middle line, and is incised vertically from the sacral promontory to the origin of the inferior mesenteric artery.

"The two edges of the incision are raised, and displaced to either side. The strands of the pre-sacral nerve are not adherent to the membrane and they are easily separable from the great vessels. The pre-sacral nerve is divided below at the right border of the left common iliac vein, and it is advised that a ligature should be placed on its distal end, on account of a small artery which accompanies it. The proximal end of the divided pre-sacral nerve is raised by gentle dissection, and the branches reaching it from the fourth lumbar ganglia are divided on each side. Similarly the branches from the third lumbar ganglia immediately below the bifurcation of the aorta are divided. When the nerve has been raised still further, its lateral/
FIG. XXXVI.

FIG. XXXVII.
"lateral roots, formed by union of branches from
"the first and second lumbar ganglia, are severed,
"the middle root, however, being temporarily re-
"served if possible, to be used as a guide to the
"inter-mesenteric plexus. (FIGS. XXXVI & XXXVII).
"The trunk of the inferior mesenteric artery is now
"identified, and, by tracing the middle root of the
"pre-sacral nerve upwards, the operator reaches the
"two large principal roots of the inferior mesenteric
"plexus, (derived from the intermesenteric plexus)
"one on each side of it, and joining it 1.5 cms.
"below its origin.

"The authors advise that, if the middle
"root of the pre-sacral nerve cannot be used as a
"guide, the main parts of the inferior mesenteric
"plexus will be found at the positions of 5 o'clock
"and 7 o'clock, with reference to the origin of the
"artery. They are large and easily isolated.

"About 2.5 cms. of each are resected, and if any
"ganglionic mass is present on either, it is includ-
ed in the resected portion. Any subsidiary peri-
"arterial strands are divided. If the manipulation
"is carefully carried out, there should be no bleed-
ing of any consequence. The incision in the
"posterior/
"posterior peritoneum is closed by continuous suture
of cat-gut and the abdomen is closed in the usual
manner.

"The operation as described, may seem a
somewhat formidable one, but in fact, it is very
simple, and, in suitable cases, may be carried out
within a very few minutes".

In selected cases the operations of
ganglionectomy and ramisectomy yield most gratifying results, results which outweigh any of the bad
after effects which might result.

Criticism of the operation is levelled
at the fact that it is unjustifiable to remove the
ganglia to produce vaso-dilatation, for the removal
of such ganglia or the impulses from the central
nervous system in the case of ramisectomy, is bound
to have some deleterious effect on the patient.

GANNON (62) in 1930 from his work on
completely and partially sympathectomised animals,
(cat and dog), was able to show the fundamental
importance of the autonomic nervous system to the
mammal. His work is a striking proof of the hypo-
thesis put forward by CLAUDE BERNARD some eighty
years previously, who referred to the necessity for keeping/
keeping the fluid matrix of the internal environment constant as the most important feature in living. CANNON states the autonomic nervous system is designed to retain the internal environment of the body at a constant level and to protect the body from external and internal stimuli.

Complete removal of the sympathetic chain resulted in a 25% diminution in the work output, cessation of lactation, no liberation of glycogen from the liver, no polycythaemia during excitement, and no control over heat loss. If those animals lived the sheltered life of a laboratory animal then no mal-effects of complete removal of the sympathetic chain were obvious but, "if these animals were set free in the outer world and had to meet its requirements of struggle there would be no delivery of sugar to the blood according to need, no polycythaemia, no splanchnic vaso-constriction with consequent rise in blood pressure and faster blood flow, no great acceleration of the heart, no shifting of the circulation to benefit the contracting muscles, no secretion of adrenaline to hasten the coagulation and abolish the effects of fatigue. The deficiencies of the sympathectomised animals are clearly revealed when/
when exposed to heat or cold. If exigencies arise it is unable to preserve the constancy of its internal environment".

But such a picture cannot apply to the post-operative cases. For a widespread removal of the sympathetic ganglia is not undertaken. The most that is removed are the lumbar ganglia (2,3-4) on both or either side and the cervico-thoracic and 1st. and 2nd. thoracic ganglia. Neither the nerve supply to the adrenals nor to the liver is interfered with, and the splanchnic area is undisturbed. If those patients lose nervous control of heat loss from the limbs, exposure to external environment can be controlled by protective means, thus preventing any undue upset to the patient.

Occasionally there have been reports of muscle dystrophy following removal of the sympathetic nerves (see KURÉ and his workers who reported in one case, facial dystrophy, similar to that of progressive bulbar paralysis, following superior cervical sympathectomy) but most of the cases have referred to dystrophies in facial muscles, few to muscles affected in the arm, and none in the lower limb. In the case of J.C. (CASE V. see page 198) no signs of any muscular wasting could be found some/
some two and a half years following lumbar ganglionectomy. There is little physiological evidence to show that denervation to the sympathetic leads to wasting in muscle.

The effects of sympathectomy in a limb are:

(i) Cessation of perspiration; where the limb was moist before it now becomes dry.

(ii) Increase in the skin temperature. During the operation this is not noticeable as the anaesthetic has paralysed the sympathetics and has already caused complete dilatation. Immediately the effect of the anaesthetic passes off, the skin temperature of the sympathectomised limb remains high, between 90-95°F, while that on the other side falls to its pre-operative level, 83-86°F. This rise in skin temperature is permanent. In the case of J.C. (CASE V) the left foot, two and a half years after left lumbar ganglionectomy had been performed, was 8.6°F warmer than the right. Experimental evidence shows that the immediate vasodilatation following ganglionectomy is greater than that after a lapse of 14 to 21 days after the operation. The blood vessels redevelop a certain amount of their tone, but the remaining dilatation is great enough/
enough to allow a sufficient increase of blood to relieve the symptoms of vascular ischaemia. In the case of J.C., who was suffering from Hirschsprung's Disease, the removal of the ganglia resulted in a permanent increase of 8.6°F in the temperature of his foot. This took place in vessels in which excessive spasm was not present. If the redevelopment of tone is due to vaso-constrictors circulating in the blood and not to a nervous influence (see page 44) then in cases of excessive spasm the permanent dilatation resulting from sympathectomy will be greater than in normal persons, the lumen of the arterioles being pre-operatively much smaller in spasm than in normal vessels.

Up to the present it has been accepted that the rise in skin temperature could be taken as an accurate indication of vascular dilatation, but, as JOHNSON and his co-workers (53) have pointed out, the decrease in sweating of the sympathectomised part leads to heat conservation, and this may account if not for all, for at least, part of the increase in skin temperature. The truth of this statement has yet to be verified.

In addition to the increase in skin temperature there is a redistribution of heat. In the/
the normal person, the skin over the anterior part of the thigh is warmer by 2-2.5°F than the skin over the calf. While the foot is 2-30F colder than the calf. Following sympathectomy, in cases of vaso-spasm, the skin temperature of the thigh is only 1-20F warmer than the foot, while the calf is actually 1-20F colder. This is shown in the following table, taken from a case of Raynaud's disease, (MRS. McQ. CASE I, page 135).

**TABLE VIII.**

<table>
<thead>
<tr>
<th>TEMP.</th>
<th>PRE-OPERAT</th>
<th>POST-OPERAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left Thigh</td>
<td>93°F</td>
<td>93</td>
</tr>
<tr>
<td>Left Calf</td>
<td>85°F</td>
<td>91°F</td>
</tr>
<tr>
<td>Left 1st. Toe</td>
<td>75</td>
<td>92.3°F</td>
</tr>
</tbody>
</table>

As is to be expected the rise in temperature is most marked in the foot, but why the foot should become warmer than the calf of the leg is more difficult to understand.

There are three possibilities:-

(1)/
(1). The vaso-constrictors to the lower limb arise from 11th. to 12th. thoracic, 1st. 2nd and 4th. lumbar. The 2nd. 3rd. and 4th. lumbar are removed at operation. That will denervate all the blood vessels passing to the foot, but it may not remove the constrictors to the blood vessels in the calf. This is very unlikely, for branches of the first lumbar nerve do not innervate any part of the limb. Any neurones which pass down from the upper ganglia will be severed when the lower ganglia are removed.

(2). That in the foot there are a greater number of arterioles subcutaneously as compared with the calf.

(3). That the arterioles in the foot have a greater number of sympathetic nerves than those in the calf, and therefore the dilatation will be more marked in the vessels of the foot.

The reaction to the external environment is changed. Sensations of pain, touch and pressure are not in any way altered, but the reflex constriction to cold is diminished.

**TABLE IX** shows the reaction in a case of intermittent claudication in which the left lumbar ganglia 2:3:4 were removed.

**TABLE IX/**
### TABLE IX.

<table>
<thead>
<tr>
<th>DAYS AFTER OPERATION</th>
<th>FALL IN SKIN TEMP. OF R. FOOT FOLLOWING EXPOSURE TO TEMP. OF 65°F FOR 10 MINUTES</th>
<th>FALL IN SKIN TEMP. OF L. FOOT FOLLOWING EXPOSURE TO TEMP. OF 65°F FOR 10 MINUTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>11.5°F</td>
<td>4.2°F</td>
</tr>
<tr>
<td>7</td>
<td>9.2°F</td>
<td>2.65°F</td>
</tr>
<tr>
<td>11</td>
<td>8.6°F</td>
<td>4.8°F</td>
</tr>
<tr>
<td>18</td>
<td>7.5°F</td>
<td>4.05°F</td>
</tr>
<tr>
<td>20</td>
<td>6.1°F</td>
<td>3.8°F</td>
</tr>
<tr>
<td>27</td>
<td>10.9°F</td>
<td>4.6°F</td>
</tr>
</tbody>
</table>

### TABLE X.

Difference between the skin temperature of both feet on these six occasions were:

(a) COVERED.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>4th. day</td>
<td>3.7°F</td>
</tr>
<tr>
<td>7th. &quot;</td>
<td>4.6°F</td>
</tr>
<tr>
<td>11th. &quot;</td>
<td>4.5°F</td>
</tr>
<tr>
<td>18th. &quot;</td>
<td>2.6°F</td>
</tr>
<tr>
<td>20th. &quot;</td>
<td>6.44°F</td>
</tr>
<tr>
<td>27th. &quot;</td>
<td>4.3°F</td>
</tr>
</tbody>
</table>

(b)/
INTERMITTENT CLAUDICATION.

TIME IN MINUTES

RESPONSE TO CHANGES IN EXTERNAL ENVIRONMENT.

A. TEMP. OF FOOT IN BED.
B. TEMP. OF A FOOT IN BED.
C. TEMP. IN FOOT BATH FOR 3 MINUTES.
D. RISE IN SKIN TEMP. OF L. FOOT FOLLOWING COOLING TO 72°.

FIG. XXXVIII.
(b) UNCOVERED.

<table>
<thead>
<tr>
<th>Day</th>
<th>Temperature (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4th.</td>
<td>11.01</td>
</tr>
<tr>
<td>7th.</td>
<td>11.15</td>
</tr>
<tr>
<td>11th.</td>
<td>8.3</td>
</tr>
<tr>
<td>18th.</td>
<td>6.05</td>
</tr>
<tr>
<td>20th.</td>
<td>9.5</td>
</tr>
<tr>
<td>27th.</td>
<td>10.7</td>
</tr>
</tbody>
</table>

These tables show that on exposure to room temperature the fall in the skin temperature was much slower on the operated side as compared with the unoperated. The foot always tends to remain at a much higher temperature than that of the other side, and should the temperature of the skin be lowered, the return to its new high "normal" is much quicker than the return of the other foot.

FIG. XXXVIII shows the skin temperatures in the same case as in TABLES IX & X in the Right and Left feet following immersion of the feet in cold water (temperature 71°F) for five minutes.

In view of JOHNSON'S statement (see page 100) that the rise in temperature of the skin is due to lack of evaporation of sweat, FIG. XXXVIII, offers direct evidence against such a hypothesis.

The/
The readings were taken 28 days after the operation
(i.e.) 7 days longer than JOHNSON and his co-
workers say the dilatation of the blood vessels
lasts. It is inconceivable that within the 14
minutes over which the readings were taken that so
much evaporation of sweat took place in the right
foot that the skin temperature only rose 3.5°F,
while the skin temperature of the left foot rose
some 10°.

The shape of the curve (XA₁), and its
rapid rise to normal is more suggestive of a vascu-
lar cause than any other factor.

The results of sympathectomy in Hirsch-
sprung's Disease are discussed in CASES IV & VI.

Causalgias may be relieved by sympathec-
tomy, the greatest benefit accruing from these
arising from vascular ischaemias. This, however,
is not the only type of pain relieved. LERICHE
has shown that the residual pain which is often
present in severe injuries to the limbs, provided
it does not arise from a painful scar, can be treat-
ed successfully by peri-arterial sympathectomy.
He believes that in such conditions there is a
neuritis of the sympathetic nerves.

It/
It has been shown that the rami communi-
cantes contain sensory fibres from the posterior
nerve root. The fibres pass through the ganglia
although they do not affect any synaptic connection
with the cells within the ganglia. Ganglionectomy
and ramisectomy, however, divide those fibres and
this may be the cause of the relief of pain which
is so striking in some cases.

Perhaps the best example of relief of
pain by sympathectomy is the removal of the infe-
rior cervical sympathetic ganglia in angina pect-
oris. If the procedure is sufficiently widespread
the pain is reduced in duration and severity.
Whether this is a sound therapeutic measure is to
be doubted, for, as MACKENZIE pointed out, sympa-
thectomy in angina pectoris only relieves the pain,
but does not attack the causal factor. The pain
is a warning that the heart muscle is distressed by
over-strain and forces the patient to rest. Remove
the pain, and the patient receives no indication
that he is over-taxing his heart.

The benefits accruing from ganglionec-
tomy in such conditions as arthritis, varicose
ulcers, and trophic ulcers depend upon the in-
crease in blood supply to the parts.
CHAPTER XI.

RAYNAUD'S DISEASE.

CASE I.

Mrs. McQ.  Age 43 years.

COMPLAINT.

Blueness and pain in hands and feet for 1 year.

HISTORY.

Three or four years ago the patient noticed that the skin over both feet began "to peel like an orange", leaving a painful reddened area underneath which turned blue on exposure to the cold. When exposed to heat the blue discolouration disappeared, but the parts were very itchy. About the same time the patient noticed that her feet perspired a great deal more than usual. This was accompanied by slight pain and redness in the feet. These attacks of perspiration lasted about twelve months and then ceased.

Two years later patient experienced a tingling sensation first in the right arm passing down/
down to the fingers. Later her left arm and hand became similarly affected.

Fifteen months ago the hypothenar eminence of the left hand showed an area which was flushed when warm, but blue and painful, when cold. It has gradually spread, until the whole of the 5th finger and the tips of the remaining fingers are similarly affected. Lately the right 5th finger of the right hand has been showing similar changes.

Patient's occupation entails her hand being often in water. She is not incapacitated when working in warm water, but owing to the numbness and loss of power in her fingers she is unable to do any outside work in cold water.

EXAMINATION.

The skin of the hands shows changes in colour. There are reddish-blue areas on the skin of the palms of both hands. This is more marked in the left and especially over hypothenar eminence where skin looks definitely cyanosed. The skin is not broken. The discolouration is in the skin itself and the area is not raised above the surrounding tissues. It is sharply demarcated from the rest of the skin which shows a glazed appearance and some thickening of superficial layers.

There/
There is a decrease in local temperature in both hands.

The feet show similar changes but the cyanosis is even more marked. The areas affected are the toes both dorsal and plantar surfaces. The sole of the foot over the heads of the metatarsals and along the lateral side of the sole.

The remainder of the skin is much thickened and glazed. The dorsalis pedis and posterior tibial pulsations just palpable in both feet.

The changes in the skin are localised to the hands and feet and are not present in other parts of the body.

**DIAGNOSIS.** RAYNAUD'S DISEASE.

This patient gives a typical history of Raynaud's disease illustrating in almost every respect the definition of the condition "A paroxysmal affection of the blood vessels of the extremities, frequently symmetrical, characterised by persistent ischaemia or a passive hyperaemia which leads to disturbance of function or to loss of vitality with necrosis". (64).

The onset was typical, tingling and numbness in the extremities to be followed by a period when those/
those parts were white and cold (local syncope). This syncope continued until the parts turned blue in colour (local asphyxia). The colour returned to normal as the attack passed off, but for a period after the attack the parts were red and inflamed-looking (passive hyperaemia). While the condition at the beginning only manifested itself when the patient was cold, lately the extremities continually showed the state of local asphyxia, unless the patient took special precautions to keep the parts warm. Thus, if the hands were in hot water, the areas were red, hot and itchy, but immediately they were removed from the water and not covered with gloves the fingers became blue, cold, and painful.

The disease had progressed from an occasional hyperactivity of the vaso-constrictors to a state of permanent hyperactivity. This hyperactivity being relieved, however, when the external local environment was raised.

The causal factors in Raynaud’s disease are unknown. It is supposed to be a manifestation of a neurovegetative diasthesis being more common in women than in men and more common, although it may occur/
occur at any age, in the second and third decade. Oppenheim lays stress upon anaemia, exhaustion, and congenital narrowness of the aorta. It sometimes complicates diseases of the spinal cord such as tabes dorsalis, syringomyelia, disseminated sclerosis and tumours. There may be a congenital or a familial predisposition. Poisoning by lead, tobacco and syphilitic toxins are all possible factors. The condition has occasionally been observed after acute febrile conditions. The exciting causes are cold, mental emotions, and trauma.

Raynaud's disease is probably the best example of advanced vaso-motor neuroses which are characterised by disordered activity of the involuntary nervous system, but this hypothesis is not equivalent to saying that the involuntary nervous system is the starting point of the condition.

The cases of Raynaud's disease may be divided into two classes.

(1) Those in which no other etiological condition is present.

(2) Those in which it is a manifestation or complication of another disease (e.g.) tabes dorsalis syringomyelia.

In the first group (i.e.) the neuroses, the immediate cause of the condition is a hyperactivity of/
of the sympathetic nerves to the blood vessels of the extremities. Once this hyperactivity is established the exciting causes trauma, mental emotion, and especially cold set up an exaggerated reflex which is manifested by prolonged constriction of the peripheral arterioles of the extremity, giving local syncope, asphyxia, and should the ischaemia be sufficiently prolonged, local neurosis. This ischaemia leads to a condition of the skin known as sclerodema. Here the skin is thickened, leathery, glazed in appearance, with diminished sensibility.

The cause of the hyperactivity of the sympathetic nervous system is unknown. The conditions are called "neuroses" for, as yet, no specific pathological lesion has been described and because they tend to occur in persons of an unstable nervous temperament.

While Raynaud's disease has a very definite and typical history, no hard and fast line can be drawn between such an advanced disorder of the autonomic nervous system and lesser disorders which are characterised by flushings, congestion, angio-spasm in all its varieties, some forms of tachycardia, migraine, vertigo, universal or circumscribed/
circumscribed hyperhidrosis and gastric disorders of certain functional types.

In the case of Mrs. McQ, it is of interest to note that with the beginning of her asphyxial attacks, her feet showed excessive perspiration, a further indication of sympathetic hyperactivity.

**TREATMENT.**

In the case of Mrs. McQ, complete examination revealed no pathological disease or no possible factor such as alcohol or lead poisoning which could in any way account for the condition. Thus this was an example of Raynaud's disease of the "neurotic" type with a hyperactivity of the sympathetic nervous system. Medical treatment in such a case is purely palliative; sedatives for the pain during attacks; wrapping up the parts to prevent exposure to cold; gentle massage; luke warm baths and dry heat to the extremities. The benefits to be derived from these methods are of only very limited value and while they may reduce the severity of the condition, they do nothing towards a permanent cure. If the cause of the condition is hyperactivity of the vaso-constrictors then removal of the vaso-constrictors should result in complete disappearance of/
RAYNAUD'S DISEASE. PREOPERATIVE TESTS FOR PRO AND NSAID
RESPONSE TO LOW EXTERNAL ENVIRONMENT (Room 98°F)
MIN.
LOW EXTERNAL ENVIRONMENT AFTER SPINAL ANAESTHESIA

FIG. XXXIX.
of the symptoms. As has been explained previously removal of the sympathetic fibres to the lower extremities is most easily and surely carried out by lumbar ganglionectomy, (the 2nd., 3rd., and 4th., lumbar ganglia being removed).

Before submitting the patient to such an operation it is necessary to carry out pre-operative tests to indicate whether the operation will result in sufficient improvement to justify the risks involved.

The following tests were carried out:

(1) COLLER AND MADDOCK TEST.

Results are shown in FIG. XXXIX. and TABLE XI.

**TABLE XI.**

<table>
<thead>
<tr>
<th></th>
<th>UNCOVERED (ROOM TEM. 75°F)</th>
<th>COVERED</th>
<th>DIFFERENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>L. Foot</td>
<td>79.08°F</td>
<td>96.96°F</td>
<td>17.78°F</td>
</tr>
<tr>
<td>R. Foot</td>
<td>79.08°F</td>
<td>96.96°F</td>
<td>17.78°F</td>
</tr>
<tr>
<td>L. Arm</td>
<td>91.04°F</td>
<td>96.96°F</td>
<td>5.92°F</td>
</tr>
<tr>
<td>R. Arm</td>
<td>88.24°F</td>
<td>96.96°F</td>
<td>8.72°F</td>
</tr>
</tbody>
</table>

RIGHT/
By this test it is shown that under the influence of a high local external environment the peripheral arterioles are capable of dilating to the fullest extent and that no part of the ischaemia of the extremities is due to organic obstruction of the arteries. Therefore the disease is one of hyperactivity/

### RIGHT ARM.
- Vasomotor gradient: 3.64
- Occlusion index: 0

### LEFT ARM.
- Vasomotor gradient: 5.92
- Occlusion index: 0

### RIGHT LEG.
- Vasomotor gradient: 16.88
- Occlusion index: 0

### LEFT LEG.
- Vasomotor gradient: 16.88
- Occlusion index: 0
hyperactivity of the sympathetics, and lumbar ganglionectomy should procure a complete and lasting cure of the condition.

(2) The other tests carried out were merely corroborative and no actual temperature readings were taken.

Thus after ten minutes in a cold bath (temperature 60°F the feet were plum colour. As gradual heating of the water took place the colour began to fade giving way to hyperaemia.

By these tests it is obvious that operation will be of natural benefit raising the temperature of limbs as much as 14-17°F in the case of the legs and 5-8°F in the case of the arms.


The abdomen was opened through a left paramedian incision below the umbilicus and extending 1" above it. The peritoneum was incised and the small intestine was packed to the right side of the abdomen. The pelvic colon was then picked up and the peritoneal attachments to the posterior abdominal wall were divided. The pelvic colon was retracted towards the right side of the abdomen and gauze dissection was continued on the posterior wall of/
of the abdomen. The ureter was identified and held aside and the sympathetic trunk was isolated and followed upwards until the 2nd lumbar ganglion had been exposed. The trunk was divided above the 2nd ganglion and below the 4th ganglion and the intervening portion of tissue removed. The hypogastric nerves were identified and divided. Bleeding was controlled by packing with gauze wrung out of warm saline. The rent in the parietal peritoneum was sutured with interrupted catgut; the pelvic colon was replaced in position and the packs were removed. The abdomen was closed in layers in the usual manner without drainage.

"Pre-sacral neurectomy and lumbar ganglionectomy left".

With a spinal anaesthetic the vaso-constrictors are paralysed - full dilatation of the peripheral arterioles are obtained and the skin temperatures during operation were:

<table>
<thead>
<tr>
<th>L. foot</th>
<th>96°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>R. foot</td>
<td>96°F</td>
</tr>
<tr>
<td>Axilla</td>
<td>98.5°F</td>
</tr>
</tbody>
</table>

Following/
TEMP. OF AXILLA

POSTOPERATIVE THEORETICAL TEMP. OF L. FOOT (average)

RAYNAUD'S DISEASE

POST OPERATIVE RESULTS.

SKIN TEMP. OF R. AND L. FEET FOLLOWING REMOVAL OF 2°, 3°, AND 4° LEFT LUMBAR GANGLIA.

A. TEMP. OF L. FOOT BEFORE AND AFTER OPERATION
B. TEMP. OF FEET ON MORNING OF OPERATION
C. TEMP. OF FEET ON MORNING OF OPERATION
D. TEMP. OF FEET FOLLOWING PRE-OPERATIVE MORPH.
E. TEMP. OF FEET DURING ORATION (SPINAL ANAESTHETIC).

FIG. XL.

RAYNAUD'S DISEASE

POST OPERATIVE RECORD.

2°, 3°, AND 4° LEFT LUMBAR GANGLIA REMOVED 24 DAYS PREVIOUSLY.

RESPONSE TO CHANGES IN EXTERNAL ENVIRONMENT

A. TEMP. OF L. FOOT IN BED
B. TEMP. OF R. FOOT IN BED
C. TEMP. OF FEET BOTH FEET IN FOOT BATH (NEW ML.) FOR 5 MINUTES
D. TEMP. OF L. FOOT FOLLOWING COOLING TO 78°F.
E. TEMP. OF R. FOOT FOLLOWING COOLING TO 78°F.

FIG. XLI.
Following the operation the patient made an uninterrupted recovery and by the following day was able to appreciate herself, the rise in temperature of the left foot.

The following observations were made. The legs were uncovered as far as the knees in a room temperature of 65°F; for 10-15 minutes before readings were taken. (FIG. XL).

<table>
<thead>
<tr>
<th>DAYS AFTER OPERATIONS</th>
<th>R. LEG °F</th>
<th>L. LEG °F</th>
<th>DIFF. °F</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 hrs. after</td>
<td>90.17</td>
<td>95.71</td>
<td>5.54</td>
</tr>
<tr>
<td>4 days</td>
<td>83.74</td>
<td>92.25</td>
<td>8.51</td>
</tr>
<tr>
<td>5 days</td>
<td>86.95</td>
<td>95.6</td>
<td>8.65</td>
</tr>
<tr>
<td>7 days</td>
<td>78.68</td>
<td>95.46</td>
<td>16.89</td>
</tr>
<tr>
<td>10 days</td>
<td>75.65</td>
<td>93.55</td>
<td>17.80</td>
</tr>
</tbody>
</table>

The post-operative level as judged by the reaction to a high local environment (Coller and Maddock's Test) and spinal anaesthesia has been gained (i.e.) 92 - 96°F. Although the left leg was under the same conditions as that of the right a marked difference in local temperature was always obtained.
FIG. XLII(a) Pre-operative.

FIG. XLII(b) Post-operative.
FIG. XLIII(a) Pre-operative.

FIG. XLIII(b) Post-operative.
obtained. It is interesting to note that although the R. lumbar ganglia were not touched in any way for five days following the operation the skin temperature of the right foot remained higher than it was before the operation (86°F compared with 76.78°F).

This rise in temperature due to the general decrease of sympathetic tone which follows interference with any one part of the sympathetic nervous system was also noticed clinically in the hands. By the seventh day, however, the temperature once more had returned to the pre-operative level.

As reported elsewhere (cf. page 129) the distribution of heat in the limb changed. The temperature of the skin over the calves of the legs was 10°F higher than that of the skin of the foot previous to operation. Following the operation, however, the skin temperature of the toes of left foot compared with that of the calf was 1.3°F higher, that is there was a change of 11.3°F.

The reaction to changes in temperature is shown in FIG. XLI.

Clinically the condition of the left foot showed marked improvement as the progress notes and photographs (FIGS. XLII & XLIII) show.
FIG. XLIV. Pre-operative.

FIG. XLV. Post-operative.
14th. January. Cyanosis less-decrease in area affected. No pain when sponged with cold water.

The condition of the hands was much improved following operation. (FIGS. XLIV & XLV).
The pain was almost completely absent, the areas of cyanosis had decreased, and it was felt that the condition had become so alleviated that, for the present, cervical ganglionectomy was not justified. The patient was discharged on February 12th, 1933. She reported back in April 1933. The condition of the left foot was entirely satisfactory, having continued to improve since her discharge. Her hands however, had begun to trouble her again and she/
she wished admission in order that the condition of 
her hands might be cured.

There are several interesting features in 
this case. First by the very typical history and 
the state of the condition when the patient reported 
for treatment. The periodical attacks were no lon-
ger the outstanding feature, but now there was a 
permanent vaso-constriction leading to local asphy-
xia and cyanosis and only relieved by application 
of warmth to the parts.

Secondly the very close approximation to 
the post-operative results obtained by the pre-op-
erative tests as to the temperatures that would 
follow lumbar ganglionectomy.

Lastly the widespread diminution in the 
hyperactivity of the sympathetic tonus following 
operation. The widespread results in this case 
was only temporary, but in others it may be perma-
nent as has been shown by FRASER (38) in a case 
of Raynaud's disease of both hands in which complete 
alleviation of all the symptoms followed peri-ar-
terial sympathectomy on the left side only.
CHAPTER XII

INCIPIENT GANGRENE.

CASE II.

Mr. C.  Age 62.

Occupation Shopkeeper.

COMPLAINT

Black patch on big toe.

DURATION

4 weeks.

HISTORY.

For many years patient has suffered from varicose veins in both legs worse on right side. Six weeks ago he had an attack of phlebitis which confined him to bed. The pain in his legs became gradually worse "settling in the left big toe". Four weeks ago he notice a small blue patch appearing on pulp of the big toe. This has gradually been getting worse, until now it involves the whole of the pulp of the toe distal and posterior to the nail.

For many years patient has suffered from a/
a chronic rheumatoid-arthritis of all the small joints in his feet and hands.

EXAMINATION

The skin over both feet is hard, thickened glazed and shining. The joints show typical arthritis in a not too advanced stage - deformity slight. The 1st toe of the left foot shows a gangrenous patch which covers the whole of the distal part of the toe. It does not affect the nail. The gangrene is dry in type, but shows no reactionary rim at the periphery. The skin over the fifth metatarsal shows signs of early incipient gangrene.

No signs of gangrene on right foot.

Varicose veins present in both legs, but no phlebitis present.

Anterior tibial artery:— a pulse just palpable on right side, absent on the left.

Posterior tibial artery:— pulse palpable on right side, just palpable on left.

Radial artery palpable no beading no tortuosity.

Blood pressure slightly raised. Skin over hands shows signs of similar changes to that/
that over feet, arthritic changes also present in joints of finger.

DIAGNOSIS

The condition of the foot obviously arose from vascular ischaemia of the slowly progressive and chronic type. It was felt, however, that organic occlusion could hardly be the entire cause of the condition for conclusive evidence of a marked degree of arterio-sclerosis was not present. The condition was more advanced in the left foot than the right, for there gangrene had developed in the big toe and was threatening over the fifth metatarsal, while in the right foot no areas of incipient gangrene were present. That the condition was affecting both feet however, was evident in the state of the skin.

Scleroderma which is a very common sequela of a chronic vascular ischaemia was present in both. That the condition was ever more widespread was evident in that the skin over the hands was showing similar changes, but of a more recent development.

Before submitting the patient to an operation it was decided to apply the COLLER and MADDOCK test.
test.

The following were the results:

TABLE XIII

<table>
<thead>
<tr>
<th>TEMPERATURE</th>
<th>UNCOVERED</th>
<th>COVERED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right Foot</td>
<td>81.6°F</td>
<td>89.0°F</td>
</tr>
<tr>
<td>Left Foot</td>
<td>79.8°F</td>
<td>83.3°F</td>
</tr>
</tbody>
</table>

Occlusion Index in Right foot = 94° - 89.0°F = 4.95
Occlusion Index in Left foot = 94° - 83.3°F = 10.65
Vaso-constriction gradient in right foot = 89.0°F - 81.6°F = 7.45
Vaso-constriction gradient in left foot = 83.3°F - 79.8°F = 3.45

From these figures it is apparent that both vascular degeneration and vascular spasm is present. As was indicated clinically, the vascular degeneration is more marked in the left foot "occlusion index" = 10.65, right foot "occlusion index" 4.95 while spasm is more prominent in the right foot 7.45 as compared with 3.45 in the left foot.

From those tests it is possible to foreshadow a rise in temperature of 7.45°F in the right foot and 3.45°F in left.

This/
This rise in temperature of the right foot is quite satisfactory, but the rise of only 3.45°F in the left foot is just about the lowest limit which justifies operation.

In view of the patient's general condition ganglionectomy was felt to be too serious an operation.

**OPERATION**

On the 15th December, PROFESSOR FRASER carried out a bilateral peri-arterial sympathectomy in Scarpas' triangles.

At operation it was noticed that the femoral artery on the Right side showed a good arterial pulsation and the walls of the artery were elastic and mobile. The left femoral artery, however, showed only slight arterial pulsation, the walls were hard and friable with an increase in fibrous tissue.

The arteries were stripped of their adventitial coats for a distance of about one inch, CAMER'A'S method being employed.

The Skin temperature readings following operations were:

**TABLE XIV**
### TABLE XIV.

<table>
<thead>
<tr>
<th>TIME after OPERATION</th>
<th>RIGHT FOOT</th>
<th>LEFT FOOT</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 minutes</td>
<td>88.35°F</td>
<td>84°F</td>
</tr>
<tr>
<td>1 day</td>
<td>88.15°F</td>
<td>83.6°F</td>
</tr>
<tr>
<td>5 days</td>
<td>85.7°F</td>
<td>82.5°F</td>
</tr>
<tr>
<td>10 days</td>
<td>87.6°F</td>
<td>82.5°F</td>
</tr>
<tr>
<td>14 days</td>
<td>87.5°F</td>
<td>81.7°F</td>
</tr>
</tbody>
</table>

i.e. in the right foot there was 14 days after operation an increase of 6.9°F while in the left foot the increase in temperature was 1.85°F.

The post-operative results were 1.55°F and 1.6°F below the test results, but the operation was peri-arterial sympathectomy and not ganglionectomy.

The clinical results were very satisfactory.

The pain in the left foot cleared up within two days.

An area of demarcation appeared round the gangrenous patch on the toe and within seven days it had sloughed off leaving healthy granulation tissue which/
which gradually healed. The area of incipient gangrene disappeared entirely.

The movements of the joints were subjectively increased, so much so, that the patient expressed the desire to return at a later date to receive similar treatment for his hands. At the end of three weeks the patient was discharged very much improved. The special features of interest in this case are (1) The corroboration on operation of the clinical examination and the pre-operative test, the arterio sclerotic changes being more marked on the left side than the right. (2) The differentiation of vascular ischaemia into the two components, vascular degeneration and vascular spasm. In this case the spasm is not excessive, in the left side it is actually less than normal, but in cases where degeneration of the arterioles leads to a decrease in the blood supply to a part the relief of any spasm present in the arterioles will result in an increase in the blood supply. This will not cure the disease which is causing the vascular degeneration, but it will alleviate the symptoms, prevent the onset of gangrene and will cause an earlier sloughing off of those parts already gangrenous.

It/
It is this factor which has produced the beneficial results reported in cases of thrombo-angitis obliterans. In this condition the thrombosis of the vessels is made worse either by excessive spasm or the normal tone of the vessels. In early cases of the disease this is sufficiently marked to justify an operation, for it often delays the onset of the more serious end results, and, according to Mayo & Adson (64), actually prevents the progress of disease in 50% of cases. (3) The sloughing off of the gangrenous patch is also important and shows how sympathectomy may help in gangrene which is due to arterio-sclerosis or diabetes. In this case the patch had been present for four weeks, steadily increasing in size and showing no signs of sloughing. Seven days after the operation it separated leaving healthy granulation tissue. In cases of gangrene which are not becoming limited sympathectomy by increasing even to a very limited extent the blood flow, often causes this demarcation to occur and a greater part of the limb may be saved than, at one time, was thought possible. (4) The excellent result was obtained even although a peri-arterial sympathectomy/
sympathectomy was carried out. If such good results are obtained by this much simpler and less dangerous operation why submit cases to ganglionectomy? An analysis of results show that the results following ganglionectomy, provided the pre-operative tests indicate that it is justified, are always good; the results following peri-arterial sympathectomy on the other hand, on similar suitable cases, are not nearly so satisfactory. The uncertainty of peri-arterial sympathectomy is well illustrated in a case of bilateral erythromelalgia in a young woman of twenty four. Peri-arterial sympathectomy in the right side was carried out in September 1931 with complete relief of symptoms in that leg. When it was done on the left side some four months later the discolouration and pain were much increased, a diametrically opposite result from what was obtained previously.
CHAPTER XIII.

INTERMITTENT CLAUDICATION AND CAUSALGIA

CASE III.

D.W. Age 49. Occupation Tramway car driver.

COMPLAINT Pains in calves of leg.

DURATION 9 months.

HISTORY

Up to nine months ago patient was perfectly well. He then began to complain of a gripping cramp-like pain in the right calf which came on during exercise. It gradually increased in severity until, lately, it develops after five minutes walking. It is so severe that he has to stop and rest for five minutes before being able to proceed. During the last four months, at night in bed, the right foot becomes numb, a feeling of "pins and needles" develop and then a burning pain. He has to get up and walk about for half-an-hour to relieve this pain. Consequently he has been losing a great deal of sleep.

A/
A similar pain, but only much less severe has been developing in the left leg.

For two months he was treated medically massage, diathermy, radiant heat, locarnal injections, but without any relief of symptoms.

The last week before admission he complains of a constant pain present in the right heel even when resting.

EXAMINATION

RIGHT LEG. While at rest fibrillar contractions of muscles of the leg are seen. The skin is not glazed or thickened. There are no areas of cyanosis or other colour changes.

Painful on palpation over calf and heel.

LEFT LEG. Occasional fibrillary twitchings present. No changes in texture or colour of skin. No pain on palpation.

The right dorsalis pedis and posterior tibial pulsations were distinctly weaker than those on the left side.

Radial pulse was regular, in time and force,
force, of good volume. The arterial wall was palpable, but no beading or tortuosity present. Blood pressure 126/82.

Knee and ankle jerks, present and normal. The patient was able to walk two and a half times round the ward before pain developed. He then had to stop and rest before continuing. The muscles at this stage felt hard and contracted.

DIAGNOSIS

The diagnosis in this case is somewhat difficult. The history starts as a typical "intermittent claudication", cramp like pains developing on exertion, passing off after a short rest, and reappearing again on exercise. This continued for five months and then another symptom developed. Numbness in the leg - pins and needles, then pain which came on when in bed and was relieved if patient moved about. This is not the history of an intermittent claudication. The final stage was a constant pain in the right heel of one week's duration.

The first part of the history is that of a/
a spasm or an organic occlusion of the arterioles resulting in diminished blood to the part with the result that movement is impossible. The pain arises from an anaemia of the sensory nerve endings or the effect of metabolites on them, the metabolites being present in excess owing to the sluggish circulation. As this condition becomes more severe the attacks of claudication have an earlier onset and as the pain increases the parts become cold, white or bluish. These changes being still related to exertion. The final stage is reached with a constant pain, and a permanent change in colour in the parts affected. Gangrene may develop.

In this case four months previous to admission a second type of pain was complained of. This came on at night while at rest, associated with a feeling of numbness, but relieved on movement of the limb. No changes in the colour of the skin present. Finally one week before admission a constant pain was present, unassociated with movement neither relieved nor increased by either rest or exercise.

These last two symptoms cannot be associated with a demand for increased blood supply to the foot. They are present not in the calves where the/
the pain of intermittent claudication is usually present, but in the foot, and no associated colour changes in the skin are obvious.

Due to the hyperaesthesia peripheral neuritis has to be considered but the points against that are:-

(1) No etiological factor. Wasserman negative. No history of undue indulgence in alcohol.

(2) Knee and ankle jerks normal.
(3) No loss of sensation.
(4) No loss in muscular power when making individual movements.

These negative findings rule out peripheral neuritis.

The most reasonable diagnosis is intermittent claudication with causalgia; the causalgia arising, not in relation to the claudication, but from some unknown cause.

The cause of the intermittent claudication had to be found. Was it due to vascular degeneration or vascular spasm?

The radial artery was palpable but no beading was present. The posterior tibial and dorsalis pedis were present in the right foot, but diminished/
diminished in strength. Any degenerative changes that are present are only slight in amount and cannot account for the whole of the symptoms.

A COLLER and MADDOCK’S test was carried out with the following results:

TABLE XV.

<table>
<thead>
<tr>
<th></th>
<th>UNCOVERED</th>
<th>COVERED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right foot</td>
<td>86.8°F</td>
<td>92.1°F</td>
</tr>
<tr>
<td>Left foot</td>
<td>90.35°F</td>
<td>93.8°F</td>
</tr>
</tbody>
</table>

vaso-gradiant index R. foot = 92.1 - 86.8 = 5.5
vaso-gradiant index L. foot = 93.8 - 90.35 = 3.5
occlusion index   R. foot = 1°
occlusion index   L. foot = 0°

From these results it is shown that the intermittent claudication is due to spasmodic contraction of the arterioles and is not due to organic degeneration. The temperature of the limb while uncovered was perfectly normal during the test 86.8°F, but during the test no attack of claudication was present the limb being completely at rest with arterioles/
arterioles in normal tone. The important feature of the test was to find if the temperature of the foot would rise to between 92-94°F when covered. If it does so, then no degeneration is present, therefore, the intermittent claudication with its resultant vascular ischaemia cannot be due to degeneration and must be arising from intermittent hyperactivity of the vaso-constrictors. This being so, ganglionectionomy is justified.

This test cannot prognosticate regarding the causalgia but the removal of the ganglia and with it the sensory fibres passing through the ganglia some diminution in the pain may be expected. Of course marked relief should be obtained from the cramp-like pains of the claudication.

**OPERATION**

**PROFESSOR FRASER**

**9.2.33**

Chloroform and Ether.

The abdomen was opened through a right lower paramedian incision. The small intestine was packed off and the caecum retracted medially. The posterior peritoneum having been incised on the lateral aspect of the caecum, the connective sub-peritoneal tissue was separated until the vena cava was exposed. The genito-moral nerve was recognised and/
and the lumbar trunk was found lying medial to it. A fairly common abnormality was found in this case. The lumbar chain was placed very high up, the second lumbar ganglion lying under cover of the third part of the duodenum (page 120). The third, fourth and part of the second lumbar ganglia were removed.

The rent in the posterior peritoneum was repaired with intermitted catgut sutures. The appendix was examined and showed signs of chronic inflammation. It was consequently removed in the usual manner and the abdomen closed in layers without drainage.

"Right Lumbar Ganglionectomy-
Appendicectomy".

The patient's symptoms by the third day after operation showed improvement. The constant pain in the foot was relieved although not absent. There were no sensations of numbness or "pin and needles" and the foot felt warmer than the left.

The first time patient walked (16 days after the operation) cramp-like pains were felt in both legs. Within 3 days these had disappeared entirely and the patient was practically free of pain.
Skin temperature readings following operation were:

**TABLE XVI.**

<table>
<thead>
<tr>
<th>TIME AFTER OPERATION</th>
<th>RIGHT FOOT</th>
<th>LEFT FOOT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 day</td>
<td>93°F</td>
<td>93°F</td>
</tr>
<tr>
<td>7 days</td>
<td>91°F</td>
<td>89°F</td>
</tr>
<tr>
<td>12 days</td>
<td>91.5°F</td>
<td>86°F</td>
</tr>
<tr>
<td>17 days</td>
<td>91.2°F</td>
<td>87°F</td>
</tr>
</tbody>
</table>

The post-operative temperature of 91.2°F seventeen days after operation is only 0.9°F below that indicated by the test.

One month later the patient reported back complaining of pain in the right leg. On examination this was found to be due to a phlebitis of the right saphenous vein. He could now walk about fifteen to twenty minutes without the pain developing. The causalgia had almost entirely ceased although he had "occasional twinges". His rest had never been disturbed since he returned home. There were no symptoms arising from the left leg.

The interesting feature in this case is the/
the relief of the pain by operation. Although the sensory fibres which pass through the ganglia are relatively very few in comparison with those in the posterior nerve roots, they seem to carry some of the fibres of painful stimuli, and ganglionectomy in such cases may relieve the symptoms.

Perhaps too much importance has been laid in this case on the different types of pain. They might after all be atypical manifestations of anaemia of the sensory nerve endings due to decreased blood supply and all that the ganglionectomy did was to increase the blood supply to the parts, decrease the anaemia, and thus relieve the pain.
CHAPTER XIV.

SPASTIC DIPLEGIA.

CASE IV.

Marjorie D.  Age 12.

COMPLAINT  Difficulty in walking.
DURATION  10 years.

HISTORY.

The patient was two years old before she began to walk, and then she walked badly, staggering and often falling.

When she was three years of age both legs were operated upon and put in plaster for three months. The condition was much improved following the operation, and patient could put both heels to the ground. Six months ago, however, she noticed that she was gradually walking more and more on her right toe, and that if she attempted to place her heel on the ground she immediately lost her balance. About four and a half months ago, she also noticed that her knee was turning in.

She has no pain on walking.

PREVIOUS/
PREVIOUS HEALTH.

The patient was a premature child (labour was not difficult), and made no attempt to walk until she was over two years old. It was then noticed that she crossed her legs, when she took a step forward.

At the age of five, a bilateral lengthening of the Tendo Achilles was performed.

EXAMINATION.

Patient is a bright intelligent child with a good memory; she has no defect of speech; no fits. Apart from a very slight left-sided facial paralysis there is no sign of involvement of the cranial nerves.

ATTITUDE.

Patient stands on the toes of the right foot with the right heel off the ground, but the left foot is practically flat on the ground. Both lower limbs are adducted.

GAIT./
GAIT.

Spastic, deliberate gait, both legs being dragged, and owing to the adduction of both limbs and the double pes equinus, patient has great difficulty in walking.

UPPER LIMBS.

There is slightly increased tonicity of the left upper limb. No apparent weakness in either upper limb, the muscles acting well against resistance.

LOWER LIMBS.

Both lower limbs are adducted, and the toes are pointed. The right is slightly thinner than the left. Both limbs are markedly spastic. There is no gross muscular weakness in either limb, but owing to the pes equinus with shortening of the tendo achilles on the right side the movements at the ankle are markedly limited.

REFLEXES.

Arms. Biceps, triceps, and supinator increased, but equal on both sides.

Abdominal
Abdominal

Increased and equal in all quadrants

Knee jerks    exaggerated equal
Ankle jerks   "    "
Ankle clonus  present on both sides

Bilateral extensor plantar response.

There are no disturbances of the sensory paths.

DIAGNOSIS

Spastic diplegia.

The case is one of a typical spastic diplegia of a severe type. The deformities which have now developed lead to the greatest difficulty in walking.

The part played by the sympathetic nervous system in the genesis of spastic paralysis following a lesion of the upper motor neurone has already been fully discussed. In this case, it was decided that for comparison of the various methods of treatment that a Stoeffel's operation would be carried out on the right side, and a lumbar ganglionectomy on the left.

OPERATION/
Chloroform and Ether.

A longitudinal incision was made on the posterior aspect from popliteal space in the middle of the leg. The saphenous nerve was exposed; the two heads of the gastrocnemius were dissected and divided for a short distance. The posterior tibial nerve was exposed with its three muscular branches, one to each head of the gastrocnemius and one to the soleus. These branches were stimulated in turn with Farradic current, and a response in the respective muscles elicited. These nerves were each divided as near the entrance to the muscle as possible and a small portion of the nerve was removed. The gastrocnemius was repaired, the deep fascia sutured and the wound closed with linen thread.

A lengthening of the right tendo achilles was also performed.

3 weeks later.

A left lumbar ganglionectomy was performed the extra-peritoneal route being used. The 2nd., 3rd. and 4th. lumbar ganglia were removed.
A lengthening of the left tendo achilles was carried out 14 days later.

Following the operations the patient showed marked improvement, in both limbs the spasticity being decreased. She was discharged on the 10th. January, 1931. The walking had improved, but the right leg showed more improvement than the left. She was given instructions to continue her exercises and massage which she had been having for the previous three weeks.

She reported back three months later, and her condition is best stated in PROFESSOR FRASER'S own words previously quoted (page 75).

"I have no hesitation in saying that the results of the latter (Stoeffels operation) were infinitely better than those resulting from sympathectomy".

The results of sympathectomy in cases of spastic paralysis have been most disappointing even when it is remembered that ROYLE only advocated it as one method in treatment. It was the "best adjuvant to correction of deformities, massage, and exercises". Even as an adjuvant it has failed in the hands of all, except ROYLE and a few other workers, to produce any improvement in the condition.
CHAPTER XV.

HIRSCHSPRUNG'S DISEASE.

CASE V.

John C.  Age 12.

COMPLAINT.

Swelling of abdomen for 9 years.
Chronic constipation for 10 years.
General weakness and "lack of vitality."

HISTORY.

The labour was normal and the child healthy. During his earlier infancy he suffered from constipation. This was controlled by giving the child enemata of soap and water, always producing a large facael result. He succeeded in getting a movement of the bowels, but would go for several days without a motion. When he was aged 3½ years he became much worse. It was found impossible to get a motion of the bowels even with giving medicine, and the child would frequently go for weeks without a motion. Following this, the bowels would move unduly freely. The/
The motions were not actually like those of diarrhoea being well formed, but rather soft in consistence and always large in amount. During the period of constipation his abdomen became exceptionally swollen. Recently this has been much worse and before admission he had no motion of the bowel for a period of three months.

Appetite is good, but diminishes during the periods of constipation. No incontinence of urine.

PREVIOUS HISTORY.

At the age of 5 years (1926) patient was admitted into Ward 7 for examination. His measurement at the level of the umbilicus was then 25". The bowel was evacuated digitally and the patient received enemata daily for a period of three weeks. He was discharged with instructions regarding enemata and daily purges, but despite careful nursing his condition became gradually worse.

PHYSICAL EXAMINATION.

The child is of normal stature for his age. He has a markedly protuberant abdomen. The thorax is rather small and appears to be shortened.

The/
The abdomen is broad, bulging, and looks longer than normal. The chest is 22" in circumference immediately below the nipple line. The abdomen at the level of the umbilicus is 30". The vessels are unduly visible. The umbilicus is protuberant. The appearance of the abdomen gives the impression that the chief bulging is situated round the flanks and more especially on the left side. There is no visible peristalsis. On palpation one can feel a swelling most marked on the left side, and especially in the left iliac fossa. The tumour is tense, and can be pitted on deep pressure. The swellings appear to extend upwards along the left flank, but it cannot be detected with anything like certainty on the right side. The abdominal muscles are well developed.

BARIUM ENEMA.

Barium enema did not pass beyond the pelvi-rectal junction. A large dilated colon is partially outlined by gas.

DIAGNOSIS. HIRSCHSPRUNG'S DISEASE.
CASE VI.

Lousia, M.  Age 12 years.

COMPLAINT  Swelling in the abdomen for 5 years.

HISTORY.

Patient never remembers being well, (as parents never visited the child whose home is in Glasgow, while she has been in hospital, her early history is unobtainable). Five years ago she was sent to Liberton Cottage Hospital as an incurable case of osteosarcoma of the sacrum. On finding there was no progressive deterioration in health, the diagnosis was reviewed and patient sent in to see Professor Fraser.

PHYSICAL EXAMINATION.

Patient is a small unhealthy looking girl. There is some atrophy of the right side of the face and an abnormality of growth in the right ear.

SPINE.

Scoliosis concavity to the right of the cervical and dorsal spine.

X-RAY/
X-RAY REPORT.

Appearance of spina fida of cervical vertebrae. Apparent synostosis of upper 4 or 5 dorsal vertebrae with wedged shaped appearance of 5th. Dorsal scoliosis with concavity to the right. Malformation and position of the upper four or five ribs on both sides.

HAND.

Double thumb on right hand.

ABDOMEN.

INSPECTION. There is a large rounded swelling projecting into the abdomen from below. It reaches to above the umbilicus, but the whole abdomen is more prominent than normal.

PALPATION. The swelling is tense, but not hard in consistence; it cannot be pitted on deep pressure. It appears to arise from the pelvis. There is incontinence of urine and faeces. Barium enema showed that the large intestine as far as the internal anal sphincter was enormously dilated. This was carried out after the rectum was emptied (under ether anaesthesia) of a great amount of hard scybillous masses.

DIAGNOSIS/
DIAGNOSIS.  

HIRSCHSPRUNG'S DISEASE.

CASES V & VI are typical examples of Hirschsprung's Disease. The cause of this condition is now considered to be a result of the imperfect balance between the parasympathetic and sympathetic nerves of the large intestine.

The condition found on post-morten examination and at operation is a markedly hypertrophied and dilated large intestine. The dilation and hypertrophy extends either from the pelvi-rectal junction or the internal anal sphincter along the intestine for a varying distance, sometimes only affecting as far as the pelvic colon, or sometimes involving the whole of the large intestine. The small intestine is never involved. Microscopic examination reveals a hypertrophy in the muscle fibres, and an actual increase in their number, both the longitudinal and circular layers being affected. If the condition is longstanding the marked dilatation leads to atrophy of the muscles and degeneration of Auerbach's and Meissner's plexuses. It was this that led to the feeling that the original cause was a degeneration or absence of the intrinsic nerves to the large intestine. The degenera-
degeneration of these nerves, however, is not the primary cause, but the result of the marked dilatation which always occurs. The fault lies in the extrinsic nerves.

The condition which may arise from, or have as, an etiological factor, an imbalance of the extrinsic nerves of the alimentary canal are:

(I) CONGENITAL HYPERTROPHIES OF INFANCY.

(a) Congenital Pyloric Stenosis (spasm and arrhythmia).
(b) Congenital ileal Hypertrophies (spasm and arrhythmia).
(c) Hirschsprung's Disease. (spasm and arrhythmia).

(II) ARRHYTHMIAS OF EARLY CHILDHOOD.

Intussusception (arrhythmia).

(III) DISORDERS OF ADULT LIFE.

(a) Achalasia of the cardiac sphincter.
(b) Caecal spasm.
(c) The vague abdominal symptoms which are not typical of any recognisable lesion.

The extrinsic and intrinsic nerves are essential for a proper regulation of the gut movements. If however, the extrinsic nerves are cut, after/
after a period, varying in different animals, the gut resumes its normal function, and relaxation, contraction and peristalsis are once more performed in balance with one another. In the individual, however, it is essential that both should be present for extrinsic nerves have a controlling influence over the intrinsic nerves, and relate their activities in co-ordination with the rest of the body.

DISTRIBUTION.

The distribution of the sympathetic and parasympathetic nerves in the alimentary canal is important, in relation to the diseases which may arise from their disfunction. Unfortunately the anatomists cannot agree on this point. The following table shows the difference between the two schools.

TABLE
TABLE XVII.

<table>
<thead>
<tr>
<th>POTTINGER.</th>
<th>KUNTZ.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oesophagus</td>
<td>Vagus</td>
</tr>
<tr>
<td>Cardiac sph.</td>
<td>&quot;</td>
</tr>
<tr>
<td>Stomach</td>
<td>&quot;</td>
</tr>
<tr>
<td>Pylorus</td>
<td>Vagus &amp; sympathetic</td>
</tr>
<tr>
<td>Small intestine</td>
<td>&quot;</td>
</tr>
<tr>
<td>Ileo-caecal</td>
<td>Sympathetic</td>
</tr>
<tr>
<td>Caecum up to descending colon</td>
<td>&quot;</td>
</tr>
<tr>
<td>Rectum and anal canal</td>
<td>and nervi erigentes</td>
</tr>
</tbody>
</table>

FUNCTION.

The stimulation of the sympathetic causes relaxation of the plain muscle in the alimentary wall, but closure of the sphincters.

Stimulation of the para-sympathetic causes contraction of the muscle and relaxation of the sphincters.

Thus, both sympathetic and parasympathetic contain/
contain excitor and inhibitor fibres.

PATHOLOGY.

The late Dr. JOHN THOMSON of EDINBURGH was the first to suggest that the congenital pyloric stenosis seen in children was not due to an idiopathic hypertrophy of the longitudinal muscular layer of the pylorus, but was consequent upon a spasm of the pylorus arising from an imperfect balance of involuntary nerves of the stomach.

HURST (66) in 1919 reviewing the movements of the intestinal canal suggested that congenital dilatation of the oesophagus or cardio-spasm was an example of inco-ordination of relaxation and contraction of the cardiac sphincter and should therefore be called achalasia.

FRASER (67) in 1926 & 1927 reviewing the relationship between the involuntary nervous system and certain types of diseases of the alimentary canal was the first to postulate a tenable theory of the causation of those, and to correlate on a similar basis several allied conditions, the etiology of which was quite unknown.

The disorders which may affect the extrinsic nerves are:-

(1)/
At a. and Oa symptoms of the enteric system ascribable to the involuntary nervous system appear.

**FIG. XLVIII.**

(by courtesy of Prof. Fraser)
(1) An abnormal stimulus to contract (spasm)
(2) A non-relaxion of contraction (achalasia)
(3) Inhibition of relaxation (atony).
(4) Irregularity of the co-ordination of relaxation and contraction. (arhythmia).

FRASER postulates that of the two primary stimuli, excitation and inhibition, inhibition develops after excitation. If there be any delay in the development of the inhibition, then the balance between the two is upset, and it is this that is the primary etiological factor in the development of these conditions.

If such is the case, then these diseases should manifest themselves in the early years of life, before perfect co-ordination can occur, or before functional education overcomes the lack in balance. (FIG. XLVIII).

The hypertrophies of infancies are usually manifest from birth. The intussusceptions show the greatest age incidence between 6 months and 2 years. It is only when we come to the disorders of adult life that the age incidence fails.

But this imbalance in the nervous mechanism, while being the only etiological factor in the/
the hypertrophies of infancies, is not the complete story in the others. The imbalance is greatest in this group, and therefore makes itself evident from the earliest days.

In the arrhythmias of early childhood it requires a predisposing cause to bring out the underlying imbalance. In intussusception the site is almost invariably in the region of the ileo-caecal sphincter. The muscles of the small intestine show three movements:

(1) A segmentation movement.

(2) True peristalsis.

(3) Peristaltic rush.

The last is probably not a physiological movement, but a reaction to some abnormal stimulus. If this movement is preceded by a wave of inhibition nothing occurs apart from the exceedingly rapid expulsion of the intestinal contents. If however, when the wave reaches the ileo-caecal region, and inhibition does not occur, due to a lack of inhibition of the existing contraction, then intussusception begins.

In the genesis of the peristaltic rush, SMLTZER & AUBR could reproduce it in rabbits by intravenous injections of substances designed to produce/
produce simultaneously, stimulation and inhibition of intestinal activity. The most effective pair was ergot and calcium chloride.

Failure of rotation and a loose mesentery are mechanical reasons for intussusception occurring. But as FRASER suggests, given an imperfectly balanced mechanism and some dietetic error which results in absorption of stimulant and depressant factors, then the stage is set for the development of an intussusception. The age incidence of intussusception is 6 months to 2 years, the period when the child first receives other than its perfect food milk.

The autonomic nervous system and the endocrine glands control the vegetative life of the body. Upset of one, will cause upset of the other. During the menopause the whole endocrine system undergoes a change, should there be an imbalance of the autonomic nervous system which up to the menopause was insufficiently great to manifest itself, then this disturbance will accentuate the imbalance and produce symptoms.

On POTTINGER'S distribution of the extrinsic nerves to the alimentary canal all the above/
above conditions could be explained on the lines of arrhythmias (i.e.) and inco-ordination between the parasympathetic and sympathetic and, therefore, the site of the "lesion" is where there is a meeting of the two different types of nerves.

(1) Congenital pyloric stenosis occurs where the sympathetic first enervates the pylorus and meets a purely parasympathetic distribution.

(2) The vagus ceases at, or near, the ileo-caecal sphincter, and from there onwards there is a purely sympathetic distribution, here congenital ileal-hypertrophy and intussusception occur.

(3) The nervi-erigentes innervate the large intestine from O'Beirne's sphincter to the anal canal, and it is at O'Beirne's sphincter that Hirschsprung's Disease (in many cases) occurs.

It does not explain however, achalasia of the cardiac sphincter, nor the cases of Hirschsprung which extend as far as the internal anal sphincter. Moreover, on Kuntz's distribution this explanation fails entirely, for the alimentary canal according to Kuntz receives a double innervation throughout its entire length. True, the sympathetic fibres to the oesophagus appear to have no functional ability, and achalasia might be explained on the grounds of inco-ordination.
inco-ordination between the vagus supplying the oesophagus and the vagus and sympathetic which supplies the cardiac sphincter, but then congenital pyloric stenosis cannot be explained. The vagus distribution does not stop at the ileo-caecal sphincter, but passes as far as the descending colon, so congenital ileal-hypertrophy and intus-susception cannot be explained.

It is not necessary, however, to postulate that these conditions arise at the site of either the commencement or cessation of the double innervation.

If we return once more to the function of the parasympathetic we see that it has two functions

1) Contraction of the ordinary muscle.

2) Inhibition of the sphincteric muscles.

If the inhibition factor has failed to develop then contraction at the site of the sphincters will be excessive, and it is this failure of parasympathetic inhibition which is the primary cause in this condition. What anatomical evidence is there for supposing that failure of inhibition of the parasympathetic should develop rather than some other disturbance of the function of the nerves.

The/
Fig. XLIX.

Diagram showing the relation of the diseases, arising from imbalance of the autonomic nervous system, to the sphincters of the alimentary canal.
The parasympathetic nervous system is later in phylogenetic development than the sympathetic nervous system. Therefore a developmental error is more likely to affect the parasympathetic system rather than the sympathetic.

Inhibition is secondary to excitation in development, and therefore any delay or upset in development will be more marked on inhibition than on excitation.

If such is the case, what are the sites where the inco-ordination will be most marked? At the sphincters. If a list is made of the conditions enumerated above and the site where the lesions occur there is one factor common to all.

**TABLE XVIII (FIG. XLIX).**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Sphincter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Achalasia</td>
<td>Cardiac sphincter</td>
</tr>
<tr>
<td>Congenital pyloric Stenosis.</td>
<td>at and around the pylorus.</td>
</tr>
<tr>
<td>Congenital Ileal Hypertrophy.</td>
<td>around the iléo-caecal sphincter.</td>
</tr>
<tr>
<td>Intussusception.</td>
<td>Iléo-caecal sphincter.</td>
</tr>
<tr>
<td>Hirschsprung's</td>
<td>(1) O'Beirne's sphincter.</td>
</tr>
<tr>
<td></td>
<td>(2) Internal anal sphincter.</td>
</tr>
</tbody>
</table>
The common feature is that they all occur at, or near, sphincteric areas where it is essential that inhibition should occur if the contents of the intestines are to be expelled.

But does this theory fit in with the upsets of adult life? In these conditions the imbalance between the two sets of stimuli, excitation and inhibition, is of the least degree. There has been sufficient co-ordination to carry these persons through the first period of life, childhood, puberty, and early adult life without any symptoms arising. At the menopause the upset in the endocrine system is marked throughout the whole body, but it affects most of all the other systems, the autonomic nervous system - with which it is so closely related - and especially so if that already has any degree of inco-ordination. This further "lesion" of the autonomic nervous system increases the imbalance affecting the inhibition side. Thus, degrees of achalasias and chronic constipation may become manifest. The diathesis towards these conditions has always been present. It only required this change in life to make the inco-ordination sufficiently marked to produce symptoms.

The prognoses of the conditions relate closely/
closely to the degree of inco-ordination present. Those of early infancy, where the inco-ordination is most marked, require surgical interference, if life is to be preserved. Those of adult life, the danger to life is small; they usually subside, if sufficient time is given for endocrine upset to readjust itself on a new basis.

The spincters normally are always in a state of contracture (i.e.) there is a high sympathetic tonus at the spincteric areas. A peristaltic wave occurs. This wave of contraction is preceded by a wave of inhibition which is of sufficiently great intensity to overcome the sympathetic tonus of the spincters. The spincter relaxes and the contents of the proximal loop of gut pass into the distal. In cases where the inhibition has not developed sufficiently it has not sufficient intensity to overcome the sympathetic tonus, the spincter does not relax and the contents are forced back into the proximal loop. A peristaltic wave again arises and again the spincter fails to relax. The gut proximal to the spincter is thus working against a force greater than itself. The contents of the gut increases, the number of peristaltic waves increase in an endeavour to expel the increasing contents/
THOMSON states that "the muscle is hypertrophied because from an early period in its development it has been worried into overgrowth by constantly recurring over action, such as would result from even a slight degree of habitual incoordination ....".

"We have the knowledge which JOHN HUNTER first gave us that the tendency of hypertrophy as the result of repeated forcible contraction is peculiarly well marked in involuntary muscle". (67)

The continuance of this hypertrophy and dilatation depends upon the fact that the sympathetic tone is higher than the parasympathetic. If the sympathetic nerves could be removed partially then a decrease in tone would take place sufficient to allow the congenitally weakened inhibitory stimulus to overcome it. In this way the coordination could be overcome.

[ Although it is nowhere so misleading, as in work on the movements of the intestines to put too much weight on experimental evidence, it is perhaps of significance to note, that CARLSON in 1922/
1922 was able to show that in rabbits, cats and dogs, stimulation of the vagus, when the cardiac sphincter was relaxed, resulted, not in further relaxation, but in contraction; when the cardiac sphincter was closed stimulation of the vagus resulted in relaxation. That is to say, if, for any reason, the cardiac sphincters were normally in a state of relaxation, the passage of a bolus of food, instead of causing further relaxation, would result in closure of the sphincter.]

The congenital iléo-hypertrophies in time gradually cure themselves. For congenital pyloric stenosis longitudinal incision of the hypertrophied muscle leads to a cure. For uncomplicated intussusception usually reduction of the intussusception is all that is necessary, and it is only for Hirschsprung's Disease that actual interference with the sympathetic (the true physiological operation) is carried out.

These pathological conditions do not occur in animals and the first observation made on the effect of removal of the sympathetic nerves to the large intestine was by ROYLE (45) in 1924.
195a.

**Fig. 91.**—Cat B. Pre-operative appearance.

**Fig. 93.**—Cat B. Fifteen weeks after operation.
on his first cases of spastic diplegia. Where these cases suffered from chronic constipation, the removal of the lumbar ganglia usually resulted in a marked improvement of the mobility of the lower bowel. It only required corroborative evidence of Wade (68) Adson & Judd (69) to introduce lumbar ganglionectomy in cases of Hirschsprung’s Disease as the most rational line of treatment.

The first and only piece of experimental work which has been done on the development of Hirschsprung’s Disease was carried out by Adson & Aird (70) in 1932. Working on cats they resected on both sides the nervi erigentes leaving intact the sympathetic supply to the lower bowel. In five animals within 3 weeks a massive dilatation of the large intestine developed. (FIGS. L & LI) By their operation they had caused inco-ordination between the normal movements of the duct and a condition comparable with Hirschsprung’s Disease had resulted.

In addition, the animals developed a loss of power to empty the bladder resulting in megabladder. The significance of this will be referred to later.

Whether a bilateral sympathectomy should be carried out or not has been much discussed, but the results after removal of the left lumbar ganglia 2, 3 and 4 have been as satisfactory as those after the bilateral excision.
On opening the abdomen a greatly dilated bowel was presented at the wound. The distention reached as far up as the splenic flexure, involved the descending pelvic colon, and the first part of the rectum. The lower part of the rectum and the anal canal were normal. The caecum, ascending and transverse colon were not distended.

The intestines were packed off. The posterior peritoneum incised, the left sympathetic chain dissected out and the 2nd, 3rd, and 4th. lumbar ganglia removed.

The rent in the posterior peritoneum was repaired and the abdomen closed in layers in the usual manner.

"Left lumbar ganglionectomy".

PROGRESS.

For eighteen days after the operation the bowels only moved with soap and water enemata. After that they moved with the administration of liquid paraffin and cascara, the motions becoming more frequent up to the time of discharge. The abdomen/
FIG. LII(a). Flatus distension.

FIG. LII(b). Faecal distension.

FIG. LIII. Post-operative Result.
abdomen became less distended, the measurements being:

<table>
<thead>
<tr>
<th></th>
<th>On admission.</th>
<th>at the umbilicus</th>
<th>20 days after operation.</th>
<th>34 days after operation.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>30&quot;</td>
<td>25 1/4&quot;</td>
<td>24 1/2&quot;</td>
</tr>
</tbody>
</table>

The week before being discharged (29-34 days after operation) the bowels were moving on an average of two out of every three days and on several days twice.

At the end of this time the paraffin was stopped and instruction was given to take a purge on any day he did not have a motion. Measurement at the umbilicus was 23 1/4".

Five months after the operation he reported again. He was now completely free of all symptoms. There was a marked improvement in his general condition and his mental abilities had much increased. The bowels were moving regularly every day, a purge being very seldom necessary.

(FIGS. LII & LIII).

He reported two years later. General condition still showing the same improvement.
Regular motions every day, a purge seldom necessary.
The temperature of the left foot was 8-9°F higher
than that of the right. He complains of no disabi-
licity in the left leg. There were no signs of wast-
ing in the muscles.

The interesting features are:

(1) the interval of 18 days between the opera-
tion and the commencement of defaec-
tion and the rapid progress made, af-
ter this became established.

(2) The localisation of the distension in
the region between the splenic flexure
and O’Regan’s sphincter.

(3) The permanent increase in skin tempera-
ture of 8-9°F. No signs of inter-
ference with the trophic functions
either in the abdomen or in the leg.

CASE VI/
In this case there was a very marked degree of distension which passed beyond O'Beirne's sphincter and involved the large intestine as far as the internal anal sphincter.

The left lumbar ganglia 2nd, 3rd, and 4th, were removed by the trans-peritoneal route.

It was noticed that at operation the bladder was much enlarged and slightly hypertrophied, megabladder being present.

The rent in the posterior peritoneum was repaired and the abdomen closed in the usual manner.

Following operation the progress for six weeks was very good when she was discharged to Liberton Hospital. The bowels at first required enemata (13 within twelve days) and a twice daily dose of 1/2 drs. liquid paraffin to obtain a regular motion. After that, for the next twenty five days, the regular daily motion was obtained with only two/
FIG. LIV. Pre-operative.

FIG. LV. Post-operative.
two enemata and ii drs. paraffin, twice daily. The motions were well formed and of normal colour. There was no incontinence of faeces.

The urinary incontinence was still present, but this also showed some improvement and could be practically controlled by pituitrin and strychnine.

The most marked improvement, however, was in her general condition. Her colour improved, her vitality increased, she became very interested in her surroundings and more contented with hospital life. (FIG. LIII & LIV)

She was readmitted three months later with a history of gradually increasing difficulty in getting the bowels to move. She had been receiving a purgative regularly, but had had no enemata for the last month. The swelling in the abdomen was again apparent.

The bowel was manually evacuated under a light anaesthesia and, thereafter, patient received enemata twice weekly in addition to cascara. Following her discharge she remained perfectly well on a weekly enema and syrup of figs daily for over six months when manual evacuation had once more to be carried out.
It was decided then to put her on the waiting list for further treatment.

Although this was another case of Hirschsprung's disease it differed in one important feature from Case V., in that the inco-ordination was at the internal anal sphincter.

Cases of Hirschsprung Disease have to be divided into two groups:

(1) those in which the error lies at O'Beirne's sphincter.
(2) those in which the error lies at the internal anal sphincter.

In the first, lumbar ganglionectomy will relieve the case completely. In the second, lumbar ganglionectomy will help but not cure, for the lower part of the large intestine receives its sympathetic nerves from the pre-sacral nerve.

The pre-sacral nerve is made up of sympathetic nerves from two sources:

(1) Connections from the 1st, 2nd, and 3rd, and perhaps the 4th, lumbar ganglia of both sides.
(2) From the intermesenteric plexus on the abdominal aorta.

Such being the case removal of the left lumbar chain only removes a of the fibres of the sympathetic nerves of the rectum and anal canal.

To
To overcome this difficulty and to remove only the sympathetic nerves to the intestine, RANKIN & LEARMO ath in 1930 introduced a new technique. The sympathetic nerves to the pelvic colon, rectum and anal canal pass by two routes:

(1) Inferior mesenteric nerves.
(2) Pre-sacral nerve.

RANKIN & LEARMTH advise the removal of the pre-sacral nerve and a stripping off of the nerves surrounding the inferior mesenteric artery as described on page 121.

There is one warning and that is following pre-sacral neurectomy ejaculation is interfered with. This is an important contra-indication, as Hirschsprung's disease is more common in the male than in the female.

It is interesting to note that in this case the relation between the megacolon and megabladder. DOTT previously reported three cases of these conditions being present and ADAMSON & AIRD (70) found that one of the greatest difficulties in keeping their animals alive after the removal of the nervierigentes was the retention which developed. This was overcome, however, by destroying.
destroying the internal sphincter by over stretching it.

While the operation did not result in a complete relief of symptoms the patient was very much relieved.

The change for the better in the general condition was very marked indeed; while the bowels with careful attention and only occasional enemata could be kept clear of inspissated faeces for about five months.

The incontinence of faeces which was really an incontinent overflow had completely disappeared, and the gastric-colic reflex was being established.

The incontinence of the urine, also an overflow, showed some improvement and is now only troubling her at night.

It is intended that on her re-admission pre-sacral neurectomy should be performed.
SUMMARY.

The six cases which I have chosen illustrate the five main groups in which sympathectomy has been attempted:

I. Vasospasm.
II. Spasm as a factor in the development and progress of the disease.
III. Causalgia.
IV. Inco-ordination in intestinal movements.
V. Spastic diplegia.

As a summary to the position of surgery in relationship to the autonomic nervous system I should like to quote PROFESSOR FRASER (38) "... "it is my own impression that the indications for the operation are more strictly limited than we at one time imagined; but, if that is so, we can claim that its benefits are exerted upon conditions which hitherto were either beyond the aid of surgical intervention or were treated by mutilating, unsatisfactory and often fatal procedures. Sympathectomy may be described as a physiological operation; and, applied"
applied under appropriate conditions, its effects are invariably beneficial and sometimes dramatic.

Speaking generally we may say that sympathectomy achieves two things; it relieves the contraction of non-stripped muscle and it prevents the transmission of pain impulses, if these originate in the structures innervated by the sympathetic nerves.
ACKNOWLEDGMENTS.

All the cases have been treated in Wards 7 & 8 Royal Infirmary, Edinburgh, and I have to thank PROFESSOR FRASER for allowing me to use the records of Cases I, II, III, IV, and VI, and MR. MERCER for Case V.

The majority of the illustrations are from the Laboratory of Clinical Surgery Department, including FIGS. XLII to XLV, and I have to thank PROFESSOR FRASER for their use.

FIGS. L - LI are reproduced by permission of W.A.D. ADAMSON, F.R.C.S., Ed., and are taken from his article in the British Journal of Surgery 1932.
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