THE MODERN HEALTH BOOKS

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NERVES, MASTER-SYSTEM OF THE BODY

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BY

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"*and my firm nerves shall never tremble*"
MACBETH III, 4

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To

MY WIFE

WHOSE COURAGE AND ENCOURAGEMENT
HAVE MADE THIS BOOK POSSIBLE

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EDITOR'S INTRODUCTION TO THE MODERN HEALTH BOOKS

THE general attitude towards Health, in this country, has changed perceptibly during the last fifty years. Scientific analysis of the factors determining health and the increasing recognition that many of them are within human control have been responsible for the change. Passive acceptance has given way to active interest and to a conviction that the conditions of health, so far as they depend on the efforts of the individual, or of the community, should be regulated to the best advantage.

This general impulse towards a healthier state of life is of immense value, but the driving force must be directed: we must know what we want. Practical aims must be based on scientific facts; but facts as distinct from theories and notions are not easy to come by. The Modern Health Books are designed to bring within the reach of every one the latest expert opinions on the chief problems of health. They will help the reader not only to live a healthy life himself, but to form a right judgment on all those questions which affect the health of the community. The subjects to be dealt with are not only important; they are of fascinating interest.

People speak of their "nerves" being affected or of their friends suffering from "nerves", without having the faintest idea of what the nervous system is. This little book is intended to explain *where* the nervous system is, *what* it is, and what it should not be allowed to attempt.

D. F.-H.

CHAPTER I

WHERE AND WHAT THE NERVOUS SYSTEM IS

THE nervous system is the one system in the body of which we can never get even a glimpse. The muscular system we know, for the "flesh" we eat is muscle; the bony system we know, for most of us have seen a skeleton; we know something about the heart and blood-vessels, for we can feel the pulse; we know something, sometimes too much, about the digestive system; but the nervous system is at all times completely hidden from our view.

We can perceive muscles acting under the skin; but the nervous system—brain and spinal cord—is altogether shut up inside the skull and in the vertebral column or "backbone". The interior of the skull communicates with the interior of the so-called "joints" of the backbone, really a series of small, irregular bones (vertebræ) which, united by very strong ligaments, constitute the vertebral column.

The brain (cerebrum) and the cerebellum are inside the skull; the spinal cord occupies the interior of the vertebral column.

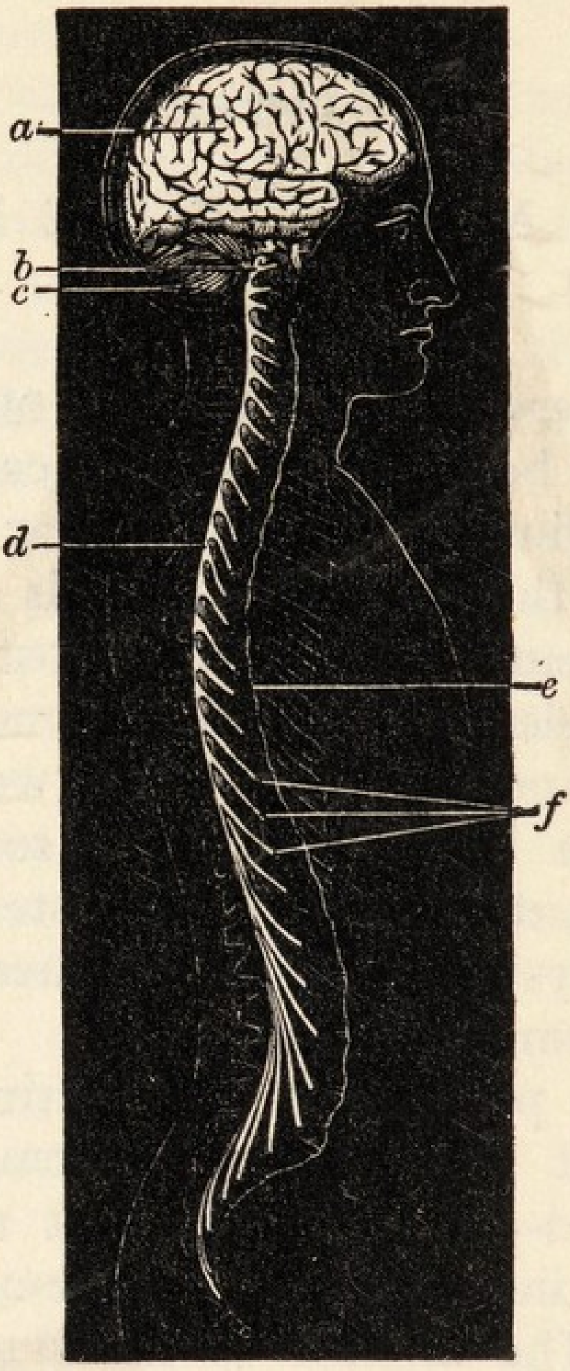

FIG. 1.—The Central Nervous System from the Right. *a*, the convolutions of the right cerebral hemisphere; *b*, the cerebellum; *c*, the commencement of the spinal cord (Bulb) in the neck; *d*, the spinal cord in the back; *f*, the roots of the spinal nerves cut short.

(From M'Kendrick's *Elementary Human Physiology*.)

The enlarged upper end of the spinal cord which unites the cord below to the brain above is called the Bulb or Medulla Oblongata:

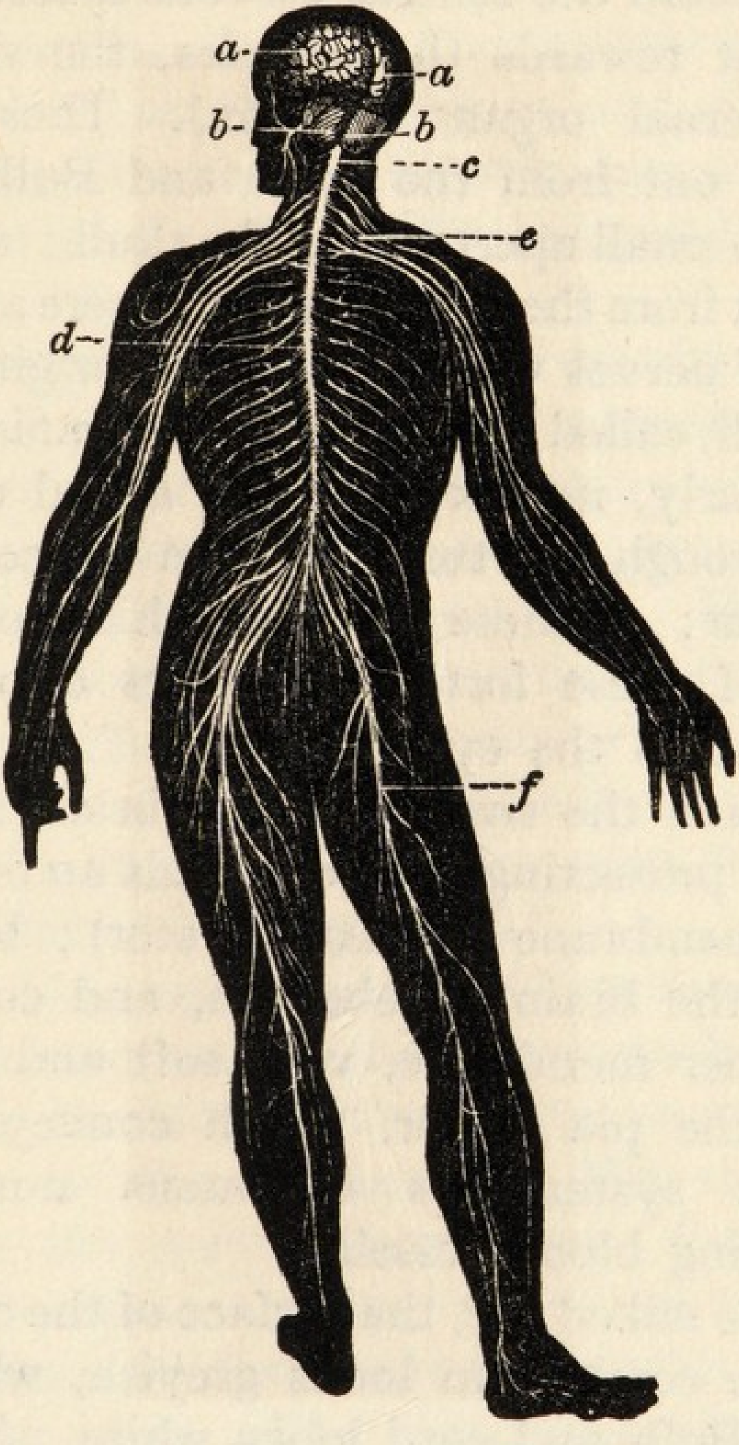

FIG. 2.—View of the Nerves of the Body from the Back.
a, b, c, d, as in Fig. 1; *e,* nerves supplying the arm; *f,* the great sciatic nerve in the thigh.
(From M'Kendrick's *Elementary Human Physiology.*)

these structures are referred to as the Central Nervous System.

This system is symmetrical about a mid-plane: it has a right and a left half. At intervals from the central nervous system nerves pass out towards the muscles, the skin, and the internal organs (viscera). Those nerves passing out from the brain and Bulb emerge through small apertures in the skull; no nerves pass out from the cerebellum. There are twelve pairs of nerves which have their origins within the skull, called on that account cranial nerves.

Similarly, nerves leave the spinal cord and pass through apertures between the contiguous vertebræ: of these there are thirty-one pairs. None of these forty-three pairs of nerves is apparent to the eye.

Between the surface of the brain and cord and the protecting bone one finds an extremely tough membrane (the dura mater); but clinging to the brain, cerebellum, and cord there is another membrane, very soft and delicate, called the pia mater, which conveys to the nervous system its enormous number of nourishing blood-vessels.

To the naked eye, the surface of the cerebrum and the cerebellum looks greyish, while that of the Bulb and cord looks white. Thus the surface of the former is said to be composed of "grey matter", that of the latter of "white matter".

If we sliced the central nervous system down the middle, we should find that in the brain, the white matter was underneath the grey, whereas in the Bulb and cord the white matter is on the surface and the grey matter is inside. The surface of the cerebrum and the cerebellum is all wrinkled exactly like a walnut inside its shell; the shell corresponds to the skull.

At a very early stage in the development of the human brain, the surface is smooth; but as age advances, it becomes more and more folded, so that the area of the grey matter becomes considerably increased. The cerebrum is a double organ, each half being called a cerebral hemisphere: similarly the cerebellum has a right and a left hemisphere. The Bulb and cord together may be called "The Central Nervous Axis".

The naked eye cannot tell us much more about the nervous system than we have now learned; for further information we must have recourse to the microscope. We shall first examine the nerves themselves. On cutting down to expose a nerve, we notice that it is rather like a tendon, for both are white, tough, glistening cords. The ancient Greeks in fact confused tendons or sinews with nerves and called them all *neura*, the word that gives us our modern technical term for a nerve, "neuron".

The largest nerve in the body, the great sciatic in the thigh, is about as thick as a man's thumb; the others vary in size down to mere threads.

If we cut out a short piece of nerve and tear it to pieces with a couple of needles, we can make out under the microscope an immense number of very long, very narrow, opaque, whitish threads. Each of these is a nerve-fibre. We call them "microscopic"; but that description applies only to their width, for their length may be one, two, or even three feet. Since the nerves for muscles extend all the way from the spinal cord to the remotest muscle, the nerve to the muscles of the great toe could easily be three feet long in a man of six feet.

In order to make out any more of the structure of a nerve-fibre, we require to put the nerve through a long series of chemical processes known as "fixing and staining", before it can be cut into slices thin enough for microscopic examination. When this has been done, we see that each fibre consists of a minute cylinder the centre of which is occupied by a strand of delicate nerve-protoplasm (the axis-cylinder process) surrounded by a sheath of fatty material (the medullary sheath) outside of which there is a second but extremely thin sheath called the neurilemma. Fig. 3 shows these appearances in cross-section and in length.

The central strand is the true conducting substance, and the fatty sheath outside is a pro-

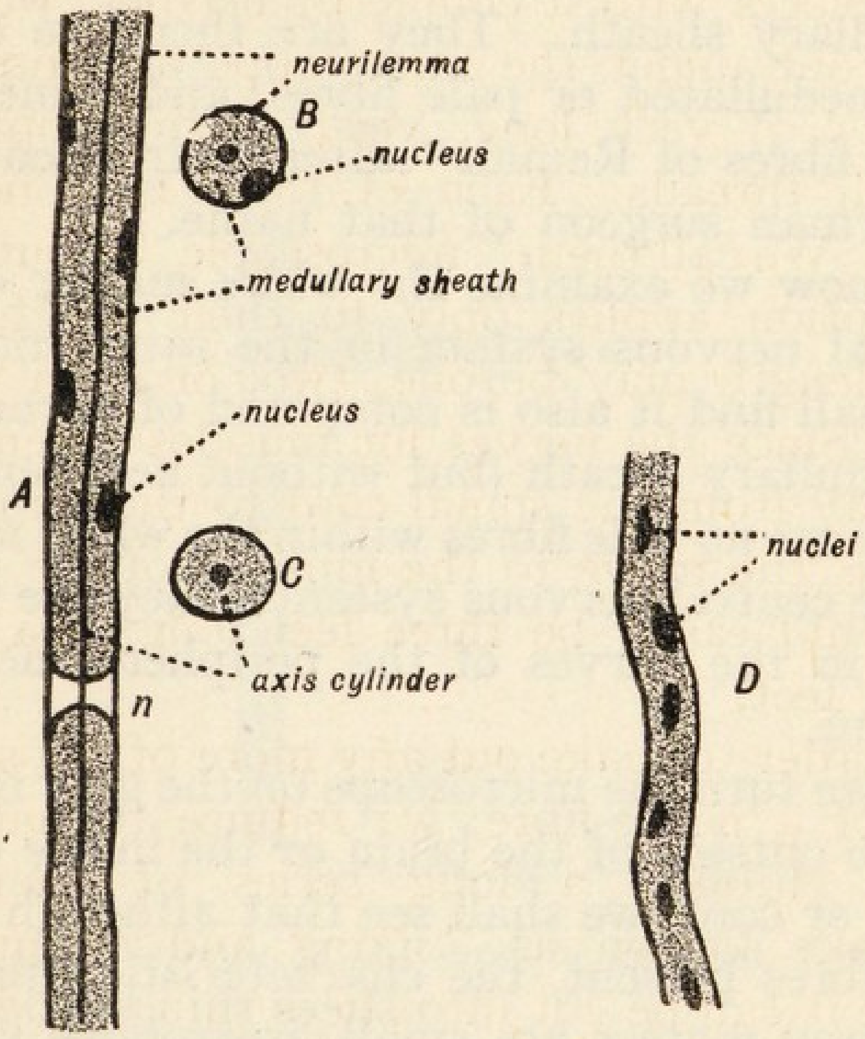

FIG. 3.—Nerve Fibres (Highly Magnified).

A, Medullated fibre, longitudinal view.
B, Medullated fibre, transverse view.
C, White fibre from central nervous system, transverse section.
D, Non-medullated fibre, longitudinal view.
n, Node, or place where medullary sheath is interrupted.

tective and nutritive structure. These fibres are called medullated fibres on account of their possessing this medullary sheath. They are also called "white" fibres from their colour *en masse*.

Not all the fibres of a mixed * nerve are white or medullated; some, on the contrary, are pale, translucent ribbons which have no medullary sheath. They are therefore called non-medullated or pale fibres, and sometimes "the fibres of Remak" after their discoverer, a German surgeon of that name.

If now we examine the white matter of the central nervous system in the same manner, we shall find it also is composed of fibres with a medullary sheath (but without neurilemma). There are no pale fibres within the white matter of the central nervous system: they are found only in the nerves of the peripheral nervous system.

If we turn the microscope on the grey matter of the outside of the brain or the inside of the Bulb or cord, we shall see that although there are fibres present, the characteristic things in the grey matter are small, irregularly shaped bodies which are called *nerve-cells*. Some are globular, some spindle-shaped, some star-shaped, some pyramidal,—of all shapes, in fact. Though so varied in form, they all agree in possessing a small central body called the nucleus, and in giving rise to one conducting

* A mixed nerve is one which contains both sensory fibres and motor fibres.

process, the axis-cylinder process or neuraxone. Each nerve-cell gives rise to *one* such process, which some little distance from this cell of

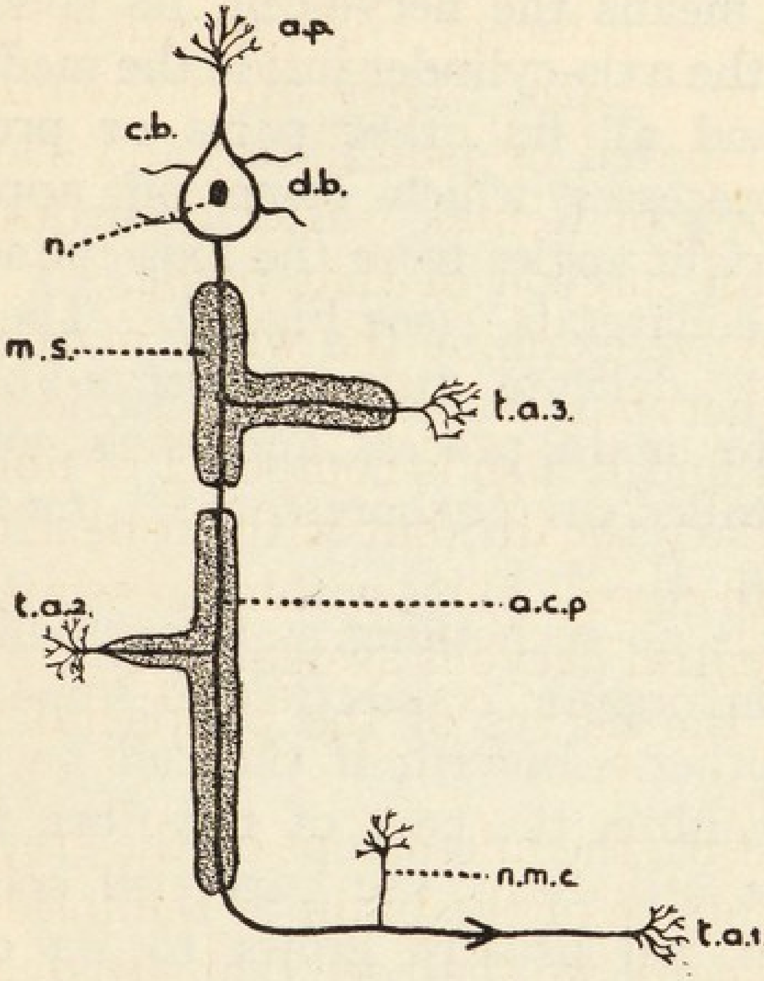

FIG. 4.—Diagram of a Complete Efferent Neurone.

c.b., Cell-body, with nucleus, *n.*
d.b., Dendrites of the body.
a.p., Apical process.
a.c.p., Axis-cylinder process (neuraxone).
m.s., Medullary sheath.
t.a.1, Terminal arborescence of neuraxone.
n.m.c., Non-medullated collateral.
t.a.2 and 3, Terminal arborescences of medullated collaterals.

The arrow shows the direction of impulses.

origin is found to have acquired a medullary sheath (*m.s.*, Fig. 4).

The nerve-cell and the nerve-fibre, once supposed to be quite independent structures, are now known to be two parts of a single structure which formerly had no name. The term " neurone " has been suggested for it. The neurone means the nerve-cell, its conducting process, the axis-cylinder inside the medullated nerve, and all its other parts or processes. Those processes which come off approximately at right angles from the axis-cylinder are called " collaterals " (see Fig. 4). The much-branched, delicate tuft of nerve-fibrils in which the main process and each collateral ends is called an " arborescence " (*t.a.*1, *t.a.*2, *t.a.*3, Fig. 4).

There is no such thing as a nerve-fibre not related in organic connection to some nerve-cell or other. Indeed, if the cell be cut off from the fibre, the part of the fibre severed from the cell dies; the part still connected with the cell usually grows to its original length. This dying of the part of the fibre severed from its cell of origin is called " Wallerian degeneration " after Dr. A. Waller who discovered it in 1850.

The stump or central end grows again because it is still part of the nucleated cell, it being a law amongst living things that only that portion of the divided cell which contains the nucleus can live and reproduce the rest of its body. The axis-cylinder of a nerve is a process of the nerve-cell. A nerve-fibre unrelated to a nerve-cell would be like a railway line that began in no station and went to no station—it would not be the slightest use.

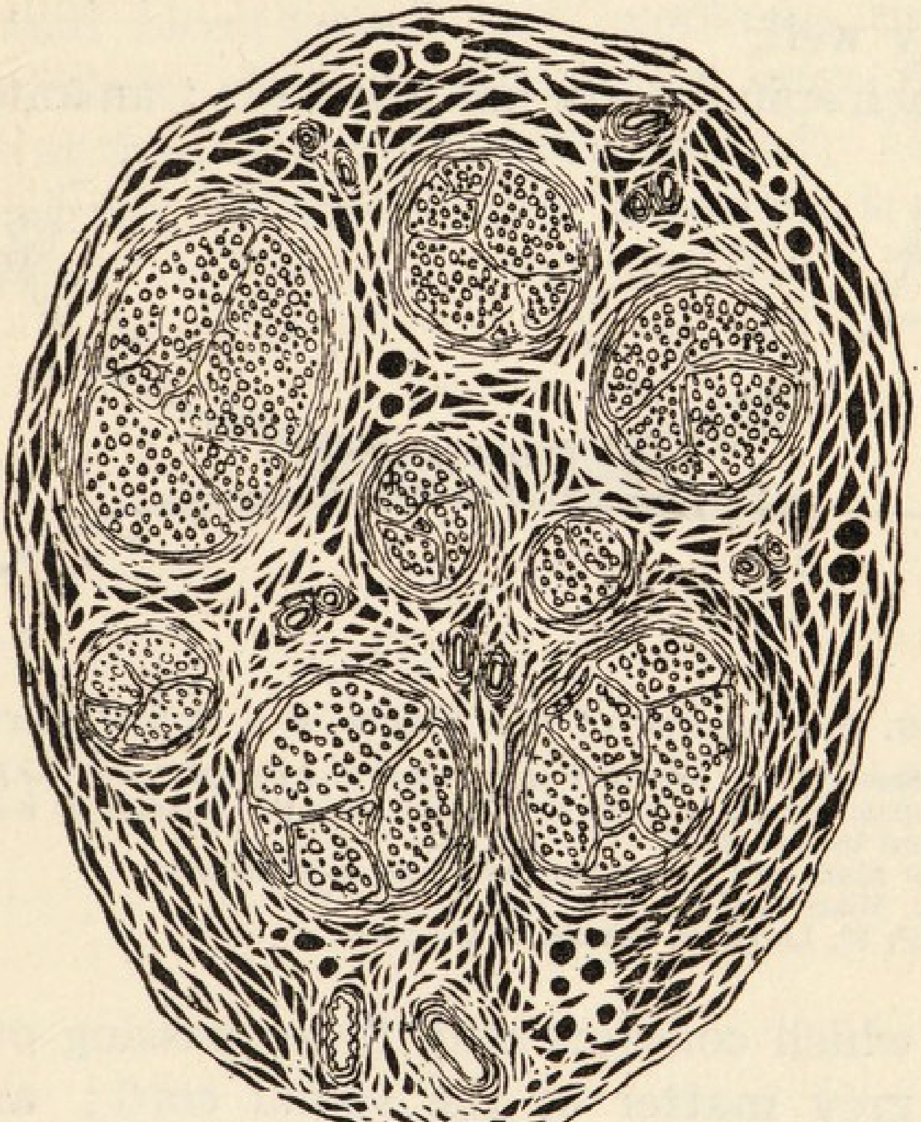

FIG. 5.—Transverse Section of the Large Nerve Trunk, showing its resemblance to an Electric Cable.

Medullated fibres when cut across and magnified in the microscope suggest very strongly the appearance of an electric cable. The axis-cylinders correspond to the wires, the medullary sheaths to the gutta-percha or other insulating material. That the medullary sheath is not a structure indispensable to the conduction of impulses, is made clear by the fact that the non-medullated nerves conduct impulses perfectly well.

Each spinal nerve has two roots: an anterior

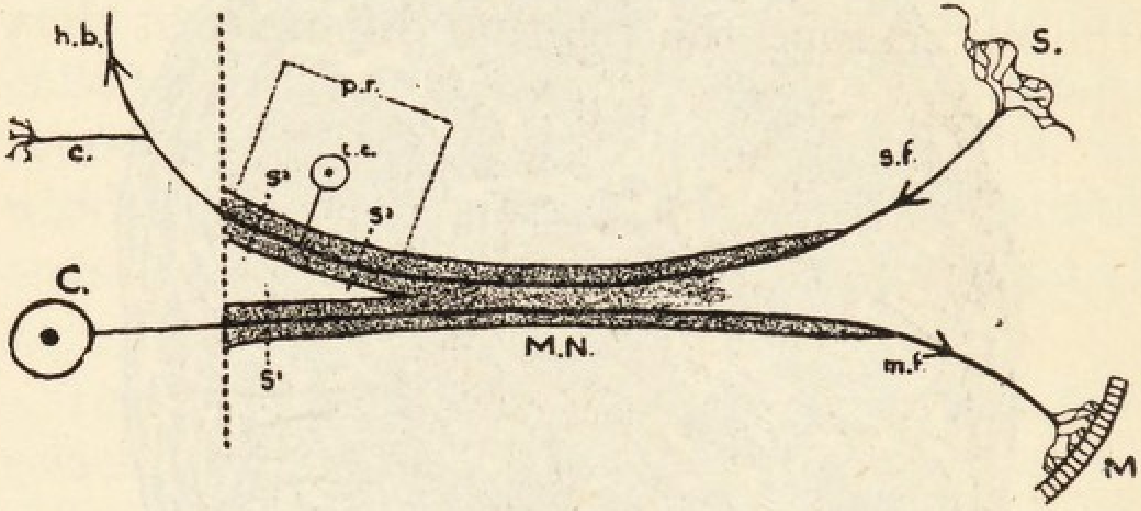

FIG. 6.—Scheme of two Roots of a Spinal Nerve.

s.f., Sensory fibre, arising in skin, passes into posterior root (*p.r.*), which has trophic cell (*t.c.*): it divides, in the cord, into a collateral (*c.*) and a headward branch (*h.b.*).
Motor fibres (*m.f.*) leave the cord in an anterior root.
M.N., Mixed nerve.
S^1, S^2, S^3, Levels of sections of the roots.

one which contains only fibres passing out of the grey matter of the spinal cord; and a posterior one made up of fibres which are entering the grey matter of the cord. It is usual to speak of the roots as the motor and the sensory respectively.

The blood-supply to the nervous system is exceedingly important; some parts of that system never rest in the sense of sleeping, and even the parts that do sleep need blood in them all that time to carry off their waste products. Everything is designed to make certain that the blood-supply to the grey matter of the brain shall not be interfered with. The supply of small blood-vessels and capillaries to the grey matter is very abundant, very much more so than that to the white matter. Under the microscope the relative difference is very striking.

CHAPTER II

A GENERAL IDEA OF HOW THE NERVOUS SYSTEM WORKS

THE Nervous System is the master system; as seen under the microscope it is the most complicated system in the body. Compared with it, muscles, heart, blood-vessels, and glands are very simple.

It is a well-recognized "law" among living things, that the more complicated the structure of the organ, the more complex is the function that organ performs. Since the nervous system is so elaborate in its finer details, we should be prepared to learn that it is the most specialized system in the body.

Virtually no portion of the body is outside the influence of the nervous system; practically everywhere there are nerves; nerves go from all parts into the central nervous system, and others go from the central nervous system to all parts. This does not, of course, mean that we are conscious of all parts—that is quite another matter.

For instance, if we take muscle, which, so far as bulk and weight are concerned, is the most abundant tissue, we find that the muscle is supplied with motor nerves, nerves to make the muscle move, as well as with nerves of a sensory character.

Many years of study have shown us that all the nerves of the body may be classified in two great groups—those which have their origin in the central nervous system and go out to the periphery, for which the general name of "efferent" is used; and those which arise in some tissue or organ and pass inwards to end in the central nervous system, for which the general name of "afferent" is used. Literally, efferent means carrying from or out of, and afferent carrying towards or into, impulses being understood.

But if all nerves are either going into or coming out of the central nervous system, it is clear that there must be places in that system where the former end and the latter begin; such places are called nerve-centres.

A centre is a group of nerve-cells from which nerve-fibres go and to which other fibres come: no centre can have fibres of only one class. A centre is like a bank; money is coming into it all the time, and money is going out of it all the time; a bank which received without paying out, or paid out without receiving, would be a fiasco.

Just as money is taken into and out of a bank, so nerve-impulses are taken into and out of the central nervous system.

A nerve-impulse is a state of activity travelling in a nerve; and a nerve, or at least its axis-cylinder, is a living, elongated conductor for the purpose of conveying nerve-impulses into or out of the nervous system. In nerves there is nothing else than impulses; nerve-centres deal only with impulses.

A simple experiment will show us what we mean by a nerve-impulse, although in the nature of things the impulse cannot be seen. Let us kill a frog and dissect out intact from the back of the leg the large muscle with the nerve (sciatic) that supplies it. If now, by means of an appropriate electrical apparatus, we give the nerve a single shock at the end farthest from the muscle, we shall find that the muscle makes one "contraction" or twitch. If we pinch the nerve at the far end, the muscle again twitches; if we put a chemical irritant, e.g. salt, on the nerve, the muscle also twitches; and finally, if we touch the nerve with a hot rod, the same activity in the muscle is produced.

All these things, the electric shock, the pinching, the chemical irritants, and the heat, are called *stimuli*, and the twitching of the muscle is called the *response*.

Now it is evident, if stimulation occurs at one end of the nerve and the response at the other, that *something* must have travelled from the one end of the bit of nerve to the other end in order that the muscle could be affected; this *something* is called the *nerve-impulse*. Evidently an active state has descended the nerve, and, falling on the muscle, has acted as a stimulus to it, because it has contracted.

The nerve-impulse is a state of molecular disturbance aroused in the nerve, in this case, by the stimulus, and able to travel to and affect the affectable tissue—in this case the muscle—at the other end of the nerve.

Such an excitable tissue is called an "effector"—since it effects something, in this case movement.

We should note that no matter how varied was the kind of stimulus, the response of the muscle was always the same—a twitch or a succession of twitches.

From this at once we conclude that no matter what is the nature of the stimulus—electricity, pressure, chemical irritation, heat—the disturbance in the nerve is always the same, for it causes always the same result in the muscle: stimuli are manifold, the nerve-impulse is one.

The conduction of nerve-impulses by nerves may be illustrated by a very simple experiment due to Tyndall: in a shallow wooden groove you place a row of a dozen marbles, taking care that they are all touching. Then, placing your finger on number one, you roll a loose marble sharply at number one, when you notice that number twelve rolls smartly away along the groove. Evidently there has been propagated from marble to marble the state of shock that was given to number one, for number twelve rolls away; but number twelve was not struck, and nothing apparently has been done to marbles two to eleven inclusive. By the unaided eye, you cannot see any propagated disturbance in the row of marbles, yet we must believe that something travelled through them. In exactly the same way, although we cannot see it, we must believe that a state of excitement travels through the living nerve.

Now we cannot be wrong in supposing that while the nerve was an intact structure in the living frog, extending from the grey matter of the spinal cord to the muscles of its leg, whenever the frog wanted to jump, impulses were sent down from a centre in the cord through the nerve to the muscles of jumping. We infer that impulses are emitted in this condition of the normal activity of the muscle, because the muscle twitches only when impulses reach it, and impulses are the result of the application of every known kind of stimulus.

We have, however, a very delicate instrument whereby we can detect the passage of nerve-impulses; it is known as the galvanometer. It records impulses by means of the electric disturbances which they induce. If a nerve be connected with this instrument, and the far end of the nerve be stimulated in any manner, then for each stimulus there is a movement in the galvanometer which can be

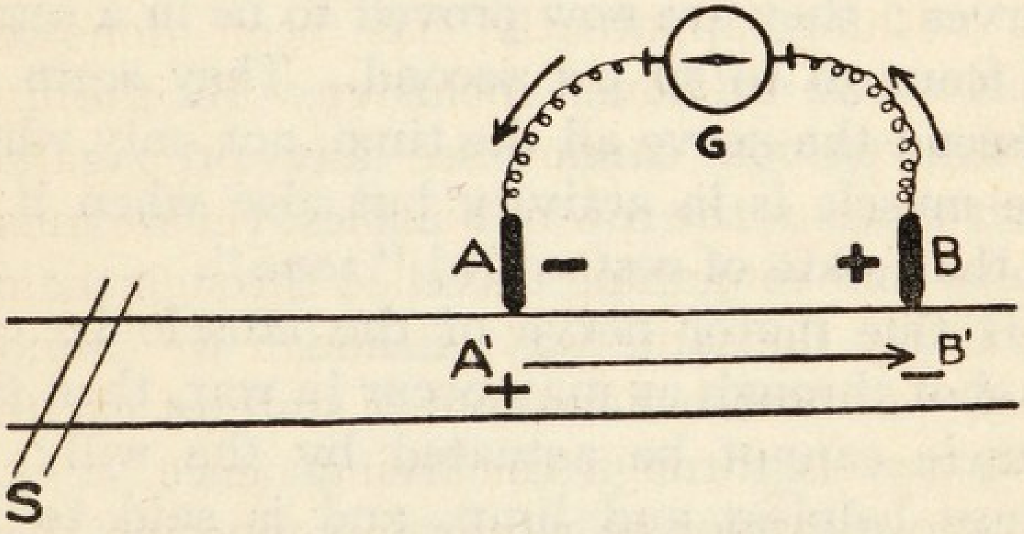

FIG. 7.—Galvanometer on a Nerve.

Current of action runs in nerve from A′ to B′, and outside through galvanometer from B to A. B is a positive, A a negative pole. A′ corresponds to the positive plate, B′ to the negative plate of a battery. S, stimulating electrodes.

photographed, indicating the passage of an electric current.

We have every reason to believe that this evolution of electric current in the nerve is the visible accompaniment of the invisible impulse. We give the name of "artificial" to the stimuli we have used; but clearly there must be normal or physiological stimuli in the intact motor nerve, in order to have given rise to the normal impulses which reach the muscle in the voluntary activities of the animal. These normal or physiological stimuli can only have arisen in the nerve-cells whence the nerve came.

One of the most recent researches in the physiology of nerves deals with the photographing of these very impulses in musculo-motor nerves; they are now proved to be in a series of from 50 to 70 per second. They seem to descend the nerve all the time, not only when the muscle is in activity but also when it is in that state of rest called "tone".

If this motor nerve of the muscle be cut or shot through as may occur in war, then the muscle cannot be actuated by the will; it hangs helpless and limp, and is said to be paralysed. Unless it is passively exercised by being massaged or electrified, it will waste away and become watery and weak.

Besides muscles, the heart, blood-vessels, glands, the stomach and intestine, the reproductive organs, the muscles in the eye are all innervated by motor nerves.

The other great division of nerves in our bodies is that which conveys impulses from all parts into the central nervous system. These are the nerves whereby we have our various sensations of touch, heat and cold, light, sound, pain, and muscular sensation. These ingoing nerves convey impulses just as truly as do the outgoing.

That they do so is proved by the electrical method applied just as for motor nerves.

If a sensory nerve be cut, the part supplied by it loses sensation wholly or in part because the sensory impulses can no longer reach the brain which is the only seat of sensory perception.

There are very few parts of the body which are not provided with these ingoing nerves; indeed it is believed that there are really more of them than of the outgoing in the mixed nerves. A "mixed" nerve is one which has afferent as well as efferent fibres in it. Some nerves, such as those from the eye, ear, nose, and the tongue, are exclusively sensory. A few, such as the nerve to the muscles of the tongue, are purely motor.

A part not supplied by nerves has neither sensation nor pain. Take the case of the horse being shod at the forge; the blacksmith burns the hoof with the hot metal and then drives nails into the hoof to keep the shoe in position. But the horse suffers no pain because there are no nerves in that part of the hoof. Similarly we can cut our nails or hairs without pain as there are no nerves at the extremities of these structures. In the disease leprosy, in which the nerves of the fingers and toes die, sensations are lost in these parts.

Not all ingoing nerves are sensory; from some organs of the body, e.g. heart and blood-vessels, impulses arise which do not normally arouse consciousness, or only do so when something has gone wrong with the parts in question. Thus in healthy conditions we have no sensations from the beating heart; but in angina pectoris the pain is terrific. We shall return to this point later.

The first notion we should have, then, of the nervous system is that of one vast system of fibres arising at all points of the periphery and ending in centres of the central system, and of another vast system of fibres arising in these cell-masses and ending in all the various organs and tissues which make up the body itself.

Over these nerve-fibres impulses are continually passing into and out of the nervous system.

It is interesting to note that the sensory or ingoing paths are ready for function some time before the outgoing; it has been ascertained that those parts of the infant's brain we call sensory are ready some little time before those we call motor. The principle that sensory impressions must precede motor in the training of the nervous system is nowadays regarded as of immense practical importance in education.

The nervous system is like a number of railway lines all running into and out of a great city. The up lines correspond to the sensory nerves; the down lines to the motor. The great termini correspond to the various centres in the nervous system. All day long trains from the country are pouring their passengers on to the arrival platforms; and all day long down trains are carrying theirs into the country. The arrival platforms are sensory centres, the departure platforms are motor centres; the trains with their passengers are the nerve-impulses. All sorts of impulses are poured into centres and there rearrange themselves, just as all sorts of passengers are poured into a station and depart on all kinds of business and on various occupations.

It is the business of the railway company to provide for and supervise this continual flow of trains into and out of the terminus. The company attends to the needs of the country both as regards up trains and down trains. Similarly the nervous system attends to the needs of the body; it sends out impulses to all parts of it and receives messages from all parts. That is called *innervation.*

The officials in the station and its offices are the nerve-cells ; they are receiving trains and despatching them all day. The nerve-cells are receiving impulses, modifying them and despatching them all the time ; this is innervation. The nervous system not only superintends the innervation of the body, it also is the means whereby one part of the body can influence some other.

Let us suppose that it is necessary for one organ, e.g. the stomach, to have some more blood ; the stomach is provided with nerve-fibres whereby it can call upon a centre in the Bulb the purpose of which is to maintain the calibre of the blood-vessels in a state of moderate closure. The stomach sends up a message to this centre, and in consequence the centre lets go somewhat its hold on the vessels so that they now accommodate much more blood than previously. This was what the stomach wanted so as to provide its glands with more blood in digestion. In the language of the telephone, the stomach "called up" the centre for maintaining the tone of its blood-vessels, and requested it to innervate these a little less vigorously.

If one subscriber, A, wants to communicate with another, B, he has to "ring up the central" even if he lives next door. The blood-vessels of the stomach are quite close to the glands of the stomach, but the glands cannot command the blood-vessels to do anything except through the intermediation of the nervous system; so the impulses travel all the way from the stomach to the Bulb and back again to carry this out.

The "central" is the nerve-centre; the wire from A's house to the central is a sensory nerve, the wire from the central to B's house a motor nerve.

The nervous system is the great system of inter-communication between any two parts of the body, however distant; this communication between different parts of the body is the most rapid method there is, much more rapid, for instance, than through the blood-stream. The blood indeed does carry nourishment and heat from one place to another, but that method is extremely slow compared with the rapidity of action of the nervous system. The blood may take several seconds to travel a distance which could be bridged by the nerve-impulses in a few tenths of a second.

But the railway organization and the telephone exchange are not the only things which the nervous system resembles. The similarities between an army and the nervous system are numerous. There is in the army what is called a chain of commands which extends from general head-quarters down to the men of the rank and file. The men of the regiment receive their orders and are drilled from time to time in order that they may be ready "on the word of command" to perform some action with rapidity and precision. The soldiers, we may say, correspond to the muscles which are kept in a tightened-up state, in a state of tension, in virtue of which they are ready at a moment's notice to twitch when impulses impinge on them.

The commands are the nerve-impulses, and the accurate movements performed by the well-drilled soldiers are the activities of the muscles themselves.

The soldiers are attended to by their officers and by head-quarters, by persons in authority who correspond to nerve-centres innervating muscles and other tissues. The officers look after the welfare of the men; they see they are fed, clothed, exercised, and drilled. The drilling and the giving of orders correspond to innervation. The men are kept up to the mark by the words of command; but these commands give them no strength to fight; that is given by their food, by the commissariat.

The innervation of muscles means keeping them taut—"tonic"—ready for instant action; it is not feeding them. The feeding, the nourishing of the muscles comes through their blood-supply, as the feeding of the soldiers comes from the canteen.

The words of command confer no power to march or to fight; but they put the men into the best condition for utilizing the food which they have obtained. The food is provided, and the men must help themselves to it and make the best use of it.

The guaranteed food-supply of the army is analogous to the "trophism" of muscles and other tissues. When the motor nerve of a muscle is cut, the muscle soon wastes away, becomes flabby, watery, and weak, although it still has its blood-supply. In the absence of its innervation, it does not seem able to make use of its potential nourishment; it becomes "atrophic", as the exact term is. Trophism is the name given to that normal state in which a tissue, by means of its innervation, is enabled to take up nourishment and so perform its functions. This healthy condition is said to be its "trophic" state, and the motor nerve is called its "trophic nerve".

There is a further analogy between the nervous system and the organization of an army: just as all the officers are not of equal rank, so all centres are not of equal functional value. There are subordinate officers and subordinate centres. As subordinate officers receive commands from their seniors, so do subordinate centres from higher ones.

Except in very special circumstances, junior officers do not have to show initiative, they carry out orders from higher ranks ; so there are centres which do not originate impulses but are merely centres subordinate functionally to others above them.

" High " and " low " as regards centres are quite relative terms, but one meaning attached to them is that the former direct and control the latter.

Finally there is another sense in which " high " and " low " are applied to centres ; namely, whether they possess consciousness or not.

Centres which have to do with sensations, emotions, the will, memory, reasoning, etc., are higher than those in which consciousness is not involved at all, such as those for the maintenance of muscular tone, the breathing, the heart-beat, the diameter of blood-vessels, and for the trophism of various secreting glands.

A speech centre is immensely " higher " than one for keeping up the tone of the sphincter muscle closing the orifice of an internal organ : the centres are not all on a functional equality. The centres of the nervous system are co-operating, functional units, but there are grades of their importance. The nervous system is not a socialistic congress, it is an assembly where several ranks are recognized.

CHAPTER III

THE PORTALS OF ENTRY INTO THE NERVOUS SYSTEM

THE nervous system not only forms the means of communication between different parts of the body; it is the only system whereby we receive communications from the world around us.

The senses are the avenues of approach to the person. We have sense-organs, sensory nerves, and sensory centres devoted to nothing else than receiving impressions from our environment. Without senses we should have no knowledge either of the world in space and time or even of our own bodily organs; the mind would have no content, for sensations are the raw material of thought.

We have many more than the Five Senses recognized in earlier times; modern physiological research, aided especially by the microscope, has discovered as many more.

The old five are seeing, hearing, smelling, tasting, and touching; but we now recognize the senses of heat, of cold, of pressure, of muscles, of orientation (our position in space), and of pain.

A " new " sense is discovered when by the microscope we discover a form of " end-organ " not previously known to exist. But by psychological analysis we may discover a sense, as when we find that in vision we have three varieties of seeing, namely, the sense of mere luminosity, which we can have through the closed eyelids, the sense of outline, and the sense of colour.

The sense of colour (chromæsthesia) may be absent wholly or in part, as in colour-blind people, and yet their perceptions of luminosity and form remain perfect. If, then, we count the sense of sight as triple, this gives us thirteen senses instead of five.

The history of the discovery of the muscular sense is instructive. A hundred years ago Charles Bell, in a paper to the Royal Society (1826), spoke of " a sense of condition of the muscle communicated to the brain ". This " sense of condition " of a muscle is, of course, " the muscular sense ". About twenty-five years ago the end-organs of this muscular sense were, with the help of the microscope, discovered to be spindle-shaped bodies embedded between the muscular fibres. It was soon proved that nerves going into the nervous system originated in these sensory muscle-spindles.

Later still, workers with the microscope found end-organs upon tendons and ligaments, so that the notion grew up that these organs as well as muscle cooperated in producing sensations which accompanied movement round joints. The muscular sense is often therefore called the sense of movement (kinæsthesia).

These thirteen are the External or Special Senses; they do not include the Internal Senses, much vaguer forms of sensation related to states of the internal organs (or viscera), such as hunger, thirst, air, sex, and fatigue.

What exactly is a sensation? What is a sense-organ? The first question is psychological, the second anatomical.

A sensation is a form of awareness of some exhibition of energy in the outer world or of some change of condition in a bodily organ or tissue.

A sense-organ or end-organ of sense is that particular kind of tissue which is specialized to receive the stimulation of a form of energy and to originate impulses in the nerve to which it is related. The general term now applied to these microscopic structures which are the functional intermediaries between the environment and the sensory nerves is *receptor*.

Each kind of end-organ is specialized to respond to one kind of energy only, as, for instance, light waves for the receptors in the eye, sound waves for those in the ears, odoriferous particles for the end-organs in the nose, and so forth.

On the physical side, then, we must have for any one sense

1. A specific peripheral apparatus ; all those known as yet are of microscopic dimensions.
2. An afferent nerve commencing in intimate relationship to the end-organs and passing inwards to some definite region of the central nervous system, which region is
3. A sensory centre always found in the cerebrum.

All these three factors are needed to cooperate in order to produce a definite kind of sensation in the mind of a conscious percipient. A study of the eye will give us an example of what is meant. The part of the eye which receives the focussed rays of light, called the retina, is composed of thousands of receptors, the rods and cones. These are so named from their shape, although the cones are more like minute " nine-pins ". Related to the bases or attached ends of these end-organs are the origins of the nerve of vision, the optic nerve. This nerve ascends to the posterior part of the cerebrum, to terminate in a region of grey matter known functionally as the visual centres ; they are under that part of the skull called the occiput. There are, of course, two such centres, a right and a left, in the occipital lobes.

Receptors, nerve-fibres, and centres are the three organs required for the elaboration of any one sensation : all three must cooperate. Only the receptor is in contact with the environmental energy.

These receptors act as transformers, transforming the particular kind of energy into nerve-impulses. Light, for instance, never gets beyond the retina ; it never gets to the optic nerve, far less to the visual centre in the cerebrum. This is, however, where the seeing is done ; thus we see in the dark, in the profound darkness of the interior of the skull.

By transformers is not, of course, meant that the rods and cones change light into nerve-impulses, but the light acts on some chemical material in their substance, and that in its turn sets up impulses in the related fibres of the optic nerve. The rods and cones are the indispensable intermediaries between light and nerve-impulses.

No matter how the rods and cones are stimulated, nerve-impulses always ascend the optic nerve, and a sensation of light always occurs, consciousness being present.

There seems to be nothing common to light, nerve-impulses, and the sensation of sight, yet these are causally related.

Besides light, pressure on the retina, and a discharge of electric current across it, will produce the appearance of light. This is because these forms of energy—pressure and electric current—produce impulses in the optic nerve which on reaching the centre for vision *must* give rise to the sensation of light, no matter how these impulses originated. When the pressure on the eye-ball is not excessive, we get the (subjective) impression of a spot of light somewhere inside the nose, the so-called "phosgene"; if the pressure be violent and suddenly applied, as in a blow on the eye, we are said to "see stars".

The opening and closing of a constant electric current sent across the level of the eyes produces the impression of a yellowish luminosity like summer lightning.

Clearly, blindness may have its seat in the retina, in the optic nerve, or in the visual centre. If the retina is destroyed or the nerve severed or the visual centre destroyed (all of which happened, for instance, in the Great War), then one has respectively blindness of peripheral, of neural, or of central origin.

The same principles are found to apply to other senses. For the sense of hearing there is an elaborate receptor apparatus called the organ of Corti in the depths of the internal ear. The cells here are of that variety called hair-cells, because each one has a number of minute bristles on its fine surface. These hair-cells act as the transformers of sound-waves into nerve-impulses in the auditory nerve which passes to the auditory centre, situated on the side of the brain in a region called the temporal.

Sound falling direct on to the auditory nerve gives rise to no sensations of sound ; but certain abnormal stimulations of the auditory nerve such as pressure of a growth (tumour) or of the products of its inflammation set up nerve-impulses in it which on reaching the auditory centre produce singing or ringing sounds. The sound-waves in air do not themselves reach the organ of Corti ; they fall upon the " drum " of the ear and cause it to vibrate to and fro. These movements are communicated to a chain of minute bones in the middle ear, and from this the vibrations are sent into a mass of fluid in the internal ear : it is this fluid pressure which reaches the hair-cells. In fact the complexities interposed between sound-waves and the auditory nerve-impulses are much greater in the case of hearing than of seeing.

Analogous to the varieties of blindness there are forms of deafness, for destruction of the cochlea, of the nerve, and of the auditory centre, respectively, is responsible for different types of deafness.

Quite similar although simpler is the receptor apparatus for the sense of smell. Over the highest part of the mucous membrane covering

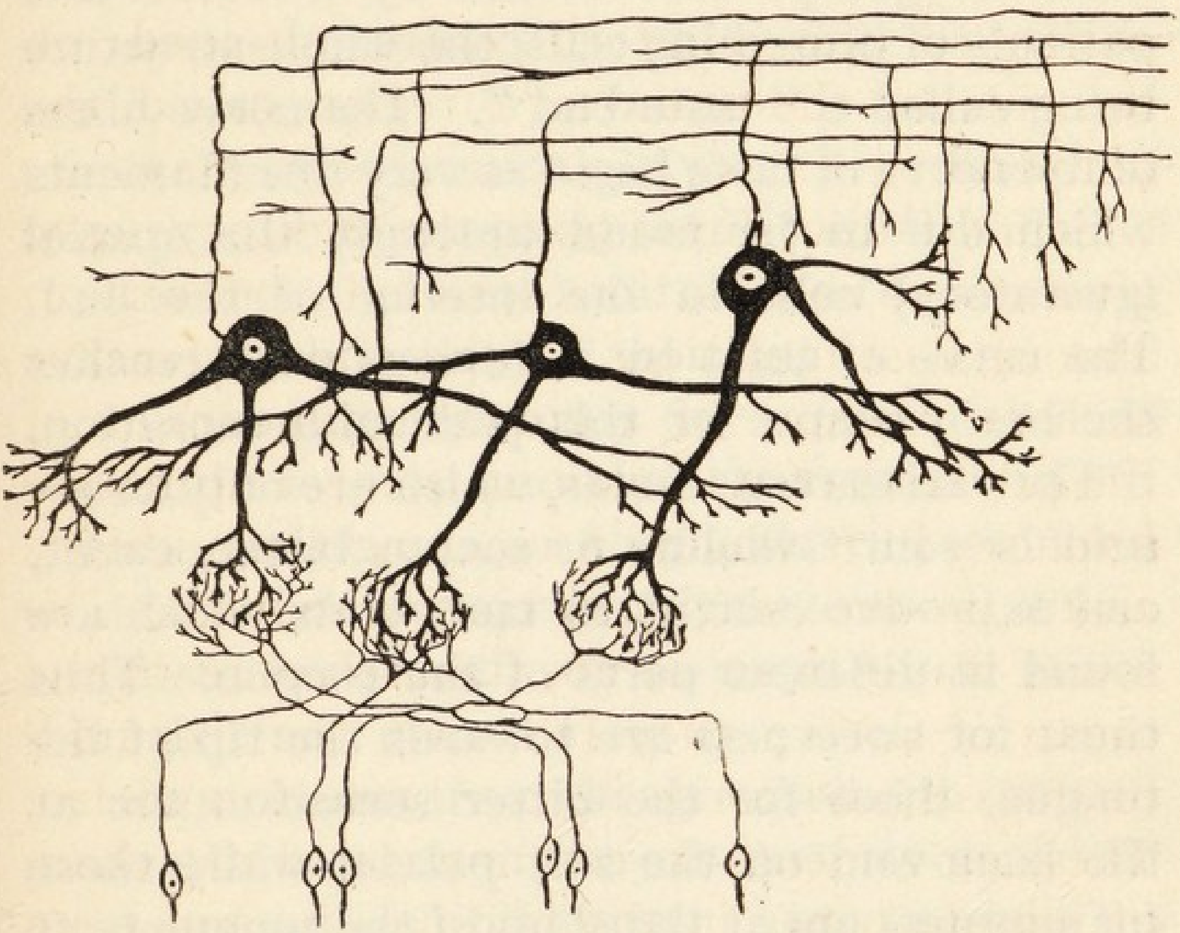

FIG. 8.—End-organs of the Sense of Smell from the Mucous Membrane of the Nose.

the bones inside the nose are to be found large numbers of cells with tiny hairs on their fine surface. The attached or deep side of these (olfactory) cells is in relation with the filaments of origin of the nerve of smell, the olfactory, which passes backwards to end in the deep aspect of the front part of the cerebrum.

Here again we have the same three factors, end-organs, nerve, and centre; and similar kinds of injuries bring about loss of smell.

The end-organs of the sense of taste are once more hair-cells, but in this case we find them in groups surrounded by a barrel-like palisade of protecting cells, the whole structure being called a "taste-bud". The nerve-fibres of the nerve of taste begin as very fine filaments which are to be found amongst the special (gustatory) cells in the interior of the bud. The nerve of taste by a devious path reaches the brain centre for this particular sensation.

The various true tastes, which are only five—acid or sour, alkaline or soapy, bitter, sweet, and salt—are related to taste-buds which are found in different parts of the tongue. Thus those for sweetness are towards the tip of the tongue, those for the bitter sensation are at the back and on the soft palate, while those for sourness are at the sides of the tongue next the teeth, hence the meaning of the passage in Ezekiel, "The fathers have eaten sour grapes; and the children's teeth are set on edge."

The fifth of the long-recognized senses is that of touch, the sense by which we perceive contact (as distinguished from pressure) and by which we discriminate between two points very close together.

This sense is related to the skin, but it is by no means the only sense so related. The end-organs of the sense of touch are distributed under the epidermis in the interior of the minute papillæ of the true skin (cutis). These are naturally called "touch-corpuscles", for they are stimulated by contact of objects with the epidermis.

A nerve-filament, having enwrapped the corpuscle, passes away to join a sensory nerve of the skin and so become one of the sensory fibres in the "mixed" nerve.

A great many tactile nerve-fibres are wound round the deep parts of the hairs, forming a type of sense-organ highly developed in some of the lower animals, for instance, cats, in which, as vibrissæ or whiskers, they attain a large size.

Sensations of pressure, which are quite distinct in our consciousness from those of touch, are related to end-organs which are below the skin and are much larger than the touch-corpuscles. Each of these pressure-corpuscles has a nerve of its own which leaves for the central nervous system.

We shall postpone our study of the sense of pain until a little later, for the skin is by no means the only part of the body where that sensation may be felt.

The sense of heat is related to the presence of heat in the environment ; but we have a sense of cold although there is no such thing as cold as a form of external energy. Heat entering our body from a fire, or heat leaving our body as in blushing, is the stimulus for the heat-perceiving nerves, whereas heat leaving our body, as it does in a cold bath or to cold moving air, is interpreted as cold.

There is no doubt we have cold-perceiving nerves as distinct from heat-perceiving, and yet there is no such thing as cold in the outer world.

It is quite clear that in certain circumstances several senses may be active at one time, as, for instance, when we seize a heavy, cold mass of metal and, balancing it in the hand at arm's length, estimate its weight and then lay it down again. Here the senses of touch, of cold, of pressure, and of the muscles are all co-operating.

Estimations of weight by means of the muscular sense are much more accurate than by the sense of pressure.

The sense of our position in space or orientation is perhaps the most unfamiliar of our special senses, and that for several reasons ; the terminology is unfortunate, the end-organ is anatomically complicated, and the presentations of the sense are vague.

It is only comparatively lately that the end-organ—hair-cells lining a cavity filled with fluid—has been recognized as the receptor for the sense of position with regard to the direction of gravity. In the interior of the cavity, called the "statocyst", is a solid mass of mineral matter, the "statolith". In some of the lower animals these statoliths are of sand; in others, including man, they are salts of lime. These minute stones will press on a different set of hair-cells according as the position of the head with reference to the vertical is changed.

There are in ourselves two statocysts close to each internal ear, and these are now regarded as part of the end-organs for the perception of *gradual* changes of position; whereas we have no less than three other sets of end-organs on each side of the head for the perception of rapid changes of position. These are hair-cells in the "semi-circular canals" which are close to the internal ear; they possess no statoliths. It is these receptors for orientation that are tested for in air-men.

The senses hitherto described are known as the Special Senses because the end-organ of each is specialized to respond only to one kind of energy in the outer world.

The specialization is complete; thus the retina responds to light and light only; sound-waves have no effect on it. Similarly light has no effect on the cochlea. The skin does not " see " because there are no rods and cones developed in it ; if there were, it would " see ". Even in the retina itself there is a blind spot because at that place there are no rods and cones.

In addition to these Special Senses, we have a number of senses quite distinct from them and from each other which we call the Internal Senses. They are all related to the varying states of our internal organs and tissues. They comprise the sense of hunger, related to the state of the tissues when deprived of food ; the sense of thirst, related to their state when deprived of water ; the sense of the absence of oxygen (" air-hunger ") ; the sense of the needs of sex ; a vague sense of well-being (cœnæsthesia) ; a sense of illness (malaise), of fatigue, and of internal pain—seven or more varieties of our sensational awareness.

These " internal " senses are related to internal organs or viscera, just as the Special Senses are related to environmental exhibitions of energy.

The sense of thirst is perhaps the easiest of these " visceral " sensations to analyse. There is no doubt that two factors are involved in it —a local factor, the sensation of a dry mouth, and a general one due to a diminution in the amount of water in the tissues generally. The local factor, as is well known, can be removed merely by holding water in the mouth ; whereas the general factor can be removed only by swallowing and absorbing the water. This general or massive factor of thirst can be produced not only by the absolute diminution of water in the tissues, but also by our having taken an excess of salt or of sugar, substances which in the blood withdraw water from the tissues, the result in consciousness being thirst. Hence the thirst of diabetics.

The sensation calls the person's attention to something in the body which needs a remedy. Put quite generally, thirst is the subjective aspect of that of which lack of tissue-water is the objective.

Clearly, the other internal senses are constructed on similar principles ; the need for solid food, for air, and for sex activity. The senses of malaise, of nausea, and of fatigue are all probably related to the presence in the blood and body-fluids of certain chemical substances of abnormal origin. Bile salts, certain acids, etc. circulating in the blood produce vague, disagreeable sensations difficult to describe but quite familiar to the sufferer.

The importance of fatigue warrants our devoting a separate section to it in a later chapter.

We are still in ignorance respecting the " end-organs " of these internal sensations ; it is unlikely that at this late date in microscopical research any highly differentiated receptors can have escaped the histologists' scrutiny.

Some kind of end-organs must exist even for these different kinds of internal and vague sensations, for we know certainly that if naked nerve-filaments of whatever kind be directly stimulated, that is, not through the intermediation of end-organs, pain and not a specific sensation is the result in consciousness.

A good example is the exposure of the nerves of touch in a blister. In a blister most of the cells of the epidermis have been removed so as to expose to the air the very delicate nerve-fibres which normally have the epidermis between them and any object which may make contact with them. We know well that everything is now interpreted as pain : the contact even of smooth things is painful, a breath of air is painful, warm water, cold water, anything that can touch the raw surface of that blister, is now more or less painful.

We may sum up what we have so far learned by saying that impulses travelling over the nerves of special senses and of the internal organs are continually being poured into the centres of the nervous system so that the person is kept informed of the state of his environment, of his muscles, of his internal organs, and of the position of his entire body in the space of three dimensions in which he lives and moves.

Besides impulses travelling over the nerves of sense, there are many impulses pouring in to our afferent nerves which are not sensory, for we have good reason to believe that such nerves exist. They arise in such structures as glands, heart and blood-vessels, stomach and intestines, bones, and probably still other tissues. Later we may try to find out what office these multitudinous afferent impulses fill in the scheme of things neural : every sensory nerve is afferent, but every afferent nerve is not sensory. But no impulses, whether they arouse consciousness or not, can be lost in the mazes of the grey matter ; they must have a function : later we shall try to discover what that is. Some psychologists firmly believe that all impulses reaching the brain leave traces which later can be revived by appropriate means, no matter how long they may have been forgotten.

As we have seen, the specificity in relation to the senses resides in the end-organ and in the centre, the end-organ responding only to one kind of natural stimulus, the centre giving rise only to one kind of sensation, no matter how stimulated.

Let us see what exactly would follow from this in so far, at least, as the centre is concerned.

To be concrete, take the case of the centre for vision. Normally this centre is roused to action by the arrival in it of impulses which have ascended the optic nerves; but if impulses arrive by any other route, then, notwithstanding that fact, the centre on being thus roused to activity will see visions—it can see nothing else. It is in this manner that the centre dreams, that is, sees visions when the eyes are shut and all is dark. Certainly under these conditions impulses are not ascending from the eyes and yet the centre sees things—the dream.

This activity of the centre without the normal peripheral stimulation is technically known as a hallucination; a dream is a visual hallucination of a sane person asleep.

But any kind of activity of the centre, for instance from the irritation of a tumour, from pressure of any kind, from diseased blood, etc., can stimulate the centre and give rise to a hallucination in the waking state. The person thinks he sees in the outer world something which is absolutely non-existent.

When the hallucination occurs in the auditory centre, for instance, in an insane person, then it is mistaken for external reality and the voices, warnings, commands, etc. may be most disastrously interpreted; murder has not infrequently been the outcome of these voices.

One hallucination is particularly interesting; it is that called "the hallucination of the absent member". It arises in the following manner: suppose a man of middle-age has had his arm amputated at the shoulder, then he finds that from time to time afterwards he has a distinct sensation of the presence of the limb which is no longer there. The nerves involved in the scar or stump give rise to impulses which ascend to the centre which for many years had perceived the presence of the arm. Here they can arouse only the sensations registered, as it were, in that centre, and these sensations are of a (now absent) limb.

Finally, suppose that, in an animal which had attained to maturity, we could make the nerve from the eye grow into the centre for hearing, and the nerve from the ear grow into the centre for vision; then every time that light fell on the eye, the animal would hear a sound, and every time a sound fell on the ear it would see a flash of light. In short, in such a case, the lightning would be heard as thunder, and thunder seen as lightning.

At the present day it is usual to speak of end-organs as "receptors" because they receive the action of the various forms of energy in the outer world or our own bodies. They may be classified as follows.

First into:

1. Extero-ceptors or those on the surface of the body.

2. Entero-ceptors or those in the interior.

Then the Extero-ceptors may be divided into:

1. Distance receptors: those in eye, ear, and nose.

2. Contact receptors: those in skin and tongue.

3. Proprio-ceptors. The proprio-ceptors found in the skeletal muscles and in the organs of balancing are so named because they are stimulated not by external energy but by states *proper* to the tissues themselves.

CHAPTER IV

PAIN AND ITS VARIETIES

PAIN may be described as a disagreeable form of sensation which we desire to terminate. We distinguish bodily pain from mental pain, but in a sense all pain is mental in that a certain degree of consciousness is required for it to be perceived at all ; no brain, no pain.

We have a good deal of evidence that there are in some parts of the body nerves of " pure " pain, that is, nerves whose stimulation gives rise only to pain.

The sensations for which the skin is responsible are touch, heat, cold, and pain. These may be tested for by the use of a metal rod (like a pencil) ground to a not too sharp point which is pressed vertically on the skin. Beginning with the rod at the temperature of the body and exploring an area of skin in this way, we may get any of the following sensations—contact, heat, cold, or " no response ". In the case of the last, if we increase the pressure very slightly, a distinct pain is suddenly developed. The nerve-endings for these various skin sensations are disposed in a punctate manner, that is as a multitude of points,* and we are stimulating mechanically the nerve-endings for pain in the skin. The cornea—very specialized skin—is another tissue which has nerves only of pure pain.

To test the absence of superficial pain in a patient, a perfectly clean needle may be made to transfix a fold of the skin : but to investigate analgesia of deeper structures a specially designed instrument must be used ; this is the algometer, which registers the amount of pain-producing pressures employed.

Pain, as a term, indicates a number of very different conditions. We speak of toothache being painful ; we say that a particular juxtaposition of colours is "positively painful" ; and we talk of the pain of parting and of a painful duty to perform. As regards physical pain, it may be taken as certain that no pain can be felt unless a nerve is involved in the process ; thus persons afflicted with leprosy, in whom the nerves of the fingers have degenerated, can have their fingers burnt, crushed, or scalded without experiencing the slightest inconvenience whatsoever.

We may distinguish various species of physical pain.

(1) There is first the species due to *normal*

* Each point is probably the termination of a nerve-filament.

stimuli reaching nerve-fibres in an abnormal manner; under this head fall all such pains as those from cuts, burns, contusions, lacerations, stabs, gun-shot wounds, and all irritations of exposed nerves. The pain due to the familiar corn is an example of nerve-fibres being stimulated directly, for the fine, sharp, downwardly-directed processes of horn (which constitute the corn) are driven by pressure on the surface into the delicate network of nerve-fibrils in the true skin. As far as consciousness goes, it is as if the nerve had been stabbed by some foreign body such as a needle or the sting of an insect. The very well-known pain of toothache is due to the mechanical stimulation of the naked fibrils of the dental nerves, which have been irritated by food particles, hot or cold water, or even air having got access to them by the decay and removal of the protecting dentine or enamel.

(2) The next species of pain is that due to *excessive stimulation of sensory end-organs*, for instance, the pain from an extremely bright light, a screeching penetrating sound, extremes of heat or cold, great pressures, and so forth. As regards the senses of smell and taste, we can hardly speak of stimulations producing pain; fatigue is what is most noticeable. It is true that we may greatly dislike certain stenches and detest certain tastes, but this is a matter

of æsthetic aversion rather than of physical pain. Nevertheless some smells and tastes affect certain persons so profoundly that the most distinct physiological results follow—pallor, fainting, and sickness.

We are far from understanding what it is makes one pain "burning", another "tearing", and another "stabbing". We cannot tell what it is that underlies a "dull" pain and makes it quite different in consciousness from a "sharp" pain.

(3) Passing from pains that are virtually abnormal or pathologically intense sensations, we come to a group of *pains related to organs which in health are not represented in consciousness* at all. In perfectly healthy conditions of body we are not aware of any of the following: heart, the covering of the lungs (pleura), stomach, intestines, liver, gall-bladder, bile-duct, spleen, kidneys, ureter, or the periosteum, the membrane covering the bones. In other words, perfect health means that our consciousness is not occupied with the normal state or activity of our internal organs; the healthy man does not know he has a stomach or a liver at all. But in proportion as the states of these organs are not normal, they affect consciousness at first as uneasiness, then as discomfort, and finally as actual pain. Thus, in the case of the heart: normally,

stimulation of its afferent nerves never enters consciousness; in other words it has afferent but not sensory nerves. But if the circulation through the heart becomes defective or locally abolished, then the state known as *angina pectoris* is set up, accompanied by what has been described as the most awful pain which any one can be called upon to suffer.

Normally we are not aware of the presence of the liver, gall-bladder, or bile-duct. But in the event of a gall-stone's having entered the duct, then the muscle of that tube contracts so violently upon the resistant body that a most painful state—biliary colic—is brought on. The pain is sickening and exhausting in a high degree. This is an example of "pure" or visceral pain; the nerves concerned are purely algesic. These colics resulting from dietetic indiscretions are pains arising from spasms of the muscular coats of the stomach and intestine, which are endeavouring to reduce to pulp the too resistant masses within them. Excessive pressures on algesic nerve-fibres are then the physical basis of this order of visceral pain.

Our last example of pure pain may be taken from the inflammation of the periosteum, the membrane covering the bones. When normal, this tissue is entirely outside our consciousness; but when inflamed, in periostitis, it can give rise to pain of a persistent and torturing description.

We do not need to rely on merely indirect evidence that the healthy viscera are insensitive, for surgeons have been assured by patients who have come out of the chloroform too soon, that the manipulations of the intestines and other internal organs were painful only when the diseased regions were touched.

The inference to be drawn from these observations is that the healthy internal organs, even when cut down on and exposed to view, are painless. The handling of the healthy heart or other viscus in the normal animal is not attended by pain. This is a fact known to few, and of course is totally denied by "anti-vivisectionists", who assume that because an animal's viscera are exposed to view and "writhing", the animal must necessarily be suffering pain. Such organs as exhibit peristalsis are always "writhing"; and this peristalsis, so far from being painful, does not even enter into their consciousness. Still more remarkable is the fact vouched for by men skilled in the surgery of the brain, that the removal of portions of that organ is unattended by sensation.

(4) Closely allied to pure visceral pains are pains associated with lesions or inflammation of the nerves themselves—*neuralgias*, literally nerve-pains. In a sense, as we have seen, all pains are neural, but in neuralgia the nerve-

trunks themselves are the seat of the pressure or irritation. The pains due to lesions of the nerves might be called " visceral ", if only we could call nerves " viscera ", but that would be an abuse of anatomical terminology. The healthy nerve-trunks no more obtrude themselves into consciousness than do the healthy viscera. Since, then, we possess normally no sensations referable to nerves in their course, and since there are pains unquestionably related to disordered conditions of nerve-trunks—neuralgia, sciatica, or neuritis—it is more than probable that the " nervi nervorum " or " nerves of nerves " are for the conveyance of purely algesic impulses.

On ultimate analysis these nerve-pains are due to the pressure of the blood or of lymph accumulated between the fibre-bundles and their dense inelastic sheaths—that is, congestion with pressure-effects. Why there should be a pain-perceiving mechanism in connection with our nerves is a question which physiology as such cannot answer with certainty. To the biologist, no less than to the theologian, there is a " mystery of pain ".

(5) The next species of pain we must notice is the theoretically interesting condition known as " *referred pain* ". The following are examples :—In heart disease pain is felt in the left arm ; in liver disease pain is felt under the

right shoulder; in gastric catarrh it is referred to the breast-bone and through the chest to the back. Now, strictly speaking, referred pains are special cases of what psychologists call "illusions". An illusion is a mistake on the part of the mind with regard to the source and character of a sensation. The real cause of the irritation is at the terminations of certain internal nerves, but the mind "refers" it to the

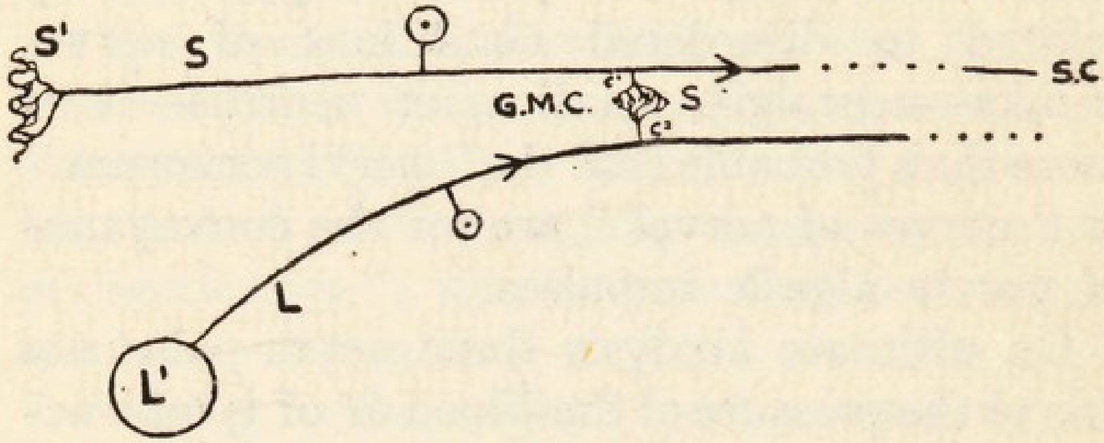

FIG. 9.—Scheme of Referred Sensation and Pain.

L^1, Liver. L, Afferent neurone from liver. In grey matter of cord (G.M.C.), by synapses, impulses are probably transferred to collaterals of afferent neurone (S) from skin (S^1). C^1 and C^2 are collaterals.

terminations of certain (corresponding) nerves on the surface of the body.

How this can be will be understood from a diagram.

An afferent neurone, L, ascends from the liver, L^1, and enters the spinal cord in common with other such through a posterior root. It is lost in the grey matter of some segment of the cord. From an area of skin, S^1, over the right shoulder-blade the neurone, S, ascends to the cord, which it enters in the same segment of grey matter as that by which L entered. In this segment the two neurones, L and S, come into very close association; and for some reason, not well understood, the excited state in L is communicated to the neurone S. The transference may be by means of non-medullated collaterals (C^1 and C^2, Fig. 9), ramifying very close together in the grey matter of the common segment; but however it occurs, S is found to be in a state of excitation.

Now the neurone S ends in some part of a sensory centre, S.C, related to the skin-area in which S arose, so that any stimulation of S is perceived as arising in the area of skin S^1 from which S came.

Thus, by the law of outward reference, a sensation is referred to this skin-area S^1, over the right shoulder, when all the time it is the liver, L, that is the source of the irritation.

As the result of extensive and careful observations of persons suffering from diseases of internal organs, the neurologists have been able to map out the entire surface of the body into areas each of which corresponds to some internal organ. By noting, therefore, the particular skin-area in which there is pain when there is clearly nothing in the skin to account for it, the physician is enabled to say which particular internal organ—heart, liver, kidney, etc.—is at fault. Sometimes when there is severe referred pain, there may be very little primary pain in the internal organ itself. The area of the referred pain may therefore give a valuable clue to the hidden organ which has become diseased.

The referred pain may be more prominent in consciousness than the primary pain, and it may be removed or ameliorated by a counter-irritant which leaves the source of the disease, the internal organ, untouched. Some " cures " are effected in this manner; some of the " miracles " of faith-healing are of this kind.

Referred pains have for long been known as " sympathetic ", and have frequently but incorrectly been called " reflex ". A large number of headaches are referred pains. The tendency to peripheral reference, especially in regard to pain, is well known in the case of what is called by psychologists " the hallucination of the absent member " (see page 58). In such cases pain is at once truly physical and truly mental; no better example of this could be given.

Of course, pain is a mental state; but it is equally a physical one. " Christian scientists " have magnified the former fact to the exclusion of the latter. The great fatigue and depression which come on after severe or prolonged suffering, is unquestionably the conscious result of damage to the sensory portions of the central nervous system.

Mankind has at all times made efforts to escape from physical pains; some kind of hypnotic or narcotic is known in every part of the habitable globe. In strict terminology, we mean by "anæsthesia"* abolition of sensation, as distinguished from "analgesia" or abolition of pain. The analgesia produced from chloroform has the double advantage that it not only allows the operation to be conducted painlessly, and therefore without muscular struggling, but it protects the brain-centres from the exhaustion consequent on great pain; chloroform thus mitigates shock, one of the conditions so dreaded in the days before Sir James Simpson discovered chloroform anæsthesia.

True pain may, then, on several grounds be distinguished from the many other modes of sensation. Since this is so, it is reasonable to suppose that pain-impulses have a separate path of conduction within the spinal cord on their way to the seats of consciousness. Neurologists believe that they have found such paths. It seems fairly certain that pain-producing impulses travel in a region of the spinal cord which is not shared by those of the other senses.

* A term coined by Oliver Wendell Holmes in 1846 to designate loss of feeling or sensation.

Thus it is found that if, in certain kinds of accidents to the back, the lateral strands of white matter in the spinal cord have been severed, the patient retains his senses of touch and movement but loses the sense of pain. This phenomenon is known as the " dissociation of the senses " ; usually, when the pain-sense is abolished, the senses of heat and cold are abolished along with it.

There were cases during the War where the injuries to the back were of such a kind that the pain-tracts were severed or pressed upon, with the result that the patient felt no pain ; his skin could be cut, pinched, or crushed without any discomfort ; he could lift up red-hot coal and yet feel no pain.

There is no doubt that in an earlier and darker age persons with this ability (or disability) were persecuted as wizards and witches in league with the devil.

That there is such a thing as pain by itself and as distinct from other sensations is corroborated by the interesting fact that in chloroform anæsthesia all the varieties of sensation are not abolished at the same time, but, on the contrary, in the following order :—the muscular sense and sense of weight, smell and taste, sight, hearing, pain, and lastly the sense of contact. Thus people " going off " have a sense of floating or flying or sinking because their sense of weight and of movement has been abolished : they can still smell the chloroform and see and hear. Next smell and taste vanish, but the patient can see and hear; then sight goes, and then hearing. The experienced anæsthetist knows that within the next few moments pain will have been abolished, although the sense of touch will still be present. Finally this last point of contact with the outer world goes, and nothing whatever is present to consciousness.

CHAPTER V

NERVE-IMPULSES AND CONDUCTIVITY

ALL living protoplasm possesses affectability, the power or property of responding to a stimulus. For our present purpose we may define the "stimulus" as that agent or agency which elicits a response from the living matter. The three concepts, stimulus, affectability, and response, are thus causally linked, and no one of them has any meaning apart from the other two.

A living muscle, in virtue of its affectability (irritability), on receiving a stimulus—electric shock, a blow, a chemical irritant, responds by a twitch or "contraction", really a shortening. Similarly a nerve, by reason of its affectability, on receiving a stimulus conveys a nerve-impulse.

Reverting to the experiment in Chapter II, we noticed, if we sent a momentary electric shock through the far end of the nerve, that the muscle at the other end shortened for an instant and then elongated, the whole action being called a twitch. If we give two stimuli to the far end of the nerve, the muscle will twitch twice. Evidently the stimulus to the end of the nerve has caused something to descend the nerve and throw the muscle into activity. This something we call the nerve-impulse. No one has ever seen nerve-impulses, but we infer their existence. Similarly no one had ever seen the air, until it was liquefied a few years ago; but every one inferred its existence from its effects—draughts and storms of wind. The nerve-impulse, however, is in itself completely invisible since it is a disturbance in the molecules of the invisible axis-cylinder within an opaque nerve-fibre. But all nerves do not go to muscles (musculo-motor); if we stimulate the nerve to a blood-vessel, the latter will narrow its calibre; if the nerve to a gland, the gland will secrete; if one of the nerves to the iris, the pupil will be dilated, and so on.

All we are concerned with at present is that if you stimulate an efferent nerve, something happens in the tissue to which that nerve is distributed and therefore something must have travelled from the point of stimulation to the periphery; that something we call the nerve-impulse.

The stimulation starts a state of excitation which travels down the nerve and becomes the stimulus for the muscle to contract, the vessel to constrict, the gland to secrete or the pupil to dilate, as the case may be. Because such a state of excitation can travel down the nerve, we speak of the nerve possessing the property of conductivity.

This property of conductivity—the power of transmitting a molecular disturbance—is possessed in some degree by all living matter—most obviously by muscle. If we chill a long muscle, we can actually *see* the state of contraction passing over it from one end to the other. The nerve-fibre, however, has been especially differentiated to *conduct*; in fact we know of no other function or property than that of conducting impulses. A nerve is a living specialized elongated conductor of impulses and of nothing else. Neural conductivity is to be sharply distinguished both from thermal and electrical.

Abolition of Conductivity.—Conductivity can be mechanically abolished by a ligature drawn sufficiently tightly around the nerve. Any kind of pressure, if powerful enough, will interfere with the passage of the impulses. Thus the pressure of an unsuitable crutch in the armpit will paralyse certain muscles of the arm, because it has cut off the impulses in the nerve innervating those muscles.

Sometimes this interruption to conduction can be effected by the pressure of inflammatory tissue around one of the minute apertures through which many nerves have to pass. The surgeon can relieve conditions of this kind. If the pressure is not sufficiently powerful to cut off impulses, it will only irritate (stimulate) the nerve-fibres and produce twitchings or spasms in the muscles supplied by those fibres.

Pressure on a sensory nerve, if sufficiently strong, will prevent the ascent of impulses in it and produce a loss of whatever kind of sensation the nerve is concerned with. There is a complication, however, in regard to sensory nerves as compared with motor, namely that while the pressure is being produced, there is great liability for pain to be engendered owing to the mechanical injury to the afferent fibres. Thus sometimes persistent pain is the forerunner of sensory paralysis.

Pressure injures the fibres whereas freezing them does not. By freezing the nerve we can abolish its conductivity, partially or entirely. This method, as applied to sensory nerves of the gum, is sometimes used by dentists who freeze the gum before they pull out a tooth. It is known as local anæsthesia—really analgesia, for the contact of the instrument is still felt after the pain has been abolished.

In yet another way we can abolish the conductivity of a nerve, namely by applying to it —and especially to its terminations—various drugs or chemical substances such as alcohol, ether, chloroform, ethyl chloride, carbon dioxide, morphia, and other alkaloidal poisons. Such substances are called local anæsthetics or narcotics.

The only evidence we have, then, of the passage of a nerve-impulse is some activity at the periphery in the case of outgoing nerves and of some modification of consciousness in the case of ingoing.

There is luckily an objective accompaniment of the passage of the nerve-impulse in an electrical disturbance which is propagated along the nerve exactly as the nerve-impulse itself is. This has been explained in Chapter II. The experiment can be varied in the manner designed by the late Professor A. D. Waller. The stimulations can be given in the middle of a length of nerve which has still its muscle at one end, and is placed on the galvanometer at the other. For each stimulus, we obtain simultaneously a muscular twitch and a galvanometric deflection. This clearly shows that the muscle and the galvanometer are both actuated by the same thing—a nerve-impulse. Incidentally it shows that an efferent nerve can conduct equally well in both directions, a phenomenon sometimes called "the law of double conduction". This "law" is equally true of afferent nerves.

The electric disturbance in a nerve is not an isolated phenomenon; all protoplasm in activity gives rise to electric current; muscle and the heart notably do so. It would appear that just as muscle cannot contract without producing heat and electric current, so nerve cannot conduct without also producing electric current. A frozen nerve will conduct electricity but not nerve-impulses.

So far as we know, nerve-impulse is of exactly the same nature in an efferent as in an afferent nerve, and no matter by what different kinds of stimulus it has been started. The muscle of a nerve-muscle preparation will twitch whether the nerve has been stimulated electrically, chemically, thermally, or mechanically. The stimuli are many; the response is one. Exactly the same may be said of the nerve-impulse. We have no evidence to show that, however different may be the ways of stimulating the nerve, the response in the galvanometer is not always the same. The galvanometer merely shows an electric current.

Applying this to the living body, we do not believe that there is any difference between the impulses, whether they are sensory, musculo-motor, vaso-motor, cardio-motor, or glandulo-motor. This was not, however, the view once held: on the contrary it was supposed that all these impulses were different from one another. All recent evidence points to nerve-impulses being identical when travelling in the nerves; the result or action at the periphery depends entirely on the kind of organ or tissue in which the nerve ends.

The late Professor Langley of Cambridge performed the crucial experiment to test this belief in the non-specificity of nerve-impulses. He caused one of the nerves that go to the heart to be cut and made it grow into the nerve which dilates the pupil and constricts the blood-vessels of the ear. After waiting until perfect union had taken place, he stimulated the upper end of the nerve that formerly went to the heart with the result that now the pupil was dilated and the blood-vessels constricted. This proved that a nerve which originally carried impulses to the heart to slow it, now carried such as dilated the pupil: in other words, the impulses in the nerve could not have been specific. The effect produced depended on where the impulses fell at the periphery. This kind of operation, which is painless, is called "nerve-crossing". Surgeons have taken advantage of this non-specificity of impulses in nerves to carry out the operation of nerve-crossing in order to alleviate certain conditions of paralysis. One example of this may be given. If it should happen that the nerve on one side of the face which supplies the muscles of expression has been cut so that those muscles are paralysed, a most disfiguring deformity results, because the sound muscles of the opposite side pull the paralysed muscles to the sound side. Not very far away from the nerve to the face is the nerve that raises the shoulder. Suppose that the facial nerve on the right has been severed:

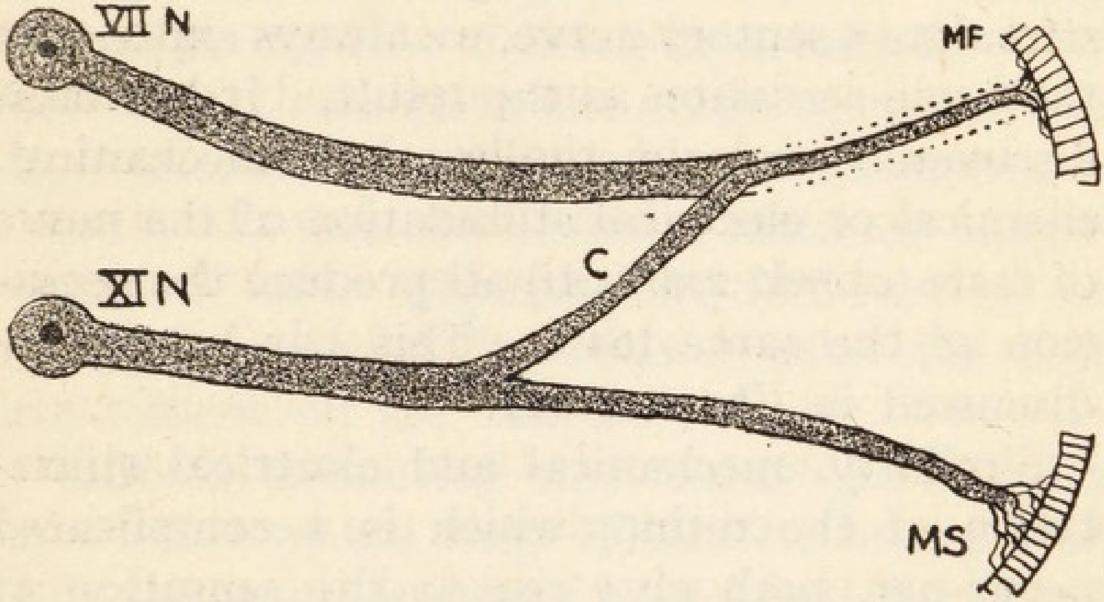

FIG. 10.—Diagram of a Nerve-Crossing from XI Cranial Nerve (Spinal Accessory) into VII Cranial Nerve (Facial).

MF, Muscle of face. MS, Muscle of shoulder. Dotted lines are the degenerated fibres of the facial nerve.

the surgeon splits off from the nerve to the shoulder a slip of nerve-fibres which he causes to grow down into the old track of the degenerated remains of the right facial nerve. In course of time this deflected portion of the nerve to the shoulder grows down to the muscles of the face, which are thus innervated once more but by a nerve which has arisen in a centre which supplied not the face muscles but the shoulder muscle. The functional result of this is that each time the man smiles he raises his right shoulder in a shrugging movement.

There is an exactly similar sort of thing in the case of the sensory nerves.

In no matter how many different ways we stimulate a sensory nerve, we always experience the same sensation as the result. It has been discovered experimentally that mechanical, chemical or electrical stimulation of the nerve of taste (*chorda tympani*) all produce the sensation of the same taste. This has been fully discussed in Chapter III.

Similarly, mechanical and electrical stimulation of the retina, which is a complicated nerve-net, both give rise to the sensation of light. Again in the case of the ear, not only sound-waves but pressure on the nerve of hearing will give rise to sounds. A plug of wax pressing on the membrane of the drum of the ear can give rise to a ringing sound. A too high pressure of blood in the neighbourhood of the auditory nerve will give rise to sounds—so-called subjective sounds: all these singings in the ear are called "*tinnitus aurium*".

Since, in any one sensory nerve, the kind of stimulation does not determine the kind of sensation, the kind of sensation must depend on what particular part of the brain the nerve ends in. In other words, as in efferent nerves the specificity resides in the peripheral organs, so in afferent nerves it resides in the central locations of the senses.

The Rate of Propagation of the Nerve-impulse.—If the nerve-impulse is a real state of excitement travelling along a nerve, its velocity should be capable of being ascertained. This was first calculated in the motor-nerves of the frog, and was found to be about 28 metres a second. It was the eminent German mathematician and physiologist Helmholtz, at Königsberg, who in 1850 made the first experiment on the subject.

Besides estimating the rate of the impulse in a nerve of the frog, Helmholtz ascertained it in the intact nerve of man, where he found it about 120 metres a second. From very accurate observations in 1912, by an electrical method by Piper of Kiel, the rate in human nerves was found to be 123 metres a second.

The rate in afferent is the same as in efferent fibre. All workers are agreed that the strength of the stimulus does not affect the velocity; but that the temperature of the environment has a distinct influence on it. All living matter becomes more active with a rise and less so with a fall in temperature; and to this the propagation of the nerve-impulse, being a vital phenomenon, is no exception. In fact, we always note the temperature at which every physiological activity is studied. The conduction-rate in frog's nerve is 28 metres a second at about 18° C., but only 16 metres at 9° C. Chilled to below zero, the nerve will not conduct at all.

The rate of the propagation of the impulses is by no means the same throughout all classes of animals. The more lowly the animal in the zoological scale, the slower is the rate of its neural conduction.

Nerve-fibres and Fatigue.—We will now investigate the alleged impossibility of fatiguing a nerve.

By "fatigue" we mean relative functional incapacity due to previous activity which can be recovered from, whereas by exhaustion we mean a state which cannot be recovered from. In physiological fatigue, no permanent damage is done ; in exhaustion, it is.

By no known experimental method can we discover the presence of fatigue in nerve-fibres ; nerve-fibres stimulated electrically for many hours still give galvanometric evidence of the passage of nerve-impulses. This indefatigability of nerves is true of nerves both in the body and when excised. Excised nerve will, if kept in saline solution, remain alive for several days.

Physiologists have long ago come to the conclusion that a state of fatigue has its chemical side; and that fatigue is always accompanied by an accumulation in the fatigued organ of certain chemical substances which have not had time to be removed in the blood-stream.

In fatigued muscle, for instance, we find an acid condition due to unremoved sarco-lactic acid, one of the products of the prolonged activity. Such products are called "katabolites". In the neighbourhood of nerve-cells after their prolonged activity we can similarly detect a certain amount of acidity; but after the most prolonged conducting of impulses no traces of katabolites can be found in nerves. The chemical evidence as regards the absence of fatigue corroborates therefore the galvanometric.

Except that nerves require oxygen for their functional integrity, we know of no unassailable fact to indicate that they have anything but the feeblest metabolism.

Further, no heat can be detected during the activity of nerve-fibre. By a method which could detect six millionths of a degree Centigrade rise of temperature, Professor A. V. Hill could observe no effect after twenty-five minutes' continuous stimulation. All these negative findings do not mean that axis-cylinders are not living protoplasmic strands ; it means only that they are very highly specialized to conduct impulses with the minimum of metabolic effort and output of energy.

The relations of the nervous impulse to nervous energy will be discussed in a later chapter ; all we need say here is that it cannot be doubted that *in situ* the cell-body of the nerve originates the energy for the propagation of the nerve-impulse.

There are two views regarding the exact nature of the impulse : (1) that it resembles the transmission of an electric current along a wire, and (2) that it resembles more closely the burning of a train of gunpowder in a narrow trench in the ground. The bulk of the evidence is to the effect that it resembles the burning of gunpowder more closely than the passage of a current meeting resistance in a wire.

CHAPTER VI

THE NOTION OF A CENTRE

SO far we have learned that the nervous system consists essentially of nerves ingoing from the periphery—the surface of the body and the internal organs—and of other nerves outgoing from the central nervous axis to the periphery, namely to muscles, the heart, blood-vessels, stomach and intestine, glands, the eye, and other organs.

The latter nerves, since they innervate or are trophic for such wholly different organs and tissues as those just named, must have arisen in nerve-cells whose functions cannot possibly be all the same.

Let us consider a nerve to a muscle and a nerve to a small blood-vessel. Since these nerves must have arisen in nerve-cells—for there are no nerves which do not so arise, the group of cells giving rise to the nerve to the muscle must be a different one from that which gives rise to the nerve for the vessel.

Our conception of the cells of the nervous system must then be that they are divided up into groups with different activities inasmuch as one group gives rise to nerves which have to do with maintaining the tone of body-muscles, others to nerves which go to the heart, the glands of the mouth, the stomach, the intestine, the kidneys, and the reproductive organs.

These different groups of nerve-cells charged with different " functions " are what we mean by " centres ". The concept is primarily a physiological one. A centre is a mass of nerve-cells which presides over some particular activity of an organ or tissue—the contraction of a muscle, the rate of the heart-beat, the calibre of the blood-vessels, the activities of the intestine, or the secretion of a gland. A centre is " for " a function ; it presides over that function ; it regulates, controls, restrains, or stimulates that function. It does not create the function ; it supervises it.

The term " centre ", like so many others which are not technical in the sense of being devised to express one idea and one only, is even in physiology a rather wide term. It sometimes means no more than " ganglion ", by which word anatomists allude to a mass of nerve-cells, whether that is inside the central nervous system or out amongst the tissues (peripheral nervous system). But the anatomists have a third term—" nucleus "—which is equivalent to ganglion when that term is used to mean the cells giving origin to a nerve. Thus, for instance, the group of cells from which the nerve of the muscles of the face arises (the facial nerve) is alluded to as the nucleus or ganglion or motor centre of the Seventh Nerve. The nucleus of a motor nerve is nothing more than those cells which give origin to the fibres of the nerve, and from which, if the nerve be severed, the fibres will die (degenerate).

Often such a centre is called " the trophic centre " for the nerve, on account of this very fact that the nerve-fibres die if separated from the cells. At present we are more interested in the physiological notion of a centre as a mass of nerve-cells specifically related to the activity of an organ or tissue.

It is evident that an organ could not be left entirely to itself without control of some kind, because at one time it might do too much, and at another too little. Thus the heart might at one time pump the blood much too vigorously for the needs of some particular organ, and at another not vigorously enough. So a nerve-centre provides for the possibility of one organ calling for more or less blood as it requires. It would not do for any one organ to receive constantly, day in and day out, exactly the same amount of blood at the same pressure. For instance the stomach, when it is not digesting a meal, requires very little blood compared with what it requires a few minutes later when a meal has been taken.

The heart, as we have said, must be under the supervision of a centre which can at one time increase its rate and force, and at another restrain it. And if there is such a centre, evidently a motor or emitting centre, there must also be nerves going to it from the heart to inform it of the state of the heart and whether the heart needs stimulating or repressing.

A centre, therefore, functionally cannot be isolated from the nerves going into it and coming out of it. It is the intermediary between the two sets of nerves ; it must receive, and it must give out.

We will take a particular centre as an example : the centre for breathing is a typical one.

The respiratory centre is a mass of nerve-cells in the Bulb which puts out at regular intervals impulses to many muscles which carry on the mechanical ventilation of the lungs. Between the chest and the abdomen is a large up-curved muscle, the diaphragm, which at rest is convex towards the lungs, and which in action descends towards the abdomen to enlarge the cubic contents of the chest. This descent of the diaphragm is performed at the same time as the ascent of the ribs, the object of both movements being to enlarge the capacity of the chest, and so for a short time to cause an inrush of air into the expanding lungs. Both these simultaneous movements are directed from the centre in the Bulb, for if the latter be suddenly destroyed, as in hanging, breathing ceases instantly.

The centre is a bilateral one. If the Bulb be split down the middle, there is no impairment in the movements of breathing, one half of the body being in this respect independent of the other. If half of this region of the Bulb is destroyed, the breathing of the injured side ceases, but that of the other half continues as usual. Now this symmetrical centre controls the diaphragm by two nerves known as the "phrenics", and by a number of nerves (called "intercostal") which are motor for the (intercostal) muscles which raise the ribs. That this is so is evident from the fact that if one phrenic nerve be cut, the diaphragm on that side immediately stops moving and remains at rest (paralysed); if both phrenics are cut, the whole muscle is quiescent. Similarly the intercostal muscles are paralysed after section of their nerves.

The most noticeable thing about breathing is that it is rhythmic; approximately eighteen times in the minute the ribs rise and the diaphragm falls, and eighteen times per minute these actions are reversed. But this means that the cells of the respiratory centre must be putting out inspiratory impulses at eighteen to twenty per minute, the respiratory rhythm in man.

Now this regular periodicity is quite independent of our consciousness, for it proceeds quite as well while we are asleep. It is, in other words, an automatic rhythm : it goes on "of itself", is not dependent on consciousness, and is not regulated consciously.

The centre, though possessed of the property of automatism, is quite accessible to stimulations and inhibitions from without, for it is well known that breathing can be altered in rate and depth and, for a time, suspended altogether.

This ceasing to breathe can be brought about voluntarily, as when we decide to stop breathing for a little while after the manner of divers. We call this the voluntary inhibition of breathing ; and it is clearly brought about by impulses of a restraining nature having descended from the brain on to the centre for breathing. It is interesting to note that this stoppage cannot be indefinitely maintained ; if it were, we could suffocate ourselves to death. Chemical changes in the blood traversing the respiratory centre start it into activity again, no matter how strongly we may will otherwise.

Another way in which the centre may be restrained is through emotion. If an emotion, say, of fear or of surprise, be sufficiently powerful, the breathing may be slowed or for a little while even stopped. "It quite took my breath away" is the popular version of this emotional inhibition of the Bulbar centre. Once more the impulses have originated in the brain and descended thence on to the automatic centre.

So much for restraining the centre; but it is equally familiar that we can accelerate the rate and increase the depths of breathing by an effort of the will. Shallow breathers are urged to breathe deeply; this is a voluntary interference with the rhythmically discharging centre.

But there are other ways yet in which the state of the centre may be influenced. Take the case of a cold douche to the body; this causes a deep, gasping inspiration after which the breath may be "held" (expiration inhibited) for some little time. Here the restraining influences must have come from the skin and influenced the centre without any cooperation on the part of the brain. A dash of cold water makes us gasp, but that gasp is neither volitional nor emotional. The cold water is perceived ; but the part of the brain having to do with consciousness does not enter into the chain of causal events.

Practical use of this method is made when a child is born which does not breathe (" still-born ") and is induced to take the first breath by being flicked with a wet towel. This again is quite outside consciousness ; it is the strong sensory stimulation of the skin arousing the latent activity of the automatic respiratory centre. The child, if it is going to live, is thus reflexly made to take its first breath, after which the centre keeps up its inherent rhythm.

We see, then, that the centre is accessible to stimulation arriving at it either from the brain or from a sensory surface, such as the skin. But it is also accessible to impulses from within the body. One of the features of the pain of peritonitis (inflammation of the delicate covering of the internal organs) is a holding of the breath—an inhibition of inspiration, the supposed meaning of which is to restrain the movements of the diaphragm so as to give rest to the inflamed abdominal organs. But beyond all this, the nerves from the lungs themselves seem to have an influence on the breathing centre. For if we cut both the nerves which go from the lungs to the Bulb, we find that the interval between successive breaths is immensely prolonged. The rhythm of the breathing becomes very much slower; the animal takes a deep inspiration, and then there is a long pause at the end of which it takes another deep breath.

Finally, as regards the modes of stimulating, this centre is a typical instance of direct stimulations; of these heat is the chief.

As the temperature rises above the normal for the blood, the breathing gets faster and faster. That this is due to the direct action of the heated blood on the centre is proved by the fact that if the carotid arteries of an animal be surrounded by a jacket through which warm water can be passed, then, as the temperature of the water rises, the inspirations become faster and faster. This is what is happening in fever, and in the earlier stages of sunstroke before the heated blood has damaged the nerve-cells. The hot blood makes the heart beat faster and faster, just as it stimulates the respiratory centre to put out its rhythmic impulses more and more rapidly.

The chemical condition of the blood powerfully affects the respiratory centre. Indeed the presence of carbonic-acid gas above a certain pressure in the blood is the normal stimulus for the centre. A very slight excess of this gas above its normal quantity has an immediate and powerful effect on the Bulbar centre, causing it to put forth impulses of greater potency that lead to increased ventilation of the lungs and therefore to more rapid elimination of the excess of the gas.

Just as urea stimulates the kidney to more abundant excretion, and therefore elimination of urea itself, so there is a mechanism for eliminating carbon dioxide from the lungs.

Certain drugs, if they have gained access to the blood, affect the respiratory centre. Strychnine rouses it to activity as it rouses all centres, whereas morphia, exercising its narcotic effect, lowers the excitability of the centre and greatly slows the rate of breathing. The poison, cyanide of potassium, has a very definite action on the centre for breathing; it is the prussic acid which is so deadly, paralysing the centre with amazing rapidity. No other poison is known to act with such speed. This must mean that there is something in the chemical constitution of prussic acid which causes it to combine with the living matter of the respiratory centre and immobilize it rapidly.

Centres may evidently be classified on several different principles. For instance, we could divide them into those which act "of themselves" and those which require control or commands from a centre or centres physiologically higher.

The respiratory mechanism once more gives us an example of this condition. The nerves to the diaphragm do not arise in the centre itself, but by themselves form two groups of nerve-cells in the spinal cord called the "phrenic nuclei". If the central nervous axis be cut between the Bulb and the cord, the diaphragm ceases to move. This can only mean that the phrenic nuclei are *not* independent, automatic centres like the main respiratory centres, but are dependent, subsidary centres under the control of the physiologically higher centre. The phrenic centre is an excellent servant that carries out orders with perfect fidelity, but is incapable of initiating anything and never assumes responsibility. There are, thus, functional levels in the nervous system; all centres are not equally endowed.

Lastly we may divide up centres according to whether or not they are "conscious centres". There are a great many centres which are not related to consciousness, which carry out their duties even when we are asleep; some of these are—the centres in the cord for maintaining the tone of the body-muscles and that of the sphincters, for innervating the heart and blood-vessels, the digestive tube, the glands, the reproductive system, and the eye-muscles. The respiratory centre and the vomiting centre exercise their functions outside the conscious realm. This does not mean that in certain circumstances states of consciousness may not influence these centres, but they are not centres whose normal activity requires the presence or cooperation of consciousness, as do the centres in the brain. The activities of the cerebellum are entirely outside consciousness.

On the other hand, there are centres whose activity is essentially dependent on consciousness, whose activity is meaningless without it. Such are the brain-centres for the special senses, the centres for voluntary movements, and, highest of all, the speech centres. This does not mean that these centres cannot act unless consciousness is present, for there is such a thing as *unconscious* cerebration ; but it means that those centres are the physical basis—the organs—of sensation, volition, and speech.

It might be well to enumerate the centres in the Bulb ; they are for muscles of the iris and for focussing by the lens of the eye ; the centre for the heart, for the small blood-vessels, for breathing, vomiting, perspiring ; for secretion of saliva, gastric and pancreatic juices ; and for the muscles of the alimentary canal.

CHAPTER VII

REFLEX ACTION

THE particular type of action called "reflex" is fundamental in the nervous system. If a neural action is not automatic or voluntary, it is reflex. Reflex actions, or for short "reflexes", have this in common, that some form of activity take place at the periphery in consequence of stimulation having previously occurred at the periphery. By the "periphery" we virtually mean any region of the body which is not the central nervous system itself; the skin and muscles on the one hand (ecto-periphery), and the internal organs (ento-periphery) on the other.

A specific example will make clear the kind of action described as "reflex". The eye is said "to water" when grit gets into it. In more accurate language physiologically, when an irritant lodges between the sensitive cornea and the eyelid, the lachrymal or tear-gland secretes its fluid called "tears". Evidently the grit at the periphery is the cause of the secretion of the gland which, situated in the eye-socket, is at the periphery as far as the nervous system is concerned.

The notion in calling this action " reflex " clearly is that something has gone up from the surface of the body to a nerve-centre and has

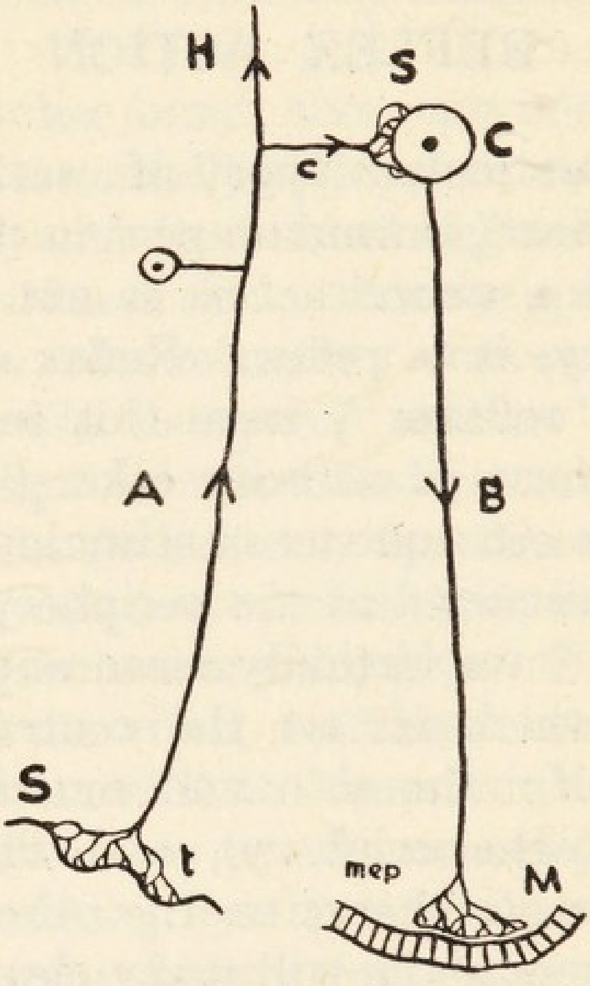

FIG. 11.—Diagram of a Simple Reflex Arc.

A, Afferent neurone. H, Its head-ward extension. B, Efferent neurone, of which C is trophic cell. C is in spinal cord. S, Synapsis of collateral of A over C. C is a reflex centre. *t*, A telodendron. *m.e.p.*, Motor end-plate.

there been *reflected* back to the surface again. The analogy is with a beam of light reflected from a mirror at the same angle as that at which it struck it.

Let us take another example of a reflex

action. When the dentist begins to probe amongst the teeth and touch the gums with one of his steel instruments, we know that the saliva begins to flow into the mouth with uncomfortable freedom. Here, then, once more, the stimulation was at the surface—the gums—and the glands of the mouth were stirred to activity. Once more impulses have originated at the periphery and have returned to the same region of the periphery again.

Now we must note that there is no connection between the cornea and the tear-gland except a roundabout one by means of nerves; and similarly there is no connection between the gums and teeth and the salivary glands except by nerves.

We may have regions related reflexly, but much farther apart than any of these. For instance, a pin may have been accidentally driven into the great toe so that the person jumped and gave a scream.

The nerve-cells innervating the muscles that pull up the foot are situated in the lower portion of the spinal cord two or three feet away from the muscle which has been so suddenly thrown into action. Here once more there has been reflexion of impulses, in this case in the central grey matter of the spinal cord. A violent painful stimulation of the toe will not only reflexly influence the toe-muscles, but may interfere with the heart's action, and cause flushing, a secretion of saliva, of tears, and of sweat. The reflex effects may therefore be quite widespread.

In order to study reflexes under experimental conditions of much greater simplicity, we should make a preparation of a cold-blooded animal such as a frog. The frog is decapitated in order to abolish all consciousness, and the preparation consisting of Bulb and spinal cord is allowed to hang by a hook through its lower jaw. We call this a bulbo-spinal frog; and it lives for many hours because the heart continues to beat very much as before.

The first thing we notice is that this preparation does nothing spontaneously; to the casual observer it seems to be dead; it hangs motionless for hours at a time, and unless kept moist will hang there until it dries up. That it is not dead can be proved by lightly touching a spot of skin, when at once some muscle or group of muscles becomes active; and the headless frog may kick and wriggle in a lively fashion.

We begin our systematic study of reflex action by preparing some solutions of very weak sulphuric acid of known strengths, and keeping these in beakers into which the frog's toe can conveniently dip. We must also have a basin of water in which we can wash away the acid from any part of the skin.

We begin the series of observations by allowing the largest toe, say, of the left foot, to dip into the beaker containing the weakest acid. Nothing seems to be happening; then all of a sudden the toe is withdrawn by a contraction of the muscles of the leg. The toe is next washed in water, and, after an interval, is dipped more deeply into the same beaker of acid; the foot is now withdrawn after a shorter interval. If we allow still more of the skin to be immersed in the acid, we find that the foot is withdrawn after a still shorter interval.

Here we have a series of reflex actions where the stimulus is given to the skin and the response is in the muscle; a certain time elapses between the application of the stimulus and the response (reflex time), and the larger the area of skin stimulated, the shorter is the reflex time.

The muscular movements are evidently not the outcome of volition on the part of the frog, which is not only unconscious but bereft of all spontaneity.

Let us vary the experiment a little by placing a piece of blotting-paper moistened with the dilute acid on the (left) flank of the frog. After an interval (reflex time) we see that the foot of the same side is brought up towards the paper; and in a large number of cases the longest toe actually flicks off the acid paper with astonishing neatness. So full of purpose does the action seem that, unless we knew to the contrary, we could not but admit that the " preparation " was conscious.

The " reflex time " (T) is evidently made up of the following factors: (A) time of impulses to travel from skin to centre in cord, (B) time consumed by central activity, (C) time taken by impulses to travel from cord to muscles. The total time (T) can be measured, as also can A and C, so that if we subtract A and C from T we shall have the value of B. It appears that B is actually greater than either A or C. It is sometimes called the " time of central delay ".

Reflex action seems, then, to be sharply marked off from both automatic action and from voluntary: the former is proceeding in the heart and the viscera of the now headless frog in which no volition is possible; but reflex actions can be aroused when and only when the proper (reflexigenous) stimuli are present. A reflex action is motor action at the periphery in consequence of stimulation at the periphery.

Destruction of the spinal cord—" pithing "—abolishes all reflex actions, as it destroys the centres for them.

Evidently, for any given reflex action a definite anatomical path is being used, consisting of afferent nerve, centre, and efferent nerve, a path which, for convenience, we may call the "reflex nerve-arc". It is also clear that there can be spreading of the excitement to neighbouring arcs, as in the experiment where we held down the left leg and the right was brought over to act for it. Here the impulses must have crossed the mid-line in the cord to a centre on the other side, in order to bring the right leg into action. In this case the spreading of the excitement is symmetrical.

If the original stimulation to the spinal frog is very powerful, as by the application of the Faradic electric current, the whole body may be thrown into convulsions. This phenomenon is known as irradiation ; it is a spreading of the activity in an over-stimulated centre into others more or less distant.

The phenomenon of irradiation is by no means confined to reflex action nor even to the nervous system : it is a general property of all living matter that a state of activity at one spot should tend to travel outwards in all directions from the spot where it originated. It is on this account that a white square looks a little larger than a black one of exactly the same size by actual measurement.

What strikes us about reflex actions is their inevitableness. Every time the frog's toe is placed in acid, the toe is lifted out ; the machine-like regularity is surprising ; the action will continue to be repeated until fatigue of the centre sets in. The reason, of course, for this is that in this headless preparation consciousness cannot intervene to modify the reaction in any way whatever. Later we shall see that consciousness is able to modify reflex actions or the tendencies to them.

The spinal frog is indeed a living thing and not a machine; but in the constancy of its reactions to its environment, it is not an individual so much as a series of living neural segments. For the whole central nervous axis can be regarded as a series of centres or segments for the performance of reflex actions, each with the functional but not the anatomical separateness of such segments in the worms, insects, lobsters, and similar "jointed" animals.

It is therefore possible to isolate one of these functional segments and obtain its appropriate reflexes. It was indeed by this procedure that one of the classical experiments on reflex action was made by Professor Whytt in Edinburgh about 1750. Using the frog, he found that he could isolate that part between the brain and the Bulb through which the reflex closure of the pupil to light was carried out. This region, called the mid-brain, was severed from the cerebrum above and the Bulb below, and yet the pupil duly contracted when light was allowed to fall on the retina. This reflex was evidently essentially independent of any events that might be aroused in the brain (consciousness), as well as of any reactions that might take place in any other segments of the neural axis.

Of course this light reflex takes place in the human being. When a bright light falls into our eye, the pupil is made smaller; but this is not a conscious act because we happen to be aware of the light itself. That is all we are aware of. Most people do not even know that this is the effect of light on the iris. The movements of the iris are quite outside our consciousness. This reflex can go on in complete unconsciousness, as for instance in a chloroformed person.

The iris is outside our voluntary control; but although we cannot will to influence the pupil, emotions, as is well known, can affect it noticeably. It is equally true that our will cannot prevent the reflex closure of the pupil from taking place.

We seem, then, ready to summarize what we have learned about this type of reflex action.

(1) Such reflexes can take place without the aid or cooperation of consciousness, that is, they are outside the sphere of consciousness.

(2) The will cannot prevent them from

occurring, that is, they are not amenable to voluntary inhibition.

(3) They are inevitable, machine-like, or predictable.

Reflex actions of which these three things are true are called "excito-motor", and are regarded as belonging to the lowest type of reflexes. Evidently all reflexes in a decapitated animal must belong to this type.

A reflex nerve-arc of only two neurones is sufficient for the reflex to proceed. The afferent neurone enters the cord by the posterior root of the spinal nerve, and the efferent neurone leaves the cord by the anterior root. The centre in this case is the nerve-cells belonging to (trophic for) the motor nerve-fibres.

Interference with or disease of any part of this arc will impair the reflex action: thus, if the afferent limb of the arc is destroyed, the reflex cannot be produced; if the efferent limb is damaged, the reflex is abolished; and finally, if the centre is destroyed, the reflex cannot take place at all.

In the serious disease Locomotor Ataxia, the sensory nerves are damaged chiefly after they have entered the spinal cord; in the disease Infantile Paralysis the centre is involved in an infective inflammation: in both of these conditions the muscular reflexes are interfered with. Although an excito-motor reflex is, under most conditions, inevitable, yet by appropriate means it can be suppressed—a process called Inhibition. For instance, when we wish to prevent a sneeze taking place at an awkward moment, strong pressure on the upper lip will often suppress the reflex altogether. What is probably happening here is that the impulses set up in the nerve from the lip interfere effectively with those in the centre about to discharge the sneeze—a muscular convulsion. The inhibition—most probably by interference—is at the respiratory centre.

But the converse of inhibition—augmentation—can also occur. We can reinforce reflexigenous tendencies just as we can restrain them. The following is a device for augmenting a feeble reflex. The reflex action in question is known as "the knee-jerk", the kick which the leg, crossed over the other, gives when it is struck just below the knee-cap. Sometimes when the reflex is feeble or inelicitable, if you tell the patient to clench his hands as forcibly as possible at the moment that you strike the knee, the jerk will occur quite vigorously. In this case motor impulses, liberated in a part of the brain, have been forced down on to the rather inert centre for the contraction of the muscle which raises the leg at the knee-joint.

The total number of reflex actions in the body must be very large when we consider that the will can influence only the skeletal muscles, whereas reflexes concern themselves not only with all the internal organs but with the skeletal muscles in addition.

We may first classify reflexes according as they are or are not accompanied by consciousness.

The excito-motor group is the only one from which consciousness is completely absent ; in the second group—the sensori-motor—it is present, but is not of the essence of the action ; in the third group, the psycho-motor, it is present causally.

The excito-motor group can be divided up into sub-groups according to the organ or tissue which acts as an effector. Thus we distinguish excito-muscular, excito-vascular, and excito-glandular reflexes according as muscles, heart and blood-vessels, or glands are involved. Excito-muscular reflexes are seen typically in man in cases of broken back or *paraplegia* as it is called. Here the spinal cord has been injured in the back so that the lower part of the cord is isolated from the rest. Since the cord is the great conductor of impulses ascending to and descending from the brain, it follows that the patient will have lost all sensations in his feet and legs, the muscles of which will also have become paralysed. He has no " control " over his lower limbs, or over the internal organs in the pelvis. But since all the afferent and efferent nerves to and from the feet and legs are intact, and since the related centres in the cord are also intact, reflexes can go on perfectly well. Indeed, they are exaggerated, for the unconscious restraint exercised on them by the brain is removed.

Tickling the soles of the feet produces jerking of the muscles which cannot be prevented and is not felt by the patient. It is a true musculo-motor (excito-motor) reflex action.

An instance of an excito-glandular reflex is the flow of gastric juice which occurs when food is taken into the stomach. After the food is swallowed we know nothing about what is going on ; but in the interior of the stomach the glands are secreting juice, which in the resting state they are not secreting, and the blood-vessels there have dilated so as to allow a supply of extra blood from which the glands may manufacture the pepsin and the hydrochloric acid of the juice.

But a large number of reflex actions *are* accompanied by consciousness ; that is to say, consciousness is simultaneously aroused but is not the cause of the action. This is due to the anatomical fact that the afferent neurone, on passing the centre in the central nervous axis, sends upwards through the cord a headward extension (H in Fig. 11), which reaches the brain itself. Thus, at the moment that the reflex occurs, there is a sensation produced.

The light reflex to which reference has already been made is an example of *a sensori-motor reflex*. That the sensation of light is not the cause or source of it is certain, since we know that it can go on in complete unconsciousness. The sensation is merely concomitant, or, as it has been called, an "epiphenomenon" (Huxley).

Similarly many of the reflexes of visceral origin are painful, that is, they are accompanied by pain, but they are not due to the presence of pain as an unpleasant fact in consciousness.

The reflex of vomiting, for instance, set up by the painful passage of a gall-stone through the narrow bile-duct, may be extremely painful; but it is the violent stimulation in the mucous membrane and muscles of the duct that is the source of the impulses which produce the stimulation of the vomiting centre and give rise to the pain at the same time. An unconscious person can vomit, much to the inconvenience of the surgeon operating at the time.

Vomiting is always a reflex action; it cannot be started by the will, but must be induced by tickling the throat with a finger or a feather, or by irritating the mucous membrane of the stomach with mustard and water or some other "emetic".

The afferent impulses which set up an attack of vomiting, being so violent, usually overflow from the vomiting centre into others in the Bulb.

Take the case of the vomiting in sea-sickness; this is rarely due in the first instance to irritation in the stomach itself, but arises from the unusual stimulation to the end-organs in the apparatus known as the semi-circular canals. Owing to the movements of the ship, these receptors are stimulated in a highly abnormal manner, and impulses of unaccustomed intensity are sent inwards to the central nervous axis. For some reason we do not understand, they impinge upon the vomiting centre and arouse it to violent action although there may be nothing abnormal about the state of the stomach. When the food contents of the stomach have been brought up, the vomiting will go on from the empty organ, a condition known as "retching". Then bile becomes regurgitated and the vomiting continues. But meanwhile other bulbar centres are stimulated, the first of which to be affected is the centre for slowing the heart, the cardio-inhibitory centre. As a result of overflow of impulses into this centre, the heart is slowed and weakened, and the blood-pressure in consequence lowered. The patient must lie down or he would faint. This fall of the blood-pressure, with consequent enfeeblement of the circulation in the head, is, of course, the cause of the well-known pallor and chilliness which are characteristic features in these cases. Indeed, before vomiting sets in, some reflex cardio-inhibition has begun. Sufferers from sea-sickness know they are going to be ill when they feel chilly all over, and are told they look pale.

The reflex inhibition of the heart may be so severe that the circulation is within a very little of failing altogether, and the person is said to be in "collapse"; he is in need of expert medical aid.

Another bulbar centre into which there is often an overflow of impulses is the perspiration centre, so that, to add to the sufferer's discomfort, he breaks out into a cold sweat.

We see then that vomiting is a sensori-motor reflex action with a special centre in the Bulb which can neither be voluntarily roused to action nor voluntarily restrained therefrom. It is also very liable to be associated with the stimulation of neighbouring centres.

The sensori-vascular reflexes that arise in consequence of a chilling draught on the skin and constitute the familiar congestion of the internal organs are of the highest importance in clinical medicine.

The last group—*the psycho-motor reflexes*—is that which includes emotions or ideas as of the essence of the action. Blushing may be taken as a concrete case. Blushing is distinguished from flushing because the latter is merely a sensori-motor reflex dilatation of blood-vessels, whereas blushing is the result of a conscious state of mind—an emotion. The centre involved in both cases is the bulbar centre for maintaining the tone of the circular muscle of the small arteries (arterioles) so that these vessels are left in moderate contraction. In the case of flushing, an inhibitory stimulus arrives by a reflex route and so influences the centre that it innervates the muscles less intensely: the muscles relax, and the vessels dilate. In the case of blushing, the inhibitory stimulus descends on the bulbar centre from some district of the cerebrum. The emotional impulses traverse a cerebral arc, those for flushing a spinal; but it makes no difference to the inhibition of the centre for the blood-vessels whether the impulses had a central or a peripheral origin—a reflex inhibition is being carried out in both cases.

Blushing is, then, an inhibitory emotio-vascular reflex.

This group of emotio-motor and of ideomotor reflexes is a very large one. Emotions or ideas with emotional colouring can alter the physiological condition of nearly every organ or tissue in the body. Their influence on the heart is notorious, to such an extent that "heart" has become a synonym for an emotional condition.

Emotions affect the heart in two opposite directions: they either quicken its rate or increase its force and so raise the blood-pressure, or they slow and enfeeble it, thus lowering the pressure. The cardiac centres so affected are in the Bulb.

Similarly glands are demonstrably under the influence of emotional states, both those which increase and those which decrease their activity. Perspiring in consequence of shame or apprehension is an example of the former; the drying-up of the glands of the mouth through fear, an example of the latter. The inhibition of the gastric juice through worry, disappointment, etc. is another example of an emotio-glandular reflex. Not only the flow of juice but the churning movements of the stomach also may be annulled, which of course brings on an attack of indigestion.

The whole alimentary system is very susceptible to emotional influences. A happy, contented state of mind is a tonic to digestion as it is in reality to all the bodily functions. This sort of thing is sometimes alluded to as the influence of mind over matter ; it is psycho-motor reflex action.

Now just as the centre for the control of the blood-vessels can be acted on either by impulses which have arrived there from the periphery or from the brain, so can the vomiting centre. For we can have psychic vomiting, a smell or a sight arousing such powerful emotions of disgust that the vomiting centre is actually stimulated.

Other emotions, more difficult to describe, tend to cause nausea and a " sinking feeling " difficult to locate : it is evidently to these that the old saying, " Hope deferred maketh the heart sick ", alludes.

The effects of emotion on the kidneys are a matter of common knowledge.

The psycho-motor reflexes are by no means confined to man. They are to be found throughout the animal kingdom. Darwin's book, *The Expression of the Emotions in Men and Animals*, is a description of the different muscles used for the different emotions. The specificity of the expression is very remarkable : each emotion would seem to have its own special muscular apparatus of expression.

Indeed the very largely reflex character of the activities of the lower animals is striking. Much that is called automatic in them is reflex in consequence of a pre-adjusted neural disposition. Take the case of the newly hatched chick which, the moment it sees a bright object, will peck at it: it has not had time to learn this. Volition is out of the question.

An infant without cerebral hemispheres (" acephalic monster ") can carry out such a reflex as sucking. It is a bulbar reflex that is being carried out with perfect accuracy and must be due to an inherited disposition in the neurones concerned. For many days the normal infant is little more than a bundle of reflexes.

A great many of these preformed dispositions to perform reflex action are called " instincts ". Consciousness may later on accompany them; but in their origin it plays no causal part.

Now the converse process can go on, namely, where an action is learned laboriously and later becomes reflex or, as it is sometimes but incorrectly called, " automatic ".

For instance, learning to play the piano is a case in point. At first this is learnt with difficulty, the brain being slowly educated to it. After a while it becomes more and more easy, less and less attention or consciousness being required, until at last the playing of a quite familiar " piece " is entirely reflex. So little has it to do with consciousness that a person is able to play the piano and carry on a certain amount of conversation with some one standing near-by. Here arcs which pass through the brain are functionally involved; but in course of time the passage of impulses over them ceases to arouse consciousness. These are sometimes referred to as "reflexes through cerebral arcs".

Thus "habits" are established. They are things learned with effort and by concentration of attention; and then, as though the intraneural resistances were being overcome, the actions proceed more and more easily and unconsciously until they are purely reflex.

Physiologically certain activities such as walking are in reality of quite the same neural order as habits. The child laboriously learned to walk and balance himself; later he did so with less and less effort until at last walking could be carried out unconsciously. We can walk along reading and yet not stumble; this is an acquired reflex and has become unconscious. It is indeed a series of alternating contractions and inhibitions of muscles mutually adjusted to maintain balance and promote progression—co-ordinated in fact; and elaborate as it is, it does not involve consciousness.

The bulbo-spinal dog can walk; that is, an animal in which the central nervous axis has been divided above the bulb, thus separating the brain from the control of the body, can nevertheless walk as though the cord-centres were being normally directed from the brain.

Again, walking in sleep—somnambulism—is an example of the essentially reflex character of walking. The person is asleep, that is, unconscious, but on the subconscious plane a dream can be acted through the mechanism of reflex walking.

It is well known that once one of these co-ordinated, unconscious reflexes has become established, the conscious intrusion or voluntary interference will disorganize the smooth flow of events. The little boy on "speech day" gets on nicely with his recitation until something quite unforeseen occurs, when he is "put out" and forgets it. Reflexes once established are better left to themselves.

CHAPTER VIII

THE FUNCTIONS OF THE BRAIN

TO understand exactly the place which the brain occupies in our neural life, a good way is to see how an animal from which the brain has been removed behaves. Such an animal is called " decerebrate ".

The cerebrum or cerebral hemispheres in man are two large layers or sheets of nerve-cells (cortex cerebri) which overlie the central nervous axis and come well down at the sides, so that unless the brain is split down the inside nothing of the central axis can be seen.

Each hemisphere sends fibres down to the single central axis and so to the cord, and from the cord via the central axis each hemisphere receives certain fibres.

Since from each hemisphere (cortex) fibres are descending towards the axis, there must be a place where the two strands of converging fibres meet in the mid-line. This place is called the Mid-Brain ; it is just headward of the Bulb.

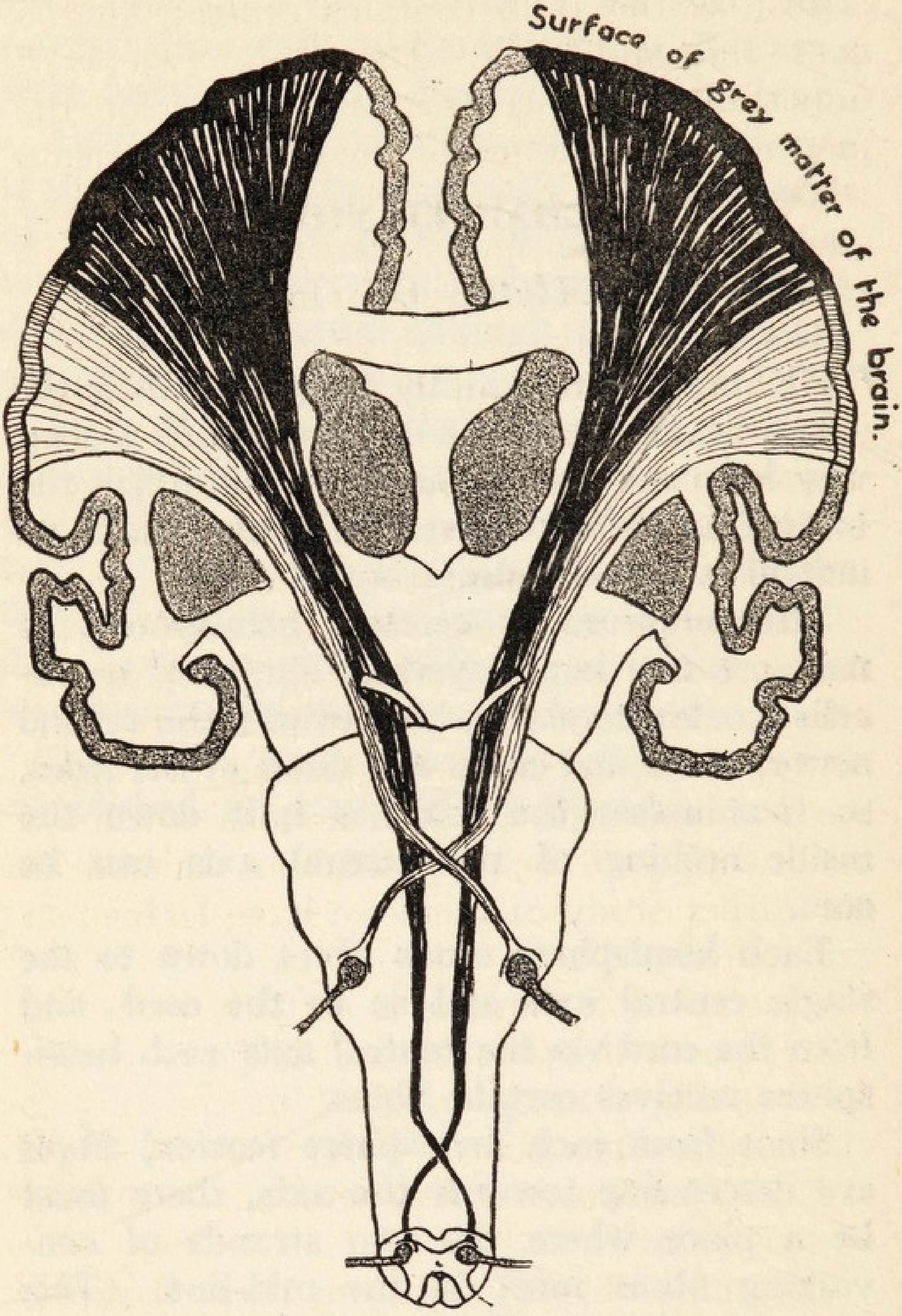

FIG. 12.—View of Fibres descending from the Grey Matter of the Brain to cross at lower levels.

Just as the Bulb contains centres, so too does the Mid-Brain. There are two very important reflex centres here; one for the movements of the iris of the eye—the curtain whose central aperture is the pupil—and another for the muscle in the eye which enables the lens to focus for near objects.

The most noticeable thing about a decerebrate animal is that all its spontaneity is gone. Brainless animals sit or lie "like logs"; they seem to have lost all interest in life. If it is a decerebrate dog we are examining, we find that food placed before it remains untouched; a decerebrate male pigeon will "coo" incessantly, but if placed beside the hen bird will take no notice of her. There is loss of will-power, of the faculty of originating anything: these animals will perform actions which we might suppose to be purposeful but which from our earlier study of them we have learned to call reflex.

Once the dog's muzzle is actually placed in contact with the food, he will begin to eat it, because the centre for smell in the dog is virtually a reflex centre. The sense of smell, as is well known, is a very unintellectual form of sensation.

The most obvious function, then, that the cortex cerebri subserves is that of perception. It is the absence of sensation and absence of the subsequent perception from the decerebrate animal which isolate it so completely from its environment and contribute to making it so mechanical an organism.

The various sensations are now known to be located, with surprising distinctness, in different parts of the cortex cerebri. A particular example will be the best to study at first: let us take the visual centre.

This is a double centre situated in each half of the most posterior portion of the cortex (occipital). When both these centres are removed, the animal is totally blind. In war it has sometimes happened that this portion of the brain has been blown off, and the sufferer has become as blind as though both his eyes had been destroyed. This region of the cortex is that whereby we actually see, for unless it is intact we cannot see anything even though the eyes are retained. Here are stored visual memories; and as we shall learn later, this centre is the physical substratum of dreaming.

Both visual centres require to be removed to produce complete blindness; if only one is removed, neither eye is totally blind, but each eye is half blind—a curious arrangement of Nature.

The centres for hearing are at the sides of the brain (temporal region) and are similar in their arrangements, for destruction of only one causes partial deafness in each ear.

The sense of smell has also a location in the grey matter ; and the seats of most of the other senses have been ascertained.

This is what is meant by " cerebral localization " ; on the sensory side, it means that a certain area of cortex is devoted to the registration of the impressions of one particular sense and is the necessary physical basis for the consciousness of that variety of sensation. There is, in other words, a specialization for the reception of impulses coming from sense-organs, just as there is a division of labour amongst these organs themselves. The cortex, in fact, does not act as a whole in this respect ; each sensation has a separate cortical seat or centre. Thus an abnormality—a tumour, for instance—in the centre for vision impairs vision but not hearing, and *vice versa.*

These sensory areas are not, as was formerly thought, all collected into one part of the brain which was named " *sensorium commune* ", but are found in all the cortical regions except the frontal lobes.

Observations on the living brain, as well as careful analysis of data obtained in cases of human diseases and injuries, have given us the facts on which our knowledge of this sensory localization is based.

So far, then, we have seen that the grey matter on the surface of the brain has to do with our perceptions of the changing states of the outer world and those of our own internal organs. Sensation is the first mode of consciousness to arise in our mental life. But along with sensations, from a very early date, emotions arise also. There are very few sensations which have not what is called nowadays " affective tone " ; we either like or dislike what we receive by the senses.

Only for purposes of purely scientific observation are perceptions not emotionally coloured. We cannot restrain or inhibit the uprising of emotion although we may restrain its expression. Either I desire to perpetuate a particular kind of sensation or I wish to end it ; the dislike of it may in some cases amount to pain. This emotional colouring is the " meaning " which becomes associated with the sensation.

Now there is no known part of the brain (locus) in which emotion can be said to be located as sensation is : there is no centre for " meaning ". A deeply seated part of the brain (optic thalamus) has recently been supposed to have to do with certain kinds of severe pain, but that discovery does not invalidate the statement just made that " affective states " or " meaning " have no localization such as have sensations themselves.

We may now proceed to consider the localization of the motor functions. In point of time, this was discovered earlier than the sensory localization; and the man to whom we are indebted for this knowledge is still living—Sir David Ferrier, F.R.S., born in 1843.

Briefly the discovery was that there were areas of the grey matter on both sides of the brain devoted to the movements of certain groups of muscles. These are naturally known as the motor areas, and sometimes as "Ferrier's areas"; in them the representation of the muscles, or more strictly of muscular movements, is remarkably detailed. The muscles are "represented" in the cortex, in that artificial stimulation of a spot sufficiently small will throw a single muscle into contraction. When a muscle contracts naturally, its antagonist * is relaxed; and usually this reciprocal activity is what is observed to take place when a portion of the motor area is stimulated.

The movements elicited by artificial stimulation of the surface of the brain are of exactly

* The antagonist of a muscle is one with the opposite function; thus the extensors are the antagonists of the flexors, the abductors of the adductors, and so forth.

that character which would be called volitional if the animal were conscious and in possession of its liberty. These movements are indistinguishable from voluntary actions; and there is no reasonable doubt that the areas of Ferrier on the sides of the cortex are the physical bases of volitions, of the mental initiation of bodily movements. It is in consequence of this belief that these areas are often called the "psycho-motor" areas.*

That one side of the brain is functionally related to the opposite side of the body is a fact known since the earliest times of medical observation.

The effects of serious disease, either in one motor area or in the fibres descending from there towards the Bulb, had been known for a long time, namely a paralysis of the muscles of the limbs on the opposite side of the body. An apoplexy, "fit", or seizure is the result of blood being poured out either amongst the cells of the superficial grey matter or more commonly amongst the fibres on their way down to the level of the Bulb and cord. The pressure of this cerebral hæmorrhage cuts off impulses descending from the motor cortex to the muscles, so that the patient is unable by

* They are sometimes called Rolandic areas, because they are situated close to a fissure in the cortex, known to anatomists as the Fissure of Rolando.

any effort of his will to move certain groups of muscles in arm or leg. He is exerting his will as before, but owing to the damage to the instrument of the will, his volitional efforts cannot be made effective. The paralysed leg is dragged, the paralysed arm hangs limp.

We have now assigned locations in the brain to the senses and to the bodily movements; but when the regions for these are carefully mapped out they do not by any means occupy the whole of the cortical grey matter.

There are regions which on artificial stimulation do not give rise to sensations or to movements, nor do tumours of these produce either hallucinations or twitchings. These are known as "silent areas" or, much better, "association" areas. They are regions which neither receive sensory impressions nor initiate motor messages, but they behave as intermediary between these two sets of impulses in that they receive impulses from sensory centres and, having integrated them, send them onwards in due synthesis towards the motor centres. These association centres are the places where association of ideas occurs; they are the "seats" of intellect as distinct from perception on the one hand and volition on the other.

Before we leave the subject of sensory and motor regions of the brain, we must refer to what is called the " reaction time ", since this interval of time, short as it is, is of considerable importance in daily life.

The Reaction Time is the interval between the moment of the perception of a sensory stimulus and that of signalling in some way or other that it has been perceived. This is its laboratory definition ; in ordinary circumstances, it is the time taken to respond to, react to, a sensation.

A short reaction time makes for " safety first ". When we hear the hoot of a motor horn, the more quickly we step from the road to the foot-path, the better for ourselves. In all games, also, a short reaction time is a great asset. What is called " training the eye " is really establishing a short visual reaction time where the hand reacts. The instant the tennis ball is seen, the appropriate muscular adjustments are made to deal with it accurately and powerfully. The length of the reaction time, apart from the element of accuracy in the response, may make all the difference between failure and success at the game or sport. Of course judgment must be used : you could in certain circumstances fire at the bird too soon.

Curiously enough the reaction time for touch is shorter than for sight.

Reaction times have been elaborately investigated by the experimental psychologists. The simple demonstration of reaction time is to signal by the hand (say) when a prearranged stimulus, the sight or sound of something, is perceived. The time is of the order of fifteen-hundredths of a second.

What is called "discrimination time" is measured when the stimulus may be one of *two* things, say, a green disc or a red one: the time of this response is always longer than that of the simple test. The time is of the order of seventeen-hundredths of a second: therefore the extra time consumed by the central processes involved in the recognition of one of two things seen in this way, is two-hundredths of a second. In the case of discrimination, the attention is concentrated on the perceptive side.

Lastly, let us make an effort to estimate the time occupied on the emissive side. The following experiment will suffice: the left hand is to be used to signal with when the left little finger is stimulated, and the right hand when the right little finger is stimulated. Here a decision involving motor events has to be made, in other words a volition; and now we find the volition time may be as long as three-hundredths of a second.

From a very large number of observations of this kind it is ascertained that cerebral processes occupy time; and that the mental attitude we call attention can shorten these processes. This time is known as "the time of central delay". It should be noted that attention to the executive side shortens the time of central delay more effectively than attention to the sensory side.

It must be the central processes which are consuming the variable time, for, as we have seen, the speed of impulses up the sensory nerve and down the motor is the same every time and varies only with the temperature. That mental processes take a measurable time is of course contrary to the old belief that "thought" was incalculably rapid.

Summarizing, we have learned that the cerebral cortex is the physical substratum of sensations, perceptions, voluntary movements, and a number of mental processes described as association of ideas, attention—thought in general. We usually "react" to our sensations, but this reaction is not inevitable; we may or may not react. We have, in fact, the power of choice not to react. We are entirely "free agents"; we may decide *not* to signal that we have perceived a sensation. This is still volition, but it is volition *not* to do something, voluntary inhibition, as it is still more technically called. There is active restraint by the will, which is another power of the brain and of the mind. The will means more than the will to do; it also means the will to refuse to do, and this is frequently the more difficult of its two aspects to realize.

In this connection it is significant that certain experimentalists have found that the inhibition of certain muscles results from the stimulation of areas of the cortex which appear to be intermingled with the motor areas ; in other words, there is a physical basis for the inactivity as well as the activity of muscles. Inhibitions have a cortical representation. This conscious cerebral inhibition is an exceedingly important factor in the development of character : in this sense the cerebrum is the physical basis of character. We speak of the training of character, but that is only possible when there is a certain minimum of cerebral cortex present : microcephalic idiots are mentally and morally idiots because they are microcephalic ; they have too little brain substance to have a physical basis of character at all.

To this extent " morality " has a physical, a material basis. It was for affirming this that Gall was forced to leave Vienna in 1809 ; it was considered " irreligious " and " materialistic " to teach that morals had a physical substratum.

We cannot speak of a moral or an immoral infant ; there is not sufficient grey matter developed to be the basis of morality. Similarly you cannot speak of an immoral cat or dog. By associating with man, a dog can be made to understand that some things it wants to do are displeasing to its master ; but that state of mind is brought about solely by the association of the idea of approbation from the master when he does so-and-so, and a whipping when he does the opposite. And this primitive moral teaching is easier in the dog than in the cat, because the dog has relatively more grey matter. When you get down to the rabbit and the guinea-pig, it is quite impossible to teach them at all, as the grey matter in these types has gone below the necessary minimum. How superficial is this " training " in ideas of right and wrong may be seen in the case of the cat, which will to the end of her days steal the fish the moment your back is turned.

The next state or condition which requires the presence of grey matter is emotion, a term used to cover all aspects of consciousness which are not sensations, volitions, or concepts (notions). Some psychologists prefer the term " affective states " ; but the idea is the same : the person is affected ; and emotion means the same thing : the person is *moved*.

An emotion is an ultimate fact of consciousness ; I like or dislike instinctively ; it is something I feel without teaching or training. A certain colour or sound or smell may do one of three things—leave me unaffected, afford me pleasure, or distress me. This emotion of pleasure or of distress is evidently not the sensation itself; it is a mental condition entirely of its own kind.

And emotion is probably the earliest and psychologically most primitive of mental happenings. Very few sensations are entirely without emotional colouring. A sunset either has no effect on a man whatever, or it gives him some degree of pleasure. This emotion of delight, æsthetic joy, simply comes, arises of itself; it is found in consciousness, it does not require to be worked up, it does not come or go to order. An emotion is an effortless occurrence in consciousness. If I like a thing, I like it and that's an end of it: there is no use telling me not to like it; that cannot alter it. Emotions are fundamental psychic existences; children have them at an early age; animals have them as soon as born. The very first time the chick sees a hawk, it is afraid. The infant put to the breast does not need to be taught to dislike something bitter and enjoy something sweet. Later we may, in "training" children, interfere with their emotions and criticize them; but the emotions cannot be banished.

It is evident that we have now entered the large field of the understanding of the child-mind and the formation of its character. Restraint or control of the emotions has led us to this. The child cannot be allowed to grow up a savage; the savage does not control his emotions; they are expressed as soon as they arise. The uprising of the emotion itself cannot be controlled; it is only its expression which may be modified and inhibited. Emotions and reflex actions are alike in this, that they are inevitable; only certain reflexes can be inhibited; the full expression of certain emotions can be modified—that is all.

We must now note that emotions tend instinctively to *appropriate* expression. This tendency to expression is as fundamental as the existence of the emotion itself. The natural tendency is to motor, emotio-motor, overflow. The dog wags its tail the instant it is pleased; it cowers and puts its tail between its legs the moment it is frightened. Without the expression, we should never know of the existence of the emotion. The infant shows every sign of displeasure if a little bitter aloes instead of sugar touches its lips.

We have already studied to some extent the expression of the emotions under the heading of emotio-motor reflexes, their reflex character accounting for their inevitableness, by which we mean that a certain emotion employs consistently the activity of certain muscular groups and only these. There is a high specificity in this emotional expression: one emotion increases the flow of saliva, another stops it, and so on.

Some psychologists have held that the emotion was not essentially a cerebral condition but the reverberation in consciousness of the state of excitement in the skin and in the various internal organs. This was putting the visceral cart before the cerebral horse. It will not work. It was shown that in an animal almost the whole of whose spinal cord had been severed from the rest of the nervous axis, and in which therefore the sensory impressions from the internal organs could *not* reach the brain, emotions were nevertheless well developed.

Emotions are, then, not so much independent states of mind as the accompaniments of these, especially of sensations and ideas. "Emotional colouring" is a serviceable phrase. This characteristic of emotion may be related in some way to there being no localization for emotions as there is for sensations and for movements.

Clearly emotions are the raw material of our æsthetic life. The true artist must love colour and harmonies. These and other sense-factors are the groundwork of beauty. The so-called "sense" of beauty is that emotional perception which produces pure delight. It is evidently this perception of beauty, these intellectual emotions, which distinguish animals from men, and lower from higher races of men.

Finally, the cerebral cortex is evidently the organ of the mind, in that it is the organ whereby the mind carries out its various activities culminating in ideation or abstract thinking. It is the physical basis of ideas and of the processes of reasoning. Above all, it is the organ whose activity underlies the formation of concepts. Once more it is this process of abstraction that distinguishes the lower animals from man, and the lower from the higher races of man. The cat forms no abstract ideas; it passes from one concrete experience to another. But the life of man in civilized communities is possible largely because he can deal with problems far beyond his merely concrete needs by means of his faculty of framing abstract conceptions. From the existence of concepts we are led at once to consider the mechanism in the brain whereby they are expressed in symbols, the power of speech.

In a sense this function of speech, of the use of words, spoken, written, or printed, to convey ideas, is the most important activity of which the human cerebrum is capable. No level of the nervous system lower than the cerebrum can speak. Speech is the voluntary expression of ideas: ideas and their symbols (words) are quite different things. Just as the emotion of shame is not the same thing as the facial blush which is the vascular expression of it, so the word is not the thought but the muscular conveyance of it. But whereas the expression of emotion is quite outside the volitional control of the individual and is not learned, the verbal expression of ideas is of the essence of education, and has to be learned laboriously by each human being. The cerebral cortex is the organ of educability. Like walking, talking has to be acquired by more or less laborious learning.

The acquiring of a vocabulary is rightly regarded as the index of intellectuality. If a child is slow to learn to speak, the mother is naturally anxious about him, and takes him to the doctor "to see what is wrong". It is rightly assumed that a great command of appropriate language, such as John Bright and Mr. Gladstone possessed, is an indication of intellectual eminence.

The epigram of Talleyrand, "Speech was given to conceal thought", has concealed in it a grain of truth, which is that if we will it so we do not need to express every idea in words.

I am not one of those who believe that there can be no thought without words. Animals

" think " without speech ; savages must have thought before language was evolved ; persons whose brains have suffered damage have thoughts which they cannot express : but the use of words in their correct senses clarifies thought and greatly facilitates the thinking-processes. Learning to talk is, in its earliest stages, as pure a piece of imitation of sounds on the part of the child as it is on the part of the parrot. It is in this sense that uneducated people " speak ", people who cannot read or write their own language ; they associate sounds with a few ideas about concrete things, for they hardly ever use abstract terms.

The first centre, then, that a child uses in learning to speak is the " heard word centre ", from which proceed impulses to some other district of the cortex whence issue impulses to centres in the Bulb which give rise to nerves that innervate the muscles of articulation. These muscles are those of lips, tongue, cheek, and soft palate, and they are all innervated by nerves of a bulbar origin. This must be the order of speaking, since it is at first a sensorial acquirement ; sounds which acquire " meaning " are registered in a specialized part of the sensory cortex (heard word centre) whence impulses proceed towards the motorial or executive side of the brain. No more than this is involved in learning to speak a language

" by ear " alone ; it is the irreducible cerebral minimum for speech.

We should note that this heard word centre is a specialized or extended portion of the auditory centre: for the sake of precision, we may call the latter the lower hearing centre, the former being the higher hearing centre. All animals with ears possess a lower hearing centre ; only those human beings with adequate cortex have the higher centre where verbal sounds acquire meaning.

The heard word centre is not merely a hypothetical centre ; the surgeon-neurologist can point to an area of cortex as being the region where heard word memories are stored. A place is known where local disease or injury renders the patient unable to reply to questions because, though he hears sounds as before, he no longer comprehends the meaning of the words used (" sensory " or " receptive " aphasia). Such a person's muscles of articulation are not paralysed nor is there anything wrong with the emissive side of the brain ; but because he does not understand, he cannot make an appropriate reply. Such a person can utter words, especially under strong emotion. He retains what is called " interjectional speech ", which includes swearing, but he has lost the faculty of intellectual statement.

Cases have been described of congenital

non-development of the heard word centre, with the result that as soon as the child went to school, it was set down as " too stupid to learn ".

A centre for speech on its emissive side would seem, then, to be a necessity, if we judge by the way in which, as we have seen, other cerebral functions are related to centres.

The motor centres for the actual innervation of the muscles of the larynx and of articulation are in the Bulb, while Ferrier's motor areas in turn innervate the bulbar centres; but the " motor speech centre " is not in either of these regions.

The motor or emissive speech centre is an ideational (associational) centre receiving impulses from the higher sensory centres and emitting impulses towards such centres in Ferrier's areas as innervate speech muscles.

One hundred and twenty-five years ago Joseph Francis Gall, a German physician, declared, from his studies of cases of disease and from his dissections and post-mortem examinations, that this speech centre was in the frontal lobe. The French anthropologist, Paul Broca, in 1861 gave further evidence from clinical medicine of a similar site for such a centre, a centre for the memory of words, as Gall put it.

So far, then, we have found it to be a centre functionally intermediate between the heard word centre and the motor centres for muscles whose activity enables a person to learn to repeat (heard) words. But it is equally evident that at a very early age this emissive speech centre is instructed from the seen word centre, a centre where seen words acquire meaning. This is the centre employed in learning to read aloud and to write. As regards writing, there is a centre higher than Ferrier's for the muscles of the hand which is indeed on a functional level with the motor speech centre ; this is the writing centre or, as it is sometimes called, the cheiro-kinæsthetic (Bastian).

In learning to read, the seen word centre instructs the motor speech centre ; in learning to write, it instructs the writing centre.

It is clear, then, that both the word centres are connected to the speech centre (for replying to questions and reading aloud), and both the word centres are connected to the writing centre (for writing to dictation and copying words respectively). The speech centre and the writing centre are " association " centres.

As in so many other cases, much of our knowledge of the normal working of these mechanisms has come to us through a study of their derangements. Aphasia is the term used to denote a number of defects in speech some of which should be called dysphasias, for literally *a*phasia means speechless*ness*, and complete

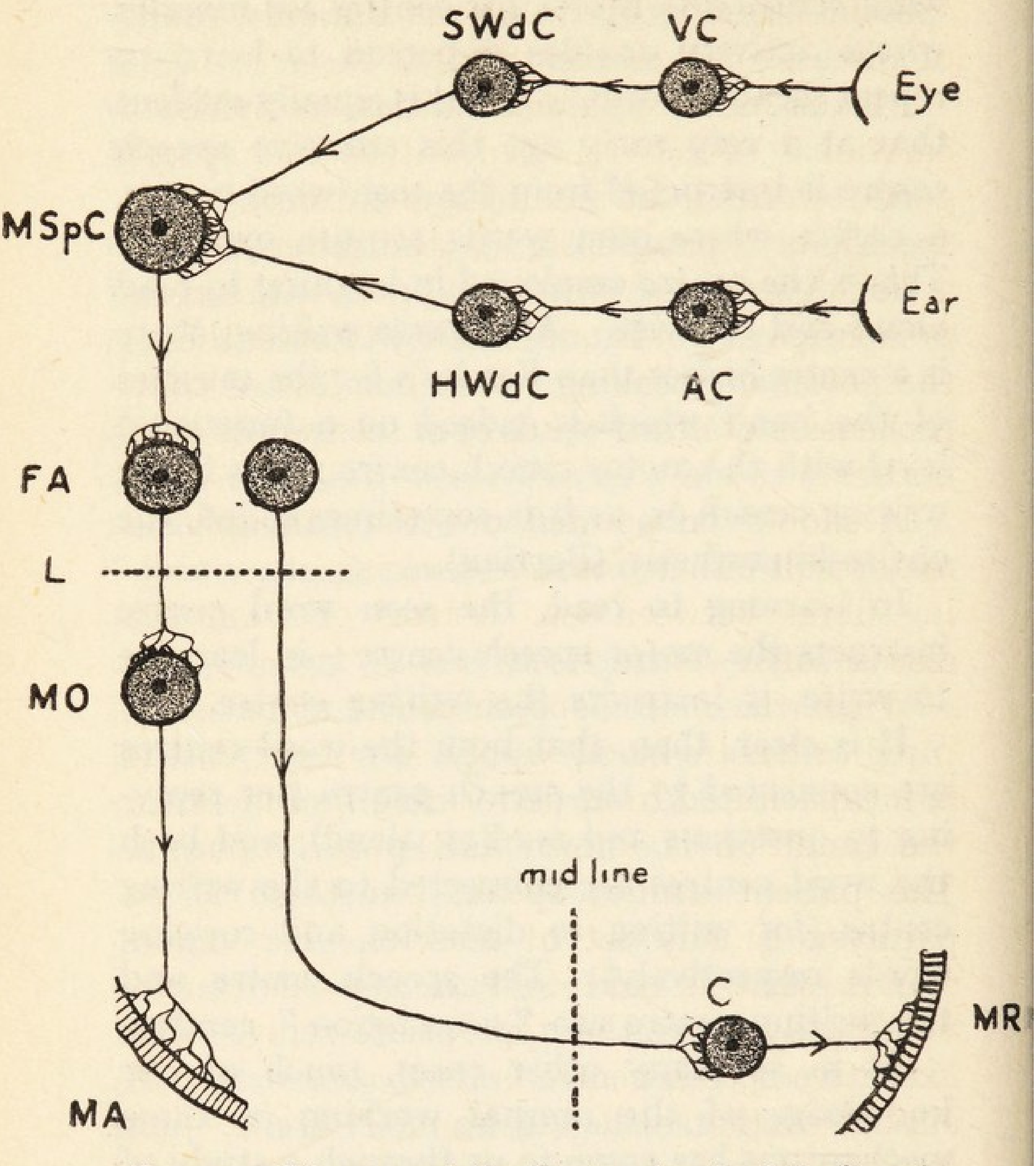

FIG. 13.—Diagram of the Centres involved in Speech.

VC, visual centre. AC, auditory centre. SWdC, seen word centre. HWdC, heard word centre. MSpC, motor speech centre. FA, Ferrier's centres. MO, centres in Medulla Oblongata for muscles of articulation. L, a sub-cortical lesion : level of Internal Capsule. MA, a muscle of articulation. MRL, a right-sided body muscle. C, a centre in the spinal cord.

speechlessness is by no means the only result of disease of these centres.

All the following abnormalities are aphasic: emotional speech retained, intellectual speech gone; words in an unintelligible order, jargon speech, or "paraphasia"; the reiteration of a single word as "yes" or "no"; the comprehension of words but inability to utter them; the power of speaking words but loss of comprehension of heard words or of seen words or of both.

It should be pointed out that an aphasia may result either from the severing of connecting fibres between two centres or from the disease of a centre itself.

When the motor speech centre alone is injured or has its blood-supply so cut off that it is incapacitated from performing its functions, the condition is known as "pure" aphasia. The patient cannot speak, but there is no paralysis of any set of muscles. He understands what is said to him, but he cannot voluntarily make the appropriate reply. The executive speech centre is itself thrown out of action, so that although impulses are coming towards it from the higher sensory centres, it cannot operate upon the motor centres at the next functional level. Such a patient can however write his reply.

A much commoner form of aphasia is that

associated with one-sided paralysis of the muscles of leg and arm. This condition (called a " fit ", " seizure ", or apoplexy) is produced by an effusion of blood having cut below the cortex certain fibres which pass down close together from the motor centres in Ferrier's areas to the bulbar and spinal centres for the nerves supplying the muscles of articulation and of the limbs. The result of the pressure of this blood is to interfere with the passage of impulses innervating the muscles of articulation and of the limbs, which therefore become paralysed. They are paralysed in the sense that voluntary impulses cannot reach them, so that the patient can neither talk nor walk. Reflex impulses however can still reach these muscles, so that all their tone does not vanish.

Since now the motor centres for the right side of the body are in the left hemisphere, and since the vast majority of people are right-handed, it is a left-sided bleeding which causes a right-sided paralysis. It is this right-sided paralysis which is so very often associated with speechlessness, so that one looks for the speech centre in the left side of the brain.

There is a great deal of evidence that this is its location: Gall, Broca, and all the earlier observers did indeed teach this. Although in recent years this belief has been assailed, the clinical evidence which indicates that the emissive speech centre in right-handed people is in some region of the left frontal lobe, is much too extensive to be overthrown.

In learning to read aloud, the functional association is between the seen word centre and the speech centre. Clearly if the seen word centre is destroyed, or if the fibres connecting it with the speech centre be severed, then the person cannot read aloud, because in the former case he does not understand what he is looking at, and in the latter he cannot actuate the speech centre. This defect is called "alexia".

In learning to write, which always consists in copying what is set before one, the seen word centre and the writing centre are connected. Similar defects in this neural mechanism will give rise to the impossibility of writing from a copy, a condition called "agraphia". Finally, if the connection between the heard word centre and the writing centre be interrupted, the patient cannot write to dictation, another variety of agraphia.

The cerebrum is therefore the organ which can be educated; it is the organ of behaviour; it is in the fullest sense the organ of memory and of thought. It is the organ of inhibition, of that restraint which is exercised—unconsciously all the time, consciously from time to time—on centres at lower levels. It has been repeatedly found, when the brains of highly intellectual persons were examined post-mortem, that the development of the convolutions was notably in excess of the average amount. The spaces between the convolutions (called "sulci") were therefore deeper than in ordinary brains, the result being that, as compared with average brains, there is more cortical substance, there are more cells in the grey matter, more of which is folded into a given space. Furthermore, the frontal region in which the speech centre is placed is always generously developed in mentally gifted individuals.

The mere size of the brain is not what determines intellectuality so much as its cellular richness and the complexity of its connecting fibres. These unquestionably are the material bases for the association of ideas.

Gall believed that mentally capable men had a prominent development of the skull in the region of the forehead to accommodate their large frontal lobes. In particular he thought he had observed that persons who were good linguists had the skull prominent over the eyes. From this he was led to believe that prominences of the skull always indicated corresponding local development of the brain under the skull. On this he laid the foundations of the pseudo-science of phrenology, which in the early years of last century claimed many adherents. But that was fifty years before the experiments of Ferrier revealed the truth regarding the localization of function in the brain. It is a fact that from the general shape of the head we can infer the character and mentality of a person ; we know we shall not find a mighty brain inside the receding forehead of the congenital idiot ; but it is not the case that various *abstract* qualities have their " seats " all over the surface of the grey matter.

Gall began on the sound lines of practical cerebral physiology but ended in absurdity. His system was popularized by his uncritical lieutenant Spurtzheim, who elaborated it into that tissue of puerilities which has long since been demolished. No scientifically trained neurologist at the present day believes in " phrenology ".

If we survey the cerebral cortex throughout the animal kingdom, we notice that the lower in the animal scale we go, the less there is of it. In the Fishes there is none of it ; in this great family the brain is represented by a number of masses of grey matter which correspond to certain cell aggregations belonging to the central nervous axis (Basal Ganglia). In the Amphibia and Reptiles a primitive cortex has appeared as a thin sheet of grey matter superadded to and covering over the basal ganglia.

The cortex can be seen to be an outgrowth which, growing forwards, backwards, and to the sides, covers and overhangs the central nervous axis, and the more completely, the nearer to man we come. It is a relatively new struc-

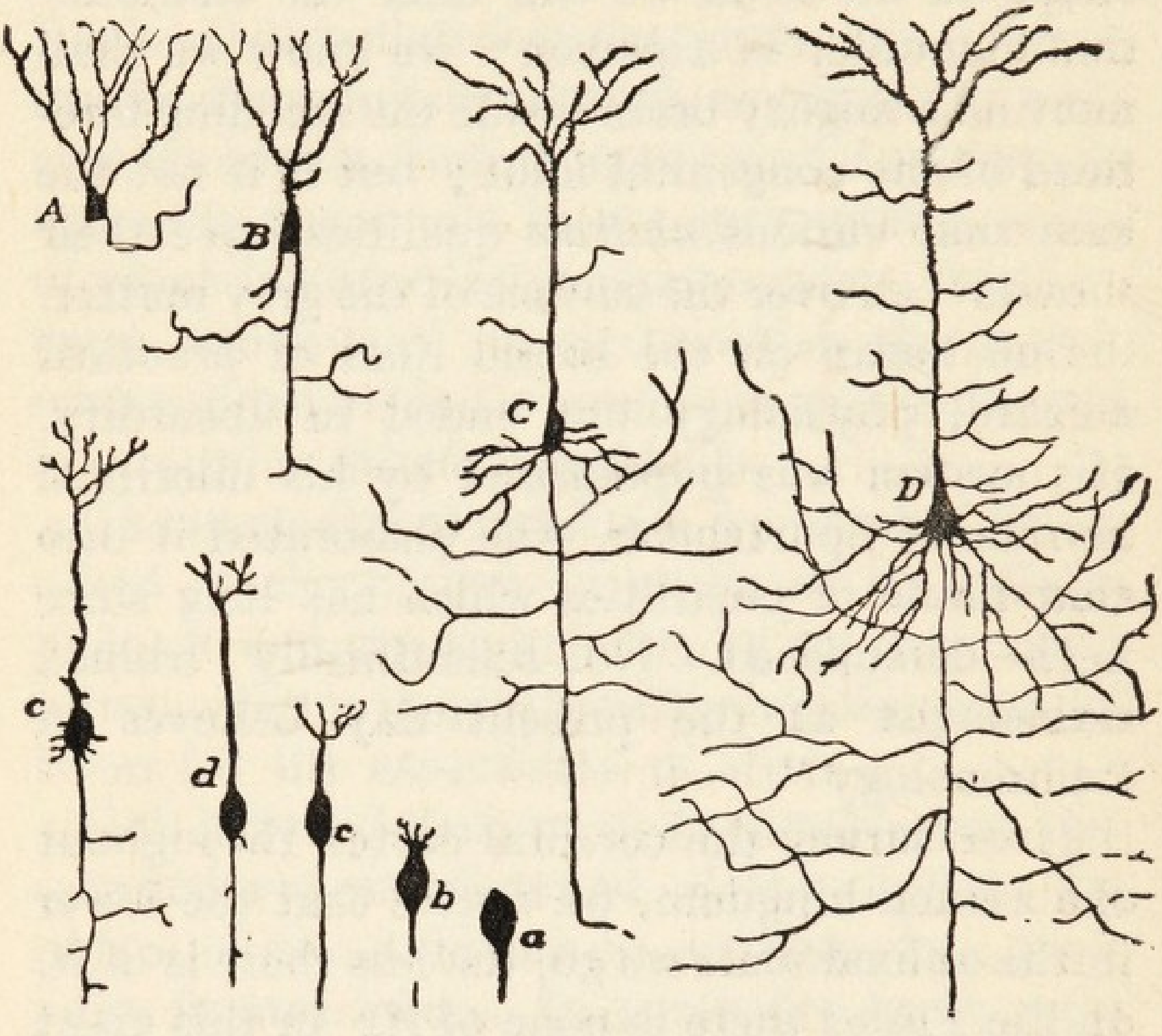

FIG. 14.—Series of Neurones from the Grey Matter of the Brain, of four ascending types (*A–D*).

Stages in the development of a single neurone from the grey matter of the brain (*a–e*).

(From Stewart's *Manual of Physiology*.)

ture in the history of the races of animals, geologically speaking, and has therefore been named the " neo-pallium " (new cloak). This structure, the " cortex " of the older terminology, is anatomically and functionally superadded. The neo-pallium, smooth in frog and guinea-pig, becomes increasingly convoluted as we ascend the animal series and end with the elephant, monkey, and man. It is smooth in the human fœtus, but continues to become more and more folded to its maximum at about the fortieth year. The brains of women are less convoluted than those of men. Fig. 14 shows the increasing complexity in the form of the neurone as found in the cortex of a frog, a lizard, a rat, and man. The left-hand corner of the diagram shows the phases in the embryonic development of a cell (neuroblast) of the mammalian cortex.

The cortex is functionally superadded, for it is the organ of perception, memory, the will, the emotions, and the intellect. As the organ of the association of ideas, it is the physical basis of abstract thinking. As the organ of emotions, it is the physical substratum of the æsthetic side of life. As the material substratum for inhibition, it is the organ of conduct, personality, and moral and religious conceptions.

CHAPTER IX

THE PHYSICAL BASES OF CONSCIOUSNESS

THE evidence that the cortex cerebri is the anatomical "locus" of consciousness is full and varied. The brain, as Bastian put it, is "the organ of the mind".

First of all we have the broad anatomical consideration that according as there is more or less grey matter the person is the more or less intellectual.

It is the depth and cellular richness of the cortex that is important.

The first condition or basis of consciousness is, then, an anatomical and quantitative one—the presence and number of cortical neurones. The neurones of the cerebellar cortex have no relation to consciousness; for neither experimental removal of portions of the cerebellar cortex nor such pathological states of it as destroying lesions compromise consciousness in any way.

It will, however, be apparent that consciousness does not reside in cerebral neurones

—the expression "reside" is at present used only for brevity—until they have attained to a certain degree of histological differentiation. They must have attained to a certain degree of cellular complexity before consciousness can become related to them. While they are yet embryonic there is no consciousness, no memory of events: hence we do not remember being in the womb, and as a matter of fact we remember scarcely anything for the next two years. The organ is too simple as yet for such complexity of function. It appears that only when the cerebral neurones have attained to a certain internal complexity, can there be what we call the registration of events, memory, the revivability of impressions.

The constitution of the cortical neurones in intra-uterine life is too simple to be the "seat" of psychical processes, so that all theories in "psycho-analysis" based on the supposition that "intra-uterine impressions" are retained are theses of gratuitous nonsense.

The second factor is, then, degree of differentiation of the body of the individual. The cerebral neurones in man continue to "grow", to become more complex, up to middle life, about the fortieth year. As old age comes on we find the brain-cells showing signs of "wear and tear", of physiological atrophy; and the mind is concomitantly affected. Under the microscope the cells exhibit the following changes: the nucleus shrivels, pigment becomes deposited in the cells, the processes atrophy. This is the physical basis of senility. All the tissues are more or less participating in the loss of functional elasticity; no tissue can last for ever; there is the normal inevitable ageing.

The third factor underlying the presence of consciousness is the integrity of the microscopic nerve-cells.

This can be compromised in several ways, first of all by concussion. It is well known that a fall on the head or a blow on the head can make consciousness vanish. The neurones of the cortex terminate in extremely delicate, elongated, semi-fluid, protoplasmic threads interlacing with the others of like tenuity, forming "synapses" of inconceivably fine structure, so that it is not in the least surprising that the violent mechanical jar we call "concussion" should dislocate these delicate mechanisms.

The living arborescence at the termination of a neurone may be likened to the tentacles of a sea-anemone expanded in the water of the tank in the aquarium. If you give a sharp tap to the glass plate of the tank, the tentacles are immediately withdrawn and curled up. There is no doubt that the limits of physical insult which these delicate synapses can withstand, is easily overpassed. The high explosives used in modern warfare develop concussive power far beyond what the cell-processes of the human brain can endure. The mental effects of the violent mechanical injury are generally referred to as " shell-shock ".

The unconsciousness which ushers in the train of symptoms of this condition is the immediate result of the vibrational injury to the cells of the grey matter. The more permanent results may be far-reaching. The effects of the physical jarring of so delicate an organ as the brain illustrate the dependence of consciousness on histological integrity.

An analogous condition in the spinal cord—engine-drivers' disease—is set up by the continual vibration conveyed from the foot-plate into the man's central nervous system.

Compression, another mechanical agency which can affect the central nervous system, is due to the increase of pressure within the skull. The neurones cannot perform their functions if pressed upon unduly.

The sources of compression are many: they may be—depression of bone, a foreign body under the skull, a brain tumour, or an abscess in its earlier stages. Compression may act as a mechanical stimulant to the brain-cells and give rise to convulsions by the pressure on the cerebral motor centres; but prolonged intracranial pressure is always in the end anti-vital.

The physico-chemical integrity of the nerve-cell depends upon a certain upper limit of temperature not being exceeded. In the mammal this temperature is 47° C. (116° F.): at this temperature one of the chemical constituents in the nerve-cell, known to chemists as α-neuro-globulin, coagulates, and the cell is killed. This temperature, 116° F., is about eight degrees above the highest fever temperature known. If the temperature of the blood goes to anywhere near this height, irreparable damage is done to some cerebral cells, and consciousness to that extent is compromised. A nerve-cell so killed is never replaced. The heat of high fever always tends to injure the cortical neurones; and we know that consciousness is altered in the delirium of high fever.

When the temperature of the blood rises to a dangerous height from the presence of extreme heat, whether of the sun or otherwise, unconsciousness sets in, and the condition is called "heat-stroke". A "sun-stroke" is the name given to that condition of heat-damaged brain which results in a permanent alteration of the person's mentality. Very often the mind is left slightly enfeebled in certain of its activities. A person who has had a "touch of the sun " is apt to be peculiar or " queer " for the rest of life.

Heat, then, is an agency which by injuring the chemical condition of the brain-cells is responsible for the concomitant alteration of consciousness.

The next condition on which consciousness depends is the blood-supply to the brain.

We saw in Chapter I how very abundant is the blood-supply to the cortex cerebri. The whole purpose of the free union of the arteries at the base of the brain (circle of Willis) is to ensure that the blood-supply of any region of the brain shall not be cut off by the blocking of any one of its constituent vessels. Nothing brings on unconsciousness so rapidly as the absence of blood: the blood-pressure has only to fall below a certain amount for a second or two to ensure fainting (syncope) with its concomitant of " the mind's becoming a blank ". In syncope the heart for some reason or other has failed to empty itself into the arteries for the space of a beat or two, with the result that the blood-pressure falls in those few seconds to a point incompatible with consciousness. The muscles become toneless because imperfectly innervated, and the person falls down.

Low blood-pressure really entails the nerve-cells' being deprived of oxygen. The whole object of the circulation is to supply the cells of the body with oxygen. Even the taking away of waste substances is subsidiary.

Similarly a low blood-pressure brought about through a great diminution of the volume of blood in consequence of a serious hæmorrhage —external or internal—causes loss of consciousness through oxygen-want. Thus on the battle-field the severely wounded soldier becomes unconscious, and may be picked up as dead. A person faints and falls down, if he is suddenly the victim of a large internal hæmorrhage, as for instance from the bursting of an aneurysm.*

Short of fainting, consciousness may be temporarily lost when for any reason the cerebral blood-pressure is suddenly reduced. In the upright posture the blood *tends* at all times, under gravity, to pool in the abdominal veins and therefore not to reach the heart in sufficient amount : if, in addition to this, there is a definite functional determination of blood to the abdominal viscera, the brain may not get enough for its needs. When a man rises to make an after-dinner speech, these conditions are realized, for the gravity factor is at work, and blood is being drawn off from the brain into

* An aneurysm is a local enlargement and thinning of the wall of an artery : it is liable to burst from any sudden increase of the blood-pressure.

the stomach for the work of active digestion. For a second or two the brain may not be receiving quite enough blood to give the orator full command over the expression of his ideas, so that the beginning of a speech may often be a little delayed. It is here that the stimulant properties of alcohol are found useful. A tight abdominal bandage is useful in such circumstances, and also when people have to stand without food and in the heat.

One way to revive a fainting person is to press the head between the knees: the compression thus exerted on the abdominal veins forces the stagnant blood towards the heart and so restores the pressure in the brain.

The extreme degree of cerebral anæmia brought on by cutting across the two carotid arteries and the two jugular veins in the neck of an animal brings on a more rapid disappearance of consciousness than any other method. It has been experimentally proved that in two seconds after this procedure, the pressure in the circle of Willis has fallen to zero and therefore consciousness has disappeared. This is, in fact, the Jewish method of slaughtering animals, and it is as humane a method as it is possible to devise.

Blood-supply, which ultimately means oxygen supply, is then one of the most important physical bases of consciousness.

The next factor underlying consciousness is the chemical state of the blood. Consciousness can be made to vanish by the inhaling of nitrous oxide, chloroform, ether, and many other chemical substances.

The exact cause of unconsciousness is in all probability once more the reaction of the delicate processes at the synapses, because these are by far the most vulnerable places of the neuronic chains. We have evidence that cerebral neurones have retained the power of a certain degree of movement ("neuro-amœboidism"). There is some histological evidence, from the brains of animals killed in chemically induced unconsciousness, to show that before death there had been some retraction of fibrils. In the analogous condition of very deep sleep there is also some evidence of a similar state.

These chemical substances are the well-known anæsthetics of surgery and midwifery, which by abolishing pain—a disagreeable and injurious variety of consciousness—enable the surgeon to accomplish his beneficent work in peace.

We have to remember that the action of these anæsthetics is essentially a poisoning; the least harmful of them tends to devitalize the nerve-cells. Administered beyond a certain concentration in the blood, they soon immobilize the cells, and finally they kill them.

This chemical poisoning of cerebral neurones is of course the cause of unconsciousness in acute alcoholic intoxication. The sleep of extreme fatigue, and the comas of diabetes and of other abnormal states, are other examples of unconsciousness due to the operation of chemical factors.

We have learned, then, that to maintain normal consciousness requires a particular, normal, chemical condition or constitution of the blood, and that certain alterations of this are accompanied by corresponding alterations in the quality of the conscious states retained. As to the precise "seat" of consciousness, Professor MacDougall of Harvard has made an effort to arrive at a conclusion. He believes that it is related to the synapses rather than to the cell-bodies, because the synapses are pre-eminently the places where *changes* in the resistance to the flow of impulses can occur.

It is empirically true that consciousness can be maintained only in so far as there are changes in the volume and intensity of the impulses flowing over the synapses. When the flow is zero or minimal, unconsciousness (sleep) intervenes; when the flow is unaltered in intensity for long periods (monotonous reading, droning preaching, prolonged vibration of a motor-car etc.), it ceases to be a stimulus to the cerebrum, which goes to sleep. This is comparable with the well-known *non*-stimulating power of a galvanic current of constant intensity traversing a muscle or nerve.

Lastly, the question is often asked, "Can consciousness exist apart from a body?" The physiologist can only answer, "Not within my experience." His attitude has to be an agnostic one; he simply does not know. All he can say is he never knew of consciousness disembodied; and he knows of no evidence for such a belief. He dare not deny that it might be; but so far as the evidence of his senses goes, he has no knowledge of it. It is difficult to conceive how a disembodied consciousness could appeal to or inform an inquirer as to its existence. In this connection, Professor MacDougall points out that there are certain aspects of consciousness which do not seem to have cerebral counterparts; he is referring to such undoubted mental existences as pleasure, displeasure, and what psychologists call "meaning" or "significance". This, after all, is an argument derived from our ignorance of cerebral physiology: what is meant is that though we know of the localization of the senses in the brain we do not know where, if anywhere, the more vague or diffused mental states just mentioned have their seat or physical basis.

CHAPTER X

FATIGUE, SLEEP, DREAMS, AND HYPNOTISM

WE have now seen that the nervous system is as truly an organ with definite functions as is the stomach, the heart, or the liver. But the stomach is not for ever digesting nor is the heart continually in systole.* Certain organs, indeed, such as the liver and kidneys, do seem to work continuously; but others as obviously have their periods of activity and of rest. It has been calculated that the heart really rests longer than it "works", namely fourteen hours of the twenty-four.

The nervous system is so continuously at work when it is working that it is imperative it should rest some time out of the twenty-four hours' day. Consider the retina of the eye; as long as we are awake and light is gaining access to it, it never rests; hence the necessity

* The alternating states of contraction and expansion of the muscular cavities of the heart are called respectively "systole" and "diastole".

for it to have rest when the eyelids are closed and we sleep.

Rest is necessary to the nervous system because that familiar state we call fatigue tends to set in all the time. All activity tends to fatigue, which is a progressive incapacity for work; exhaustion is the end of resources reached.

Now it is certain that fatigue is essentially due to the accumulation in the blood of substances of a chemical nature, but of such degree of solubility that they can be removed by the organs of excretion. The muscles and the nervous system itself are the two chief contributors of these "waste products", substances of as yet undetermined composition for which the term "fatigue-toxins" is used. It would appear that lactic acid is one of these; for it is certain that both muscles and nerve-cells become acid after prolonged activity, and that at that time lactic acid can be detected in the urine.

As regards muscle, it seems very clear that some acid substance is at work because of the stiffness, discomfort, or pain which prolonged activity induces. An acid applied to a muscle in the laboratory tends to stiffen it.

The more vigorous the circulation of blood through fatigued organs the more rapidly are fatigue-products removed; so a tired athlete takes a hot bath after his exertions, and would be the better for some massage as well.

Now it has been discovered that there are two places *par excellence* where the effect of the fatigue-toxins is earliest and most severely felt,—one the weakest spot in the neuro-muscular chain, the other the weakest spot in the inter-neuronic chain.

The place where the nerve is distributed to the muscle—the neuro-muscular junction—is a very delicate region ; it is not muscle and it is not nerve ; it is more sensitive than either to circulating poisons. At such a place the conductivity can be diminished by the action of all manner of poisons in the blood.

As we have seen, the nerve-trunk is, for all practical purposes, incapable of fatigue ; and since the muscle itself can respond to stimulation after all impulses have ceased to pass from nerve to muscle, the junction itself must be the weakest link in the chain, weakest in the sense of most easily fatigued.

Within the nervous system we have a similar spot in the place where one neurone ends and the next begins. Such a place is called a " synapsis ", from a Greek word for a " clasping ", because at this place the delicate terminal processes of one neurone clasp either similar processes or the cell-body of the next in the chain. One neurone is related to its neighbour by contiguity not by continuity, by apposition not by fusion. We have much evidence that it is just at these synapses that in conditions of blood-poisoning the toxic effect is most severely felt.

Rest is the period during which the body gets time to eliminate the poisonous results of activity: the three chief organs which do this are the kidneys, lung, and skin. The microscopists tell us that in resting nerve-cells (prepared by a special process) they can discern certain granules within the living substance of the cell; and that, after fatigue and other toxic experiences, these granules are seen to be more or less dissolved away. In some of the insanities, also, the granules are partly destroyed. The granules are named after a German neurologist, Nissl; and the process of their solution is called "chromatolysis".

Now rest, as regards the nervous system, means sleep. Sleep is the resting-time of the brain with its concomitant abolition of consciousness. Sleep is the only method which Nature has provided whereby the cortex cerebri can rest, can refresh itself and effectually get rid of waste substances. Nothing can take the place of sleep, not even food, although sleep can take the place of food. A person is much less hungry after eight to nine hours' sleep than after four hours of being awake.

Only the cortex cerebri sleeps, in that its functions are suppressed in consciousness; for it is clear that such a bulbar centre as the respiratory is "carrying on" as before. Doubtless even it is not working quite so vigorously as during waking, but it certainly continues to put out its rhythmic impulses for the muscles of breathing during the time of sleep.

In the fact of the possibility of certain reflexes being performed in sleep we have evidence that the centres of the spinal cord are still in potential functional activity.

The cortex is resting, but we sleep to wake; this sleep is imperative; after a certain degree of fatigue is reached, nothing can prevent it, it must occur.

This is the fatigue-induced factor in sleep—the sleep of chemical origin. Not all the King's regulations nor any other code of orders can avert it; if the sentry is utterly worn out, he will sleep where he stands.

This first type of sleep, then, we may call the chemical. The chemical factor is probably the most potent in sleep-production; if we are not to some extent tired, we cannot sleep.

This type of sleep, in its extreme degree, resembles the condition of a person drugged or chloroformed. In the retreat from Mons men are said to have suffered from this profound weariness. "Towards the end of this fighting they had a drunken craving for sleep, and they slept standing with their heads falling over the parapet, slept sitting hunched in ditches, slept like dead men where they lay on the open ground."

The synapses in the cortex were so poisoned that they could transmit no more impulses; and when the cortical synapses transmit no more impulses, the brain sleeps, we sleep. In its minor degrees, this type of fatigue-induced sleep is pleasantly refreshing. Sometimes we are told that a person—an athlete or a child—is "too tired to sleep". Here the poisons of fatigue are irritating the neurones rather than diminishing their affectability.

The next factor leading to the onset of sleep is a fall in the pressure of the blood in the brain. As night comes on, there is a tendency for the blood-vessels of the skin to dilate and therefore to hold more blood. We know that rings, shoes, and collars are tighter towards evening than in the morning. This increase in the capacity of the skin-vessels means that they can now accommodate some blood which previously reached the brain. The effect of this is to reduce the vigour of the cerebral blood-flow and thus aid the fatigue factor in putting the cerebral cortex out of functional activity. The flush of the "sleeping beauty" is optical evidence that an additional quantity of blood is in the skin. For convenience we may call this second factor the *vascular* factor. Normally the chemical and the vascular factors co-operate in inducing healthy sleep.

Too low a blood-pressure in the brain always tends to somnolence, to a state of unconsciousness indistinguishable from certain other kinds of unconsciousness. Thus pressure on the two great blood-vessels of the neck, the carotids, brings on a state of unconsciousness. The sleepiness after a full meal or a hot bath is due to the vascular factor, the blood being accommodated in the organs of digestion and in the skin respectively. Indeed, so low may the blood-pressure fall after a hot bath that some delicate people who tend to faint have fainted and thereafter slipped under the water and actually been drowned. It is very inadvisable to take a hot bath after a full meal on account of this very dangerous lowering of the blood-pressure in the brain which these two factors together can induce. The degree of anæmia of the brain should never be allowed to be excessive. Children should always lie down to sleep; to allow young children to fall asleep in a sitting posture in a chair-like perambulator is not physiologically sound.

The precise cause of the skin-vessels dilating towards night-time is fatigue of the centre in the Bulb for keeping the vessels constricted;

if the centre is fatigued, it innervates the blood-vessels less intensely, and in consequence they dilate. The fatigue factor is therefore probably the first to operate in the onset of healthy sleep.

In fainting, the temporary unconsciousness resembles that of sleep induced through the vascular factor ; in fainting, as in sleep, there is the characteristic loss of tone of the muscles which allows the head to fall forward on the chest and the body to collapse " all of a heap ". This loss of tone of the muscles of the face is the reason why in sleep the aspect becomes so expressionless, and why many people look different asleep and awake. It is this lack of tone of the face-muscles in persons after death which is so often described as " peaceful " and as showing no signs of pain, the reason being that as the muscles are relaxed, they cannot contribute to what is called " the expression ".

The third factor which co-operates to produce sleep is the absence of sensory stimulation. In ordinary circumstances we cannot get off to sleep in a bright light or amid noisy surroundings. Of course, when the fatigue is excessive, then the chemical factor is overwhelming, and sleep must supervene amidst the loudest sounds and in the most unsuitable environment. But usually we retire into the dark, shut our eyes, and exclude all noise if we can. The meaning of this is clear; so long as sights and sounds are keeping the sensory centres in activity, the brain cannot, *we* cannot, sleep.

Noises are the chief obstacles to sleep; they are much less under control than lights. Persons accustomed to city traffic can in time sleep through it, provided it is fairly constant in volume; but when it is intermittent, it becomes a real menace to sleep.

Noise, if it is fairly uniform, does not banish sleep. We manage to sleep through the continual throbbing of the engines of the steamer, and only wake up when the screw stops. It is the change from continuous noise to no noise that is the stimulus to the auditory centre and the source of the awakening. Monotonous continued sounds, such as droning reading or preaching, are soporific. This is of course the effect of the lullaby or cradle-song; if the nurse stops too soon, the child wakes up.

Loud noise, long continued, especially if it is accompanied by vibrations as in a motor-car or motor-bicycle, induces sleep. Recently a young man was killed on a racing motor-bicycle, and the only conclusion the coroner could come to was that he had fallen asleep on the machine. All sensations of unaltering intensity come in the end not to be noticed, cease to be stimuli; we are not conscious of the sensations of the contact of our clothes with the skin, of the pressure of the air, etc.

Sensations can be a source of insomnia, sensations so near home as from one's own cold feet. Pain, of course, is the great sleep-banishing sensation, so that the medical man tries to the uttermost to banish pain that sleep may supervene.

However serious it may be for adults to have their sleep curtailed by noise, it is far more so for children. Just as children need relatively more food, so they need more sleep, than adults.

The last factor which co-operates to bring on sleep is the absence of mental occupation. The mind as well as muscle must be relaxed in order that sleep may supervene ; worries and problems drive sleep away. Doubtless this, like the absence of sensation, is a negative factor, but it is none the less a factor.

Great grief like great joy can keep the brain awake. This emotional form of insomnia is often the most difficult to treat. A disturbed state of the mind, influencing the brain, may disturb the heart so that the blood-pressure is raised ; but a rise of blood-pressure, by increasing the blood-flow through the brain, will of itself keep the brain active. A vicious circle has thus been established.

We have to calm the heart and banish

thoughts. Shakespeare understood this when he said :

> " Care keeps his watch in every old man's eye,
> And where care lodges sleep will never lie."
> (*Romeo and Juliet*, II, 3.)

We shall have a little more to say about sleep in connection with neural hygiene in Chapter XII.

Dreaming

A dream is the result in consciousness of some part of the brain being in activity. Complete cerebral repose has as its counterpart unconsciousness ; but if, for any reason, a portion of the cortex becomes active, then a dream is the subjective result. It would appear that the centre for vision is more liable than any other part of the brain to this stimulation, for dreams of seeing things are by far the commonest kind of dream. Although dreams involving the other centres are by no means unknown, yet dreams of the visual centre are so much the most familiar that by " a vision " we mean a dream. It is clearly because of the much greater importance in daily life of the sense of sight as compared with all the other senses, that the visual centre is the most accessible, physiologically speaking.

The curious thing is that although the visual centre is being roused to partial activity in the dream, it is not through the normal channels of the eyes, for the eyes are shut and we are (or should be) in darkness. The brain is seeing something in the pitch-dark recesses of the interior of the skull. Clearly the impulses which reach the visual centre have not originated in the eye. Impulses which are capable of producing dreams ("oneirogenetic" impulses) can arise only (1) in the skin, (2) in some of the internal organs, or (3) in sense-organs other than the eyes.

By far the commonest sources are the skin and some of the internal organs such as the stomach. A vision can, then, be aroused by impulses which have ascended from the skin, but which instead of reaching the part of the cortex where skin sensations are registered, have wandered into the centre for vision on account of its great accessibility. Thus when Dr. Gregory, having gone to sleep with a hot bottle at his feet, dreamed he was walking on the burning lava of Mount Etna, it was skin currents that were dream-producing. If the bed-clothes fall off, we may dream of being at the North Pole; if we have too many clothes on, we may dream we are being roasted alive.

Impulses from the muscular sense end-organs are probably dream-producing. Any unusual or uncomfortable position of one's limbs may give rise to dreams of floating, flying, struggling, etc. The absence of the usual sensations of resistance from the soles of the feet may, according to Bergson, be the source of dreams of falling from a height.

Impulses from other sense-organs can also be oneirogenetic. Thus sounds most certainly can give rise to dreams not necessarily of hearing but of seeing as well. On one occasion, when the source was known to an observer to be the sound of hammering on a piece of metal in a neighbouring garage, a lady asleep reported, on waking up shortly afterwards, that she had dreamt she was in a restaurant and some one at a table near by had a bangle on her wrist which knocked against her plate every time she moved, greatly to the annoyance of the company.

But, as we all know, certain states of the internal organs can be powerful excitants of the dream-state. Perfectly normal internal organs do not enter into our waking consciousness nor in sleep are they dream-producing. But if, for instance, an attack of colic has been set up by indigestion during sleep, then the powerful impulses from the convulsed stomach will ascend to the brain, and on arriving at the visual centre will awaken it to the partial activity we call a dream. It is not correct to suppose that digestion ceases during sleep, and that therefore a light meal before going to bed is bad for us ; the ordinary movements of the stomach are not dream-producing, only the exaggerated are. When the condition amounts to what in the waking state would be internal (visceral) pain, the dream may become a " night-mare" or incubus. The action of the normal lungs and heart does not enter into either the waking or the dream consciousness ; but there is no doubt that embarrassed states of breathing and abnormal action of the heart can give rise to dreams of a more or less unpleasant kind.

Closely allied to incubus in the adult are the night-terrors of children (*pavor nocturnus*). Very often what are called " growing pains "—really due to rheumatic inflammation of the membrane covering the bones (periostitis)—give rise to dreams of horrid visions and terrifying scenes ; the child may awake screaming

Most people are familiar with the dream that recurs several times ; in all probability this is due to some recurring state of an internal organ, some colicky pains which arise and then die away only to develop again.

We shall not attempt any classification of dreams other than the one just given which has regard to the sites of origin of the oneirogenetic impulses ; but we can divide dreams into those of which we are merely spectators and those in which we play a part. In the former we view dead relatives, say, with no surprise and no concern ; in the latter, we participate actively and may even awake agitated and distressed.

It is in this latter type of dream that we have the typical overflows, where the emotional colouring of the dream produces a stimulation of certain effectors, heart, glands, muscles, with the same appropriateness as in the waking state. The dreamer, usually an invalid or child, may actually be awakened by the intensity of the emotion with pulse rapid, skin sweating, and muscles trembling.

But apart from these expressions of emotional disturbance, the dream may overflow into the speech centre, in consequence of which words are spoken although the dreamer on waking can recall nothing of them. Some people more or less habitually talk in their sleep ; and while what is said is not the result of conscious activity of the speech centres, yet the words sometimes express ideas latent in the subconscious stream of cerebrations. The dream consciousness is thus distinct from the waking, and in it may be hidden those suppressed emotions and "complexes" which have figured so prominently in the psycho-analytic system of Freud. The talking in sleep may reveal the content of these latent notions. The dream plays a very important part in Freud's system ; but we cannot here discuss it further, since to understand it, and far more to criticize it, requires an extensive knowledge of psychological medicine and of morbid mental processes.

The motor overflow has another channel it may enter, namely the lower motor cord-centres which have charge of the coordinated movements of walking. This walking in sleep is called somnambulism. Here again we enter on a plane of consciousness other than that of the waking state, for the sleep-walker on waking has no knowledge of his ambulatory activities. The movements of the muscles are performed with as great precision as in the waking state, showing us once more that the spinal cord is able to carry out complicated coordinated movements without the supervision of conscious volition. Thus it is that the somnambulist may walk in the most dangerous places and not fall over.

The sub-conscious reflex mechanism is carrying out these movements ; but if consciousness is suddenly restored, it may seriously affect the person's safety, for, in the neural commotion, the balance may be upset with serious results. These muscular movements are carried out exactly as though the person had been hypnotized. The fact is that in the "hypnotic trance" which is artificially induced sleep, the patient can be commanded to talk or to walk, and on awaking he will be quite unaware of what he has said or done.

Hypnotism

To discover the salient features of hypnotism, we will take a typical case.

The patient, being in a state of tranquillity, is told to remain passive and to direct his gaze upwards, while the hypnotist, standing in front of him, slowly performs certain movements calculated to engage his attention. In a short time the patient or "subject" seems to have fallen asleep; but the eyelids need not have been closed, and this of itself distinguishes this state from normal sleep. That he is not in ordinary sleep is evident from the extraordinarily high degree of suggestibility to which he is now found to have attained. He will obey unquestioningly the commands of the hypnotist; he will even experience sensations and emotions to order. Told to walk off, he will stride away and only halt when an obstacle like a wall or fence bars his progress, and even then he will "mark time" because the fiat to walk has not been revoked. A hypnotized person is told that in ten minutes he will feel cold; punctually to the moment he gets up and shivers. If told he will be overcome with heat, he will, at the appointed time, burst out into a flush and a perspiration. The affectability of the cerebrum is exceedingly high; it does uncritically what is suggested to it. The patient is completely *en rapport*, as it is called, with the hypnotist.

Medical Science has made use of the influence of the hypnotic state upon the cerebral sensory centres, for just as it is possible to induce in these an abnormally exalted state of the person's sensory consciousness, so, conversely, can a state of anæsthesia, or more correctly analgesia, be induced. Thus the hypnotized person is told that he will feel no pain while a tooth is being extracted, and, true enough, he feels none.

But more than this, the increased affectability of one centre can coexist with the anæsthesia of another. For instance, it is possible to render a hypnotized person psychically blind at the very same time that the auditory centre is made so acute functionally that the subject hears sounds quite inaudible to normal persons.

Not all persons can be hypnotized; idiots and the feeble-minded cannot, so that being capable of being hypnotized is by no means a sign of a " weak will ", as is popularly believed. The person hypnotized does, however, come to be more or less *en rapport* with the hypnotist, so that if the latter were to say, "This day week at noon you will fall asleep or stop still all of a sudden in the street," there is a great chance of this happening.

This being so, we can see at once how important it is that the hypnotist be a man of education and high character, for his chances to abuse his powers are unusually numerous. Probably no subject having a therapeutic aspect has been so overlaid by quackery and deception.

Mesmer (b. 1734, d. 1815), who introduced the practice of hypnotism under the name of "animal magnetism", died a charlatan of charlatans. Whatever he really believed, he taught that magnets could induce the abnormal mental states which we now include under the term of "hypnotic phenomena".

The title of his book, published in 1779, was *The Discovery of Animal Magnetism*; and he insisted to the last that there was such a thing. He was reported on adversely by a commission in Vienna, and was given twenty-four hours to quit the city. For a time his vogue in Paris was extraordinary, but in 1785 another commission, of which Benjamin Franklin and Lavoisier were members, reported against him, exposing his pretensions and excesses. This threw mesmerism into that disrepute from which under the better name of hypnotism it has scarcely even now recovered.

The whole subject was investigated with admirable candour and common sense by the Scotsman, James Braid (1795–1861), who was in general practice in Manchester. In 1843 he published his valuable work, *Neurypnology or the Rationale of Nervous Sleep*, in which he showed that neither magnets, magnetism, nor any known "force" was needed to produce the effects which could in some instances be produced by the subject himself merely fixing his gaze on some bright object, preferably above the level of the eyes. This has since been called "auto-hypnotism".

Braid's exposé was violently resented by the professional "mesmerists" who wished to continue to delude the laity; but his investigations provided the data on which the scientific schools of Broca and Charcot in France based their practice.

Dr. John Elliotson (1791–1868), who was the first in England to operate on a hypnotized person, encountered such opposition from his professional brethren that he was deprived of a number of his appointments. Hypnotism received an immense impetus as a psychical analgesic from the work of another Scots physician, Dr. James Esdaile (d. 1859), who could point to 261 operations performed painlessly on Hindus. It is probable that Orientals are much more susceptible than are the British to this sort of influence.

A state analogous to hypnotism can be induced in the lower animals. The classical experiment illustrative of this is known as the "*experimentum mirabile*" of the Jesuit Father, Athanasius Kircher (1602–80). The experiment is to hold down a bird, so that its beak touches the floor, and then to draw a chalk line from its beak along one of the boards. The bird becomes "fascinated", and, staring at the white line, becomes motionless for many minutes. Its breathing becomes shallower; it is in a state resembling human hypnotism, oblivious to its surroundings, artificially asleep. A sudden loud noise will "break the spell" and bring the bird back to ordinary consciousness.

Dogs, cats, and rabbits, if gently handled by persons they know well, will lie on their backs in a dazed, passive, and quiescent condition, with their legs held stiff. This is their version of being hypnotized. Even a frog may be hypnotized. It is well known that a normal frog placed on its back will at once jump up and regain its natural crouching position. But if, while it is being held on its back, a piece of tape be firmly tied round one of its forelegs, then it will remain motionless in this quite unnatural position for a very long time. Some very lively frogs require a ligature round both legs. The explanation is that the powerful and never-before-experienced sensation so engages the attention of the frog that its "mind" is completely occupied by it to the exclusion of everything else. It "forgets" to turn over. There seems no doubt that certain animals can hypnotize others, as when the snake "fascinates" the rabbit before it strikes it. This so-called "power of the eye" in the lower animals corresponds to the "passes" of the hypnotist.

Very intense concentration of the attention upon anything leaves a part of the brain in an insusceptible or inhibited state. It has been remarked in theatres where smoking is allowed that when the interest in the acting becomes intense, men "forget" to smoke, and the breath is held for a time. This state of fixity of the attention by one part of the brain, contemporaneously with a state of suspended activity or inhibition of another part, is characteristic of the hypnotic state. The functions of one part are exalted, of some other depressed. We have referred only to the sensory centres; but a similar state of matter can occur in the motor.

The hypnotist, for instance, can by suggestion induce a functional paralysis of an arm or a leg or of the tongue; he will tell the subject he cannot raise his arm, move his leg, or put out his tongue, and, lo, it is so. He has produced temporary voluntary muscular paralysis, psychically induced paralysis, which may be called " inhibition ".

But the exact converse can also take place. The hypnotist can throw a person into a state of excessive muscular rigidity or " catalepsy ". In catalepsy, which can be brought on by autosuggestion, the muscles though rigid are plastic and can be moulded so as to throw the limbs into the most extraordinary positions. The muscles also acquire a surprising degree of resilience. A favourite exhibition of this, in the days when public hypnotic *séances* were permitted, was to place the subject with his head on the back of one chair and his feet on another, and then throw his abdominal muscles into the cataleptic rigidity. An anvil placed on the man's abdomen and struck with a hammer was made to bounce up and down without giving rise to discomfort or pain. Clearly during this great exaltation of function in one part of the brain, there is a corresponding diminution in some other part; the latter is often alluded to as " inhibition ".

Doubtless in practical medicine it is the functional anæsthesias and analgesias which are such valuable results of psychic therapeutics. During the Great War many functional disabilities of the nervous system were successfully combated by hypnotic procedures—neurasthenic and hysterical states, paralyses, aphasias, insomnias, and many other conditions. This was largely due to the freedom with which men suffering from functional disorders were at once removed from the scenes of their troubles and treated not as insane or "certified" persons but as persons mentally ill yet not under the stigma of lunacy. The number of cases of cure was gratifyingly large.

CHAPTER XI

NERVOUSNESS

"NERVOUSNESS" is that state of neural health in which the nervous system bulks too prominently in behaviour. Like many popular terms, it covers a large number of conditions, some of which have nothing in common except an undue functional prominence of the nervous system. Indeed the term is of little use to the scientific physician just because it includes too much. If "nervousness" means anything, it means that the activity of the nervous system is intruding itself into consciousness in a manner not wholly normal. Related expressions in common use are "nervy", "jumpy", "all on edge", "an attack of nerves".

Perfect health is to be unaware of the behaviour of the stomach, heart, lungs, etc., and also to be unaware of the working or presence of the nervous system.

There are two chief ways in which the nervous system may obtrude itself into one's consciousness, either by over-action or by under-action.

Thus the well-fed, thoroughly rested horse, on being taken out to be ridden, may be so "fresh" as to shy at every scrap of paper he sees blowing along the road, and might be described as "too nervous" to be ridden comfortably; whereas the tired child who has had too long a day at the "Zoo" or the pantomime, is peevish all the way home, the nurse remarking, "The day has been too much for Master Tommy's nerves."

The most satisfactory condition of the nervous system, as of all other systems, is that it works smoothly and unobtrusively; it should be the physical basis of a functional equipoise.

The type of nervousness of the "fresh" horse, the result of too much nerve-energy and too high spirits, is in the human being not usually called "nervousness" at all. By "nervousness" people generally mean nervousness *by defect.*

The word "nervousness" covers a larger number of conditions than are understood by neurasthenia; but in all cases of nervousness the notion of weakness is inherent. It may be weakness of effort, it may be weakness of control, that is really the essence of what looks like excitement and commotion. An emotional disturbance is not a sign of strength ; it is the evidence of a diminished restraint over the expression of emotion.

"Irritability", the unduly violent response to an ordinary stimulus, is the evidence not of much nerve-energy but of little. A neural response should not be uncontrolled and out of all proportion to the magnitude of the stimulus ; the element of restraint, of reserve force, should always be present.

The opposite of irritability, melancholia (inertia) characterizes that form of neural abnormality where the centres are depressed and irresponsive ; this is not what is popularly understood by "nervousness", but it is neural abnormality by deficiency of nerve-energy.

A common type of nervousness is that in which quite small stimulations give rise to disproportionately large responses. An innocent remark calls forth a violent reply ; a slight noise may make the patient jump or scream. There is a lack of that due coordination between stimulus and response, between the receptive and the emissive, which the normal person would exhibit. Such people are "fussy" and "always worrying" ; small things bulk large in their minds.

What the physician calls neurasthenia is, in plainer terms, a state of chronic fatigue. This does not mean that the sufferer is incapable of effort; it means his activity is unsatisfactory, in that some small thing, which in a neurally healthy person would be performed with unconscious ease, becomes an effort. The enfeeblement of the nervous system enters into the consciousness of the person neurally ill, just as the disordered action of the heart enters into the consciousness of a person suffering from some cardiac abnormality. The nervous person responds in some way not neurally normal; it may be with too much effort, it may be too rapidly, it may be hesitatingly, incoordinately; whatever it is, it is not in a normal fashion.

A hasty glance at the sources of nervousness might permit us to divide them into mental and bodily; but if we follow out that principle too rigidly, we shall make an artificial classification. The reason of this, of course, is that these two aspects of our being are so inextricably commingled that, although now the one and now the other may predominate, at most times the two factors are simultaneously operative.

Some cases of nervousness are evidently due to a psychic factor, as when a young child has been told a "ghost story" by a silly nurse and later has started up screaming in his sleep. Here we are justified in assuming that the mental factor was the true cause of the child's "attack of nerves".

On the other hand, when a person has been suffering for years from some well-recognized form of auto-toxæmia and at last finds himself "nervy", depressed, miserable, distrait, tired of life and contemplating suicide, we are equally entitled to say that the physical factor, the poison in the blood, was the cause of the "nervous breakdown".

Among predominatingly mental causes of nervousness in the adult we may point to grief and other great emotional stresses, such as financial embarrassment, failure to secure some object of ambition, the unsatisfactory progress of love-affairs, or the exposure of moral delinquency.

In the case of children, sudden frights, outrage to the moral sentiments, and their being "forced" in their studies at school, are all, when they occur, potent factors making for nervousness. The term "neurosis" is not used here because it is not familiar to the non-medical reader, and moreover it is not quite coextensive with "nervousness". Neurosis would be rather the equivalent of nervousness due to physical factors; whereas nervousness due to mental factors is called psychoneurosis, a still less familiar term.

As an instance where a neurosis means something other than nervousness, let us take the case of spasmodic asthma. This is a violent contraction, reflexly produced, of the circular muscle of the bronchial tubes. The asthmatic suffers from a too great affectability of the centres of the nerve-fibres which innervate the circular bronchial muscles. A large number of different conditions can set up the spasm or seizure; morbid states in the nose, heart, stomach, and still more distant organs are reflexigenous. Asthma, then, is a neurosis; but it is scarcely "nervousness".

Another basis of classification we might consider is whether the determining factor of the nervousness is inherited or acquired. This distinction is of some practical importance in relation to the subject of treatment, to be discussed in the next chapter.

There is no doubt at all that just as some people inherit a sound respiratory system and a vigorous heart, so others inherit a robust nervous system; and conversely, just as some people inherit poor blood-vessels and a tendency to gout, so others inherit a nervous system which cannot withstand rough treatment. Because the make-up of his nervous system is less robust than that of average persons, the unfortunate possessor of such a system tends to succumb to strains and stresses which his more vigorous brother successfully endures.

We may put it that his nerve-energy is deficient either in quantity or in potential. These delicate nervous systems are often found in persons who have contributed much to the learning, art, pleasure, or gaiety of the world. They are, in fact, too delicate for the winds of adversity; and being thus too fragile are too sensitive for their own or other people's happiness. Thomas Carlyle's life is a case in point.

The peculiarities and the particular constitution, capacities, and endowments of the nervous system are born with a man just as is the colour of his eyes or his hair.

It is this inheritance that predisposes a person to particular lines of action. Much can be done with the nervous system in training it to withstand the assaults of the environment; but inherited dispositions cannot be got rid of, and the education or training of the child is not by getting rid of them but by getting round them.

The knowledge that a great part of the characteristics of the nervous system is inherited need not in any way compel us to be pessimistic as regards what training can do to strengthen and to correct. A great many so-called "failures" in life are failures only in the sense of difficulty in making money: and these failures have resulted from a person well adapted for one sort of life having been put into quite a different one. History is full of examples of men sent into offices and trades where their artistic temperament was the cause of their " doing badly ". They did not succeed where they were put, because they were put where they could not succeed. Such " misfits " are liable to attacks of nerves until congenial work is discovered.

Another source of neural breakdown is a deficiency of nervous energy. Whatever be the theoretical objections to the use of the expression " nerve energy ", there is no shadow of doubt that some people have a driving force in their nervous system which makes for success and happiness, while others are lacking in this respect. Many a nervous breakdown is the result of lack of the force or power to battle with the untoward, the unfriendly, and the disagreeable in one's surroundings.

Another type of neural failure is due to unadaptability to environment. Some people are born unaccommodating and unadaptable, and so carry on a wholly unnecessary warfare with the established order of things. The temperament of these people is the neurotic, because in them the nervous system is too prominent ; their point of view is always the only possible or correct one ; they are incapable of seeing that of their opponents.

Closely related to the inheritance of an unstable nervous system is the interesting subject of its susceptibility to drugs and poisons. We know well that while such drugs as opium or arsenic will produce certain effects in the vast majority of people, in a few cases the results of administering these drugs are quite different from the average. Now and again we come across a case where opium (laudanum), instead of producing drowsiness, has either no effect or a precisely opposite one. This sort of thing, which we cannot foresee, we call "idiosyncrasy"; it can only be explained by an accidental, pre-existing insusceptibility or susceptibility, as the case may be, between the tissues of the patient and the drug in question.

Now it is unquestionably the case that in certain nervous systems there is this pre-adjusted susceptibility towards certain poisons, of which alcohol and syphilis are the most familiar.

The predisposition to be intoxicated by a quantity of alcohol which would not act injuriously on the normal brain has long been recognized by careful observers. Indeed this characteristic is diagnostic of neural instability. The unstable nervous system is excited or poisoned by a quantity of alcohol which the more robust person can oxidize with ease.

The reaction towards the poison of syphilis is very similar. Neurologists are well aware that persons of neurotic disposition are more liable to be attacked by the micro-organism of syphilis than are the rest of their patients; such persons may become "general paralytics".

The nervous system is adversely affected by many poisonous substances: these may be present only in small quantities, but their cumulative effect is highly injurious. Effects of this kind are seen in certain trades where poisonous gases and vapours such as carbon disulphide and carbon monoxide are set free. Carbon disulphide is one of the substances used in the manufacture of india-rubber articles, and carbon monoxide is liberated in many trade processes. The effects of carbon monoxide are long-continued; after all the gas has left the system, the anæmia which a course of exposure to it has induced will continue to produce untoward symptoms.

That neurasthenia is a poisoning has been established beyond all doubt. This would be probable from *a priori* considerations alone, because the vast majority of all the drugs and chemical substances capable of acting on the body act on the nervous system. The great group we call "narcotics" acts wholly on the nervous system: all the depressants—

morphia, chloroform, cocaine, and hundreds of others—and the excitants, such as strychnine, owe their value as drugs to their influence on nerve-cells. Apart from the chemical antiseptics, nearly every chemical agent possesses the power of influencing the nervous system.

It would, therefore, not surprise us that poisons manufactured in the body influence the nervous system injuriously. Thus neurasthenia, the many forms of which have the common element of chronic fatigue, closely resembles chronic poisoning ; both conditions exhibit a disinclination for sustained effort, disturbed sleep, more or less tremor, slight headache, difficulty of being interested in what is going on around one, and the feeling that everything is " boring ". All these things indicate a diminution of vitality.

Now one of the most potent causes of this chronic fatigue is indigestion, using that term in its widest sense as covering everything from gastric colic to catarrhal colitis.

The results of the absorption of intestinal poisons are called auto-toxæmia ; and it is the belief of many neurologists that these toxins are responsible for many more cases of neurasthenia than is alcohol. Alcohol undoubtedly injures the nervous system and undermines character, but it is not the fruitful source of neurasthenia that the intestinal toxins are.

We may not have realized the vast amount of indigestion which exists, but the immense sales of purgatives alone bear witness to the fact. Indigestion, along with the strains and stresses of a city life, accounts for much nervousness; but indigestion alone, in presence of a nervous system predisposed by inheritance to toxic injury, is quite sufficient to produce chronic neurasthenia.

As it may not be easy to realize just how truly poisons in the blood influence the nervous system, let us take the case of what is called a "sick-headache" or "an attack of biliousness". Here undoubtedly the products of imperfectly digested food and of the action of bacteria upon these, plus the absorption of some bile into the blood, are responsible for the exceedingly disagreeable symptoms so familiar to many sufferers. There are nausea, vomiting, diarrhœa, headache, chilliness of the skin, aversion from light, and great irritability.

These outward effects on the nervous system are due to the circulating poison's injuring the nerve-cells, the correlative of which in consciousness is the depression and shortness of temper which characterize the condition.

Another potent source of neural instability is the climate of the Tropics. The most prominent cause of the irritability in hot countries is of course the high temperature; the higher the temperature the more difficult it is for the animal heat to leave the body, and this heat-retention cannot but be injurious to the nervous system. A very high temperature persisting for a relatively short time may give sunstroke or heat-apoplexy.

Another condition which prevents heat-loss in the Tropics is the humidity of the air. The more moisture that is present in such warm air, the greater the difficulty in evaporating the moisture from the skin. The less water that is evaporated from the skin, the less is the amount of heat carried off as "latent" from the body. Still another factor in the Tropics is the continual blaze of light, which leads to fatigue in the sensory cortex.

There is little doubt that the rate at which life is lived to-day has something to do with the development of certain expressions of nervousness in young people. The way in which they turn night into day, adding the excitements of the former to the fatigues of the latter, and consequently curtailing the hours of sleep, tends to bring about a condition of irritability which in some young people has had serious consequences and led even to suicide.

Of recent years a great deal has been written about the part played by glands with internal secretions, and their influence on the character and behaviour of the individual. These "endocrines" do most certainly affect the growth, nutrition, and functions of the nervous system, and through it the whole psychic aspect of the man or animal.

It is now pretty well known that the ductless adrenal * glands manufacture a secretion which, by raising the tone of the vascular system, raises the blood-pressure, and so predisposes the animal to fight its foe. On the other hand, it is equally well known that a severe emotional disturbance can impair the activity of the thyroid gland and set up a whole train of highly undesirable conditions. An undeveloped thyroid determines a state of mental deficiency. The interaction between mind and matter is nowhere so direct as in the case of the glands of internal secretion.

The neurasthenias which are consequent upon abnormalities of the functions of the reproductive organs scarcely come within our present scope. They are however unquestionably of very great importance both in the development of the individual and to the well-being of the community.

Lastly, nervousness may at times become a feature of the national life. From time to time, so-called "waves" of excitement, hysterias, dancing manias, revivalistic experi-

* Sometimes called "suprarenal" from their position above the kidneys.

ences, etc. have passed over communities in most parts of the world.

Naturally the anxieties and strains of a war produce these neuroses on the largest scale. In a chapter of Colonel House's book headed "War Nerves", the American Ambassador at Berlin is reported to have written to Colonel House (August 30, 1916), "You cannot conceive of the general breakdown of nerves among this people." Colonel House himself had written (May 1916), "The War was beginning to touch the belligerents' nerves and to create an irritability that destroyed perspective."

In those countries where people were distinctly underfed, the factor of malnutrition would have to be reckoned as one that contributed to these fits of national nervousness.

CHAPTER XII

THE MAINTENANCE OF NEURAL HEALTH

THE health of the nervous system is made or marred in the first seven years of life. It is a fact well known to those who have the care of children that these first seven are the plastic years. The Jesuits, with their profound knowledge of social psychology, know that as the child is directed in these early years, so he will be inclined for the rest of his life.

Judicious handling of the constitutionally nervous child is of paramount importance during these early years, for the child's life may be completely ruined by a comparatively small amount of injudicious handling. Clearly, the first thing to do is to appreciate just when one is dealing with a neurally unstable child. Such a child is usually precocious, certainly never stolid. The neurally unstable child may be brighter, more restless, more inquiring than a child of his age generally is. He notices more, is more difficult to please, more critical, more unbelieving than the average. These children are generally more interesting, more attractive than the children of sounder neural inheritance. They are often gentler, more affectionate, more clinging, more prone to crave sympathy than children who are more robust. They are often more fastidious about their food and their clothes, and much more affected by sense presentations. They may indeed show a high degree of affectability towards colours and odours. Thus some children may evince the strongest dislike for grey or purple or black; indeed the majority of very young children greatly dislike black, and will turn from a person dressed in black.

Their idiosyncrasy towards odours may be still more marked. A sensitive child, not yet four years of age, literally wept when on a country road he had to pass a cart carrying brewer's draff—an acrid, sour-smelling liquid given to pigs—which splashed out on to the road as the cart jolted along. It is not impossible that such a child may develop epilepsy or migraine within the first ten or twelve years of life; and if this is so, one should see that the exciting cause in each case is eliminated.

The prime cause of migraine (one-sided headache) or "biliousness" is intestinal indigestion permitting of systemic poisoning. The symptoms are clearly of a toxæmia of intestinal origin: the nausea, the vomiting, the diarrhœa, the vaso-motor paralysis, the chilliness, and the aversion from light (photophobia), all point to that conclusion. The headache may be partly due to a unilateral referred pain factor, the reference being into the sensory nerve of the face from the afferent nerve of the stomach. The vomiting, the vaso-motor paralysis, and the chilliness are reflex phenomena.

The dependence of irritability and depression on poisons which should be eliminated has long been recognized by every one.

The causes of epilepsy are still more obscure ; but at least some have an intestinal origin. One case which I attended for more than a year, a little girl of eleven or twelve, had an epileptic attack every ten days or so until we ascertained that she was suffering from an attack of diarrhœa due to intestinal indigestion. When this was anticipated, and an enema given to wash out the lower bowel, the attacks ceased.

The child's digestion must be kept as efficient as possible without allowing the child to get the idea that there is any unusual state of matters which requires special study. Children are very quick to perceive when they are being " fussed " over.

This is not the place to go into details about the feeding of children, but there is no doubt that the natural sources of the digestible fats should be largely drawn on in the dietary of the delicate ones. Where the child has an aversion from fats, which unfortunately is only too common, then one must give cod-liver oil, the virtues of which have been long known and are now explained as due to one of the vitamins. There are preparations of the oil in which the fishy taste is disguised.

From what has been already said, the importance of restful sleep will be recognized, and anything that is tending to disturb sleep, whether from within or without the nervous system, should be investigated and if possible removed. On the physical side there are "growing pains" to be remembered: these are due to rheumatic inflammation of the covering of the bones (periosteum), and therefore require specific treatment.

As regards the sleep of children, it is well to see that they are sent early to bed and not allowed to keep the late hours of the adults. A child will be more refreshed by sleeping from 8 p.m. to 6 a.m. than from 11 p.m. to 9 a.m. For children, at least, the sleep before midnight is particularly valuable.

Making children afraid of the dark by senseless suggestions is a fruitful source of trouble later when they object to go to sleep in the dark. Their inchoate imaginings, as they lie awake, are very disturbing. Nor should children of a tender age be shown pictures of a disagreeable or morbid kind, for these are very apt to remain in the memory and to give rise to distressing trains of thought. They are particularly liable to disturb sleep by giving rise to unpleasant dreams, which may be so horrible as to constitute *pavor nocturnus*, the night-terrors of children.

Children of the nervous type ought not to be "pressed" at all at school, nor ought they, in the opinion of many neurologists, to be taught to read until they are about eight years old. This may seem late to those who were trained forty or even twenty years ago; but what is aimed at in modern education is a sound nervous system which can be educated later, when it will absorb facts and principles all the better for not having had these presented at too immature a stage. The precocious child should not be encouraged in his precocity; the stolid child will take in all that is needful at its own rate. To press the nervous child is to risk making him dull for the rest of his life.

In particular, the sensitive child should not be ridiculed or laughed at: his little peculiarities, his likes and his dislikes, are very real to him: to have them made fun of is mentally painful.

The emotional acts of children, especially, ought not to be ridiculed; the failure of elders to seize a child's point of view has often a serious effect on his moral nature. Anything like an act dictated by altruism or sympathy on the part of children should never be made to look ridiculous: the stolid child will endure many things unmoved; the sensitive child is like the sensitive plant, it closes up at once within itself in an uncongenial and unsympathetic atmosphere.

Not that children should never have their peculiarities pointed out to them and corrected. Of course they should, but the correction may be done in such a kindly way that it will not produce a psychic lesion.

Closely allied to the psychic injury is the moral lesion. The unsophisticated child has clear ideas of right and wrong, so that his moral sense, which in normal children is early developed, suffers a shock from happenings which a wider knowledge of the world, its sins and its sorrows, would not produce on the grown-up person. One should, therefore, be very careful not to outrage the moral sense of children or to confuse their correct ideas of justice and injustice by exhibiting to them anything calculated to do violence to these.

Moral delinquency in any form whatever should not be presented to children, however much it may be surrounded by the tinsel halo of trans-Atlantic romance. In this respect the subjects of the majority of the "films" presented to the public are wholly unsuitable for children's attention, being vulgar, sentimental, and inane.

One should remember that what the quite normal and stolid child can endure unharmed, the neurally unstable child cannot. Neurally unstable children, if rightly handled, are capable of great achievements, provided the nervous system is not subjected to too great strains; in other words, the delicate nervous system is quite worth preserving, and it should be fostered in an environment favourable to its development.

We make a sharp distinction between the unstable nervous system and the degenerate. The latter requires treatment of a kind which is not contemplated in this book. The former is a grave responsibility, but much may be made of the opportunity to safeguard it.

The watchwords are therefore, in the case of the developing nervous system, suitable food, avoidance of constipation, plenty of sleep, an appropriate climate, and the exposure to no psychic strains.

For the adult neurasthenic, residence amongst mountains is, as a general rule, better than at the seaside, at least in spring and summer. During the winter the opposite holds good; the climate of the neighbourhood of the sea in winter is warmer than that of the mountains.

The question of recreation and exercise is of considerable importance for neurasthenics, and is one about which there is a great deal of popular misconception. Some people imagine that when a man is not at his work, he ought to be swimming or gardening or fencing or riding or swinging a dumb-bell. This indiscriminate worship of physical exercise is dangerous, because exercise, like some other good things, can be taken in too large quantity and at the wrong time.

Muscular exercise is good in proportion as it improves the circulation, makes the skin act, and produces just that amount of pleasant fatigue that leads to sleep. Exercise is bad when it overloads the heart, and produces so much fatigue that sleep is disturbed, made dreamy, or banished altogether. For a person to take exercise when he is physically tired, just because exercise is a good thing in the abstract, is unphysiological.

But physical exercise on the top of mental fatigue is just as, if not more, injurious. A man tired out with business cares sometimes takes some more or less strenuous exercise before going home. While this may suit a few men, it is otherwise with the majority. After rest and a meal, exercise may be thought of.

Certain games, which require much concentration of the attention, are not to be recommended for people when they are tired. Thus card-games, especially "bridge", in that they may add mental effort to preexisting fatigue, are for some people not a recreation at all but an extra source of worry and irritation.

We will now consider the proper treatment of a case of acute neurasthenia.

The first thing to do is to put the patient to bed. It is a remarkable thing that rest in bed should be so advantageous for so many very different kinds of illness. It rests everything, muscles and nervous system; it maintains a uniform temperature of the skin, it minimizes the work the heart has to do by eliminating the gravity-factor of the circulation of the blood. At first no visitors are to be allowed at all, for this type of neurasthenic shuns the company of other people and regards even his best friends as intruders. He wants to be alone, and to rest.

A little later, those whom he specially would like to see may visit him; and later still, any who will not depress him may be with him for a short time. If he makes a request to have visitors, it is a sign of return to normality. The mental indecision at this stage is extraordinary; the patient does not seem able to decide anything for himself; the most trivial matter becomes a burden, and an intolerably long time is consumed in deciding anything.

The loss of will-power (abulia) has to be seen to be believed. Infinite patience is required with these sufferers; they may be exasperatingly slow and irritatingly futile, but to hurry them is fatal to their recovery: the notion that they were being pressed would only recall the conditions that precipitated the attack.

Suitable feeding must be studied; and it must be remembered that now the patient is in bed and not taking exercise, his metabolism is much less vigorous than when he was up and about. The amount of food may therefore be reduced, but it should be made as appetizing as possible. The patient should be weighed once a week, for loss of weight must not be permitted.

This type of patient has often the most obstinate constipation, which the physician must deal with in the light of the special circumstances of the case. The question of intestinal catarrh, which is closely related to this condition, must be considered. In a great many cases of neurasthenia, prolonged intestinal indigestion has been a predisposing factor. The lower bowel should from time to time be washed out with a form of enema which the physician in charge will prescribe.

Quite as frequent a source of toxæmia is pus-production. The source of this infection must be looked for very carefully ; the teeth, tonsils, nasal chambers and their accessory cavities should all be scrutinized. It seems to be an established fact in medicine that pus-production can, in a marked degree, give rise to chronic poisoning.

These points having been attended to, there is lastly the problem of seeing that the patient gets plenty of sleep. Before drugs are resorted to, we should try every other possible means of inducing sleep. A glass of warm milk taken about twenty minutes before sleep is desired, will often prove sufficient ; but if it does not, we should remember the excellent soporific effect of massage. The patient should be in a position and condition to go off to sleep the moment the massage is finished ; things should not have to be found, medicines given, questions asked, or anything done that would disturb.

The massage, by inducing passive activity of the muscles, undoubtedly determines some blood to them that previously passed through the brain, so that the blood-pressure in the brain, as is desired, falls. Further, the effects of the sensory stimulation of the nerves both in skin and muscles has a pleasant, massive effect in consciousness which is soporific, so that from these various factors combined sleep is quite apt to follow massage.

The sleep-inducing properties of a hot bath should not be forgotten. Of course if the hot bath, as sometimes happens, stimulates the heart instead of lowering the blood-pressure, then it is distinctly contra-indicated. The case of alcohol is similar ; a glass of hot whisky and water will in some people so lower the cerebral blood-pressure that sleep comes soon : now and again alcohol has precisely the opposite effect, the spirit stimulating the heart to a rapid action which effectually banishes sleep. When this has been found to be so, the use of alcohol is contra-indicated. The personality of the masseur, of the nurse, or of the attendant is very important, where cases of neurasthenia are being studied. The constant presence of an attendant who for any reason has an irritating effect on the patient is sure to retard recovery. Indeed very small things—small, absolutely, to normal people—may have disproportionately great effects on nervous cases, so that it is hopeless to expect improvement if all the time the patient is worrying about the rasping voice, the irritating laugh, the red hair, or the red hands of the nurse.

Chronic neurasthenia is much more difficult to treat, since it is a long-drawn-out constitutional disability of the nervous system.

It is less a disease than a disposition. Many of these cases are labelled " incompatibility of temper " ; " chronic ill-health " ; " always irritable " ; " always on the go " ; " very eccentric " ; " always depressed " ; " always worrying ".

Our chances of success with one of these cases depends greatly on the patient's mental resources, his social environment, and his financial position.

It should be legally possible to give a patient all the special treatment that mental cases receive within the walls of an institution without incurring the peculiar stigma which intramural treatment has acquired. During the War a great many cases of shell-shock (traumatic neurasthenia with mental symptoms) were treated at once as " mental " cases without the military medical man's being trammelled by legal certification. The cases were dealt with outside institutions by hypnotism or by other appropriate measures, so that a large proportion of patients were cured or had their conditions improved.

The case of chronic nervous disability is one of the most difficult in clinical medicine, partly on account of its elusive nature, and partly because, when the patient thinks himself ill, the relatives won't admit it, and when the relatives think him ill, the patient won't admit it. The doctor is between the devil of chronic neurasthenia and the deep sea of perplexed relations.

It is the sort of case where pre-eminently the inevitable bottle of medicine won't do any good. Not that drugs are never of any use at any stage, but unquestionably they have less applicability here than in most cases. The physician in charge may think it well to prescribe some of the safer sedatives to be taken over a long period of time, if he finds any disposition for the patient not to sleep well. He certainly would not permit insomnia to continue for long. He would ascertain whether there was any absorption from a focus of pus-production ; and he might, if such were found, prescribe an "autogenous" vaccine.

The question of climate would seriously engage his attention, for he would in most of his cases have to interdict life in the Tropics altogether. Even the Riviera he might not consider suitable for many of his patients, on account not only of the peculiar form of irritability they may develop there, but also on account of the unrestful character of hotel-life in general.

A very windy climate is as a rule bad for neurasthenics. Those parts of the world where thunderstorms are frequent and where the air is highly charged with electricity are bad for neurasthenics; their irritability is increased in such climates, and they complain of headache.

The use of electricity in treatment is quite another matter; many neurasthenics benefit from one or other of the various forms of electric treatment as they do from massage. Which form of electricity should be used is another question for the medical expert to answer; he will decide not only that, but the number of treatments per week, the time of day for these, and other practical details.

There is little doubt that some of the more cultured neurasthenic patients are greatly benefited by the more intellectual forms of mental activity such as games of skill, listening to music, and witnessing the drama. It really all depends on whether the effect of any of these things is to relax the mind or to add mental fatigue to the fatigue already present.

In connexion with neurasthenia we must say something about hypnotism. It is undeniable that in skilful hands hypnotic suggestion can be a very valuable accessory to other therapeutic measures.

We have already seen that in hypnotism we have a powerful method of influencing the mind of a patient; in many cases, distinct benefits have accrued from its use. But it must be employed by a qualified person who understands morbid psychology and this particular kind of mental therapeusis. Hypnotism has been used with success in cases of insomnia, loss of memory, dual personality, obsession, and generally in some of the most troublesome cases of neurasthenia. Some of the spectacular cures in the Great War were by means of hypnosis.

Lastly, as a curative in neurasthenia we come to the use of psycho-analysis. Psycho-analysis is the name of a psychological system elaborated by Dr. Freud of Vienna in which the doctrine of the "sub-conscious" plays a very prominent part. It is also a system of mental therapeutics in which introspection is an essential feature. A third characteristic of Freud's system is the immense emphasis laid on the factor of sex-consciousness; indeed this conception may be said to dominate it.

This is not the place to give an exposition of psycho-analysis. It is a system of interpretation of abnormal psychic phenomena; and, as is liable to happen in such systems, it becomes more complicated as time goes on. Its curative power is assessed variously by different critics.

Freud teaches that a very great deal of mental unrest and irritability is due to what he calls a "submerged complex"—an undesirable state of mind resulting from the repression in the sub-conscious of certain disagreeable experiences. These have become disagreeable memories, having been laid down in very early childhood, and, not having been got rid of, have become "repressed"—relegated to the region of the "sub-conscious mind". They are not banished but only overlaid: they are rather potential than actual. Freud teaches that these repressions have the power to emerge into consciousness, especially during dreams, where they are represented by an elaborate symbolism; but whether they do this or not, they are potent to disturb the mental life of the individual, poisoning it and so rendering it ineffective and miserable.

The emergence of these repressions in dreams may give the clue to the nature of the content of the submerged complexes; this and the method of "free association" are used to discover the content. "Free association" means that to the patient an idea (word) is given, and he is to say what word is immediately associated with that word in his mind; this process is pursued until the submerged complex is brought to the surface into full consciousness, where it can be examined and disposed of.

This process of unearthing the hidden troubles of the mind is the modern equivalent of full "confession", which in practically all religious systems has been encouraged, if not insisted on. It is the modern German reply to Macbeth's plaint, " Canst thou not minister to a mind diseased ? "

There can be no doubt that a great deal in the system of psycho-analysis is sound in its psychology, and that much good may result from confession used as an agent in mental therapeutics. Freud has done good service in drawing attention to the immense importance of the psyche as a factor in ill-health, and consequently to the psychic means of cure. It is incontestable that a conflict in the mind between the repressed disagreeable events of the past and the " normal " consciousness can give rise to a great deal of mental worry which renders the patient's life unhappy and ineffective, weakening the *élan vital* and poisoning the otherwise valuable emotions at their source. Internal conflict is a source of weakness in the battle of life.

But in the actual practice of the Freudian system the conscientious physician is on the horns of a dilemma, for although it is good for a neurasthenic to tell a judicious medical adviser all that is " on his mind ", it may easily come about that the medical man in carrying out the method of free association may unintentionally put into his patient's mind thoughts of a highly undesirable if not evil content. It is easy in psycho-analysis to do more harm than good even with the best intentions.

The process is tedious and expensive, and a cure cannot be guaranteed. Some critics have insisted that a moral danger may lurk in the intimate relations of the physician and a patient of the opposite sex, especially when the factor of sex is so unduly prominent. Some of the most competent neurologists hold that with Freud sex has become such an obsession that he sees it as the beginning, continuation, and end of everything.

While it is perfectly true that thoughts involving sex form the background of a large number of psychic processes, and while sex enters as a disturbing element into the fabric of the growing mind, yet some of us think that this factor has been over-emphasized, and that a sexual origin of mental conflicts is not so common as Freud imagines. Financial worries, thwarted ambitions, and social yearnings would seem to be more frequently the sources of trouble than Freud admits. His idea of sex-symbolism has been absurdly over-emphasized, some of his interpretations of dreams being fanciful and arbitrary to a high degree.

There is much that is true in psycho-analysis, but as in all systems wrought out by a single brain, and that brain a Teutonic one, there is the inevitable tendency to lose the sense of proportion, to magnify the trivial, and to see in the accidental and commonplace a meaning and an implication that these things cannot possibly possess.