These experiments show that certain impressions made upon the sensory nerves affect the animal heat, by reflex action. As section of the sympathetic filaments increases the heat in particular parts, with an increase in the supply of blood, and their Faradization reduces the quantity of blood and diminishes the temperature, it is reasonable to infer that the reflex action takes place through the vaso-motor nerves. If it be assumed that the impression is conveyed to the centres by the nerves of general sensibility, and that the vessels are modified in their caliber and the heat is affected through the sympathetic fibres, it remains only to determine the situation of the centres which receive the impression and generate the stimulus. These centres are situated in the cerebro-spinal axis.

The existence of vaso-motor nerves and their connection with centres in the cerebro-spinal axis are now sufficiently well established. It is certain, also, that centres presiding over particular acts may be distinctly located, as the genito-spinal centre, in the spinal cord opposite the fourth lumbar vertebra, and the cilio-spinal centre, in the cervical region of the cord. An impulse generated in these centres, sometimes as the result of impressions received through the nerves of general sensibility, produces contraction of the non-striated muscular fibres of the iris, vasa deferentia etc., including the muscular walls of the blood-vessels. The contraction of the muscular walls of the vessels is tonic; and when their nerves are divided, relaxation takes place and the vessels are dilated by the pressure of blood. By this action the local circulations are regulated in accordance with impressions made upon sensory nerves, the physiological requirements of certain parts, mental emotions etc. Secretion, the peristaltic movements of the alimentary canal, the movements of the iris etc., are influenced in this way. This action is also illustrated in cases of reflex paralysis, in inflammations as the result of "taking cold," and in many other pathological conditions.

It remains only to show that the phenomena following section of the sympathetic in animals are illustrated in certain cases of disease or injury in the human subject. It is rare to observe traumatic injury confined to the sympathetic in the neck. A single case, however, apparently of this kind, has been reported by Mitchell. A man received a gunshot-wound in the neck. Among the phenomena observed a few weeks after, were contraction of the pupil on the side of the injury, and after exercise, flushing of the face upon that side. There was no difference in the temperature upon the two sides during repose, but no thermometric observations were made when half of the face was flushed by exercise. Bartholow has reported several cases of unilateral sweating of the head (two observed by himself), in several of which there probably was compression of the sympathetic, from aneurism. In those cases in which the condition of the eye was observed, the pupil was found contracted in some and dilated in others. In none of these cases were there any accurate thermometric observations. In a series of observations by Wagner, upon the head of a woman, eighteen minutes after decapitation, powerful stimulation of the sympathetic produced great enlargement of the pupil. In such a case as this, it would not be possible to make any observations on the influence of the sympathetic upon the temperature.

Vaso-Inhibitory Nerves.—There are certain nerves, the direct action of which under Faradic stimulation is to dilate certain blood-vessels. These nerves may also be excited by reflex action through the sensory nerves. In many nerves, as the chorda tympani, the nervi erigentes etc., the existence of inhibitory fibres has been demonstrated (Dastre and Morat, Eckhard, Laffont, Vulpian and others). For example, division of the nervi erigentes has no immediate effect on the penis, but Faradization of the peripheral ends of the nerves dilates the blood-vessels and produces erection. Fibres possessing this property undoubtedly exist throughout the body, in the sympathetic and in the motor and mixed nerves; and it is possible that there are vaso-motor inhibitory centres, although such centres have not been located. The mode of action of these nerves is analogous to that of the inhibitory nerve of the heart, restraining and regulating the action of the vaso-motor nerves and allowing the pressure of blood to dilate the vessels. It does not, however seem proper to call them "vaso-dilator" nerves, any more than it would be correct to call the inhibitory nerve of the heart the cardiac dilator nerve.

Trophic Centres and Nerves (*so-called*).—Collections of nerve-cells act as centres presiding over the nutrition of the nerve-fibres with which they are connected; but it has been found that the nutrition of certain parts may be profoundly affected through the nervous system. Many pathologists, relying upon the presence of certain lesions of cells in the cord, in connection with cases of progressive muscular atrophy, admit the existence of trophic cells and nerves. These views, however, rest almost entirely upon pathological observations. Direct experiments upon the sympathetic in animals do not positively show any influence upon nutrition, except as this system of nerves affects the supply of blood to the parts. When a sympathetic nerve is divided, there is an apparent exaggeration of the nutritive processes in particular parts, and there may be inflammatory phenomena, but atrophy of muscles is not observed. Atrophy of muscles, indeed, follows division of cerebro-spinal nerves only, or as cases of disease have shown, disorganization of cells belonging to what are recognized as motor centres. As regards the latter condition, there can be no doubt of the fact that progressive muscular atrophy is attended with disorganization of certain of the motor cells of the spinal cord.

Without fully discussing this subject, which belongs to pathology, the facts may be briefly stated as follows: There may be progressive atrophy of certain muscles, uncomplicated with paralysis except in so far as there is weakness of these muscles due to partial and progressive destruction of their contractile elements. The only constant pathological condition in these cases, aside from the changes in the muscular tissue, is destruction of certain cells in the antero-lateral portions of the cord, with more or less atrophy of the corresponding anterior roots of the nerves. It has never been assumed that there are cells in the cord, presenting anatomical peculiarities by which they may be distinguished from the ordinary motor or sensory elements; but the fact of the degeneration of certain cells, others remaining normal, has led to the distinction by certain writers, of trophic cells, and, of course, these must be connected with the parts by trophic nerves.

There can be no doubt of the fact that the cells of the antero-lateral columns of the spinal cord are connected with motion, and that impulses generated in these cells are conveyed to the muscles by the anterior roots of the spinal nerves. It also is a fact, no less definite, that when a muscle or a part of a muscle is for a long time deprived of the motor influence by which it is brought into action, its fibres undergo atrophy, become altered in structure and lose their contractility. Starting with these two propositions, and assuming that certain of the ordinary motor cells of the cord are destroyed, it is easy to predict the phenomena to be expected as a consequence of such a lesion.

The destruction of certain motor nerve-cells connected with the anterior roots of the spinal nerves would certainly produce degeneration of the nerve-fibres to which they give origin. This occurs when any motor nerves are separated from their cells of origin, and it involves no necessity of assuming the existence of special trophic cells or nerves.

If a few of the motor cells be affected with disease, and if the degeneration be gradual and progressive, there would necessarily be progressive and partial paralysis of the muscles to which their nerves are distributed. This paralysis, confined to a limited number of fibres of particular muscles or sets of muscles, would give the idea of progressive weakening of the muscles, and the phenomena would not be those observed in complete paralysis produced by section of the motor nerves. These are the phenomena observed in progressive muscular atrophy, preceding the paralysis which is the final result of the disease; and these do not of necessity involve the action of any special centres or nerves.

As regards the muscular atrophy itself, if the nervous stimulus be gradually destroyed, the muscular tissue will necessarily undergo progressive degeneration and atrophy.

With the above considerations, the question of the trophic cells and nerves may be left to the pathologist; and the existence of centres and nerves specially and directly influencing the nutrition of the muscular system can be admitted only when it has been demonstrated that there are lesions of particular structures in the nervous system, which produce phenomena that can not be explained by the action of ordinary motor and sensory nerves and of the vaso-motor system. In thus dismissing the question, however, it is not intended to assume that the existence of trophic centres and nerves is impossible. There are certain peculiar changes in tissue in progressive muscular atrophy, and section of nerves produces degenerations of glandular and other structures that are not muscular. Future observations may show that there are special parts of the nervous system presiding over nutrition; but at present, such parts have not been accurately described and isolated, either anatomically or physiologically.

Sleep.

When it is remembered that about one-third of each day is passed in sleep, and that at this time, voluntary motion, sensation, the special senses and various of the functions of the organism are greatly modified, the importance of a physiological study of this condition is sufficiently apparent. The subject of sleep is most appropriately considered in connection with the nervous system, for the reason that the most important modifications in function are observed in the cerebro-spinal axis and nerves. Repose is as necessary to the nutrition of the muscular system as proper exercise; but repose of the muscles relieves the fatigue due to exercise, without sleep. It is true that after violent and prolonged exertion, there is frequently a desire for sleep, but simple repose will often restore the muscular power. After the most violent effort, a renewal of muscular vigor is most easily and completely effected by rest without sleep, a fact familiar to all who are accustomed to athletic exercises. After prolonged and severe mental exertion, however, or after long-continued muscular effort which involves an excessive expenditure of the so-called nerve-force, sleep becomes an imperative necessity. If the nervous system be not abnormally excited by effort, sleep follows moderate exertion as a natural consequence, and it is the only physiological means of complete restoration; but the two most important muscular acts, viz., those concerned in circulation and respiration, are never completely arrested, sleeping or waking, although they undergo certain modifications.

In infancy and youth, when the organism is in process of development, sleep is more important than in adult life or old age. The infant does little but sleep, eat and digest. In adult life, under perfectly physiological conditions, a person requires about eight hours of sleep; some need less, but few require more. In old age, unless after extraordinary exertion, less sleep is required than in adult life. Each individual learns by experience how much sleep is necessary for perfect health; and there is nothing which more completely incapacitates one for mental or muscular effort, especially the former, than loss of natural rest.

Sleeplessness is one of the most important of the predisposing causes of certain forms of brain-disease, a fact which is well recognized by practical physicians. One of the most severe methods of torture is long-continued deprivation of sleep; and persons have been known to sleep when subjected to acutely painful impressions. Severe muscular effort, even, may be continued during sleep. In forced marches, regiments have been known to sleep while walking; men have slept soundly in the saddle; persons will sometimes sleep during the din of battle; and other instances illustrating the imperative demand for sleep after prolonged vigilance might be cited. It is remarkable, also, how noises to which one has become accustomed may fail to disturb natural rest. Those who have been long habituated to the noise of a crowded city frequently find difficulty in sleeping in the stillness of the country. Prolonged exposure to intense cold induces excessive somnolence, and if this be not resisted, the sleep passes into stupor, the power of resistance to cold becomes rapidly diminished, and death is the result. Intense heat often produces drowsiness, but, as is well known, is not favorable to natural sleep.

Sleep is preceded by a feeling of drowsiness, an indisposition to mental or physical exertion, and a general relaxation of the muscular system. It then requires a decided effort to keep awake. In sleep the voluntary muscles are inactive, the lids are closed, the ordinary impressions of sound are not appreciated, and sometimes there is a dreamless condition, in which all knowledge of existence is lost.

There may be, during sleep, mental operations of which there is no consciousness or recollection, unconscious cerebration, as it was called by Carpenter. It is well known that dreams are vividly remembered immediately on awakening, but that the recollection of them rapidly fades away, unless they be brought to mind by an effort to recall and relate them. Whatever be the condition of the mind in sleep, if the sleep be normal, there is repose of the cerebro-spinal system and an absence of voluntary effort, which restore the capacity for mental and physical exertion.

The impressionability and the activity of the human mind are so great, most of the animal functions are so subordinate to its influence, and the organism is so subject to unusual mental conditions, that it is difficult to determine with exactness the phenomena of sleep that are absolutely physiological and to separate those that are slightly abnormal. It can not be assumed, for example, that a dreamless sleep, in which existence, is as it were a blank, is the only normal condition of repose of the system; nor is it possible to determine what dreams are due to previous trains of thought, to impressions from the external world received during sleep, and are purely physiological, and what are due to abnormal nervous influences, disordered digestion, etc. It may be assumed, however, that an entirely refreshing sleep is normal.

That reflex ideas originate during sleep, as the result of external impressions, there can be no doubt; and many remarkable experiments upon the production of dreams of a definite character, by subjecting a person during sleep to peculiar influences, have been recorded. The hallucinations produced in this way are called hypnagogic, and they occur usually when the subject is not in a condition favorable to sound sleep.

As regards dreams due to external impressions, it is a curious fact, which has been noted by many observers and is one which accords with the personal experience of all who have reflected upon the subject, that trains of thought and imaginary events, which seem to pass over a long period of time in dreams, actually occur in the brain within a few seconds. A person is awakened by a certain impression, which undoubtedly has given rise to a dream that seemed to occupy hours or days, and yet the period of time between the impression and the awakening was hardly more than a few seconds; and persons will drop asleep for a very few minutes, and yet have dreams with the most elaborate details and apparently of great length. It is unnecessary to cite the accounts of literary compositions of merit, the working out of difficult mathematical problems in dreams, etc., some of which are undoubtedly accurate. If it be true that the mind is capable of forming consecutive ideas during sleep—which can hardly be doubted—there is no good reason why these phenomena should not occur and the thoughts should not be remembered and noted immediately on awakening. In most dreams, however, the mind is hardly in a normal condition, and the brain generally loses the power of concentration and of accurate reasoning.

Condition of the Brain and Nervous System during Sleep.—During sleep the brain may be in a condition of absolute repose—at least, as far as there is any subjective knowledge of mental operations—or there may be more or less connected trains of thought. There is, also, as a rule, absence of voluntary effort, although movements may be made to relieve discomfort from position or external irritation, without awakening. The sensory nerves retain their properties, although the general sensibility is somewhat blunted; and the same may be said of the special senses of hearing, smell, and probably of taste. There is every reason to believe that the action of the sympathetic system is not disturbed or affected by sleep, if the influence of the vaso-motor nerves upon the circulation in the brain be excepted.

Two opposite theories have long been in vogue with regard to the immediate cause of sleep. In one, this condition is attributed to venous congestion and increased pressure of blood in the brain, and this view probably had its origin in the fact that cerebral congestion induces stupor or coma. Stupor and coma, however, are entirely distinct from natural sleep; for in the former the action of the brain is entirely suspended, there is no consciousness, no dreaming, and the condition is manifestly abnormal. In animals rendered comatose by opium, the brain when exposed is found deeply congested with venous blood. The same condition often obtains in profound anæsthesia by chloroform, but a state of the brain very nearly resembling normal sleep is observed in anæsthesia by ether. These facts have been demonstrated by experiments upon living animals, and have been observed in the human subject in cases of injury of the head. When opium is administered in large doses, the brain is congested during the condition of stupor or coma, but this congestion is relieved when the animal passes, as sometimes happens, from the effects of the agent into a natural sleep. In view of these facts and others which will be stated hereafter, it is unnecessary to discuss the theory that sleep is attended with or is produced by congestion of the cerebral vessels.

The idea that the circulation in the brain is diminished during sleep has long been entertained by some physiologists; but until within a few years, it has rested chiefly upon theoretical considerations. The experiments of Durham (1860) seem to demonstrate that the supply of blood to the brain is always greatly diminished during sleep. These experiments were made upon dogs. A piece of the skull was removed with a trephine, and a watch-glass was accurately fitted to the opening and cemented at the edges with Canada balsam. When the animals operated upon were awake, the vessels of the pia mater were seen moderately distended and the circulation was active; but during perfectly natural sleep, the brain retracted and became pale. "The contrast between the appearance of the brain during its period of functional activity and during its state of repose or sleep was most remarkable." There can be hardly any doubt, after these experiments, that the cerebral circulation is considerably diminished in activity during sleep.

The influence of diminished supply of blood to the brain has been illustrated by compression of both carotid arteries. In an experiment performed upon his own person, Fleming produced immediate and profound sleep in this way, and this result invariably followed in subsequent trials upon himself and others. Waller produced anæsthesia in patients by pressure upon both pneumogastric nerves; but the nerves are so near the carotid arteries that they could hardly be compressed, in the human subject, without interfering with the current of blood, and such experiments do not positively show whether the loss of sensibility be due to pressure upon the nerves or upon the vessels. In some rare instances in which both carotid arteries have been tied in the human subject, it has been stated that there is an unusual drowsiness following the necessary diminution in the activity of the cerebral circulation; but this result is by no means constant, and the morbid conditions involving so serious an operation are usually such as to interfere with their value as facts bearing upon the question under consideration. As far as the human subject is concerned, the most important facts are the results of compression of both carotids in healthy persons. These, as well as experiments on animals, all go to show that the supply of blood to the brain is diminished during natural sleep, and that sleep may be induced by retarding the cerebral circulation by compressing the vessels of supply. When the circulation is interfered with by compressing the veins, congestion is the result, and there is stupor or coma.

If diminished flow of blood through the cerebral vessels be the cause of natural sleep, it becomes important to inquire how this condition of physiological anæmia is brought about. It must be that when the system requires sleep, the vessels of the brain contract in obedience to a stimulus received through the sympathetic system of nerves, diminishing the supply of blood, here, as in other parts under varied physiological conditions. The vessels of the brain are provided with vaso-motor nerves, and it is sufficient to have noted that the arteries are contracted during sleep, the mechanism of this action being well established by observations upon other parts of the circulatory system.

Little is known of the intimate nature of the processes of nutrition of the brain during its activity and in repose; but there can be no doubt of the fact that there is more or less cerebral action at all times when one is awake. Although the mental processes are much less active during sleep, even at this time, the operations of the brain are not always suspended. It is equally well established that exercise of the brain is attended with physiological wear of nervous tissue, and like other parts of the organism, its tissue requires periodic repose for regeneration of the substance consumed. Analogies to this are to be found in parts that are more easily subjected to direct observation. The muscles require repose after exertion, and the glands, when not actively engaged in discharging their secretions, present intervals of rest. As regards the glands, during the intervals of repose the supply of blood to their tissue is much diminished. It is probable, also, that the muscles in action receive more blood than during rest; but it is mainly when these parts are not active, and when the supply of blood is smallest, that the processes of regeneration of tissue seem to be most efficient. As a rule the activity of parts, while it is attended with an increased supply of blood, is a condition more or less opposed to the processes of repair, the hyperæmia being, apparently, a necessity for the marked and powerful manifestations of their peculiar action. When the parts are active, the blood seems to be required to keep at the proper standard the so-called irritability of the tissues and to increase their power of action under proper stimulus. Exercise increases the power of regeneration and favors full development in the repose which follows; but during rest, the tissues have time to appropriate new matter, and this does not seem to involve a large supply of blood. A muscle is exhausted by prolonged exertion; and the large quantity of blood passing through the tissue carries away carbon dioxide and other products of disassimilation, which are increased in quantity, until it gradually uses up its capacity for work. Then follows repose; the supply of blood is reduced, but under normal conditions, the tissue repairs the waste which has been excited by action, the blood furnishing nutritive matter and carrying away a comparatively small quantity of effete products.

It may safely be assumed that processes analogous to those just described take place in the brain. By absence of voluntary effort, the muscles have time for rest and for the repair of physiological waste, and their action is for the time suspended. As the activity of the brain involves consciousness, volition, the generation of thought, and, in short, the mental condition observed while awake, complete repose of the brain is characterized by the opposite conditions. It is true that the brain may be rested without sleep, by abstaining from mental effort, by the gratification of certain of the senses, and by mental distraction of various kinds, and that the mind may work to some extent during sleep; but during the period of complete repose—that condition which is so necessary to perfect health and full mental vigor—consciousness and volition are lost, there is no thought, and the brain, which does not receive blood enough to stimulate it to action, is simply occupied in the insensible repair of its substance and is preparing itself for renewed work. The exhaustion of the muscles produces a sense of fatigue of the muscular system, indisposition to muscular exertion, and a desire for rest, not necessarily involving drowsiness. Fatigue of the brain is manifested by indisposition to mental exertion, dullness of the special senses and a desire for sleep. Simple repose will relieve physiological fatigue of muscles; and when a particular set of muscles has been used, the fatigue often disappears when these muscles alone are at rest, though others be brought into action. Sleep, and sleep alone, relieves fatigue of the brain.

During sleep nearly all of the physiological processes, except those directly under the control of the sympathetic nervous system, are diminished in activity. The circulation is slower, and the pulsations of the heart are less frequent, as well as the respiratory movements. These points have already been considered in connection with the physiology of circulation and respiration. Physiologists have but little positive information with regard to the relative activity of the processes of digestion, absorption and secretion, during sleep. The drowsiness which many persons experience after a full meal is probably due to a determination of blood to the alimentary canal and a consequent diminution in the supply to the brain.

CHAPTER XXI.

SPECIAL SENSES—TOUCH, OLFACTION AND GUSTATION.

General characters of the special senses—Muscular sense (so called)—Sense of touch—Variations in tactile sensibility in different parts (sense of locality of impressions)—Table of variations measured by the æsthesiometer—Appreciation of temperature—Tactile centre—Olfaction—Nasal fossæ—Schneiderian and olfactory membranes—Olfactory (first nerve)—Physiological anatomy—Olfactory bulbs—Olfactory cells and terminations of the olfactory nerve-fibres—Properties and uses of the olfactory nerves—Mechanism of olfaction—Relations of olfaction to the sense of taste—Reflex acts through the olfactory nerves—Olfactory centre—Gustation—Savors—Nerves of taste—Chorda tympani—Glosso-pharyngeal (ninth nerve)—Physiological anatomy—General properties of the glosso-pharyngeal—Relations of the glosso-pharyngeal nerves to gustation—Mechanism of gustation—Physiological anatomy of the organ of taste—Papillæ of the tongue—Taste-beakers—Connections of the nerves with the organs of taste—Taste-centre.

THE description of the nerves thus far has included motion and what is known as general sensibility; and knowledge of these properties of the nervous system has been derived mainly from experiments upon the inferior animals. As regards sensation, the experiments have referred to impressions recognized as painful; and these are conveyed to the centres by nerve-filaments, anatomically as well as physiologically distinct from those which convey to the contractile parts the impulses that give rise to motion. In regard to the sensory nerves, simple impressions only have been described; but it is evident that the filaments of peripheral distribution of these nerves are capable of receiving a variety of impressions, by which, to a certain extent, the form, size, character of surface, density and temperature of objects are recognized. There is also a general appreciation of heat and cold; a sense of resistance, which gives an idea of weight; and finally, there are nerves of peculiar properties, terminating in organs adapted to receive the impressions of smell, taste, sight and hearing.

The senses of olfaction, gustation, vision and audition belong to peculiar organs, provided with nerves which have special properties and usually are not endowed with general sensibility. These nerves have been omitted in

the general description of the nervous system, as well as the accessory organs to which they are distributed.

The senses of touch, temperature and pain are all conveyed to the nerve-centres by what have been described as sensory nerves, the touch being perfected in certain parts by peculiar arrangements of the terminal nerve-fibres. Although it is possible that each one of these impressions is transmitted by special and distinct fibres, this is not yet a matter of positive demonstration. The so-called muscular sense, by which weight, resistance etc., are appreciated, undoubtedly depends to a great extent upon the muscular nerves. What are generally recognized as sensory impressions have been thus subdivided. These subdivisions are sufficiently distinct, as far as the character of the sensations themselves are concerned, but as regards their paths of conduction, as before intimated, exact and positive *data* are wanting. It is impossible to study with advantage the different varieties of ordinary sensation in the lower animals, for evident reasons; and physiologists rely mainly upon observations on the human subject, in the form of experiments and of pathological phenomena.

There are two ways of regarding the different varieties of general sensation: One is to look at each as a peculiar impression conveyed by special nerve-fibres, and the other is to regard the nerves of general sensibility as capable of conducting impressions of different kinds. It has never been assumed that special fibres for each variety of sensation have been demonstrated, and it is possible only to reason as to this from what is actually known of the general properties of sensory nerves.

The general sensory nerves are sufficiently distinct in their properties from the true nerves of special sense. The latter convey peculiar impressions only, such as those of sight, hearing, smell and taste. The former, when strongly stimulated or irritated, always convey impressions of pain. Separating, then, all other senses, except the venereal sense, from the true special senses, it is proper to inquire whether it be reasonable or necessary to assume that any of the varieties of general sensation require special nerves for their conduction.

It is well known that a relatively powerful stimulation of a sensory nerve or of sensitive parts is necessary to the production of a painful impression; and it is also well known that very painful impressions overpower impressions of touch, weight, pressure, temperature and the so-called muscular sense. In cases of disease, it is sometimes observed that tactile sensibility is retained in parts that are insensible as regards pain. It is possible that sensory nerve-fibres may become so altered in their properties as to be incapable of conducting painful impressions, while they still conduct sensations that are appreciated only as impressions of contact. This is observed in certain cases of artificial anæsthesia. In hyperæsthesia, or exaggerated sensibility to painful impressions, the tactile sense is necessarily overpowered in a greater or less degree. Impressions made on a sensory nerve in its course are always appreciated as painful, and the pain is referred to the terminal distribution of the nerve, this being a law of sensory perception. There is no sense of