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 contact at the ends of the nerve, and there is no contact. The impression, in order to be perceived at all, must be painful. These facts may be in a measure applied to local impressions produced by extremes of heat and cold or by chemical or electric stimulation of sensitive parts.

The internal organs have as a rule no tactile sensibility, although they may be sensitive; and feeble impressions may not be appreciated, while stronger impressions are painful.

Titillation is the result of unusual, feeble impressions or of slight impressions frequently repeated in the peripheral ends of certain sensory nerves. These impressions are not precisely tactile nor are they painful. They produce peculiar sensations, and they frequently give rise to violent reflex movements, by what is known as a summation of sensory stimulations.

Muscular Sense (*so called*).—It is difficult to define exactly what is meant by the term muscular sense, as it is used by some physiologists. In all probability, the sense which enables one to appreciate the resistance, immobility and elasticity of substances that are grasped or stood upon or which are in any way opposed to the exertion of muscular power, may be greatly modified by education and habit. It is undoubtedly true, however, that general sensibility regulates the action of muscles to a considerable extent. If, for example, the lower extremities be paralyzed as regards sensation, the muscular power remaining intact, frequently the person so affected can not walk unless he be able to see the ground. This difficulty occurs for the reason that the limbs have lost the sense of contact. Many curious examples of this kind are to be found in works upon diseases of the nervous system. One of the most striking is a case communicated to Charles Bell by Dr. Ley. The patient was affected with partial loss of sensibility upon one side of the body, "without, however, any corresponding diminution of power in the muscles of volition, so that she could hold her child in the arm of that side so long as her attention was directed to it; but if surrounding objects withdrew her from the notice of the state of her arm, the flexors gradually relaxed, and the child was in hazard of falling." This is like certain of the phenomena observed in cases of locomotor ataxia. In this disorder there is disease of the posterior white columns of the spinal cord, involving, sometimes, the posterior roots of the spinal nerves, with more or less impairment of general sensibility, the muscular power in some instances being intact. Patients affected in this way frequently are unable to walk or stand without the aid of the sight. One of the most characteristic phenomena is inability to stand when blindfolded; although, with the aid of the sight, the muscles can be made by the will to act with considerable power. Habit and education enable some persons to appreciate with great nicety slight differences in weight; but this is due chiefly to the sense of resistance to muscular effort and has little dependence upon the sense of touch.

In general those parts which are most sensitive to the impressions of touch, as the fingers, enable one to appreciate differences in pressure and weight with greatest accuracy. The sense of simple pressure, unaided by the estimation of weight by muscular effort, generally is more acute upon

the left side. Differences in weight can be accurately distinguished when they amount to only one-sixteenth, by employing muscular effort in lifting as well as the sense of pressure; but the sense of pressure alone enables most persons to appreciate a difference of not less than one-eighth. When weights are tested by lifting with the hand, the appreciation of slight differences is more delicate if the weights be successively tested with the same hand than when two weights are placed, one on either hand. When the interval between the two trials is more than forty seconds, slight differences in weight —the difference between fourteen and a half and fifteen ounces (411 and 425 grammes), for example—can not be accurately appreciated. In such trials, it is necessary to have the metals used of the same temperature, for cold metals seem heavier than warm.

Sense of Touch.

The different modes of termination of the sensory nerves have already been described; and in many instances it is possible to explain, by the anatomical characters of the nerves, the great differences that have been observed in the delicacy of the tactile sensibility in different parts—differences which are very important pathologically as well as physiologically, and which have been studied by Weber, Valentin and others, with great minuteness.

Variations in the Tactile Sensibility in Different Parts (*Sense of Locality of Impressions*).—In certain parts of the cutaneous surface the general sensibility is much more acute than in others. For example, a sharp blow upon the face is more painful than a similar injury to other parts; and the eye, as is well known, is peculiarly sensitive. The appreciation of temperature varies in different parts, this probably depending to a great extent upon habitual exposure. Some parts, as the soles of the feet or the axilla, are peculiarly sensitive to titillation. The sense of touch, also, by which the size, form, character of the surface, consistence etc., of objects are appreciated, is developed to a greater degree in some parts than in others. The tips of the fingers generally are used to ascertain those properties of objects revealed by the sense of touch. This sense is capable of education and is almost always extraordinarily developed in persons who are deprived of some other special sense, as sight or hearing. The blind learn to recognize individuals by feeling of the face. A remarkable instance of this is quoted in works on physiology, of the blind sculptor, Giovanni Gonelli, who was said to model excellent likenesses, being guided entirely by the sense of touch. Other instances of this kind are on record. The blind have been known to become proficients in conchology and botany, guided entirely by the touch. It is related of a blind botanist, that he was able to distinguish ordinary plants by the fingers and by the tip of the tongue. It is well known that the blind learn to read with facility by passing the fingers over raised letters but little larger than the letters in an ordinary folio Bible.

An easy method of determining the relative delicacy of the tactile sensibility of different portions of the cutaneous surface was devised a number of years ago (1829) by E. H. Weber. This method consists in the application to the skin, of two fine points, separated from each other by a known distance. The individual experimented upon should be blindfolded, and the points applied to the skin simultaneously. By carefully adjusting the distance between the points, a limit will be reached where the two impressions upon the surface are appreciated as one; *i. e.*, by gradually approximating them, the subject will suddenly feel both points as one, when an instant before, with the points a little farther removed from each other, he distinctly felt two impressions. This gives a measure of the delicacy of the tactile sensibility of different parts. Of course the instrument used may be very simple—a pair of ordinary dividers will answer—but it is convenient to have some ready means of ascertaining the distances between the points. An instrument, consisting simply of a pair of dividers with a graduated bar giving a measure of the separation of the points, is the best, as it combines simplicity, convenience of use and portability. This instrument is called an æthesiometer. The experiments of Weber were made upon his own person. They showed some slight variations with the direction of the line of the two points, but these are not very important. The table which follows is made of selections from the observations of Weber, taking those that are most likely to be useful as a guide in pathological investigations. The experiments of Valentin and others on different persons do not vary much in their results from the figures given in the table.

TABLE OF VARIATIONS IN THE TACTILE SENSIBILITY OF DIFFERENT PORTIONS OF THE SKIN (WEBER).

The tactile sensibility is measured by the greatest distance between two points at which they convey a single impression when applied simultaneously. The measurements are given in lines ($\frac{1}{12}$ of an inch, or a little more than 2 mm.).

PART OF SURFACE.	Lines.	Mm.
Tip of tongue	0·50	1·05
Palmar surface of third phalanx of forefinger	1·00	2·10
Red surface of under lip	2·00	4·20
Palmar surface of second phalanges of fingers	2·00	4·20
Dorsal surface of third phalanges of fingers	3·00	6·30
Tip of nose	3·00	6·30
Palmar surface of metacarpus	3·00	6·30
End of great toe	5·00	10·50
Palm of hand	5·00	10·50
Skin of cheek, over buccinator	5·00	10·50
Skin of cheek, over anterior part of malar bone	7·00	14·70
Dorsal surface of first phalanges of fingers	7·00	14·70
Lower part of forehead	10·00	21·00
Back of hand	14·00	29·40
Patella and surrounding part of thigh	16·00	33·60
Dorsum of foot near toes	18·00	37·80
Upper and lower extremities of forearm	18·00	37·80
Upper and lower extremities of leg	18·00	37·80
Penis	18·00	37·80
Acromion and upper part of arm	18·00	37·80
Gluteal region and neighboring part of thigh	18·00	37·80
Middle of forearm where its circumference is greatest	30·00	63·00
Middle of thigh where its circumference is greatest	30·00	63·00

By comparing the distribution of the tactile corpuscles with the results given in the table, it will be seen that the sense of touch is most acute in those situations in which the corpuscles are most abundant. In the space of a little more than $\frac{1}{12}$ of an inch (2·2 mm.) square, on the palmar surface of the third phalanx of the index-finger, Meissner counted the greatest number of corpuscles; viz., one hundred and eight. In this situation the tactile sensibility is more acute than in any other part of the skin, the mean distance indicated by the æsthesiometer being 0·603 of a line, or 1·27 mm. (Valentin). In the same space on the second phalanx, forty corpuscles were counted, the æsthesiometer marking 1·558 line, or 3·27 mm. (Valentin), this part ranking next in tactile sensibility after the red surface of the lips. One can readily understand how the tactile corpuscles, embedded in the amorphous substance of the cutaneous papillæ, might increase the delicacy of appreciation of slight impressions, by presenting hard surfaces against which the nerve-filaments can be pressed.

As regards those portions of the general cutaneous surface in which no tactile corpuscles have been demonstrated, it is not easy to connect the variations in the tactile sensibility with the nervous distribution, as little is known of the comparative richness of the terminal nervous filaments in these situations.

Appreciation of Temperature.—It is not known that the sense of temperature, either of the surrounding medium or of bodies applied to different parts of the skin, is appreciated through any nerves other than those of general sensibility or that there is any special arrangement of the terminations of certain of the nerves connected with this sense. As regards the general temperature, the sense is relative and is much modified by habit. This statement needs no explanation. As is well known, what is cold for an inhabitant of the torrid zone would be warm for one accustomed to an excessively cold climate. Habitual exposure also modifies the sense of temperature. Many persons not in the habit of dressing warmly suffer but little in extremely cold weather. Those who habitually expose the hands or even the feet to cold, render these parts comparatively insensible to temperature; and the same is true of those who often expose the hands, face or other parts to heat. The variations in the sensibility of different parts of the surface to temperature depend, also, upon special properties of the parts themselves. The differences, however, are not so marked as to be of any great importance, and the experiments made upon this point are simply curious.

The experiments of Weber and others show that the skin is the chief organ for the appreciation of temperature, if the mouth, palate, vagina and rectum, by which the differences between warm and cold substances is readily distinguished, be excepted. In several instances in which larger portions of the skin were destroyed by burns and other injuries, experiments have been made by applying spatulas of different temperatures. In one of these, a spatula plunged in water at 48° to 55° Fahr. (9° to 12° C.) was applied to a denuded surface, and again, a spatula at 113° to 122° Fahr. (45° to 50° C.). When the patient was requested to tell which was the warmer, the answers were as frequently incorrect as they were correct; but the discrimination was easy and certain when the applications were made to the surrounding healthy skin. When applications at a higher temperature were made to the denuded part, the patient suffered only pain.

The venereal sense is unlike any other sensation, and is general as well as referable to the organs of generation. In this connection, however, it is important to note that the tactile sensibility of the palmar surface of the third phalanx of the fingers, measured by the æsthesiometer, compared with the sensibility of the penis, is as 0·802 to 0·034, or between twenty-three and twenty-four times greater.

Ferrier has described a diffused tactile centre in the "hippocampal region," the action of which is crossed; but the observations to determine the loss of the sense of touch after destruction of this part, which were made on monkeys, are by no means satisfactory. It must be very difficult to study tactile sensibility in the inferior animals.

Olfaction.

The nerves directly connected with the senses of olfaction, vision and audition, have little or no general sensibility. As regards the olfactory nerves, the parts to which they are distributed are so largely supplied with branches from the fifth, that it is difficult to determine the fact of their sensibility or insensibility to ordinary impressions. The olfactory nerves, however, are distributed to the mucous membrane of that portion only of the nasal cavity, endowed with the special sense of smell.

Nasal Fossæ.—The two irregularly shaped cavities in the middle of the face, opening in front by the anterior nares and connected with the pharynx by the posterior nares, are called the nasal fossæ. The membrane lining these cavities is generally called the Schneiderian mucous membrane, and sometimes, the pituitary membrane. This membrane is closely adherent to the fibrous coverings of the bones and cartilages by which the nasal fossæ are bounded, and it is thickest over the turbinated bones. It is continuous with the membrane lining the pharynx, the nasal duct and lachrymal canals, the Eustachian tube, the frontal, ethmoidal and sphenoidal sinuses and the antrum. There are openings leading from the nasal fossæ to all of these cavities.

The essential organ of olfaction is the mucous membrane lining the upper half of the nasal fossæ. Not only has it been shown anatomically that this part alone receives the terminal filaments of the olfactory nerves, but physiological experiments have demonstrated that it is the only part capable of appreciating odorous impressions. If a tube be introduced into the nostril, placed horizontally over an odorous substance so that the emanations can not penetrate its caliber, no odor is perceived, though the membrane below the end of the tube might receive the emanations; but if the tube be directed toward the odorous substance, so that the emanations can penetrate to the upper portion of the nares, the odor is immediately appreciated.

That portion of the lining of the nasal fossæ, properly called the olfactory

membrane, extends from the cribiform plate of the ethmoid bone downward a little less than an inch (25 mm.). It is soft and friable, very vascular, thicker than the rest of the Schneiderian membrane, and in man, it has rather a yellowish color. It is covered by long, delicate, columnar cells, nucleated, and each one provided with three to eight ciliary processes, the movements of which are from before backward. The olfactory membrane is provided with a large number of long, racemose, mucous glands, which secrete a fluid that keeps the surface moist, a condition essential to the accurate perception of odorous impressions.

Olfactory (First Nerve).

The apparent origin of the olfactory nerve is by three roots, from the inferior and internal portion of the frontal lobe of the cerebrum, in front of the anterior perforated space. The three roots are an external and an internal white root, and a middle root composed of gray matter. The external white root is long and delicate, passing outward, across the fissure of Sylvius, to the temporo-sphenoidal lobe. The internal white root is thicker and shorter than the external root, and it arises from the most posterior portion of the frontal lobe. The middle, or gray root arises from a little eminence of gray matter situated on the posterior and inner portion of the inferior surface of the frontal lobe.

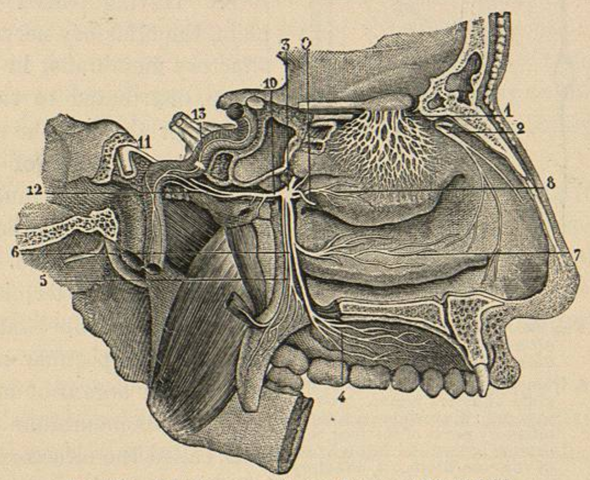

Fig. 235.—*Olfactory ganglion and nerves* (Hirschfeld).

1, *olfactory ganglion and nerves*; 2, branch of the nasal nerve; 3, spheno-palatine ganglion; 4, 7, branches of the great palatine nerve; 5, posterior palatine nerve; 6, middle palatine nerve; 8, 9, branches from the spheno-palatine ganglion; 10, 11, 12, Vidian nerve and its branches; 13, external carotid branch, from the superior cervical ganglion.

The deep origin of these three roots of the olfactory nerves is still a matter of discussion. The external root passes through the gray substance of the island of Reil, to a gray nucleus in the temporo-sphenoidal lobe, in front of the pes hippocampi. The fibres of the middle root have not been traced farther than the gray eminence from which it arises. The fibres of the internal root probably are connected with the fibres of the gyrus fornicatus. The three roots converge to form a single cord at the inner boundary of the fissure of Sylvius. This cord passes forward and slightly inward, in a deep groove between two convolutions on the under surface of the frontal lobe, covered by the arachnoid membrane, to the ethmoid bone. This portion of the nerve is soft and friable. It is composed of both white and gray matter, the proportions being about two-thirds of the former to one-third of the latter. The gray substance, derived from the gray root, is situated at the upper portion of the nerve, the white substance occupying the inferior and the lateral portions.

By the side of the crista galli of the ethmoid bone, the nerve-trunk expands into an oblong ganglion called the olfactory bulb. This is grayish in color, excessively soft, and contains the ordinary ganglionic elements. From the olfactory bulb, fifteen to eighteen nervous filaments are given off, which pass through the foramina in the cribriform plate of the ethmoid bone. These filaments are composed entirely of nerve-fibres, and are quite resisting, owing to fibrous elements prolonged from the dura mater. It is strictly proper, perhaps, to regard these as the true olfactory nerves, the cord leading from the olfactory bulb to the cerebrum being properly a commissure. Having passed through the cribriform plate, the olfactory nerves are distributed to the olfactory membrane, in three groups: an inner group, distributed to the mucous membrane of the upper third of the septum; a middle group, to the upper portion of the nasal fossæ; and an outer group, to the mucous membrane covering the superior and middle turbinated bones and a portion of the ethmoid.

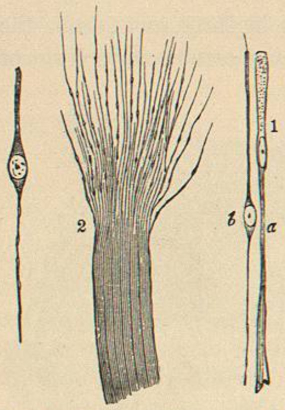

FIG. 236.—*Terminal filaments of the olfactory nerves; magnified 30 diameters* (Kölliker).

1, from the frog.—*a*, epithelial cell of the olfactory region; *b*, olfactory cell; 2, small branch of the olfactory nerve of the frog, separating at one end into a brush of varicose fibrils. 3, olfactory cell of the sheep.

The mode of termination of the olfactory nerves differs from that of the ordinary sensory nerves, and is peculiar and characteristic, as it is in the other organs of special sense. The olfactory mucous membrane contains terminal nerve-cells, called the olfactory cells, which are situated between the cells of epithelium. These are long, delicate, spindle-shaped, varicose structures, each one containing a clear, round nucleus. In the frog there is a fine, hair-like process projecting from each cell, beyond the mucous membrane, which has not been observed in man or the mammalia. The delicacy of the structures entering into the composition of the olfactory membrane renders the investigation of the termination of its nervous filaments exceedingly difficult.

Properties and Uses of the Olfactory Nerves.—It is almost certain that the olfactory nerves possess none of the general properties of the ordinary nerves belonging to the cerebro-spinal system, and are endowed with the special sense of smell alone. The filaments coming from the olfactory bulbs and distributed to the pituitary membrane have not been exposed and stimulated in living animals; but experiments upon the nerves behind the olfactory bulbs show that they are insensible to ordinary impressions. Attempts have been made to demonstrate, in the human subject, the special properties of these nerves, by passing an electric current through the nostrils; but the situation of the nerves is such that these observations are of necessity indefinite and unsatisfactory.

Among the experiments upon the higher orders of animals, in which the olfactory nerves have been divided, may be cited, as open to no objections, those of Vulpian and Philipaux, upon dogs. It is well known that the sense of smell usually is very acute in these animals. Upon dividing or extirpating the olfactory bulbs, "after the animal had completely recovered, it was deprived of food for thirty-six or forty-eight hours; then, in its absence, a piece of cooked meat was concealed in a corner of the laboratory. Animals, successfully operated upon, then taken into the laboratory, never found the bait; and nevertheless, care had been taken to select hunting-dogs." This experiment is conclusive; more so than those in which animals deprived of the olfactory bulbs were shown to eat fæces without disgust, for this sometimes occurs in dogs that have not been multilated.

Comparative anatomy shows that the olfactory bulbs generally are developed in proportion to the acuteness of the sense of smell. Pathological facts show, in the human subject, that impairment or loss of the olfactory sense is coincident with injury or destruction of these ganglia. Cases have been reported in which the sense of smell was lost or impaired from injury to the olfactory nerves. In nearly all of the cases on record, the general sensibility of the nostrils was not affected.

Mechanism of Olfaction.—Substances that have odorous properties give off material emanations, which must come in contact with the olfactory membrane before their peculiar odor is appreciated. This membrane is situated high up in the nostrils, is peculiarly soft, is abundantly provided with glands, by the secretions of which its surface is kept in proper condition, and it presents the peculiar nerve-terminations of the olfactory filaments.

In experimenting upon the sense of smell it has been found difficult to draw an exact line of distinction between impressions of general sensibility and those which attack the special sense, or in other words, between irritating and odorous emanations; and the vapors of ammonia, acetic acid, nitric acid etc., undoubtedly possess irritating properties which overpower their odorous qualities. It is unnecessary in this connection to discuss the different varieties of odors recognized by some of the earlier writers, as the fragrant, aromatic, fetid, nauseous etc., distinctions sufficiently evident from their mere enumeration; and it is plain enough that there are emanations, like those from delicately scented flowers, which are easily recognizable by the sense of smell, while they make no impression upon the ordinary sensory nerves. The very marked individual differences in the delicacy of the olfactory organs in the human subject and in different animals are evidence of this fact. Hunting-dogs recognize odors to which most persons are absolutely insensible; and certain races of men are said to possess a remarkable delicacy of the sense of smell. Like the other special senses, olfaction may be cultivated by attention and practice, as is exemplified in the delicate discrimination of wines, qualities of drugs etc., by experts.

After what has been said concerning the situation of the true olfactory membrane in the upper part of the nasal fossæ and the necessity of particles impinging upon this membrane in order that their odorous properties may