be appreciated, it is almost unnecessary to state that the passage of odorous emanations to this membrane by inspiring through the nostrils is essential to olfaction, so that animals or men, after division of the trachea, being unable to pass the air through the nostrils, are deprived of the sense of smell. The act of inhalation through the nose is an illustration of the mechanism by which the odorous particles may be brought at will in contact with the olfactory membrane.

It is a curious point to determine whether the sense of smell be affected by odors passing from within outward through the nasal fossæ. Persons who have offensive emanations from the respiratory organs usually are not aware, from their own sensations, of any disagreeable odor. This fact is explained by Longet on the supposition that the olfactory membrane becomes gradually accustomed to the odorous impression, and therefore it is not appreciated. This is an apparently satisfactory explanation, for it could hardly be supposed that the direction of the emanations, provided they came in contact with the membrane, could modify their effects. Longet has cited a case of cancer of the stomach, in which the vomited matters were exceedingly fetid. At first, the patient, when he expired the gases from the stomach through the nostrils, perceived a disagreeable odor at each expiration; but little by little this impression disappeared.

Relations of Olfaction to the Sense of Taste.—The relations of the sense of smell to gustation are very intimate. In the appreciation of delicate shades of flavor, it is well known that the sense of olfaction plays so important a part, that it can hardly be separated from gustation. The common practice of holding the nose when disagreeable remedies are swallowed is an illustration of the connection between the two senses. In most cases of anosmia there is inability to distinguish delicate flavors; and patients can distinguish by the taste, only sweet, saline, acid and bitter impressions.

It is undoubtedly true that the delicacy of the sense of taste is lost when the sense of smell is abolished. The experiment of tasting wines blindfolded and with the nostrils plugged, and the partial loss of taste during a severe coryza, are sufficiently familiar illustrations of this fact. In the great majority of cases, when there is complete anosmia, the taste is sensibly impaired; and in cases in which this does not occur, it is probable that the savory emanations pass from the mouth to the posterior portion of the nasal fossæ, and that here the mucous membrane is not entirely insensible to special impressions.

It is unnecessary, in this connection, to describe fully the reflex phenomena which follow impressions made upon the olfactory membrane. The odor of certain sapid substances, under favorable conditions, will produce an abundant secretion of saliva and even of gastric juice, as has been shown by experiments upon animals. Other examples of the effects of odorous impressions of various kinds are sufficiently familiar.

According to Ferrier, the olfactory centre is on the inner surface of the anterior extremity of the unicate gyrus; but this location of the centre is not regarded as definitely determined. Stimulation of this part in monkeys simply produces peculiar movements of the nostril and lip of the same side.

Gustation.

The special sense of taste gives the appreciation of what is known as the savor of certain substances introduced into the mouth; and this sense exists, in general terms, in parts supplied by filaments from the lingual branch of the fifth and the glosso-pharyngeal nerves.

It is assumed by some physiologists, that the true tastes are quite simple, presenting the qualities which are recognized as sweet, acid, saline and bitter; while the more delicate shades of what are called flavors nearly always involve olfactory impressions, which it is difficult to separate entirely from gustation. Applying the term savor exclusively to the quality which makes an impression upon the sense of taste, it is evident that the sensation is special in its character and different from the tactile sensibility of the parts involved and from the sensation of temperature. The terminal filaments of the gustatory nerves are impressed by the actual contact of savory substances, which must of necessity be soluble. To a certain extent there is a natural classification of savors, some of which are agreeable, and others, disagreeable; but even this distinction is modified by habit, education and various other circumstances. Articles that are unpleasant in early life often become agreeable in later years. Inasmuch as the taste is to some extent an expression of the nutritive demands of the system, it is found to vary under different conditions. Chlorotic females, for example, frequently crave the most unnatural articles, and their morbid tastes may disappear under appropriate treatment. Inhabitants of the frigid zones crave fatty articles of food and will even drink rancid oils with avidity. Patients often become accustomed to the most disagreeable remedies and take them without repugnance. Again, the most savory dishes may even excite disgust, when the sense of taste has become cloyed, while abstinence sometimes lends a delicious flavor to the simplest articles of food. The taste for certain articles certainly is acquired, and this is almost always true of tobacco, now so largely used in civilized countries.

Any thing more than the simplest classification of savors is difficult if not impossible. It is easy to recognize that certain articles are bitter or sweet, empyreumatic or insipid, acid or alkaline, etc., but beyond these simple distinctions, the shades of difference are closely connected with olfaction and are too delicate and too many for detailed description. Some persons are comparatively insensible to nice distinctions of taste, while others recognize with facility the most delicate differences. Strong impressions may remove for a time the appreciation of less powerful and decided flavors. The tempting of the appetite by a proper gradation of gustatory and odorous impressions is illustrated in the modern *cuisine*, which aims at an artistic combination and succession of dishes and wines, so that the agreeable sensations are prolonged to the utmost limit. This may often be

regarded as a violation of strictly hygienic principles, but it none the less exemplifies the cultivation of the sense of taste.

Nerves of Taste.—Two nerves, the chorda tympani and the gloss-pharyngeal, are endowed with the sense of taste. These nerves are distributed to distinct portions of the gustatory organ. The chorda tympani has already been referred to as one of the branches of the facial; the glosso-pharyngeal has not yet been described.

Chorda Tympani.—In the description already given of the facial, the chorda tympani is spoken of as the fourth branch. It passes through the tympanum, between the ossicles of the ear, and joins the inferior maxillary division of the fifth, at an acute angle, between the two pterygoid muscles, becoming so closely united with it that it can not be followed farther by dissection. The filaments of this branch probably originate from the intermediary nerve of Wrisberg.

The course of the filaments of the chorda tympani, after this nerve has joined the fifth, is shown by the effect upon the sense of taste and the alteration of the nerve-fibres following its division. Vulpian and Prevost, by the so-called Wallerian method, after dividing the chorda tympani, found degenerated fibres at the terminations of the lingual branch of the fifth, in the mucous membrane of the tongue, the fibres being examined ten days or more after the section. Observations upon the sense of taste show that the chorda tympani is distributed to the anterior two-thirds of the tongue.

The general properties of the chorda tympani have been ascertained only by observations made after its paralysis or division. All experiments in which a stimulus has been applied directly to the nerve in living animals have been negative in their results. According to Longet, when the nerve has been isolated as completely as possible and all reflex action is excluded, its stimulation produces no movement in the tongue.

In cases of facial palsy in which the lesion affects the root so deeply as to involve the chorda tympani, there is loss of taste in the anterior two-thirds of the tongue, tactile sensibility being unaffected; and many cases illustrating this fact have been recorded. Aside from cases of paralysis of the facial with impairment of taste, in which the general sensibility of the tongue is intact, instances are on record of affections of the fifth pair, in which the tongue was absolutely insensible to ordinary impressions, the sense of taste being preserved. A number of such cases have been reported, which show conclusively that the fifth pair presides over general sensibility only, and that it is not a gustatory nerve, except by virtue of filaments derived from the chorda tympani.

Passing from the consideration of pathological facts to experiments upon living animals, the results are equally satisfactory. Although it is somewhat difficult to observe impairment of taste in animals, Bernard and others have succeeded in training dogs and cats so as to observe the effects of colocynth and various sapid substances applied to the tongue. In a great number of experiments of this kind, it has been observed that after section of the chorda tympani, or of the facial so as to involve the chorda tympani,

the sense of taste is abolished in the anterior two-thirds of the tongue on the side of the section. In a case reported by Moos, the introduction of an artificial membrana tympani in the human subject was followed by loss of taste upon the corresponding side of the tongue, and upon both sides, when a membrane was introduced into each ear. This disappeared when the membranes were removed, and the phenomena were referred to pressure upon the chorda tympani. Other instances of this kind are on record.

As regards the gustatory properties of the anterior two-thirds of the tongue, certainly in the human subject, it may be stated without reserve, that these properties depend upon the chorda tympani, its gustatory filaments being derived from the facial and taking their course to the tongue with the lingual branch of the inferior maxillary division of the fifth. In addition, the lingual branch of the fifth contains filaments, derived from the large root of this nerve, which give general sensibility to the mucous membrane.

Glosso-Pharyngeal (Ninth Nerve).

The glosso-pharyngeal is distributed to those portions of the gustatory mucous membrane not supplied by filaments from the chorda tympani. It is undoubtedly a nerve of taste; and the question of its other uses will be considered in connection with its general properties, as well as the differences between this nerve and the chorda tympani.

Physiological Anatomy.—The apparent origin of the glosso-pharyngeal is from the groove between the olivary and restiform bodies of the medulla oblongata, between the roots of the auditory nerve above and the pneumogastric below. The deep origin is in a gray nucleus in the lower part of the floor of the fourth ventricle, between the nucleus of the auditory nerve and the nucleus of the pneumogastric. From this origin the filaments pass forward and outward, to the posterior foramen lacerum, by which the nerve emerges with the pneumogastric, the spinal accessory and the internal jugular vein. At the upper portion of the foramen, is a small ganglion, the jugular ganglion, including only a portion of the root. Within the foramen, is the main ganglion, including all of the filaments of the trunk, called the petrous ganglion, or the ganglion of Andersch.

At or near the ganglion of Andersch the glosso-pharyngeal usually receives a delicate filament from the pneumogastric. This communication is sometimes wanting. The same may be said of a small filament passing to the glosso-pharyngeal from the facial, which is not constant. Branches from the glosso-pharyngeal go to the otic ganglion and to the carotid plexus of the sympathetic.

The distribution of the glosso-pharyngeal is quite extensive. The tympanic branch, the nerve of Jacobson, arises from the anterior and external part of the ganglion of Andersch, and enters the cavity of the tympanum, where it divides into six branches. Of these six branches, two posterior are distributed to the mucous membrane of the fenestra rotunda and the membrane surrounding the fenestra ovalis; two anterior are distributed, one to

the carotid canal, where it anastomoses with a branch from the superior cervical ganglion, and the other to the mucous membrane of the Eustachian

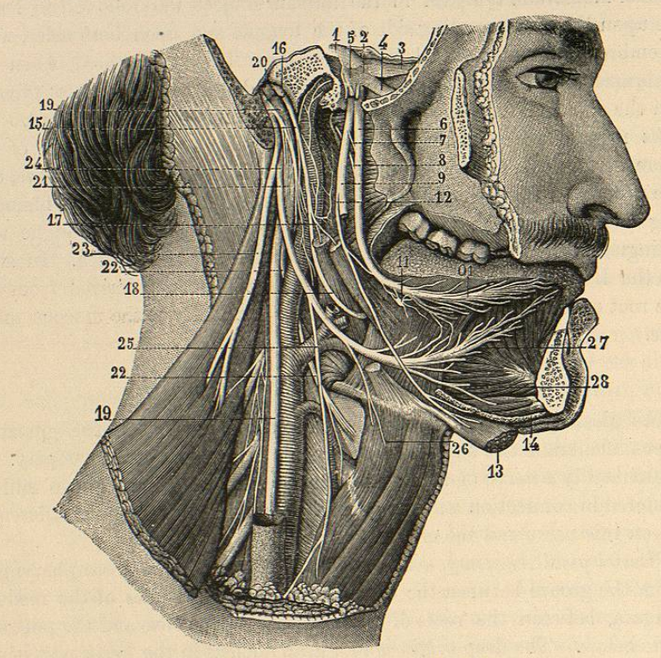

FIG. 237.—*Glosso-pharyngeal nerve* (Sappey).

1, large root of the fifth nerve; 2, ganglion of Gasser; 3, ophthalmic division of the fifth; 4, superior maxillary division; 5, inferior maxillary division; 6, 10, *lingual branch of the fifth, containing the filaments of the chorda tympani;* 7, branch from the sublingual to the lingual branch of the fifth; 8, *chorda tympani;* 9, inferior dental nerve; 11, submaxillary ganglion; 12, mylo-hyoid branch of the inferior dental nerve; 13, anterior belly of the digastric muscle; 14, section of the mylo-hyoid muscle; 15, 18, *glosso-pharyngeal nerve;* 16, *ganglion of Andersch;* 17, *branches from the glosso-pharyngeal to the stylo-glossus and the stylo-pharyngeus muscles;* 19, 19, pneumogastric; 20, 21, ganglia of the pneumogastric; 22, 22, superior laryngeal nerve; 23, spinal accessory; 24, 25, 26, 27, 28, sublingual nerve and branches.

tube; two superior branches are distributed to the otic ganglion and, as is stated by some anatomists, to the spheno-palatine ganglion.

A little below the posterior foramen lacerum the glosso-pharyngeal sends branches to the posterior belly of the digastric and to the stylo-hyoid muscle. There is also a branch which joins a filament from the facial to the stylo-glossus.

Opposite the middle constrictor of the pharynx three or four branches join branches from the pneumogastric and the sympathetic, to form together the pharyngeal plexus. This plexus contains a number of ganglionic points, and filaments of distribution from the three nerves go to the mucous membrane and to the constrictors of the pharynx. The mucous membrane probably is supplied by the glosso-pharyngeal. It is probable, also, that the muscles of the pharynx are supplied by filaments from the pneumogastric, which are derived originally from the spinal accessory.

Near the base of the tongue branches are sent to the mucous membrane covering the tonsils and the soft palate.

The lingual branches penetrate the tongue about midway between its border and centre, are distributed to the mucous membrane at its base and are connected with certain of the papillæ.

General Properties of the Glosso-Pharyngeal.—To ascertain the general properties of this nerve, it must be stimulated at its root, before it has contracted anastomoses with other nerves, and the nerve must be divided in order to avoid reflex phenomena. Taking these precautions it has been found that stimulation of the peripheral end of the nerve does not give rise to muscular movements (Longet). There can be no doubt of the fact that the nerve is sensory, although its sensibility is somewhat dull. In experiments in which the nerve has seemed to be insensible to ordinary impressions, it is probable that the animals operated upon had been exhausted more or less by pain and loss of blood in the operation of exposing the nerve, which, it is well known, abolish the sensibility of some of the nerves.

Experiments upon the glosso-pharyngeal are not very definite and satisfactory in their results as regards the general sensibility of the base of the tongue, the palate and the pharynx. The sensibility of these parts seems to depend chiefly upon branches of the fifth, passing to the mucous membrane, through Meckel's ganglion. Experiments show, also, that the reflex phenomena of deglutition take place mainly through these branches of the fifth, and that the glosso-pharyngeal has little or nothing to do with the process. In fact after division of both glosso-pharyngeal nerves, deglutition does not seem to be affected.

Relations of the Glosso-Pharyngeal Nerves to Gustation.—Relying upon experiments on the inferior animals, particularly dogs, it seems certain that there are two nerves presiding over the sense of taste: The chorda tympani gives this sense to the anterior two-thirds portion of the tongue exclusively; the glosso-pharyngeal supplies this sense to the posterior portion of the tongue; the chorda tympani seems to have nothing to do with general sensibility; while the glosso-pharyngeal is an ordinary sensory nerve, as well as a nerve of special sense.

Where there are such differences in the delicacy of the sense of taste as exist usually in different individuals, it must be difficult to describe with accuracy delicate shades of savor, particularly in alimentary substances; but the distinct impressions of acidity or of bitter quality are easily recognizable. It is certain, however, that saline, acid and styptic tastes are best appreciated through the chorda tympani, and that sweet, alkaline, bitter and metallic impressions are received mainly by the glosso-pharyngeal.

Mechanism of Gustation.—Articles which make the special impression upon the gustatory organ are in solution; introduced into the mouth, they increase the flow of saliva, the reflex action involving chiefly the submaxillary and sublingual glands; there is usually more or less mastication, which increases the flow of the parotid saliva; and during the acts of mastication and the first stages of deglutition, the sapid substances are distributed over the

gustatory membrane, so extensively, indeed, that it is difficult to exactly locate the seat of the special impression. In this way, by the movements of the tongue, aided by an increased flow of saliva, the actual contact of the savory articles is rapidly effected. The thorough distribution of these substances over the tongue and the mucous membrane of the general buccal cavity leads to some confusion in the appreciation of the special impressions; and in order to ascertain if different portions of the membrane possess different properties, it is necessary to make careful experiments, limiting the points of contact as exactly as possible. This has been done, with the result of showing that the true gustatory organ is quite restricted in its extent.

Physiological Anatomy of the Organ of Taste.—Anatomical and physiological researches have shown that, at least in the human subject, the organ of taste probably is confined to the dorsal surface of the tongue and the lateral portion of the soft palate. The upper surface of the tongue presents a large number of special papillæ, called, in contradistinction to the filiform papillæ, fungiform and circumvallate. These are not found on its under surface or anywhere except on the superior portion; and it is now well established that the circumvallate and fungiform papillæ alone contain the organs of taste. Experiments upon the gustatory organs, by the application of solutions to different parts through fine, glass

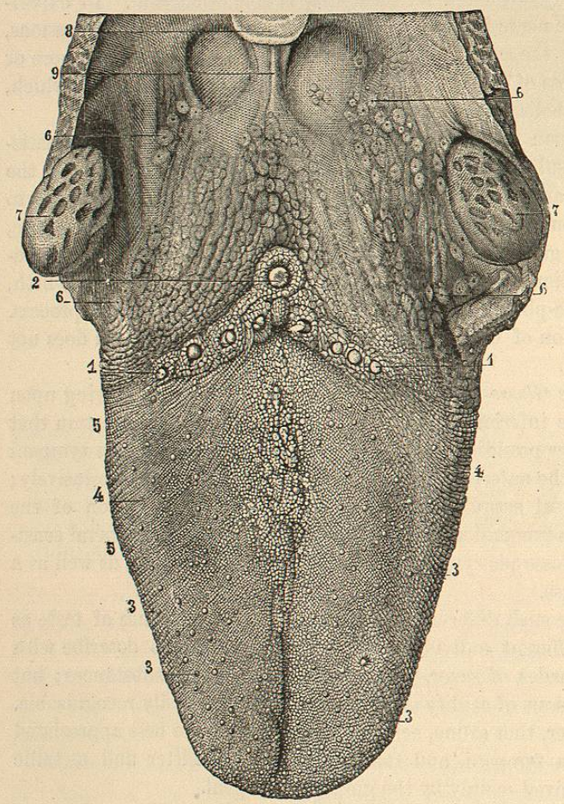

FIG. 238.—*Papillæ of the tongue* (Sappey).

1, 1, circumvallate papillæ; 2, median circumvallate papilla, which entirely fills the foramen cæcum; 3, 3, 3, 3, fungiform papillæ; 4, 4, filiform papillæ; 5, 5, vertical folds and furrows of the border of the tongue; 6, 6, 6, 6, glands at the base of the tongue; 7, 7, tonsils; 8, epiglottis; 9, median glosso-epiglottidean fold.

tubes, have shown that the mucous membrane around a papilla has no gustatory sensibility, but that different savors can be distinguished when a single papilla is touched (Camerer).

In Fig. 238, which represents the dorsal surface of the tongue, the large, circumvallate papillæ, usually seven to twelve in number, are seen in the form of an inverted V, occupying the base of the tongue. The fungiform papillæ are scattered over the surface but are most abundant at the point and near the borders. Both of these varieties of papillæ are distinguishable by the naked eye.

The circumvallate papillæ simply are enlarged, fungiform papillæ, each one surrounded by a circular ridge, or wall, and covered by small, secondary

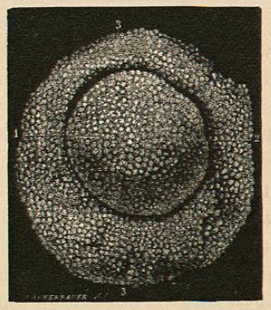

FIG. 239.—*Medium-sized circumvallate papilla* (Sappey).

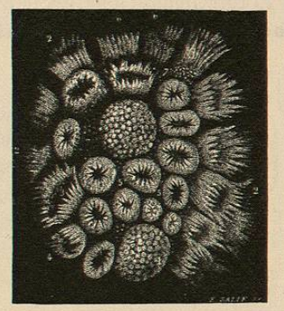

FIG. 240.—*Fungiform, filiform, and hemispherical papillæ* (Sappey).

FIG. 239.—1, papilla, the base only being apparent (it is seen that the base is covered with secondary papillæ); 2, groove between the papilla and the surrounding wall; 3, 3, wall of the papilla.

FIG. 240.—1, 1, two fungiform papillæ covered with secondary papillæ; 2, 2, 2, filiform papillæ; 3, a filiform papilla, the prolongations of which are turned outward; 4, a filiform papilla with vertical prolongations; 5, 5, small filiform papillæ with the prolongations turned inward; 6, 6, filiform papillæ with striations at their bases; 7, 7, hemispherical papillæ, slightly apparent, situated between the fungiform and the filiform papillæ.

papillæ. The fungiform papillæ have each a short, thick pedicle and an enlarged, rounded extremity. According to Sappey, one hundred and fifty to two hundred of these can easily be counted. These, also, present small, secondary papillæ on their surface. When the mucous membrane of the tongue is examined with a low magnifying power, particularly after maceration in acetic or in dilute hydrochloric acid, their structure is readily observed. They are abundantly supplied with blood-vessels and nerves.

Several glandular structures are found beneath the mucous membrane of the tongue. On either side of the frenum, near the point, is a gland about three-quarters of an inch (20 mm.) long and one-third of an inch (8·5 mm.) broad, which has five or six little openings on the under surface of the tongue (Blandin and Nuhn). Near the taste-beakers, are small, racemose glands, which discharge a watery secretion, by minute ducts which open into the grooves within the walls of the circumvallate papillæ (Ebner).

Taste-Beakers.—Lovén and Schwalbe (1867) described, under this name, peculiar structures which are supposed to be the true organs of taste. They are found on the lateral slopes of the circumvallate papillæ and occasionally

on the fungiform papillæ. Their structure is very simple. They consist of flask-like collections of spindle-shaped cells, which are received into little excavations in the epithelial covering of the mucous membrane, the bottom resting upon the connective-tissue layer. Their form is ovoid, and at the neck of each flask, is a rounded opening, called the taste-pore. Their length is $\frac{1}{350}$ to $\frac{1}{300}$ of an inch (71 to 83 μ), and their transverse diameter, about $\frac{1}{600}$ of an inch (41 μ). The cavity of the taste-beakers is filled with cells, of which two kinds are described. The first variety, the outer cells, or the cover-cells, are spindle-shaped, and curved to correspond to the wall of the beaker. These come to a point at the taste-pore. In the interior of the beaker are elongated cells, with large, clear nuclei, which are called taste-cells. According to Engelmann, delicate, hair-like processes are connected with the taste-cells and extend through the taste-pores, in the form of very fine filaments.

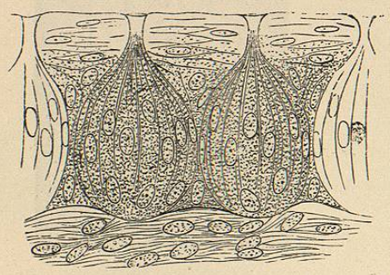

FIG. 241.—*Taste-beakers, from the lateral taste-organ of the rabbit* (Engelmann).

Bodies similar to the taste-beakers have been found on the papillæ of the soft palate and uvula, the mucous membrane of the epiglottis and some parts of the top of the larynx. As regards these structures in the tongue, it has been found that four or five months after section of the glosso-pharyngeal on one side in rabbits, the taste-buds on the corresponding side of the posterior portion of the tongue disappear, while they remain perfect on the sound side (Vintschgau and Hönigschmied).

According to the views of those who have described the so-called taste-beakers, sapid solutions find their way into the interior of these structures through the taste-pores and come in contact with the taste-cells, these cells being directly connected with the terminal filaments of the gustatory nerves.

Ferrier has described a taste-centre near the so-called olfactory centre in the unicate gyrus; but his observations are not very definite, and the location of a centre for gustation must be regarded as undetermined.

CHAPTER XXII.

VISION.

General considerations—Optic (second nerve)—General properties of the optic nerves—Physiological anatomy of the eyeball—Sclerotic coat—Cornea—Choroid coat—Ciliary muscle—Iris—Pupillary membrane—Retina—Crystalline lens—Aqueous humor—Chambers of the eye—Vitreous humor—Summary of the anatomy of the globe—The eye as an optical instrument—Certain laws of refraction, dispersion etc., bearing upon the physiology of vision—Refraction by lenses—Visual purple and visual yellow and accommodation of the eye for different degrees of illumination—Formation of images in the eye—Mechanism of refraction in the eye—Astigmatism—Movements of the iris—Direct action of light upon the iris—Action of the nervous system upon the iris—Mechanism of the movements of the iris—Accommodation of the eye for vision at different distances—Changes in the crystalline lens in accommodation—Changes in the iris in accommodation—Erect impressions produced by images inverted upon the retina—Field of indirect vision—The perimeter—Binocular vision—Corresponding points—The horopter—Duration of luminous impressions (after-images)—Irradiation—Movements of the eyeball—Muscles of the eyeball—Centres for vision—Parts for the protection of the eyeball—Conjunctival mucous membrane—Lachrymal apparatus—Composition of the tears.

THE chief important points to be considered in the physiology of vision are the following:

1. The physiological anatomy and the general properties and uses of the optic nerves.
2. The physiological anatomy of the parts essential to correct vision.
3. The laws of refraction, diffusion etc., bearing upon the physiology of vision.
4. The action of the different parts of the eye in the production and appreciation of correct images.
5. Binocular vision.
6. The physiological anatomy and uses of accessory parts, as the muscles which move the eyeball.
7. The physiological anatomy and uses of the parts which protect the eye, as the lachrymal glands, eyelids etc.

OPTIC (SECOND NERVE).

The bands which pass from the tubercula quadrigemina to the eyes are divided into the optic tracts, which extend from the tubercula on either side to the chiasm, or commissure; the chiasm, or the decussating portion; and the optic nerves, which pass from the chiasm to the eyes.

The optic tracts arise each one by two roots, internal and external. The internal roots, which are the smaller, arise from the anterior tubercula quadrigemina, and pass through the internal corpora geniculata, to the optic chiasm. The external roots, which are the larger, arise from the posterior part of the optic thalami, pass to the external corpora geniculata, from which they receive fibres, and thence to the chiasm.

Partly by anatomical researches (Wernicke) and partly by experiments on the cerebral cortex in the lower animals and pathological observations on the human subject, it has been shown that fibres from the apparent origin of the optic tracts pass backward to the gray matter of the occipital lobes of the cerebrum. It has also been stated by Stilling that fibres pass to the medulla