CHAPTER 116

Sense of Smell (Olfaction)

Competency achievement: The student should be able to:
PY10.13: Describe and discuss perception of smell sensation.
PY10.14: Describe and discuss the pathophysiology of altered smell sensation.

INTRODUCTION

Like taste, smell is also a chemical sensation. For taste, the substance must be in liquid form; for smell it must be in gaseous form. Volatile substances have generally strong odours. After reaching the nose, the vapour gets dissolved in the local secretion and stimulates the olfactory epithelium.

Olfactory sensation is the most primitive of all special senses and is much more acute than taste. A man can detect mercaptan and artificial musk in a dilution of one part in several billion parts of air. In many animals, the sensation of smell is much more acute than in man. Such animals are called macrosmatic. In macrosmatic animals, the olfactory sense plays an important role in protecting the animals from enemies; search for food and in the reactions of sex. In comparison to them, man is microsmatic.

Smell sensations are often blended with simultaneous taste and general sensations and thus often become a complex admixture, viz. sweet smell (chloroform), pungent smell (ammonia), etc. An instrument called olfactometer is used to determine the minimum identifiable odour (MIO) of a substance.

Olfactory Mucous Membrane (Fig. 116.1)

The olfactory receptors are located in a small specialised portion of the nasal mucosa which is called the olfactory area. This area differs from the rest of the nasal mucosa both in its gross appearance as well as in its histological structure. The dog is a macrosmatic animal and its olfactory area is large. The human being is microsmatic and his olfactory area is comparatively very small.

Olfactory Epithelium

The olfactory epithelium is that part of nasal epithelium which is sensitive to smell and confined to the nasal mucosa of the olfactory area. Smelling sensation is developed mainly from the stimulation of receptors in the yellow brown olfactory mucosa that lines the surface of the superior turbinate and the upper third of the nasal septum. In man, the total area of olfaction on each side is about 250 mm^2. The olfactory area is formed by the superior nasal concha, the upper part of the septum and the roof of the nose (Figs 116.1 and 116.2).

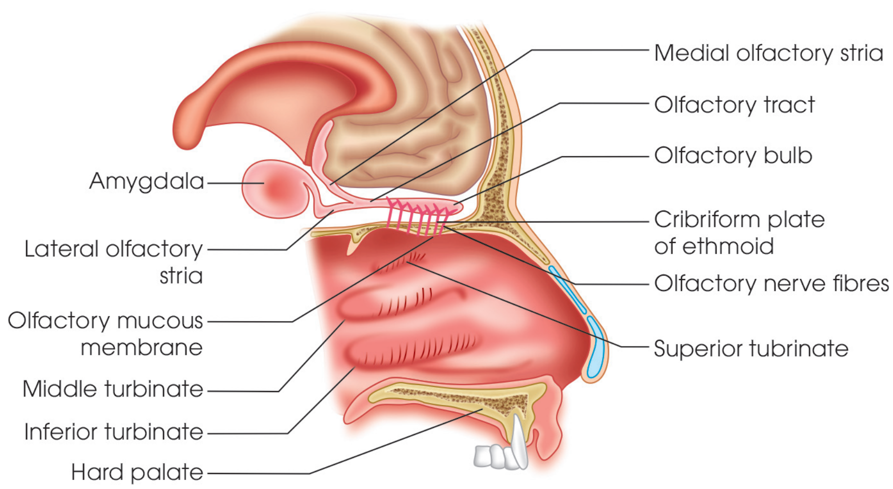

Fig. 116.1: Anatomy of the olfactory mucous membrane

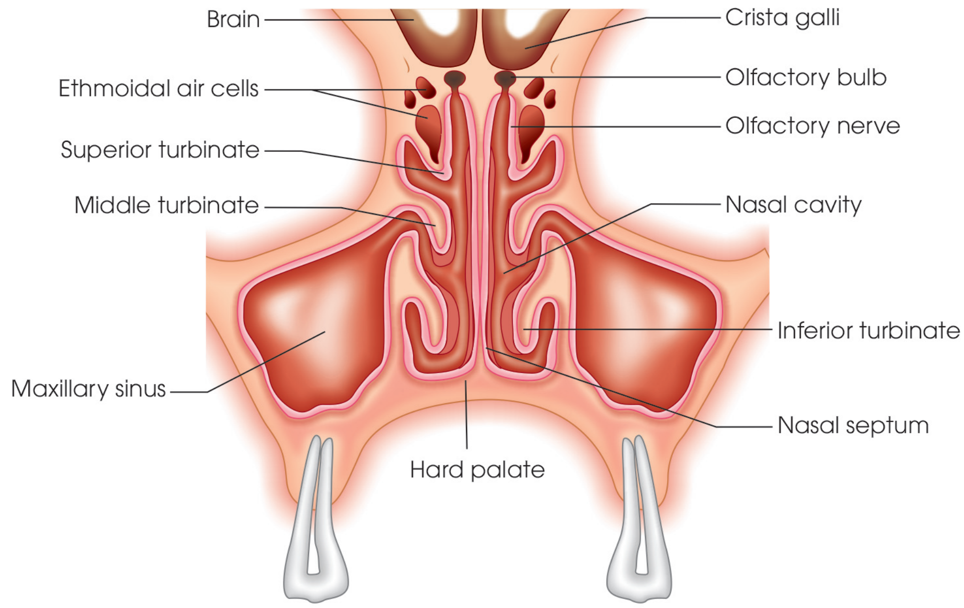

Fig. 116.2: Anatomical position of the receptors for the sense of smell in the interior of the nose in between the median nasal septum and the superior turbinate (Crellmen)

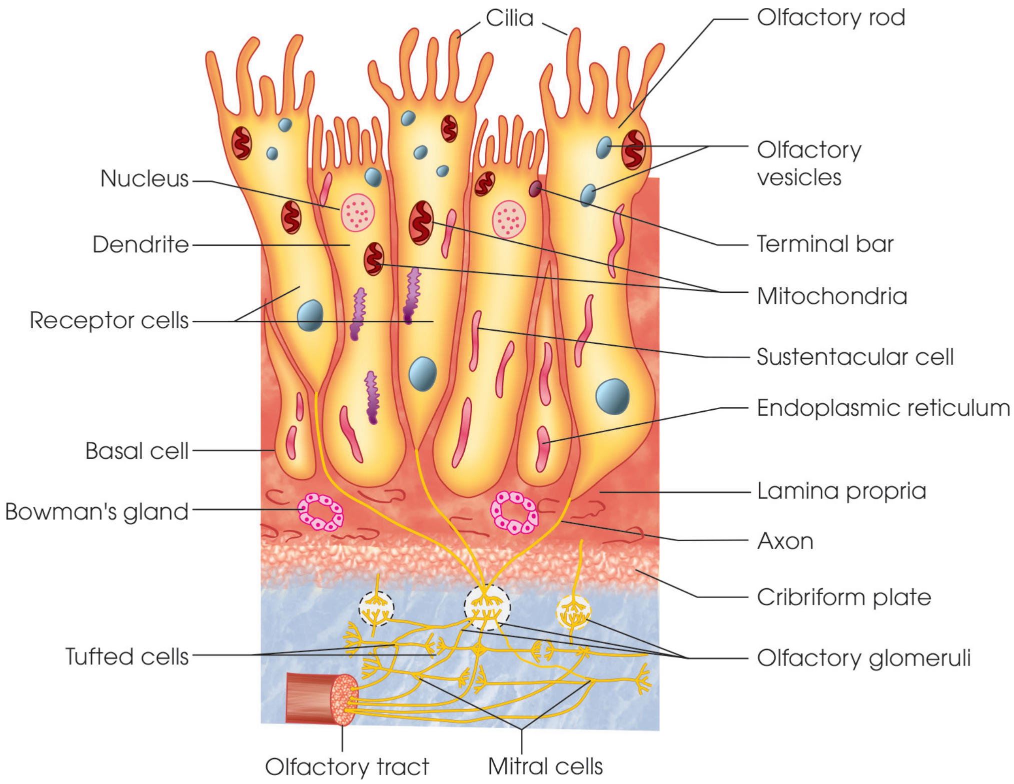

Fig. 116.3: Histological representation of the olfactory epithelium and connections of olfactory nerve fibres (diagrammatic)

The olfactory epithelium (Fig. 116.3) is composed of mainly two types of cells. These are supporting (sustentacular) cell and receptor cell. There is a third type of cell which is called the basal cell. This basal cell is not numerous but mainly parent cell and gives rise to supporting cell. The supporting cell is highly columnar with large oval nuclei and ends in microvilli that secrete mucus. Cytoplasm contains granules of a golden-brown pigment that gives the golden-yellow colour of the nasal mucosa. Bowman's glands also secrete golden-yellow pigment.

Olfactory Receptors

The olfactory receptors cells are supported by tall sustentacular cells. The receptor cells are bipolar neurons and are about 10–20 millions in number in man. They function both as receptor and ganglion cells. Dendrite arises from superficial pole and the axon arises from the deeper pole of the fusiform receptor cell. These axons are very fine having about only 0.2 µm in diameter and several run together within a single Schwann cell sheath. Because of this, it is very difficult to record from single axons and it is debatable whether this has ever been done successfully. The axons pass through the cribriform plate to reach the olfactory bulb. Beside these, the lamina propria contain certain glands—Bowman's glands, which secrete fluid containing the watery and oily substances (Fig. 116.3).

Olfactory Bulb

The dendrite projects out through the space in between the supporting cells and expand slightly to form the olfactory rods. In the olfactory bulb, there are a large number of nerve cells called granules intermingled in an interlacement of nerve fibrils, mitral cells and tufted cells with their dendrites and axons forming the layer of olfactory glomeruli. The olfactory rods contain numerous vacuoles, mitochondria as well as vesicles. Unmyelinated cilia project out from the rod. There are about 10–20 cilia per receptor cell.

The two main cell types tufted and mitral cells (Fig. 116.3) give off innumerable bushy dendrites on the side nearest the bulb surface and it is with these dendrites that the olfactory nerve axons make connections. The tufted cells send their axons via the medial olfactory tract to the opposite side of the brain. The mitral cell axons enter the lateral olfactory tract which is primarily ipsilateral.

OLFACTOMETER

The most well-known method of investigation of the olfactory sensation is the olfactometer of Zwaardemaker (Fig. 116.4). This instrument consists of a glass-tube sliding over another tube. The inner tube A is graduated into 10 equal divisions of 0.7 cm each. Both ends of the inner tube are open but one outer end C is curved and tapering. This tapering end is introduced into the nostrils. The inner wall of the outer tube B contains the odorous substance. The subject inhales the substance as he breathes within the tube because other nostril is kept closed. The intensity of smell is increased with the gradual withdrawal of the outer tube because this process facilitates the dilution with increasing concentration in the inspired air. This method gives only an approximate result.

Another method is the blast method of Elsberg and Levy. Here a controlled volume of odour-laden air is forced into the nose. Blast of such air is given successively so as to just perceive the odour. The minimum volume of odour-laden air necessary for identification is called the minimum identifiable odour (MIO) or the olfactory coefficient. This method has been a great aid in localisation of tumours in the anterior part of the skull.

Physiology of Olfaction (Table 116.1)

The substances which remain in the gaseous state, e.g. turpentine, essential oil, etc. produce strong odours, whereas non-volatile substances, viz. the heavy metals, etc. are in-odorous. The odoriferous substances after inhalation do not reach the olfactory areas immediately but remain in the middle of the nose, e.g. below the level of the superior concha. The odorous particles of molecular size emitted by the odoriferous substances ascend upwards through the air and reach the olfactory

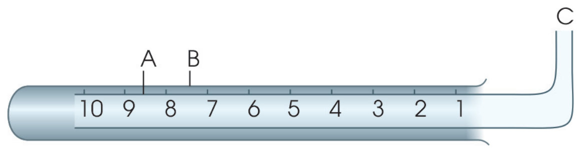

Fig. 116.4: Zwaardemaker's olfactometer

Table 116.1: Classification of odours by Zwaardemaker

S.no.	*Class*	*Subdivisions*
I	Alliaceous	Arsine
		Chlorine
		Hydrogen sulphide
II	Ambrosial	Amber
		Musk
III	Aromatic	Bitter almond
		Camphor
		Clobes
		Lavender
		Lemon
IV	Caprillic	Cheese
		Rancid fat
V	Empyreumatic	Benzene
		Coffee
VI	Ethereal	Beeswax
		Ether
		Fruit
VII	Fragrant	Flowers
		Vanilla
VIII	Nauseating	Carrion
		Faeces
IX	Repulsive	Bedbug
		Belladonna

areas either by eddy current or by diffusion. Diffusion is a slow process and so eddy current is the main factor. After reaching the olfactory area, the odorous particles get dissolved in the fluid secreted by Bowman's glands. The secretion of Bowman's glands contains both water and oil. The odoriferous substances, which are soluble in water and oil, produce strong odour. The high solubility in oil is of greater importance than that of water-solubility for olfactory stimulation. The odorous particles after getting into solution become adsorbed on the surface of the cilia. There is some specificity or selectivity in the adsorption of odorous substances onto the olfactory receptors. After the odorous substances being adsorbed onto the olfactory mucosa, generator potentials of 4–6 second durations are developed. These generator potentials when reached to its threshold value, initiates action potential which is then propagated along the axons to the olfactory bulb.

The odour producing molecules react with chemical groupings on the surface protein film of the receptor thereby increasing the surface area of the proteins which would distort the receptor surface and thus a generator potential is initiated.

Olfactory Discrimination

Man can distinguish between 2000 and 4000 different odours, and different parts of the olfactory mucous membrane respond differently to the same odours and receptors. Classification according to the different odours is still unsuccessful.

Olfactory Adaptation

The olfactory receptors become insensitive to a particular odorous substance after exposure to a specific period of time. As for instance, the odour of the oil of lemon is not perceptible after an exposure varying from 2.5 to 10 minutes.

This is due to sensory adaptation. It is partly a central phenomenon, but it is also due to a change of the receptors themselves. It is mediated by the calcium ions.

Threshold of olfactory sensation: It is the minimum concentration of different odorous substances to arouse olfactory sensation. Artificial musk, iodoform, butyric acid, etc. are perceptible in minimum concentration.

Chemical Compounds and their Relation to Olfactory Sensation

The intensity of olfactory sensation varies with different chemical compounds. If the chemical compounds belong to homologue series, then the intensity of stimulation will increase from the lower members to higher one. In alcoholic series, the odours increase in strength (from lower to higher one), i.e. from methyl, ethyl, propyl, butyl to amyl.

Relation of Odorous Substances

Weaker odours are masked by the stronger ones. If the odorous substances are of equal strength, then the odours of both are perceived. Some of the odorous substances are antagonistic to each other, e.g. iodoform antagonises balsam of Peru.

Pathways of Olfactory Impulses

Key Points

1. Bipolar nerve cells of the olfactory epithelium are the first-order neurons. Each receptor cell gives rise to only one axon which joins with those derived from other receptors forming collectively the fila olfactoria or the olfactory nerves. The olfactory nerves are unmyelinated and have got neurolemmal sheath. The sheath is continuous with the subarachnoid space.
2. The nerves pierce the cribriform plate of the ethmoid bone and enter the olfactory bulb. Here, the axons make synapses with the dendrites of the mitral cells and the tufted cells to form the complex globular structures which are known as olfactory glomeruli.
3. Approximately 26,000 receptor cells converge on each glomerulus and each glomerulus again passes impulses to about 24 mitral cells and 68 tufted cells. The mitral and tufted cells are the second-order neurons and their axons constitute the olfactory tract.
4. The olfactory tract proceeds towards the anterior perforated substance and divides in the olfactory trigone into well-defined olfactory striae—medial, intermediate and lateral (Figs 116.5 and 116.6).

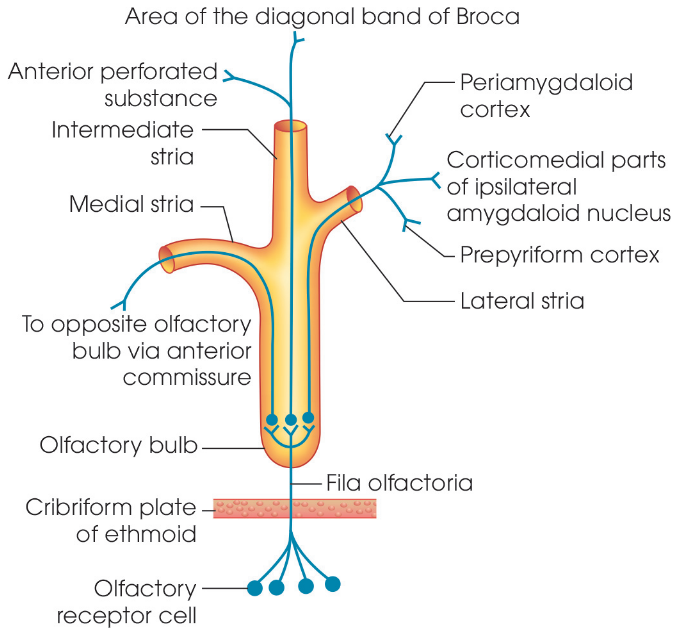

Fig. 116.5: Path of olfactory impulses showing olfactory rods (receptor cells) and supporting cells in the olfactory mucosa

5. The axons of the tufted cells leave the tract and most probably end in the opposite bulb via the anterior commissure through the medical olfactory stria. This tract after entering the anterior commissure passes bilaterally to the nucleus of the stria terminalis; olfactory tubercle and to amygdaloid nuclear complex.
6. The axons of the mitral cells pass through the lateral olfactory stria and ends in the anterior olfactory nucleus. Cortical and medial portions of the ipsilateral amygdaloid nucleus and in the prepyriform cortex and periamygdaloid cortex.
7. The prepyriform cortex and the periamygdaloid cortex are the primary olfactory cortices. Entorhinal cortex (area 28) is the secondary olfactory area because it receives fibres from primary olfactory cortex or adjacent neocortex. There is no thalamic representation to the olfactory system.
8. Another groups of fibres which are less significant in man pass through the intermediate stria and ends within the anterior perforated substance and the area of the diagonal band of Broca.

Olfactory sense and its control by higher centres

a. ***Amygdala*:** It is responsible for emotional response to olfaction.
b. ***Anterior olfactory nucleus*:** It co-ordinates the impulse input which is relayed to it from the contralateral olfactory cortex. Thus it helps to convey the olfactory memories to contralateral side.
c. ***Piriform cortex*:** It perceives and discriminates and differentiates the olfactory sense.
d. ***Entorhinal cortex*:** Olfactory memories are subserved here.

Olfactory System: Primitive and New Olfactory System

1. ***Primitive olfactory system*:** The medial olfactory area represents the primitive olfactory system. This

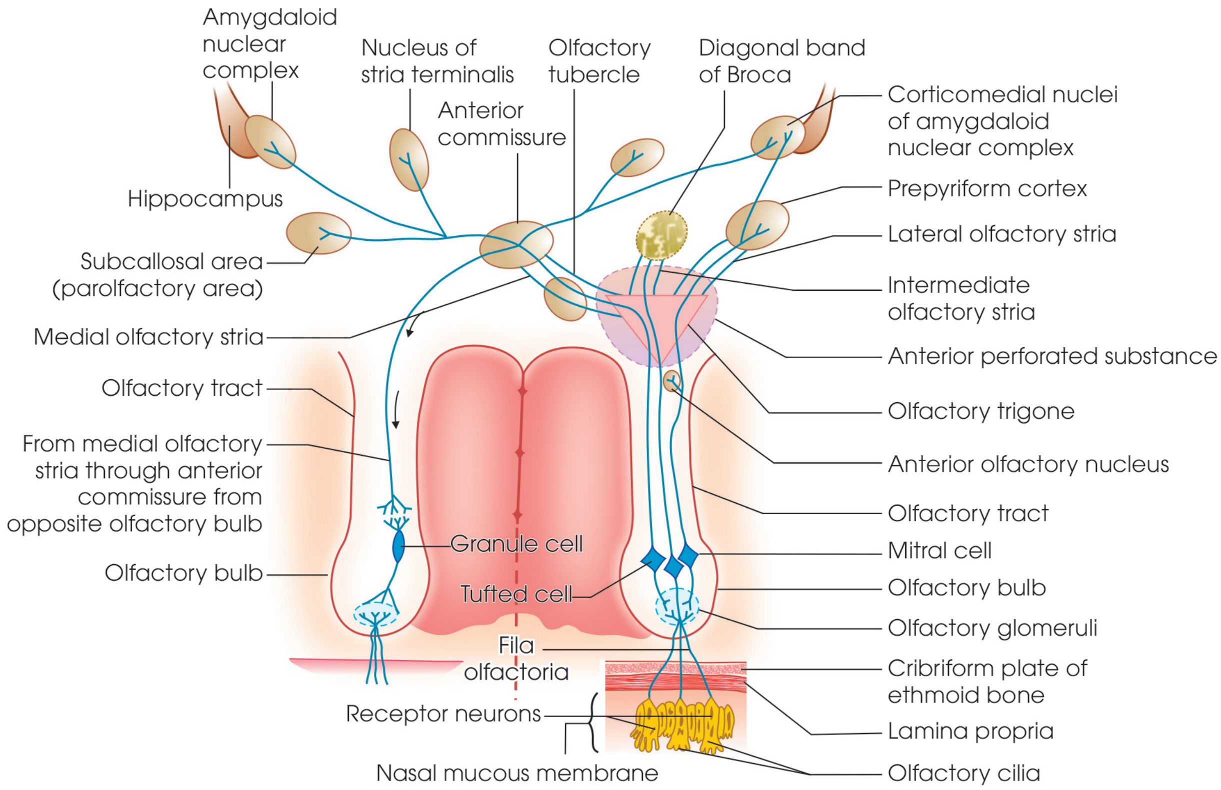

Fig. 116.6: Olfactory bulb and its connections

primitive area constitutes the group of nuclei, prominent among these are septal nuclei which relay information to hypothalamus and other parts of the limbic system. It is responsible for visceral and emotional response to odours.

2. ***Less older olfactory system***: The lateral olfactory area constitutes the less older olfactory system. The pyriform cortex, prepyriform cortex and cortical portion of amygdaloid nuclei are important component of lateral olfactory area. The less older olfactory system is involved in conscious perception of smell.
3. ***Newer olfactory system***: Experimental studies on monkeys revealed that the newer olfactory system passes via the dorsomedial thalamic nucleus to the lateroposterior quadrant of orbitofrontal cortex. The newer olfactory systems are involved in conscious perception and analysis of olfaction.

Note

The characteristic features of olfactory system include:

a. There receptors are exterioreceptors which are in contact with external environment.
b. They are confined of being telereceptors as well as chemoreceptors
c. Olfactors sensation may project directly or via thalamus to the cortex.

Competency achievement: The student should be able to:
PY10.14: Describe and discuss pathophysiology of altered smell sensation.

Pathophysiology of Altered Smell Sensation

The generally identified abnormalities of olfactory sensation include:

1. ***Anosmia:*** The loss of sense of smell is known as anosmia. It occurs due to congenital abnormalities of olfactory bulb or nerves.
2. ***Hyposmia:*** The decreased sensitivity to smell is hyposmia. This is observed in any inflammatory conditions affecting nasal mucosa.
3. ***Hypersomia:*** It is the morbid sensitiveness to odors. It occurs in hysteria and in conditions in which intracranial pressure is raised.

Dysosmia: The qualitative alteration or distortion of the smell perception is referred as **dysosmia**.

There are two classified types of dysosmia: 1. **Parosmia** and 2. **Phantosmia**

1. ***Parosmia:*** It is a distortion in the odorant perception. The smell of the odorants differs from that which is recognized as part of olfactory memories.
2. ***Phantosmia:*** It is the perception of persistence of an odor when no odorant is existing.

Note

Torquosmia: The term used to define smell perception of chemical, burning or metallic nature.

Etiology: The causes of dysosmia are not yet fully understood. Though etiology is idiopathic but the associate clinical conditions with dysosmia (parosmia) include head trauma, upper respiratory tract infections, nasal and paranasal sinus disorders, frontal lobe tumors, olfactory bulb tumors, epilepsy, etc. It may also be observed in psychiatric illness such as schizophrenia.

The proposed theory for its attributable cause includes the peripheral and central theories.

Parosmia: As based on the principle of peripheral theory, the individuals are unable to form a complete picture of a present odorant due to the functional derangement of olfactory receptor neurons. While as per central theory; the pathophysiology of integrative centres in the brain is responsible for the distorted odour.

Phantosmia: As based on the principle of peripheral theory, the etiology is attributed to neurons emitting abnormal signals to the brain or as a loss of inhibitory cell control which otherwise is functioning under physiological conditions. As per the central theory principle, the hyperfunctioning brain cells area generate the order perception.

Pathophysiology: The common pathophysiology observed is due to inflamed nasal mucosa (occurs in infections or exposure to toxic fumes), damage caused to the bipolar receptor neurons (especially affecting cilia on the dendritic ends of bipolar receptor neurons), or axons of the mitral and tuft cells or to the primary olfactory cortex (the anterior olfactory nucleus, the piriform cortex, the anterior cortical nucleus of amygdala) the periamygdaloid complex, and the rostral entorhinal cortex secondary to head trauma, nasal and paranasal sinus disorders, frontal lobe tumours, olfactory bulb tumours, or due to surgical trauma.

EXAM-ORIENTED QUESTIONS

Essay

1. Describe the physiology of olfaction. Describe the pathways of olfactory impulses.

Short Notes

1. Olfactory pathway
2. Olfactory bulb
3. Anosmia
4. Hyposmia
5. Hyperosmia