

CHAPTER I

RESPIRATION

PRĀṆĀYĀMA is a Yogic exercise in respiration. It is therefore desirable that a student of Prāṇāyāma is acquainted with some important details of the respiratory system. Hence, we propose to describe in this chapter a few broad features of the anatomy and physiology of respiration.

Respiration consists of the alternate expansion and contraction of the thorax, by means of which air is drawn into or expelled from the lungs. In this chapter we shall first consider the various organs that are directly concerned with this passage of air to and from the lungs; and then we shall see how these organs act in the different stages of respiration.

The organs of respiration may be enumerated as the nose, the pharynx, the larynx, the trachea, the bronchi and the lungs. Nerves and blood-vessels connected with these parts may also be looked upon as organs of respiration. Generally, however, the nose is not included in such an enumeration. But when we want to write on respiration from the Yogic point of view, the nose has not only to be included but also to be studied in detail. In dealing with these organs we shall proceed along the passage of the air from outside into the lungs and as we meet with the nose first, we shall start this chapter with a description of that organ.

THE NOSE - - We shall be able to study the nose both externally and internally with the help of a mirror and of the charts given in this chapter. In using this mirror the reader should allow light to come from his back and fall upon the mirror held in his front. The

mirror should be so adjusted as would easily throw reflected light into the nostrils when the head is thrown backward, but would not dazzle the eye.

We always see our nose in the mirror. But what we generally see is only the external part of the nostrils. Let our reader have a peep into the internal portions of the nostrils also. He will find that by the side of the dividing wall, up in the cavity there is a hole in each of the two nostrils. He might think that these holes are a sort of communication between the nose and some other organ situated inside the head. But he would be seriously wrong in thinking that way. In fact the external nose is only a small part of the organ anatomically known as the *nose*. The most important part of it is situated inside the head, behind the two holes our reader has seen, and above the hard palate that forms a part of the roof of his mouth. We shall presently examine this internal part of the nose. But before we do so let us finish with the external part of that organ.

If we feel our nose with our fingers, we find that a very large part of it is mobile. This is because this portion of the nose, including the dividing septum, is made of different cartilages attached to one another by a tough. Fibrous membrane and covered over by the skin. If our reader again looks into his mirror and examines the inside of his nostrils, he will find that the skin which covers the external surface of the nose, continues inward and also covers the lower chamber of the internal nose. He will find even the lower portion of the septum clothed similarly in skin. This portion of the nasal cavity is called the *vestibule*. From the walls of this vestibule, our reader will find, a number of stout and stiff

hair projecting. Out of these hair, those that grow from the front part project backward, whereas those that rise from the back part project forward. Thus a sievelike arrangement is provided just at the entrance of the nose. The external nose has two ends. The upper end which is connected with the forehead is called the root and the lower end which is free, is called the *apex* of the nose.

If we again feel the flexible part of our nose and examine the upper as well as posterior borders of it, we find them hard. This is because the elastic part of the nose is attached to bones at the top behind. In Fig.2 the mobile nose has been removed and bones to which it is attached are exposed to our view. Our reader will immediately see that the bony borders which carried the flexible attachments of the nose, represent a picture exactly similar to that of the heart drawn in the playing cards. Let us observe a few facts about this bony aperture that directly concern us. Below the forehead and between the eyes there are two bones which we can feel externally. They are called the *nasal bones* (1) and form what is known as the *bridge of the nose*. A vertical line (3) is seen dividing the aperture into two exact halves. This represents the nasal septum. The circular curves at the bottom belong to the two upper jaw-bones. (5). These curves mark the lower borders of the two holes observed by our reader in the back part of his external nose.

We have already stated that the external nose is only a small part of the real organ. The most important part of it is situated inside the head. We have now removed the mobile nose and come to the entrance of the inner cavities. Let us now note what is there inside the aperture that lies before us in Fig. 2.

The aperture which is divided into two halves by the nasal septum leads to two cavities that are roughly speaking ovalshaped. These cavities continue backward and open into the throat with holes similar to those we observe on the bony surface before us. Each of these cavities has a floor, a roof, and a medial and a lateral wall.

The septum which divides these cavities stands for the medial wall of both. It is made of bones all along except in front where a large cartilage fills up the gap. The floor is also bony. A reference to Fig. 1a will show this floor in a median section. It is made of two bones. The front part is made of the upper jawbones and the back part, of the hard palate bones. There are two upper jawbones and two hard palate bones. The upper jawbones are arranged side by side and form our upper jaw in which the teeth are set. Behind the upper jaw, the hard palate bones stand side by side and form our hard palate. The lower surface of the two upper jawbones and the hard palate bones go to form the roof of our mouth. If we try to feel the roof of our mouth with our finger from the upper teeth backward, we will meet with two hard surface. One is rough and the other is smooth. The rough surface which we feel just above our teeth is presented by the upper jawbones, and the hard but smooth surface that we cross when the finger is moved backward belongs to the hard palate bones. Behind this the soft palate can easily be felt. Fig. 1 shows that the upper surface of the upper jawbones and the hard palate bones are horizontal and that is why the floor of the nasal cavities is also horizontal. So the upper jawbones and the hard palate bones at once form the roof of the mouth and the floor of the nose. That means the nasal cavities

lie just above the roof of the mouth. The lateral walls of the nasal cavities are somewhat complicated. They are also made of bones. They rise from below at some distance from the septum, but as they rise they incline towards the septum to meet it at the roof. Some idea of this inclination of the lateral walls can be had from Fig. 2. Here the bony aperture represents the external borders of these nasal walls. So these cavities are broad below, but narrow down at the top. From the lateral walls arise inside the cavities scroll-like bones. One of them has been marked in Fig. 2 (4). These scroll-like bones extend all along the length of the lateral walls and open backward into the throat.

Now we consider the roof. This is also a bony structure. The floor of the nasal cavities is horizontal; but the roof is arched. An idea of this arch can be had from Fig. 1*b*, where the septum is shown arching at the top. Now this septum rises direct to meet the roof, and therefore the upper curve of the septum fairly represents the arch of the roof. We may note especially two bones that form the roof. The nasal bones that have already been noticed form the front slope of the arching roof. Behind these nasal bones the roof is formed by a big bone called *ethmoid*. The ethmoid is at once the roof of the nose and a part of the floor of the brain. That means it separates the nasal cavities from the brain. Thus the nasal cavities stand between the mouth and the brain; and open backwards into the throat just above the soft palate.

Upto now we have studied the bony structure of external nose as well as of the nasal cavities. Now we have to note that these hard surfaces are covered over with mucous membrane. This mucous membrane is a continuous piece that lines out the inside of the

external nose except the vestibule, but it also clothes the floor, the roof and the walls of the nasal cavities and continue into the pharynx. When we examine this mucous membrane covering the nasal cavities, we find that functionally two areas are to be mapped out. The upper area covers one third of the total surface of the nasal cavities and the lower area the remaining two-thirds. Having the sense of smell situated in it, the upper district is called the *olfactory region*, the lower district being called the *respiratory region*, as it constitutes the passage for air breathed in and out during respiration. That means the cavities of the nose have got two separate tracts for the two different functions they perform. If we divide the height of the nostrils into three equal parts, the uppermost part is used for smelling and two lower parts are used for breathing. None should suppose, however, that the uppermost part is not at all available as a passage for respiration. Although in the normal and quiet breathing only the lower two parts are used, in forced breathing the upper third is also utilized. The sense of smell, however, is confined to the upper third only, having nothing to do with the two lower regions. This is because the sense of smell depends upon the presence of the olfactory nerve-endings which are distributed only over the upper third area. (Vide Fig. 1(4)).

Two features which distinguish the mucous membrane covering the olfactory region from that covering the respiratory tract, deserve our attention here. The mucous membrane which clothes the respiratory tract is thick and spongy whereas that which lines the olfactory region is softer and more delicate. The other distinguishing feature is the very great vascularity of the respiratory

tract. In fact it is marked by the presence of a rich venous plexus. These anatomical facts have a physiological significance. As noted above in ordinary quiet breathing, the air moves through the lower two-thirds of the nasal area. The air in the upper one-third is scarcely disturbed. Now that portion of the mucous membrane which lines the passage of the air must be stouter than the portion where the air is stationary the hours of normal breathing. The greater vascularity of the respiratory tract has also a purpose to serve. When external air is to be breathed into the lungs, it must be warm and moist, otherwise it may have an injurious effect upon the delicate structure of the lungs. Now the large supply of venous blood which is present in the plexus situated in the respiratory region, raises the temperature of the air during inspiration and also moistens it.

It has been stated above that the sense of smell is situated in the upper one-third of the nasal cavities. This sense consists of very fine nerve filaments from twelve to twenty in number. They are distributed like a thick brush both on the septum and the lateral walls. Here these nerves descend through the ethmoid bone which, as we have seen above, separates the nasal cavities from the brain. Through the ethmoid the olfactory nerves reconnected with the olfactory bulb which in its turn is joined to the base of the brain through the olfactory tract. Fig. 1 illustrates the olfactory nerves, the bulb, the tract as also the base of the brain. When the fine endings of the olfactory nerves are stimulated by particles carrying odour with them, sensation of smell is experienced.

Following facts may be remembered with advantage in regard to the sense of smell.

The delicacy of the sense of smell is very remarkable. It has been calculated that even $\frac{3}{1,000,000,000}$ of a grain of musk can be distinctly smelt.

But when the particles issuing from an odoriferous substance are very few, their presence in the air may not be appreciated in normal breathing, because they pass through the respiratory passage only and are not presented to the nerve-endings in the olfactory region. If under such circumstances a sudden sniff is made, air is forced even into the olfactory tract and the faint odour can be detected.

Even a liberal proportion of odoriferous particles in the air fail making itself felt. For the sense of smell to be excited, the mucous membrane must be neither too dry nor too moist. So When one catches cold his sense of smell is dulled owing to the presence of excessive moisture. There is another reason also why one does not smell properly during cold. The swelling of the mucous membrane covers the nerve filaments rendering them inaccessible to the odoriferous particles.

It is a matter of common experience that perfumes make the strongest impression to start with. Afterwards they grow fainter and even their presence is lost upon us, if we continue long to be in their presence. This circumstance can be accounted for by the fatigue of the sense of smell. The olfactory apparatus is soon exhausted and fails us on that account. If, however, we take a round in the fresh air, the apparatus is refreshed and we can again appreciate the odour.

THE PHARYNX--It has been stated above that the nasal chambers posteriorly open into the throat. These openings are situated above the soft palate and below the base of the cranium. This portion marks the beginning of the pharynx. Now if our reader again looks into the mirror with his mouth widely opened, he will observe that there is something like a wall of flesh covered over with the mucous membrane, stretching behind the tongue and the soft palate. This wall arches above the soft palate in something like a dome. It is exactly under this dome that the posterior openings of the nose are located. Below the tongue the wall descends in the form of a sack that ends in two openings, one of which leads to the aesophagus and the other to the larynx (Vide Fig. 3). From the backward openings of the nasal chambers to the lower openings leading to the aesophagus and the larynx, the same canal stretches continuously and is known as the pharynx. Our reader need not be told that the mouth is only an opening in the anterior wall of the pharynx. So upto now we have noticed five openings of the pharynx, two nasal, one oral, one aesophageal and one laryngeal. There are two more orifices which pierce the pharynx. They are situated in the side walls of the pharynx, one on each side, above the soft palate. They are called *Eustachian orifices*, because they mark the openings of the Eustachian tubes which run to the cavities of the ears. The portion of the pharynx that is situated above the soft palate is called the *nasal part* of the pharynx, that situated behind the mouth and the tongue is called the *oral part*, whereas the remaining portion is called the *laryngeal part*.

The pharynx is used for the passage of the air as it is breathed in and breathed out. In inhalation the air drawn through the nasal

cavities passes across the nasal and oral parts of the pharynx and then getting down the larynx goes into the trachea and the lungs. In exhalation the air expelled from the lungs follows the reverse path. At the time of breathing the aesophagus as well as the Eustachian tubes remain closed and the possibility of the air going a wrong way is avoided. Again the soft palate leaves, between it and the back wall of the pharynx, an opening sufficient for free movement of the flowing air. Hence, there is no obstruction in the way of respiration.

At the time of speaking, however, the soft palate completely covers the upper part of the pharynx, so that no air can find its way upward into the nasal part. But in some person, the soft palate is defective, there being a small cleft in it. When these people attempt speaking some of the air from the lungs escapes through this cleft above the palate, and finds its way through the nasal passages that are ever open, adds nasalized element to their voice.

Our reader knows that he uses a part of the pharynx also for swallowing. Food travels through the oral part into the laryngeal pharynx and then gets into the aesophagus. The question is why food going down the pharynx does not run into the larynx and is always pushed down the aesophagus. For this purpose we have to refer to a small organ named epiglottis.

The epiglottis is situated at the root of the tongue (Vide Fig. 3) and serves as cover for the larynx in times of need. In the act of swallowing, the larynx is raised, and the descending morsel lowers the epiglottis which meeting the raised larynx completely covers its mouth. Thus the larynx being closed, food finds its way to the aesophagus or gullet. The rising of the larynx can be felt by

anybody by lacing his fingers on the middle of his throat and imitating the act of swallowing. If, however, through mistake even a small particle of food gets the wrong way, we mean gets into the larynx, violent coughing ensues, the system forcibly tries to expel the intruder. Food does not get into the nasal part, because the soft palate completely shuts out that portion during the act of swallowing.

The mucous membrane covering the nose is continuous with the pharynx. It is also to be noted that it continues to cover all the passages leading from the pharynx. It is this circumstance which makes a trouble starting with the throat very often spreads to the nose, the ear and the larynx. That is why running of the nose, deafness of the ear and coughing are on many occasions seen going together.

THE LARYNX---We have noted above that the pharynx has two passages opening from its lower end. They are the oesophagus and the larynx. Both the oesophagus and the larynx pass through the neck, the former is situated in the posterior part of it, whereas the latter is situated in the anterior portion. The larynx begins in front of the third cervical vertebra and extends across the fourth, fifth and sixth. The oesophagus starts in front of the sixth cervical. Hence it will be clear that the larynx stands higher up in the neck than the oesophagus. (Vide Fig. 3). As the oesophagus remains constantly closed except at the time of swallowing, the air coming down the pharynx gets into the larynx is always open for this purpose, being closed only during the act of swallowing.

We have already seen that the larynx is situated in the front portion of the neck. There it extends from the base of the tongue

downwards. The larynx is a box-like anatomical structure made of different cartilages, and measures less than two inches. Two of these cartilages can be felt even from outside the throat. Starting from the jugular notch upward and feeling the surface of the throat with our fingers, we meet with the first prominence at a short distance. This is the cricoid cartilage. (*Vide Fig. 3*). Travelling further up we come across the next prominence, visibly projecting especially in the case of this persons. This is the thyroid cartilage, the prominence being popularly known as *Adam's apple*. These and other cartilages including the epiglottis which is also a cartilage, are held together by muscles which move them according to the needs of the situation. We have already learnt how the larynx is raised and the epiglottis lowered, during the act of swallowing. As soon as the swallowing is over the larynx is lowered, and the epiglottis raised, leaving the passage free for the air moving to and fro during respiration.

The larynx is popularly known as the voice-box. We want to see now how this box-like instrument is responsible for human voice. Like the pharynx the larynx is covered with mucous membrane on its inner surface, the mucous membrane that covers the pharynx continuing to cover the larynx also. This mucous membrane is thrown into several folds. Two of these start from the front of the box midway in its height, and stretching across its cavity, join the opposite side. These folds are very thin. They are joined together in the front, but are capable of being separated from behind. These folds resituated just behind the thyroid cartilage already referred to. *A* in fig. 4 represents these folds as they stand close together and *C* as they stand wide apart, *B*

illustrating the middling position. The three figures indicate the appearance of the folds that they would present to a man peeping into the larynx from above. These folds admit of being brought so tightly together, that they can completely shut up the air below even at a high pressure. These folds are capable of undergoing different degrees of approximation. During normal respiration they stand apart and the passage of the air is smooth and noiseless. But when they are brought close together the air passing through the narrow chink formed by them, throws them into vibrations which in their turn throw the passing air into ripples. It is this rippling air that produces the sound when it strikes our ear. Thus being responsible for the human voice these folds are called *true vocal cords*, the narrow chink between them being called the *glottis*. These vocal cords are called true because they are to be distinguished from another pair of similar folds situated just above them, which are called *false* vocal cords, because they are not concerned in the production of voice.

The mucous membrane which forms the true vocal cords by forming itself into two thin bands, continue to cover the lower portion of the larynx and extends into the trachea into which the larynx opens.

THE TRACHEA-- The trachea or the windpipe is a tube-like anatomical structure some four inches in length. It starts at the bottom of the larynx from behind the cricoid cartilage and extends down into the chest just behind the breastbone. In this person the upper part of the trachea may be felt with our fingers below the cricoid cartilage. The diameter of the trachea is something like an inch.

The tube of the trachea is formed by cartilaginous rings, from sixteen to twenty in number, which are arranged one above the other, and which are held together by an elastic membrane in which they are enclosed. These rings are not entire but are deficient in part. They are arranged in such a way that the circular part is placed in front and deficient part is placed behind. Of course the deficient part of the tube is covered by the fibrous membrane which clothes the whole trachea. Fig. 5a represents the appearance of the trachea as seen from the front and Fig. 5b illustrates the appearance of the same organ as seen from behind.

It has been stated above that the aesophagus is placed just behind the trachea. In fact the membranous part of the trachea and the aesophagus run together. Hence any obstruction in the aesophagus produces a sense of suffocation, although the air passage is free.

A large number of mucous glands is situated in the mucous membrane of the inner surface of the trachea. Under normal conditions the mucous secreted by these glands keeps the passage moist. But if there be an excessive secretion of mucous, it is ejected immediately. The inner mucous membrane of the trachea is lined with ciliated epithelium.¹ These cilia always maintain an upward movement and thus slowly sweep up the secretions towards the larynx from which they are ultimately coughed out.

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1. Epithelium is the delicate tissue forming the outer layer of the mucous membrane. Cilia are very minute hair-like vibrating organs on the surface of the epithelium, forming there a sort of brush.

THE BRONCHIAL TUBES -- The trachea when it descends into the chest to the level of the fifth thoracic vertebra, is divided into two tubes called the bronchi. The tube on the left side enters the left lung and is known as the left bronchus, that on the right side entering the right lung being called the *right bronchus*. (*Vide Fig. 5*). After entering into the substance of the lungs, each bronchus divides itself into several branches, these branches again dividing themselves into smaller tubes. These divisions and subdivisions continue to penetrate the substance of the lungs through and through, till at last tubes become so small that their diameter hardly measures $\frac{1}{40}$ th of an inch. The Trachea with the two bronchi and the numerous smaller and still smaller branches spreading out from them would, if they are separated from the lungs, present the appearance of an inverted tree with the main stalk pointing upward. (*Vide Fig. 5*). When the tubes are reduced to $\frac{1}{30}$ th of an inch in diameter, they stop subdividing themselves any more. Here the fine bronchial tubes widen themselves and then end in finer air-cells having a diameter of $\frac{1}{50}$ th of an inch only. A bunch of grapes can very well give a graphic idea of the minute bronchial tubes with air-cells clustering around them. When the air that comes through the nostrils, the pharynx, the larynx, the trachea and the bronchial tubes successively, reaches the air-cells, its further passage is stopped. From these cells it is diffused into blood. But before we study this diffusion, we shall note a few important points about these bronchial tubes.

We have seen above that the trachea is made up of cartilaginous rings. Similar cartilaginous portions are present throughout the bronchial tubes except in the last finest branches. The presence of these portions is absolutely for keeping the tubes constantly open for the passage of the air to and from the lungs. Otherwise the tubes would have been exposed to the danger of a collapse.

ABBREVIATIONS

आश्वालायनश्रौतसूत्र	- आश्व.श्रौ.	- Āśv. Sr.
घेरंडसंहिता	- घे. सं	- Ghe. Smt
जीवन्मुक्तिविवेक	- जी. मु. वि.	- Jī. Mu. Vi.
पातञ्जल्योगसूत्र	- पात. यो. सू.	- Pāt. Y. S.
बृहद्योगियाज्ञवल्क्यस्मृति	- बृ. या. स्मृ.	- Brhadyogi Yā. Sm.
बौधायनधर्मसूत्र	- बौधा. ध.	- Baud. Dh.
भगवद्गीता	- भ. गी	- B. G.
लघुयोगवासिष्ठ	- ल. यो. वा.	- L. Y. V
विद्यारण्य	- वि. ण्य.	- V. Nya
हठप्रदीपिका	- हठ. प्र.	- H. P.

SCHEME OF TRANSLITERATION

अ - a; आ - ā; इ - i; ई - ī; उ - u; ऊ - ū;
ऋ - ṛ; ॠ - ṛī; लृ - lṛ; लृ - lṛī; ए - e; ऐ - ai;
ओ - o; औ - au;
अनुस्वार - m; विसर्ग - h;

क् - k; ख् - kh; ग् - g; घ् - gh; ङ् - ṅ;
च् - c; छ् - ch; ज् - j; झ् - jh; ञ् - ñ;
ट् - ṭ; ठ् - ṭh; ड् - ḍ; ढ् - ḍh; ण् - ṇ;
त् - t; थ् - th; द् - d; ध् - dh; न् - n;
प् - p; फ् - ph; ब् - b; भ् - bh; म् - m;
य् - y; र् - r; ल् - l; व् - v;
श् - ś; ष् - ṣ; स् - s;
ह् - h; क्ष् - kṣ; त्र् - tr; ज्ञ् - jñ;