The fibrous tissue that holds the cartilaginous portions together throughout the length of the bronchial tubes, is very elastic. This circumstance helps the tubes to adopt themselves to the movements of the surrounding anatomical parts.

As in the trachea, so also in the bronchial tubes, the inner mucous membrane is lined with ciliated epithelium. The mucous glands embedded in the mucous membrane, keep their passage moist under healthy circumstances. But in disease when the secretion is excessive, the bronchial tubes stand in danger of being blocked up. Here the cilia try to help the situation. By their perpetual upward movement they work up the secretion up to the larynx. This organ is immediately irritated and throws out the secretion by a cough.

THE LUNGS -- In the previous section we have referred to the air-cells. These air-cells are matted together by means of fibrous tissues. Blood- vessels running through these cells divide and subdivide themselves into myriads of capillaries covering these air-cells. Again there is a network of nerves spreading throughout these structures. All these parts, the cells, the bloodvessels and the nerves form themselves into two masses of a spongy substance each of which is called a lung. We shall now study these statements in greater detail.

Alveoli is another name for the air-cells. All the alveoli developing around themselves a fine bronchial tube, presenting the appearance of a bunch of grapes, go to form what is called an ultimate lobule. Several *ultimate lobules* constitute a lobule and several such lobules are contained in a lobe. The right lung has three such lobes and the left has two. (*Vide Fig. 6*).

The walls of the air-cells which cluster around the finest bronchial tubes, are made of very elastic and circular muscular tissue. The walls are, however, extremely thin, so much so that the air which flows into the cells through the air tubes, is very freely diffused through these walls, although its direct passage is blocked up here.

We have referred to the myriads of capillaries that cover the air-cells. These are the finest ultimate subdivisions of the blood-vessels coming into the lungs and going away from them. The incoming vessels bring impure blood from the heart, to be purified in the lungs. The outgoing vessels carry the purified blood from the lungs back to the heart. Now the network of the capillaries which covers the air-cells is extremely fine, and the walls of the capillaries are extraordinary thin. So when we consider an air-cell, we find that inside the cell there is a stock of fresh air which is surrounded by two extremely thin layers of tissues, the first belonging to the cell and the second pertaining to the capillaries. Beyond these layers is the blood streaming through the capillaries in very fine currents. The two intervening layers, even when put together, are again so thin, that they allow a free interchange between the oxygen from the cells and the carbon dioxide from the capillaries.

The number of blood capillaries which surround the air-cells is so large that it passes all imagination. It is calculated that these capillaries from the two lungs would connect Bombay with London, if they were stretched out in one single line ! We can, however, understand the necessity of this huge length of capillaries, when we know the amount of blood that is presented through them to the air-cells for purification. If the quantity of blood present in the lungs at a particular moment is spread out in a very thin layer, it would cover as many as one thousand square feet at least ! So we find that the arrangement of the air-cells and the capillaries, is to secure a very large surface area for the lungs, within such small limits as the chest of a human being.

This description of the lungs would not be complete unless we explain the two coverings in which the lungs are clothed and which form air-tight bags for holding them. These coverings are called the *pleurae* and consist of a serous membrane, i.e., a smooth glistening membrane that secretes a lubricating fluid. Each lung has a separate pleura of its own, which is folded double, so that the two layers cover the lung completely. Thus an air-tight double bag, having two sheaths one inside the other, of serous membrane is prepared, and each lung is held within this bag. Our reader knows that the lungs are placed inside the thorax. Now the outer layer of the pleura lines the inner surface of the thoracic cavity, and is called the *parietal layer.* The inner layer is adherent to the lungs, and is called the visceral layer.

A tolerably good idea of the relations of the lungs, pleurae and the thorax can be had, if we compare these with a football. The coarse leather bag which forms the outer covering of a football, very well illustrates the rough thorax. Inside this leather cover there is the bladder, a rubber bag which when the ball is to be used is kept inflated. Now, instead of one bladder let us suppose that there are two, one inside the other. When air is pumped into these bags they will swell up. In this inflated condition the outer bag will adhere to the rough leather covering in which these bags are held, and the inner bag will lie closely along the outer rubber bag. The two layers of the pleura lie exactly like the two rubber bags in relation to each other. The only difference is that in the case of the pleural layers there will always be a sort of lubricating fluid secreted by the membrane that allows the two layers to glide smoothly on teach other during the constant movements of respiration. Again in the case of the football, the inside is hollow, whereas in the case of the pleural layers, the inside is filled with the spongy substance of the lungs. Needless to point out that the tube of the rubber bags through which air is pumped in, may clearly illustrate the trachea.

The space between the two layers of the pleurae is called the *pleural cavity*. Under normal conditions of health, the two layers stand so close together, that there is no space left between them. But during inflammatory changes of the membrane, as is pleurisy, the cavity becomes enlarged by an increase in the amount of fluid which it contains.

We have said above that the lungs are held in the thorax. But the lungs are not the only organs situated there. Besides these there are the heart, the big blood-vessels, the trachea and the oesophagus. These are placed between the two pleurae, the right and the left, the cavity in which they are arranged being called the *mediastinal cavity.*

The lungs are short in front and longer behind. In front they descend to the sixth ribs whereas behind they stretch up to the eleventh ribs. This position of the lungs is determined by the position of the diaphragm which forms the floor of the thorax. It is to be remembered that above they rise even a little beyond the clavicles. On an average the right lung weighs 22 ounces in an adult, and the left weigh 20 ounces only.

Thus far we have noticed the different organs through which the air moves, when it passes to and from the lungs during respiration. Now we shall consider the muscular and nervous mechanisms responsible for the movements of these organs of respiration, and shall also study the blood-vessels connected with this function.

The Muscular Mechanism[2]

"The force expended in opening the chest in inspiration each day is enough to raise the person the height[3] of St. Paul's, and is thus only about one-sixth of the force spent in the circulation. Breathing consists of two acts---*inspiration* and *expiration. Inspiration is a forced muscular effort* performed by three distinct sets of muscles--those that act on the ribs, those that act between the ribs, and the diaphragm, which is the floor of the thorax.

"In inspiration the chest cavity is made[4] broader, longer and deeper. When at rest, the ribs, hinged behind to the backbone and in front of the breastbone, hand down like the iron handle on the side of a bucket. (*Vide Fog. 7*). Now, if we raise such a handle, it not only moves upward, but also outward. The same takes place with the ribs; and, in addition, the sternum, or breastbone, being

2. In this note, paragraphs included in the quotation marks are extracted from A.T.Schofied's *Articles on Physiology.*
3. Five hundred feet.
4. Increased in the three diameters--lateral, vertical and anteroposterior.

movable, rises forward as well, and thus the chest is made *broader and deeper.* It is made longer because, when at rest, the diaphragm muscle forms an arched floor, that rises like a dome into the thorax, and on which the lungs rest. As this muscle contracts it flattens[5] the floor, pulls the lungs down and as a result makes them longer from top to bottom.

"The muscles that raise the ribs are in two sets--those that act on the ribs and those that act between them. The upper ribs are pulled upward by the action of muscles passing down from the neck.

"Between each rib is a double layer of muscles called the intercostal muscles, because they are between the ribs. The top ribs being fixed as these contract, they tend to raise the lower rib, to which they are attached; and thus, by acting together, all the ribs are elevated.

"This constitutes the movement of inspiration.

"In expiration, the chest returns to its *original size* without effort. This is mainly caused by elastic recoil. The lungs are full of elastic tissue which is stretched when the lungs are expanded; and as soon as muscular effort ceases, the elastic force is so great that the lungs pull the ribs down again, and pull up the floor of the diaphragm.

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5. As has been proved in *Yoga-Mīṃāṃsā* by means of experimental evidence, and as is now held by the medical scientists, the diaphragm does not flatten during contraction, but descends parallel to itself without altering its convexity. Even then the descent of the diaphragm does increase the vertical diameter of the lungs.

"When we draw in a breath the abdomen swells out. This is caused by the contraction of the diaphragm. Which presses all the digestive organs down and makes them bulge out the walls. In expiration the abdomen gets flat again, as the floor rises once more, and the abdominal muscles are contracted.

"The force required to stretch out the elastic tissue in ordinary inspiration is equal to 170 lb; and the total daily force used in respiration is 21 foot-tons".[6]

In extraordinary or forced breathing the force required for the act is much more than in normal respiration. Both in inhalation and exhalation additional muscles are brought into play. The additional muscles which are called into action in forced inspiration are situated in the neck and chest. In forced expiration the abdominal muscles play a very important part.

It is to be especially borne in mind that speaking, singing, blowing etc., are voluntary expiratory efforts, whereas sneezing, coughing etc., are involuntary. In all these action the abdominal muscles are brought specially into action.

When one holds his breath after inhalation all the muscles of inspiration remain contracted and the glottis is tightly closed. So also it remains tightly closed when one holds his breath after deep exhalation. At this time, however, it is the muscles of expiration that maintain their full contraction.

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6. Force required to raise one ton of weight through twenty-one feet against gravity, or to raise twenty-one tons of weight through one foot against gravity.

It is to be noted here that the air outside freely communicates with the lungs when the glottis is open. We have noted above that glottis remains closed only at the time of swallowing. So during all the twenty-four hours of the day, the air outside communicates freely with the lungs. Now this outside air always stands at an atmospheric pressure, and if it gets communication with a space that stands at a lower pressure, it will flow to that space till the pressure outside that space and inside it becomes equalized. This is exactly what happens at the time of inspiration. When the lungs become broader, deeper and longer owing to the opening up of the chest, the pressure inside the lungs is lowered and the outside air rushes in through the trachea till internal pressure becomes equal to that of the atmosphere. This constitutes the act of inspiration.

It has been stated in the foregoing paragraphs that in inspiration the ribs are elevated and the diaphragm sinks, pressing the abdominal viscera, thus leading to the bulging out of the abdomen. When the whole muscular mechanism of respiration is healthy, the rising of the ribs and the bulging out of the abdomen are proportionate. But in case of defective respiratory mechanism, either the abdominal movement or the costal movement is more prominent than the other. This circumstance has led to a distinction in the types of breathing. That respiration in which the costal movement is prominent, is called *costal breathing*. Again the breathing in which the abdominal movement is more in evidence, is called *abdominal breathing or diaphragmatic breathing.* The latter breathing bears a double name because the abdominal movements depend upon the movements of the diaphragm.

Due to old age or disease the chest becomes rigid. Under these circumstances the breathing becomes abdominal. People very often, due to their peculiarities of dress, make the movement of the abdomen almost impossible. If this habit is continued over a long time, breathing becomes costal rather than abdominal. Owing to these reasons it is desirable that the whole mechanism of respiration is allowed the greatest scope for movement.

When the chest begins to sink, the pressure inside the lungs is increased and becomes greater than the pressure outside the lungs. Hence air is driven out of the lungs through the trachea, till at last the elastic recoil is completed and again the internal and external pressures are equalized. This constitutes the act of expiration.

Whatever the amount of air inside the lungs either during inspiration or expiration, that air exerts an equal pressure on each of the lungs as a whole; and keeps it, under all conditions, closely in contact with the walls and the floor of the chest.

The number of respiration under conditions is between fourteen and twenty per minute.

Having noted the muscular mechanism of respiration, we now proceed to study the nervous mechanism of it.

The Nervous Mechanism

The respiratory centre is a nervous mechanism situated at the posterior part of the brain, almost at its lower end. The centre is responsible for controlling the activities of the muscles that cause inspiration and expiration. This central control is both voluntary and involuntary.

Practically our breathing is under our own control up to the point where life is involved. We can breathe in any manner and at any rate we please. Were it not so, speaking would become impossible. We can also hold our breath up to a certain points; but when life is beginning to be threatened the voluntary control comes to an end, and in spite of the strongest effort of will, forces us to breath. The involuntary control also acts continuously when we are not thinking of our breath at all. None of the vital processes require our constant attention; yet with some we are allowed to play up to the point of danger but not further.

We shall refer to this nervous mechanism again at the end of this chapter.

The Quantity Air We Breathe

The quantity of air we breathe depends upon the depth of respiration. In the ordinary normal respiration, the quantity of air that uniformly flows in is about 500 ml. (milli-litre). As much air also flows out during normal expiration. Thus the volume of the tide of air that constantly and uniformly flows in and our is about 500 ml. This is called tidal air and the volume of such air is called tidal volume.

But if the inspiration were to be deeper, it is obvious that a larger quantity of air will be drawn in. It is estimated that about 2500 ml. of air can be drawn in by an average adult in the deepest inspiration This is called the inspiratory capacity and includes tidal volume.

Again as average adult can expel about 1300 ml. of air by a forcible deep expiration over and above the 500 ml. which he expels in his normal exhalation. The additional air expelled by a forcible deep expiration is called expiratory reserve volume.

It is to be noted, however, that even the deepest expiration will not be able to empty the air-cells completely. There will always be a reside of air left in the lungs. This residue is calculated to be equal to 1600 ml. (milli litres) and is called residual volume.

At the end of a quiet respiration the lungs contain the expiratory reserve volume and the residual capacity (2900 ml.).

The amount of air breathed in per minute is called the respiratory minute-volume or pulmonary ventilation. Since the respiratory rate at rest is about 16 per minute and the tidal volume 500 ml., the minute volume is about 8 litres. In exercise it may go up to 70 litres.

We shall refer to this nervous mechanism again at the end of this chapter.

Upto now we have seen how we breathe and also how much we breathe. Now we will see why we breathe at all.

Why We Breathe

A solution to this problem is available in the comparison of the quality of the air we breathe in and quality of the air we breathe out. Roughly speaking, the following is the composition[7] of the two types of air : -

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7. Only those constituents that are important from the physiological standpoint have been compared here.

PER HUNDRED POINTS

	Nitrogen	oxygen	Carbon Dioxide
Inspired Air	79	20.96	0.04
Expired Air	79	16.02	4.38
		-4.94	+4.34

Here we at once find that the expired air has lost 4.94 parts of oxygen and has gained 4.34 parts of carbon dioxide in going into and coming out of the lungs. Where has this oxygen gone and whence has this carbon dioxide come ? Oxygen has been taken up by the stream of blood that circulates through the lung capillaries and carbon dioxide has been substituted for it by the same agency.

If we bring together two vessels containing two different gases without any partition between them, the two gases will mix up thoroughly. This very thing happens even if the two gases were to be separated by a thin partition of a membrane. Now we know that the blood streaming through the capillaries around the air-cells and the air in the air-cells, are separated only by a thin partition consisting of the walls of the capillaries and the air-cells. So the gases of the air and the blood mix up freely. This is what is called the *diffusion of gases.* In the figures quoted above for comparison, we find that the quantity of oxygen substituted for carbon dioxide, is greater than the quantity of carbon dioxide by 0.60. This is because oxygen is used not only in forming carbon dioxide, but also for some other physiological work.

Now we proceed to see why the circulating blood current the lung capillaries, wants to borrow oxygen and tries to lose carbon dioxide.

In this connection we are to remember that the human body is constantly at work even when apparently it is at rest. The circulatory system, the respiratory system, the digestive system etc., know no rest. They have to work ceaselessly. This perpetual work means constant wear and tear of the body tissues involved in the work. So the loss of the tissues is to be made good and waste products are to be removed and thrown out of the body. Now for making good the loss, nourishment has to be brought to these tissues. This nourishment is derived not only from food and drink, but also from the inspired air in the form of oxygen. Why oxygen form the most important factor of nourishment. We cannot live without oxygen even few minutes. So when the blood comes to the lungs, it borrows oxygen from the inspired air and carries it to the different parts of the body through the circulatory system. Again the blood when it comes to the lungs is full of carbon dioxide collected from the tissues all over the body. It is a waste product resulting from the working of the bodily machine. If this gas is allowed to remain in the system, it would poison the body. Hence it has to be got rid of. The inspired air is poorer in carbon dioxide. Hence it is willing to borrow the same from the blood and take it away with expiration.

We now understand why we breathe. We breathe in order to absorb oxygen and to throw away carbon dioxide, both the processes being absolutely essential for the life of a human being.

The venous blood when it absorbs oxygen and gets rid of carbon dioxide, is said to be arterialized. Venous blood is first collected in the heart and hence is pushed into the lungs. There it is arterialized and again sent back to the heart to be distributed to the different parts of the body and to be returned again to the heart as venus blood.[8]

The venous blood is purple because of carbon dioxide and the arterialized blood is bright scarlet because of its oxygen. This can be proved by experimentation. If a quantity of the venous blood is put into a bottle containing oxygen and shaken, it will turn bright scarlet. On the contrary if the arterial blood is put into a bottle containing carbon dioxide and shaken, it will turn purple.

We undertook to revert to the nervous mechanism of respiration at the end of this chapter. What we now want to say in that connection is this:

The quantity of oxygen and carbon dioxide and especially of the latter present in the blood, has been discovered to have great influence upon the respiratory centre. If the quantity of carbon dioxide present in the blood goes beyond its normal measure, the respiratory centre at once becomes more active and respirations become rapid. This is best seen when a man is taking hard muscular exercise. On the contrary the centre is calmed down if the quantity of carbon dioxide present in the blood falls below its normal measure with the result that respiration becomes slower than usual. Although the most important factor in the regulation of respiration is the quantity of carbon dioxide in the blood passing through the respiratory centre, the impulses reaching this centre from the

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8. For details of the circulatory system, readers are referred to our note on that system given in *Yoga-Mīṃāṃsa,* Vol. I. It appears there under the heading "A Few Facts About the Blood and Blood Circulation".

carotid body, the carotid sinus and the sinus nerve are also responsible for changing the activity of the respoiratory centre. For understanding the effects of these impulses, read Jālandharabandha (Chapter II).

CHAPTER II

ĀSANAS APPROPRIATE TO PRĀṆĀYĀMA

(Note -- Two Dṛṣṭis and three Bandhas are a part of the technique of the meditative poses. We begin this chapter with a description of these Dṛṣṭis and Bandhas, with a view to enable our readers to follow the technique of the Āsanas without any interruption.)

NĀSĀGRA-DṚṢṬI OR THE NASAL GAZE

FIXING one's eyes upon one's tip of the nose is called Nāsāgra Dṛṣṭi in Sanskrit. Nāsāgra means the tip of the *nose* and Dṛṣṭi means gaze. It is illustrated in Fig.8. It may be practised as a part of Padmāsana[1] or independent of it. In the accompanying picture, the head is thrown back a little with a view to make the position of the eyeballs visible.

The Nasal Gaze is a fine exercise for the wandering mind. Its practice if undertaken with zest and carried over a period of some months continuously, has a perceptibly beneficial effect on the unsteady mind.

Caution -- The Nasal Gaze directly works upon the brain through the optic nerves. Everybody should, therefore, develop this gaze very slowly and cautiously. Persons with weak nerves are warned not to undertake this practice except under supervision.

BHRŪMADHYA-DṚṢṬI OR THE FRONTAL GAZE

Fixing one's eyes between the eyebrows is called Bhrūmadhya-Dṛṣṭi in Sanskrit. Bhrūmadhya means the *space between the*

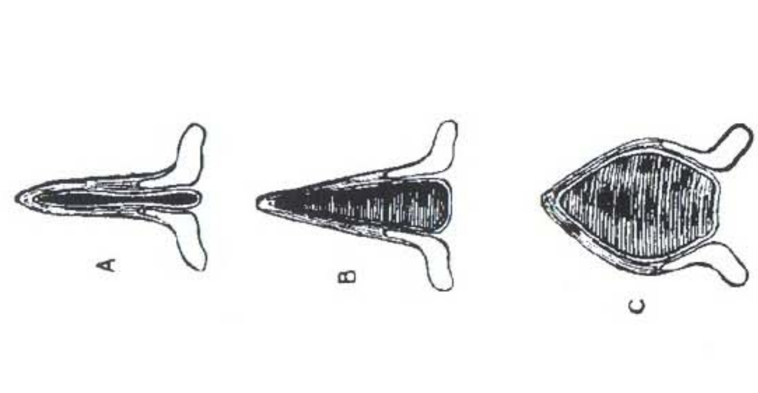

FIg. 4. - The Vocal Cords.

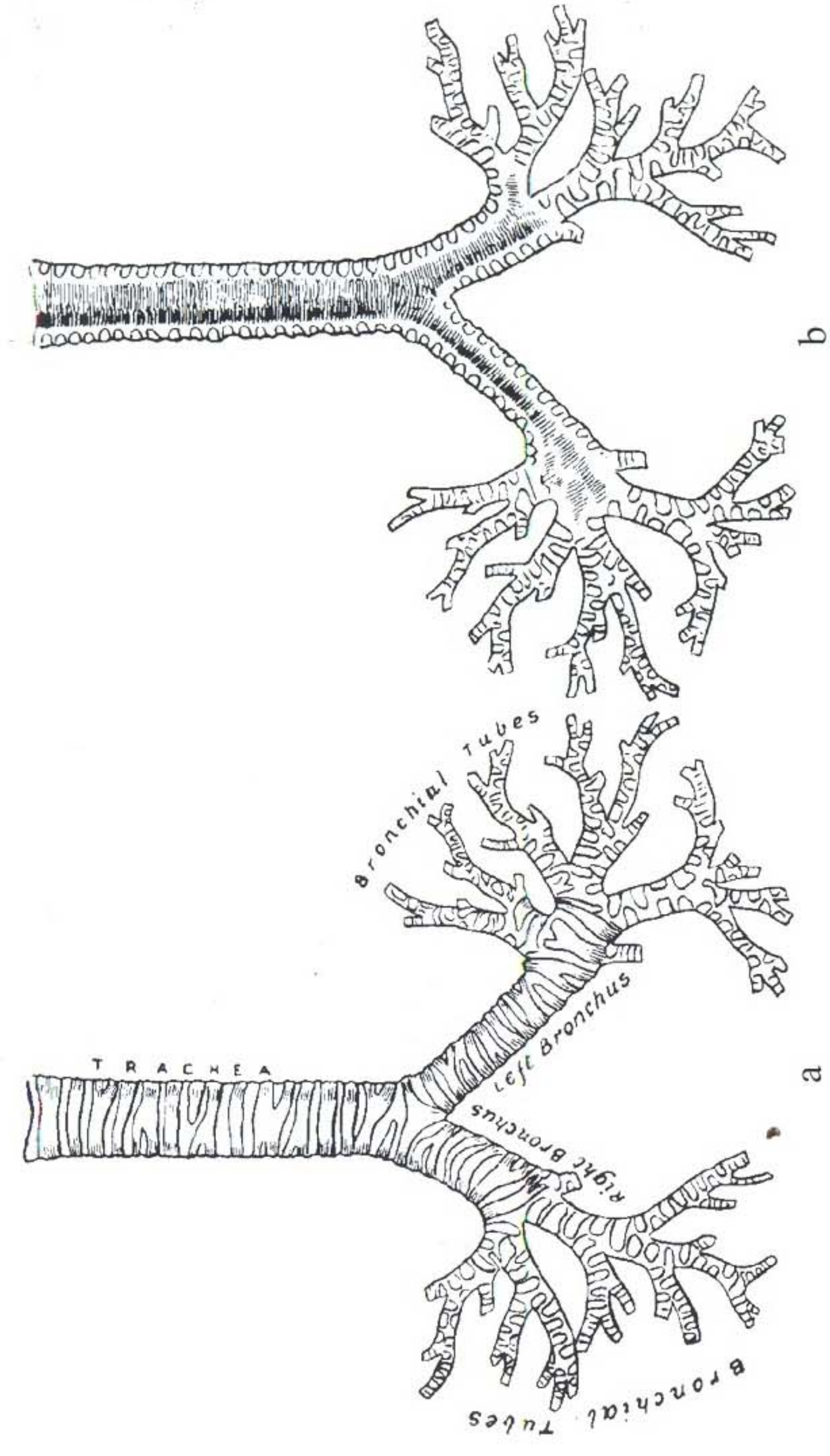

FIg. 5. - The Trachea and the Bronchial Tubes.

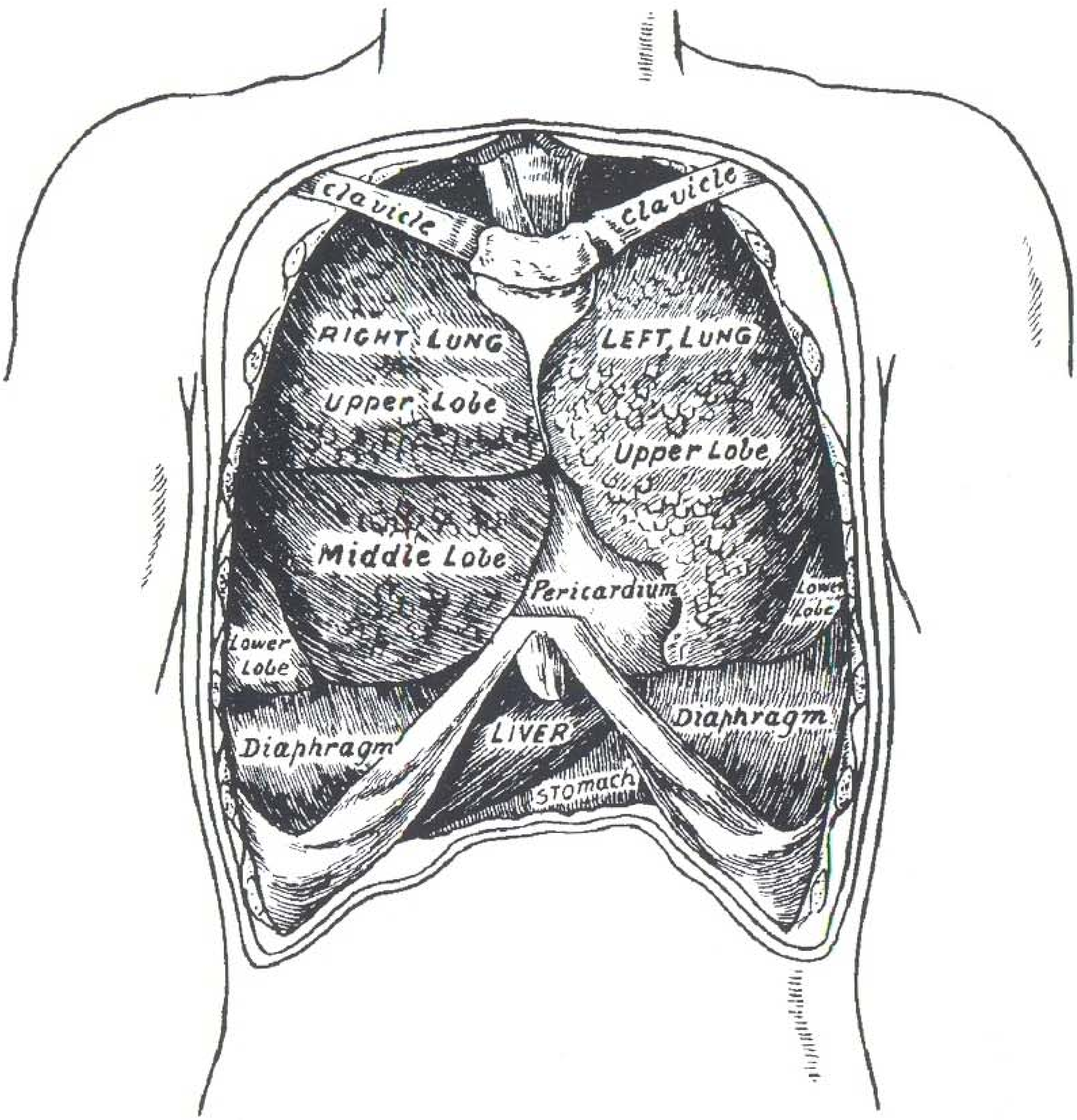

FIg. 6. - The Thorax Exposed.

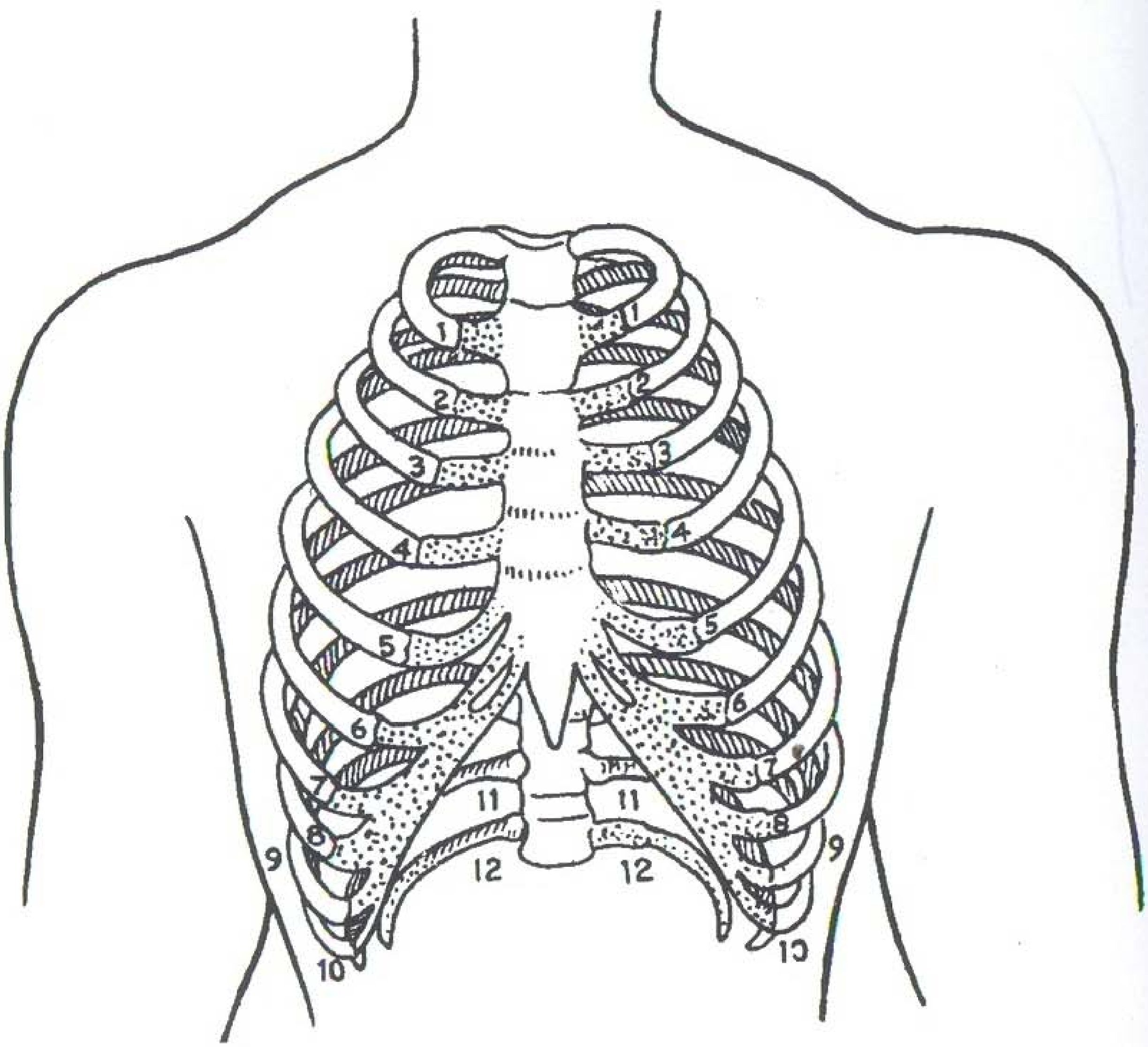

FIg. 7. - The Ribs.
(The Cartilages have been marked with dots)

FIg. 8.
Nāsāgra Dṛṣṭi
or the Nasal Gaze.

FIg. 9.
Bhrūmadhya Dṛṣṭi
or the Frontal Gaze