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The Diaphragm and its Functions

THE

DIAPHRAGM

AND ITS FUNCTIONS,

Considered Specially in its Relations to Respiration and the Production of Voice.

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THE DIAPHRAGM.

INTRODUCTORY.

The vast majority of the human race live and die in absolute ignorance of the fact that there is such an organ as the diaphragm—one of the most important structures of the human body. A certain very small proportion of the race are aware of the existence of such a structure, but that is the limit of their information in regard to the diaphragm.

It is charitable to suppose that every medical man, most naturalists, and men of science generally, have some idea of its anatomy and physiology. If the proportion of these professional men who have only a *fair* knowledge of the subject could be shown, the fractional exhibit would be very deplorable. We venture to make the statement that not over one medical practitioner in ten in the United States has a fair idea of the diaphragm and its functions, and that only a small number out of this tenth part have a comprehen-

sive grasp of the subject, or are thoroughly impressed with its importance.

The aggregate importance of the subject discussed in this essay is immense, and can hardly be over-estimated. The whole civilized world is in bondage to a pernicious habit of dress—practiced by its women and countenanced by its men—that threatens the abrogation of the diaphragm. It is pretty well proven that an animal is formed, grows and progresses upward or downward in the scale of animal existence, in strict sequence to the conditions that may environ it. In view of this fact, would it appear too far drawn and absurd to declare that it promises to take but a comparatively small segment of the evolutionary cycle of time, with persistent corset-wearing and consequent development of clavicular breathing, to bring about in mankind a chronic hereditary atrophy of the diaphragm, the debasement of that organ to one of a rudimentary form, and also the change of the God-like, Venus-de-Milo, Apollo-Belvidere form of humanity into the similitude of a pouter pigeon? But we cannot bring ourselves to believe that man will make a retrograde step and become an inferior animal. The possession of a highly developed diaphragm is a principal feature in the highly organized animal. Its possession gives to man great respiratory and vocal facilities which

would be lost with the abolition of the organ. A millennial period will come, and before its advent the corset must go.

The subject-matter under discussion may, perhaps, be treated most systematically under three headings:—

1. The Anatomical or Structural Division of the Subject.

Under this head may be considered:—Its location—General shape—Gross composite parts of the structure—Its origin—Its openings—Its tendon and muscular fibres—Its minute anatomy—Its blood-supply—Its lymphatic and nervous supply—Its relations—Its embryology and history of development—Its comparative anatomy and its important coöperative structures.

2. The Physiological or Functional Division, showing its Action and Uses.

We may study under this division:—The function of respiration generally—The movements of respiration—The varieties of respiration—The action of the respiratory muscles—Respiratory action and change of shape in the diaphragm—Respiratory rhythm of the diaphragm—Control of the diaphragm's action—Incidental functions of the diaphragm—Change of shape in the trunk

during respiration — Differences in male and female breathing — Certain natural phenomena that occur synchronously with the action of the diaphragm—Relation of the circulation of the blood to the action of the diaphragm—Actions of the diaphragm resulting from extraordinary causes—The comparative physiology of the diaphragm, and functional development of the organ.

3. Hygienic or Practical Considerations.

Among the conclusions and discussions classified under this heading, may be considered:—The diseased conditions to which the diaphragm is subject—The conditions essential to its nurture and healthy action—Corset and waist constriction—Special exercise of the diaphragm—How to breathe, etc.

THE ANATOMY OF THE DIAPHRAGM.

Definition and Position.

The diaphragm is a musculo-tendinous septum or partition separating the thoracic or chest-cavities from the abdominal cavity. It is the floor of the former and the roof of the latter. The word "diaphragm" is from the Greek, and signifies a dividing wall or a closing or cutting off from. The laity frequently call the organ the *midriff*, the term having grown out of the old Saxon word *midhrife* (*mid*, "middle," and *hrife*, "the belly"). It is a flat, thin, extended structure, composed of muscles and fibrous tendon enclosed between two serous membranes. It is placed somewhat obliquely at the junction of the upper and middle third of the trunk, or, in a general way, at the lower free border of the ribs. This position, however, is somewhat inconstant, as it is altered during the different stages of respiration, and by the state of distention of the abdominal viscera or organs.

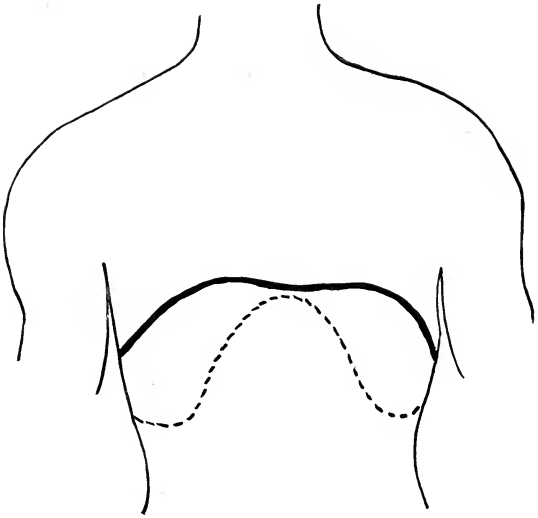


FIG. I.

Fig. I represents an outline of a lateral section of the upper part of the trunk. The extreme superior curvature of the diaphragm is represented by the irregularly convex heavy line crossing the body below the armpits. The dotted line represents the anterior and antero-lateral margins of the diaphragm, following the border of the costal cartilages. The position given is that of the diaphragm during its relaxed state.

General Shape.

The diaphragm is an irregularly shaped dome with its convexity directed upward into the thorax or chest, while into its concavity, which is directed downward, various of the abdominal organs are projected, as will be better explained further along. This irregular dome has two prominent highest points, each of which gains its eminence at the middle of the base of each chest-cavity. The curved eminence on the right side is one or two ribs higher than on the left side, a fact due to the protrusion of the liver upward into its concavity.

The circumferential outline of the diaphragm is generally elliptical in shape, its longest diameter being from side to side. Its posterior border is somewhat truncated or cut off, while from the centre of this truncated border are projected two tail-like muscles (the crura) that extend several inches down the vertebral column. This projection is nearly vertically inclined, and is joined at almost right angles to the more horizontally situated and broad elliptical portion of the structure. On this account some anatomists describe the diaphragm as two distinct muscles. The shape of the diaphragm is sometimes spoken of as representing a fan in its outlines, the crura representing the fan-handle.

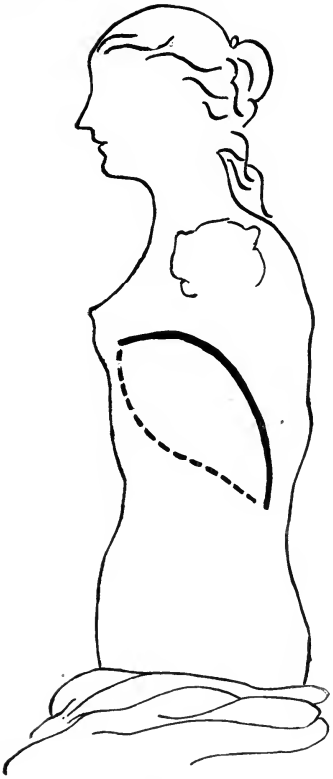


FIG. II.

FIG. II.

Fig. II represents an outline of an antero-posterior section of the trunk. The heavy, somewhat diagonally placed curved line represents the upper antero-posterior curvature of the diaphragm in the median line. The dotted line represents the lateral borders or origin of the organ. This is also the position of the diaphragm during relaxation.

To those who are familiar with its shape, and that of the dorsal surface of the common king-crab of our seacoasts, the resemblance to that crustacean will also be obvious. The antero-lateral borders are markedly indented in a saw-tooth manner, while the posterior border is also so characterized, though it has larger curved indentations. These peculiar features are due to the manner of its attachment at its peripheral origin.

Composite Parts of the Structure. (*Macroscopic or Gross Appearances.*)

From a mechanical point of view the diaphragm is an example of a convex ellipsoidal muscle. It is mainly composed of fleshy, muscular fibres arising from its circumferential border, which run inwardly to a large, flat, central tendon, curving or arching upward through their course.

This central tendon, or cordiform tendon, as it is sometimes called on account of the resemblance of its outline to that of the heart, is with

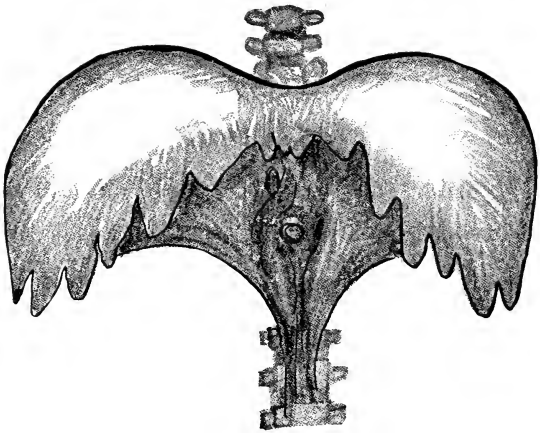


FIG. III.

Fig. III represents the irregular dome shape of the diaphragm as it is in the body during its relaxed state; the digitations of the anterior border are those which correspond with digitations of the transverse abdominal muscle. The crura running down upon the anterior surface of the vertebral column, and the aortic and œsophageal openings are also indicated.

more correctness described as being three-lobed or like the leaf of the trefoil, the common hepatica triloba of our woodlands. Clover-leaf shape would also describe it. Its three leaflets, lobes, alæ, or divisions, are separated from each other by slight indentations. The right leaflet, located at the centre of the base of the right chest-cavity, is the largest; the left leaflet is the smallest, and the middle leaflet, the one posterior to the ensiform cartilage, is between the others in size. The tendon is a fixed point, in which the muscular fibres of the diaphragm are inserted by a gradual blending of their substance.

Origin of the Diaphragm.

The muscular fibres arise from the whole circumference of the lower part of the thorax or chest, that is to say, commencing in front. (1.) From the ensiform cartilage. (2.) From the inside border of the cartilages and bony portions of the six or seven lower ribs, by as many digitations or pointed processes which correspond with the digitations of the transverse muscle of the abdomen. (3.) At the rear of the chest between the last rib and the spine, it arises from two thin, ligamentous arches known as the external and internal arched ligaments, which are thrown over the quadratus

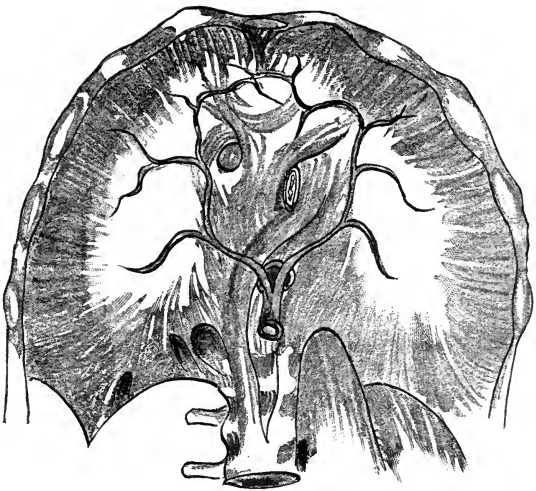


FIG. IV.

Fig. IV is a representation of the diaphragm, looking from below upward. The horseshoe-shaped border is formed by the costal cartilages. The vertebral column is shown with the crura running upward and forward from its vertebræ. The arched ligaments are shown on either side. The aortic opening has the aorta passing through it, which gives off the phrenic arteries that are represented as being distributed to the lower surface of the diaphragm, the branches being seen coursing over the central tendon. The openings for the œsophagus and vena cava are shown, and the peculiar crossings and curvings of the muscular and tendinous fibres are also represented.

lumborum and psoas muscles. (4, and last.) From the front of the lumbar vertebræ.

Muscular Fibres.

The muscular fibres start closely from the attachment of the organ, but they vary in length at different parts of the structure. Those proceeding from the ensiform cartilage are the shortest, and are sometimes replaced by an extension of the middle leaflet of the tendon. At the sides of the ensiform cartilage the fibres are wanting, the interval being occupied by a thin layer of connective tissue lying between the two serous membranes that cover the superior and inferior surfaces of the diaphragm. This construction forms a weak point, where protrusion of the abdominal organs may occur. This accident would be known as a phrenic hernia. Pus, the result of inflammatory processes in the mediastinal septum or partition dividing the two chest-cavities, may also find its way through these weak spots. The muscular fibres gradually lengthen toward the posterior part of the thorax, being longest in the crura in front of the vertebral column. The fibres mostly run directly toward the centres of the leaflets to which they are attached, describing upward curves through their course. The most marked exception to this disposition of the fibres is to be found in the

crura, where the inner fibres, after passing the aortic opening, cross each other like the figure X, and then, running farther forward, curl around and encircle the œsophagus on either side, while the other fibres from the crura diverge in fan shape as they pass upward and forward into the central leaflet of the tendon.

The Crura, or Pillars of the Diaphragm.

These are two fasciculi, or bundles of muscular fibres that connect the diaphragm to the spinal column. The origin of these crura is composed of tendinous fibres. The right crus, which is the largest and longest, arises from the anterior surfaces of the bodies, and inter-vertebral substances of the second, third and fourth lumbar vertebræ, while the left crus arises from the second and third vertebræ only. The tendons of the crura run upward and forward around the aorta, forming a tendinous arch around it. In fact these tendinous fibres form a nearly complete ring around the great artery. As the muscular bundles run forward, their outer fibres spread into fan shape, being directed into the central tendon, while the inner fibres decussate or cross one another between the aortic and œsophageal openings. Thus it will be seen that at the side of the latter opening, the fibres of the right crus are found on its left side,

and the fibres of the left crus are found on its right side.

Openings of the Diaphragm.

There are three principal, and several smaller openings or foraminæ passing through or connected with the diaphragm. The *aortic foramen* (hiatus aorticus) is most posterior and lowest, lying between the crura close to the spine in the median line, and is therefore behind the diaphragm altogether. Its walls are composed of the front of the bodies of the vertebræ and a tendinous arch thrown across in front of the aorta from one crus to the other. This opening passes the aorta, the vena azygos major, the thoracic duct, and occasionally the left sympathetic nerve.

The *œsophageal opening* is a little forward and somewhat to the left of the aortic opening. It is almost in the centre of the diaphragm. This opening is elliptical in form, and its walls are almost entirely made up of the muscular fibres of the crura which embrace it, though in rare cases its anterior margin is tendinous. It passes the œsophagus, and pneumogastric nerves.

The *foramen quadratum*, or opening for the vena cava, is the other important large opening in the diaphragm. It is farther forward than the others, being in the central tendon, and at the junction of

the middle and right leaflets or wings. As its name denotes, it is somewhat quadrilateral in form. It is bounded by four fasciculi or bundles of tendinous fibres, which run parallel with its four sides. The vena cava passing through it is intimately connected with its margin, and thus the vein is kept permanently open. The connection of the margins of these openings to the organs that pass through them must be noted, as it has a restricting effect upon the motions of the diaphragm, which will be noticed in the physiological division of the subject.

Besides these larger openings, there are smaller openings through the crura which pass the greater and lesser splanchnic and sympathetic nerves on both sides, and the vena azygos minor vein on the left side. Frequently the vena azygos major passes through the right crus.

The Ligamenta Arcuata Externum and Internum.

These are the two thin, tendinous arches thrown over the psoas and quadratus lumborum muscles. They are merely the sheaths of those muscles thickened, and are points from which arises a part of the border of the diaphragm. The *internum* arches over the psoas from the body of the first lumbar vertebra to its transverse process; while

the *externum* arches over the quadratus from the same transverse process to the last rib.

Histology, or Minute Anatomy.

The muscles of the diaphragm are composed of striped muscular fibres of the voluntary variety, though it may be possible that some involuntary muscular fibres may be scattered through the organ as they are in the heart. Owing to the directions in which the fibres of the tendon cross each other, that semi-translucent membrane presents a beautiful, glistening appearance. The fibres are arranged in several planes, which intersect one another at various angles, and unite into various curved and straight bundles.

Blood-Supply of the Diaphragm.

This is derived from the two phrenic and branches of the internal mammary and lower intercostal arteries.

The *phrenic arteries*, or inferior phrenic arteries, as they are sometimes called, arise from the abdominal aorta on a level with the under surface of the diaphragm. Sometimes they arise as two separate vessels from the parent trunk, but much more frequently they arise as one trunk, or come from the cœliac axis, or one may come from the renal arteries. They diverge as they enter the

border of the diaphragm, running over the crura, and are directed forward, upward and outward. The left artery passes behind the œsophageal opening and runs forward at its left side. The right vessel passes back of the aperture for the inferior vena cava, and ascends to the right side of that opening. As the vessels reach the central tendon they divide into two branches. The internal branch runs forward, supplying the diaphragm, and communicating with its mate of the other side and with the arterial twigs of the musculo-phrenic, a branch of the internal mammary artery, while the other branches diverge outwardly, and, traversing the lateral borders of the diaphragm, terminate in the branches of the intercostal arteries.

On the upper surface the diaphragm is supplied as follows: The *superior phrenic* or *comes nervi phrenici* is a long, slender branch of the internal mammary artery. It arises high in the chest and descends along the costal cartilages in company with the phrenic nerves to the diaphragm, in which it is distributed, communicating with the branches of the musculo-phrenic and the inferior phrenic arteries. The musculo-phrenic, another branch of the internal mammary artery, pierces the diaphragm at the eighth or ninth rib, and sends branches backward into the organ. Twigs of the lower intercostal arteries also run into the dia-

phragm, communicating with branches of the other arteries that furnish its blood-supply.

The *veins* of the diaphragm follow the course of the arteries. The two *inferior phrenic veins* empty into the inferior vena cava, though sometimes the left vein terminates in the left renal vein. The right *superior phrenic vein* ends at the junction of the two vena innominata. The *left superior vein* terminates in the left internal mammary or left superior intercostal, both having accompanied the phrenic nerve and superior phrenic artery.

The Lymphatics of the Diaphragm

are situated along the course of the blood-vessels. Some terminate behind in the hepatic and intercostal lymphatics, while those in front communicate with the anterior mediastinal and internal mammary glands.

The Nerves of the Diaphragm.

The diaphragm receives its nervous supply from the phrenic nerves, and from branches of the sympathetic nerve. The *phrenic nerve* (Bell's internal respiratory) originates from the third and fourth cervical nerves. It passes down the chest on the side of the pericardium, and in front of the root of the lung. The left nerve is the longest on account of having to wind around the obliquity of

the pericardium on that side, and because the diaphragm is lowest on the left side.

As the nerves approach the upper surface of the diaphragm, they separate into branches, which perforate the diaphragm and are distributed to its under surface.

The *phrenic* or *diaphragmatic plexus of the sympathetic* arises from the semilunar ganglion of the solar plexus. It accompanies the phrenic artery, giving off filaments to the diaphragm on the right side which communicate with one or two filaments of the phrenic nerve, a small ganglion being present. On the left side there is a like nervous connection, but without the appearance of a ganglion.

Relations of the Diaphragm.

As the posterior and lateral border ascends anteriorly, it is for some distance in close apposition with the ribs, the edge of the lungs not coming entirely down to its attached border. The superior surface of the diaphragm is lined by the serous membranes known as the right and left diaphragmatic pleuræ, and the pericardium. The antero-posterior arch of the diaphragm in the median line, is closely connected with the structures composing the mediastinal septum or partition; that is to say, with the organs that pass through the diaphragmatic openings, and especially

is it attached to the fibrous layers of the pericardium. These fibres blend with the central tendon, as well as with the fasciæ covering the muscular fibres of the diaphragm.

The inferior surface of the diaphragm is lined by the peritoneum, the serous membrane lining the abdominal cavity, and has in close apposition with it the convex, smooth upper surface of the liver, the stomach, the spleen, the pancreas and the kidneys. The close relationship of that important part of the nervous system, the solar plexus, is also to be noted, lying, as it does, immediately below the level of the diaphragm near the bodies of the crura.

Embryology and History of Development.

At an early age of fœtal development, the thorax and abdominal cavities are not divided from each other, being in the form of one continuous cavity, but shortly after the formation of the sternum and beginning of the budding of the lungs from the front of the œsophagus, the diaphragm commences to show itself. This time is at about the first week of the third month of fœtal life. The first appearance is that of a small lip or projection thrown out at the level of the base of the lungs. This projection gradually extends all around the circumference of the chest and grows inward from the

sides until the tissues meet from all sides and are fused together. Blood-vessels and nerves extend into the organ, and the muscles and other parts are gradually evolved. At birth the organ is still quite undeveloped, and its action is restricted and imperfect for a number of days, as the new-born infant has but little need of air.

It may be said that the diaphragm does not reach its full development until full maturity of the individual is reached, and it has been subjected to such exercise as will develop its full functional capacities.

Comparative Anatomy.

The diaphragm is an organ which, in its highly developed state, is peculiar to the class of animals known as mammals or milk-givers. Among this class is included such creatures as the monkey, dog, bear, hog, sheep, horse, tapir, elephant, sloth, ant-eater, bat, mole, hare, rat and kangaroo among the land animals; while the whale, porpoise, seal, and those curious *cetaceans*, the sea-cow and dugong, represent most of the aquatic animals that are furnished with a fully formed diaphragm.

The diaphragm is most muscular, longest, and most obliquely placed in the *cetacea*, where the central tendon is almost obsolete, and where the organ, by rising far back, permits a proportional

extension of the lungs, which in the dugong and manatee act as air-bladders.

The most striking difference to be noticed between the human diaphragm and that of the inferior mammalia, is that of shape. Man is the only mammal whose diaphragm has the antero-posterior diameter shorter than the transverse diameter. In the other examples the antero-posterior diameter is the longest.

Another difference that may be noted, is in the comparative strength of the organ. In some weak animals, as, for example, in the domestic sheep, the structure is thin and deficient in strength; while in others, as in the whale, the great strength of the organ is a notable feature. In the whale the diaphragm not only has to suffice for the ordinary work of drawing in a large air-supply through a small spout-hole, but is constructed to withstand the effect of the enormous pressures of the deep waters into which the creature descends.

But when we leave the class mammalia, and take a step downward among the *vertebrates*, and examine the birds, we find that the diaphragm is either wanting entirely, or is only partially developed. An exception to this rule is found in some of the larger birds, as in the *struthionidæ*, or ostrich family, where the diaphragm is more complete, resembling that of the mammalia, although air

passes into the pleural cavity, and respiration is not as complete as in the mammals.

In some birds a rudimentary diaphragm runs partly across the base of the lungs from the vertebral surface, and helps to extend the lungs during respiration. In birds, as a rule, the air-cavities of the pulmonary cells communicate through perforations on the lung surface, with air-cavities in the thorax, abdomen, neck, and even bones, and the large development of the breastbone, along with other peculiarities of construction, allows of a method of breathing which makes a diaphragm an unnecessary organ.

When we examine the reptiles, we find the lungs, one only of which may be developed, extended for a great length along the vertebral column, and the ribs alone are the structures provided for carrying out the mechanism of respiratory motion. The crocodile has some indications of a diaphragm, but in the inferior genera, the organ is entirely wanting. In some animals, as, for example, the common frog in its complete stage, the muscles of the floor of the mouth and throat are substituted for the diaphragm and other parts of the respiratory apparatus of man. Further down the scale of organized life, we find that with the disappearance of lungs, even a substitute for the diaphragm is wanting.

Fishes aërify their circulating fluid through their gills or branchiæ, while insects, which require much aërification of their blood, have the air carried directly to all parts of their bodies by a great number of curiously arranged tubes or tracheæ.

Important Structures that Co-operate with the Diaphragm.

In a certain sense, the diaphragm may be considered as the foundational flooring of the mechanism which fulfils, among other purposes, the great functions of respiration and vocalization. The principal parts of this structure are the diaphragm, thorax, lungs, trachea, larynx, and the oral and nasal cavities. The real foundation, which supports these structures, is the bony frame of the body. The organs mentioned which are situated lowest, gain their support from the upper two-thirds of the vertebral column, while the upper part of the apparatus finds its base of support in the bones of the skull that environ the nose, mouth and pharynx.

Let us first consider the thorax. This is a somewhat pyramidal cylinder, flattened anteroposteriorly. It has the spine at the back and the sternum or breastbone in front. These two parts are united by those bony bows, the ribs, which are attached to the spine by fibrous joints which

allow of a free motion of the ribs to the extent of a partial revolution around their points of attachment. The elastic cartilages that join the ribs to the sternum in front, do not materially interfere with their motion, though, by their elastic recoil, they help the ribs to regain the position which they take during respiratory repose. The ribs are not extended outward at right angles from the spine, but their bows ordinarily droop downward, and may be carried still farther down by forced expiratory efforts, and only assume an approximately horizontal position during a forced inspiratory effort.

Connecting the top of the breastbone with the shoulder-joints are the collar-bones or clavicles, of no particular importance to the subject under discussion, except as giving a name to the particular method of breathing with the upper part of the chest, known as clavicular breathing.

The small first or top rib is, of all others, by reason of its shape and firm attachment, a rigid bow; while, as we descend, the ribs become more extended laterally, and are less fixedly attached to the sternum, and hence are levers allowing of greater motion.

It must be noted that the superior opening of the thorax is larger in the female than in the male, and the upper ribs are more movable, swinging

more freely on their spinal and sternal attachments.

Surrounding this bony framework thus briefly described, encasing it, and attached to it, are various layers of powerful muscles. The thorax may be said to be in more or less direct relation with almost all the muscles of the trunk and the upper portions of the extremities; for even the muscles that are not attached to its bony framework act as fixed points, and coöperate with the more directly attached muscles. It will suffice here to cite only those that are most directly concerned in the function of respiration.

Inspiratory Muscles assisting the Diaphragm.—The external intercostal muscles are the outer fibres of the muscular tissue that fills in the space between the ribs. Their fibres run obliquely downward and forward from one rib to another, crossing the fibres of the internal intercostals like the letter X.

The levatores costarum are little muscles that arise from the apices of the transverse processes of the dorsal vertebræ, and are inserted in the ribs below.

The scaleni muscles arise from the transverse processes of the half dozen lower cervical vertebræ, and are inserted in the first and second ribs.

Adjuvant Inspiratory Muscles.—The serratus

posticus superior descends from the lower cervical and upper dorsal regions to the second, third, fourth and fifth ribs. The serratus posticus inferior arises from the lumbar aponeurosis, and runs upward to the four lower ribs. The quadratus lumborum and part of the sacro-lumbalis may be also classified as adjuvant inspiratory muscles.

Muscles of Forced Inspiration.—The serratus magnus passes from the scapula to the middle of the first eight or nine ribs. The pectoralis minor passes from the coracoid process of the scapula to the front part of the third, fourth and fifth ribs. The pectoralis major runs from the humerus to the costal cartilages of the second, third, fourth, fifth and sixth ribs. That portion of the latissimus dorsi, which passes from the humerus to the last three ribs, may also be named in the list.

Expiratory Muscles.—There is some doubt as to the action of the internal intercostal muscles, but they may be placed under this heading. They join the internal borders of the ribs. The triangularis sterni arises from the lower part of the internal surface of the sternum, and is inserted by digitations into the cartilages of the second, third, fourth, fifth and sixth ribs.

Muscles of Forced Expiration.—These are mainly the superficial abdominal muscles.

We have now named the framework of the

thoracic or chest-walls. The base of the thorax is, of course, closed in by the diaphragm. The interior of the chest is divided into two cavities by the mediastinal septum, which partition is composed of the heart, great vessels, œsophagus, etc.

In each cavity hangs one of the lungs. The left lung is divided into two lobes and the right into three. These organs hang from the upper and internal part of each cavity suspended by their roots, which are composed of a bronchial tube, blood-vessels, etc. Each lung is covered, and each cavity is lined, with a smooth, lubricated, serous membrane. The lungs are made up of millions of minute air-cells, many of which are grouped round an alveolus, which, in turn, communicates with a capillary bronchial tube. These tubes gradually run together and unite until they are all formed into a large bronchial tube, one of which from each lung unites and becomes the still larger tube known as the trachea. The lungs are minutely supplied with blood-vessels, etc.; but at this time we have simply to consider and describe them in their capacity as air-reservoirs.

The whole framework of the lungs, holding together the various parts, is composed mostly of an elastic tissue that readily admits of various degrees of expansibility in the organs. The capacity of the adult male lungs as an air-reservoir is

about 300 cubic inches. In the utmost state of collapse the same lungs may still hold about 50 cubic inches of air.

Leaving now the parts described, which may be called the bellows of the apparatus that is coöperative with the diaphragm, we find ourselves at the roots of the lungs, following along the air-tract into the trachea. This air-tube extends about four and a half inches upward. It is a membranous pipe, flattened at the back, and always kept open by its cartilaginous rings, which extend around its front and sides. At its upper end the trachea is continuous with the larynx, the vocal organ or main sound-producer of the apparatus under consideration.

We will merely speak of the larynx as being a complex mechanism, composed of a framework of cartilages, a muscular motor apparatus, and two fibrous projections running antero-posteriorly across its cavity, known as the vocal bands or cords. The position of these vocal bands varies at different periods of the respiratory act. They are closely approximated and parallel during the act of phonation or sound-production, while the posterior ends of the bands are widely drawn apart during a deep inspiration.

Then above the larynx we have the irregularly shaped resounding cavities,—the pharynx, mouth and nasal passages.

The whole of the parts named forms the voice and speech-apparatus, the use of which, so far as it relates to the diaphragm, will be noted in the physiological division of the subject.

However, this part of the subject must not be left without some mention being made of the *nervous supply and intercommunicating connection as a whole.*

It has been mentioned before, that the diaphragm is supplied by the phrenic nerves, and they have their rise from the third and fourth cervical nerves. The intercostal muscles are supplied by the intercostal nerves, which arise from the dorsal vertebræ. The lungs, larynx, throat and tongue are supplied by branches from the hypo-glossal, pneumogastric and glosso-pharyngeal nerves, which severally arise from nearly the same locality in the medulla oblongata.

We see here, then, a great diversity of origin; but there are a number of branches of communication between all these nerves that may be plainly traced in the neck and chest; and, furthermore, the great sympathetic nerve unites all of them by its intercommunicating branches. We cannot, as yet, say what routes and communications these nerve-tracts have in the brain and spinal cord, but undoubtedly there is a harmonious arrangement that allows of the synchronous action so plainly observed in the working of the parts of this apparatus.

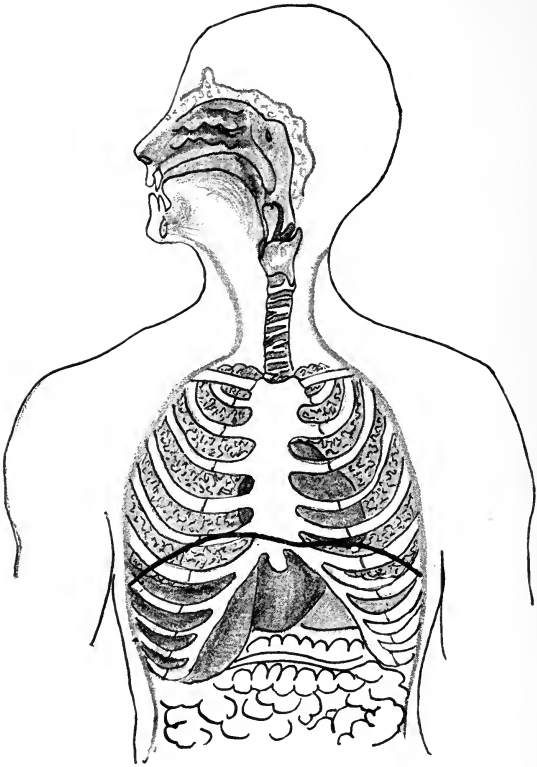


FIG. V

FIG. V.

Fig. V represents some of the important structures and organs which are in close relation with the diaphragm, or that coöperate with it in producing song and speech. The heavy curved line drawn across the lower part of the chest represents the position of the upper curvature of the diaphragm. Below it are shown the lobes of the liver, the stomach and part of the intestines. Above the diaphragm, a little to the left of the median line, the heart is represented. The lungs are seen filling the chest and communicating with the trachea, which, in turn, leads into the larynx or vocal box, and then the air-tract leads on through the pharynx, mouth and nasal cavities, the last three being the principal resounding cavities for the voice. The whole, with the diaphragm as the foundational flooring, the ribs as the framework, and the accessory muscles, which are not shown, forms the vocal and speech-mechanism.

Differences of Construction in the Male and Female Diaphragm.

These are principally those that relate to size. As the sternum is somewhat proportionally shorter in the female than in the male, the female diaphragm slopes upward most in front. In the female, the diaphragm is also slightly smaller in proportion to the size of the chest than in the male. Compensation for this deficiency is found in the larger superior opening of the female chest, and the increased mobility of the upper ribs.

THE PHYSIOLOGY OF THE DIAPHRAGM.

The writer remembers a remark once made by Professor John G. Dalton. He said that he often asked his students which was the *chief* respiratory muscle, and he added that he very frequently received incorrect answers. Of course, the correct answer to the question should be, the DIAPHRAGM. This organ is prominent above all others in the active movements which appertain to the respiratory act.

Functions of the Respiratory Apparatus.

The great respiratory act has for its principal purpose the oxygenation of the blood. This is accomplished by exposing an extended surface of blood to the oxygen-bearing element, which element may be water for the fishes and other inferior animals, or air for the higher creatures, such as the mammalia, of which man is the highest example.

As has been shown in the anatomy of the subject, the superior classes of air-breathers are furnished with lungs to accomplish this function. An immense number of capillary blood-vessels with extremely thin walls are netted around the air-cells in the lung-substance, and through the

thin walls of the air-cells and blood-vessels, gases find little difficulty in passing by means of the forces of gas-diffusion and endosmotic action.

Through the walls of these minute blood-vessels the oxygen of the air is absorbed into a loose combination with the blood, and most of the carbonic acid gas, accumulated in the blood as the result of certain chemical processes occurring in the tissues of the body, finds its way into the air-cells.

But these air-cells are located at a long distance from the outer world, and it is necessary that some mechanism should be furnished to draw fresh air into the lungs quickly, and to expel the vitiated air from them; besides, the lungs have another function to fulfil of more importance to our subject, namely, that of an air-reservoir and bellows. The purpose of this function is that of drawing in and propelling outward the column of air necessary in the production of the vocal sounds of speech and song, and in coughing, whispering, sneezing, blowing, whistling, etc.

Movements of Respiration.

The lungs are enabled to take in and expel their changing supply of air, through the formation in the thoracic cavities of a partial vacuum, alternating with a pressure that is greater than that of the atmosphere. This is brought about by

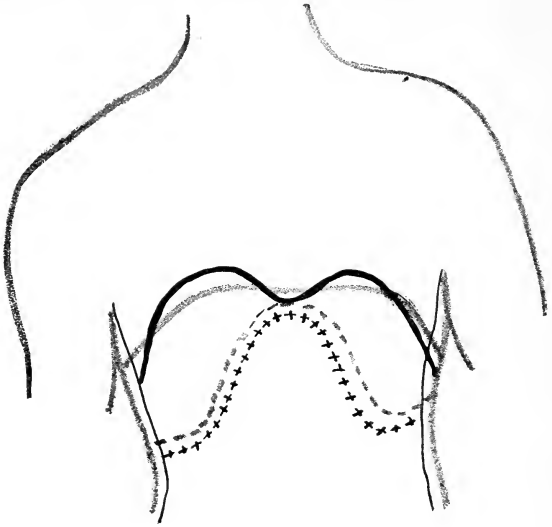


FIG. VI.

Fig. VI represents in outline the lateral cut of the upper part of the trunk. The penciled lines represent the trunk, the superior curvature of the diaphragm, and the antero-lateral borders of the organ during respiratory rest and diaphragmatic relaxation. The thin, dark lines show the change of shape made in the lateral walls of the chest during a full respiratory effort, the diaphragm contracting. It will be remembered that at the lateral curvature of the ribs, the border of the diaphragm is raised and the chest-walls are protruded laterally outward during a decided inspiration. This change of position is indicated by the starred lines. It will be also noted that the

diaphragm, in thus making a decided contraction, flattens out somewhat. The domes on either side of the median line descend, but the middle of the curvature, especially near the situation of the ensiform cartilage, and the extreme lateral borders, are somewhat elevated above the position of relaxation.

regular successive changes in the shape of the chest, which alter its capacity as a storage-reservoir for air.

In man and other mammals, the lungs, during respiratory rest, are always in a state of partial fulness; and both complete expiration and inspiration require decided muscular efforts to bring about a change in the amount of air thus present.

During *inspiration* the walls and flooring of the chest take such a shape that its interior storage-capacity is increased; and, at the same time, a partial vacuum being formed in the chest-cavities by the recession of its walls and flooring, the pulmonary surfaces are extended in all directions by the air that rushes through the air-tubes under the force of the outer atmospheric pressure.

In *expiration* the air is expelled by a compression of the lungs, which is partly due to their own elastic recoil, but more to the pressure upon them by the walls and flooring of the thorax in its return to a smaller size, and, consequently, smaller storage-capacity.

Variety in Respiratory Methods.

There are various methods of breathing designated by certain titles. The respiratory act may call into action all the motor mechanism concerned in the act, or only a part of the apparatus may be called into play; it depends altogether upon the respiratory needs of the individual.

The greater need there is for quick oxygenation, or for a large supply of air for vocal purposes, etc., the more will all parts of the respiratory apparatus be brought into use, and the quicker will be its action.

During very quiet, tranquil breathing, as in peaceful sleep, the diaphragm only may be brought into action; but with greater respiratory need, the side walls of the thorax will assist that organ in producing respiratory movements.

When the diaphragm is in use the action is called *diaphragmatic breathing*, and sometimes, though incorrectly, *abdominal breathing*.

When the lower ribs are brought into play, the act is known as *costal* or *rib-breathing*.

If the upper ribs take part, the movement is called *clavicular breathing*, so called because of the motion being prominent under the clavicles or collar-bones.

Sometimes *dorsal breathing* is mentioned. This

is when the dorsal part of the vertebral column is somewhat straightened, in which position the ribs have a better chance to act in their full capacity.

Clavicular and costal breathing are often spoken of together as *thoracic breathing*.

These various methods of breathing may be well observed in certain abnormal or diseased conditions. The clavicular type is particularly well shown in women who have constricted waists. Thoracic breathing is seen in certain cases of paralysis of the diaphragm, and in those cases where inflammation of the abdominal organs makes any motion of them or of the diaphragm exceedingly painful. On the other hand, diaphragmatic or abdominal breathing is constantly seen in males during quiet sleep, and in inflammatory states of the chest-walls, as in pleurisy.

Action of the Respiratory Muscles.

In *ordinary inspiration* the diaphragm and intercostal muscles are those that are brought into play. The diaphragm contracts, enlarging the cavity of the chest from above downward, while the contraction of the intercostals raises the ribs and increases the lateral capacity of the chest.

If *decided* respiratory effort is required, the diaphragm and intercostals contract more forcibly, and receive the aid of the levatores costarum and

scaleni muscles, which have their fixed points along the spine in the cervical or neck-region. These muscles, being attached to the upper ribs near their vertebral hinge or joint, can exercise, by a slight decrease in their length through contraction, a decided addition to the elevating motion of the ribs, particularly at the sides of the chest.

When *inspiration* is *labored or forced*, other muscles come to the aid of those already mentioned. Thus any of the muscles that can pull on or fix the points of attachment of the ordinary respiratory muscles, are contracted more or less. Among these may be mentioned the serratus posticus inferior, quadratus lumborum and sacro-lumbalis; also the shoulder-supporting muscles. Others render active aid in raising the ribs, and thus help to enlarge the chest-cavity laterally and antero-posteriorly. Those that may accomplish this purpose are the serratus posticus superior, serratus magnus, pectoralis minor, pectoralis major, portions of the latissimus dorsi, the sterno-mastoid and other neck-muscles.

Expiration, as ordinarily effected, calls no muscles into play, it being merely a relaxation of the respiratory group of muscles, and the elastic recoil of the various parts; this, together with the effect of the mere weight of the tissues, as of the falling ribs and thoracic walls, being sufficient to expel

the effete air from the lungs. This elastic recoil is amply sufficient to produce moderately loud vocal effects. The action is analogous to that of one of those squeaking toys, which are furnished with an elastic rubber-bag that may be blown up, and, when contracting, forces out the air and produces the ear-offending squeak that seems to give pleasure to the juvenile mind. It must be noted that this elastic recoil is assisted by the return to their position of the abdominal organs that have been displaced by the contraction of the diaphragm.

Forced expiration, such as is required in loud or long-prolonged tones, etc., brings into action certain other muscles. These are the triangularis sterni, the effect of whose contraction is to pull down the costal cartilages and the abdominal muscles. These latter are the principal agents used in forced expiration. By their contraction, they pull down the sternum and the middle and lower ribs, and thus lessen the antero-posterior cavity of the chest, and, by pressing on the contents of the abdomen, thrust those organs and the diaphragm up into the chest-cavity, and thus shorten its vertical diameter.

It would seem almost needless to add that a harmonious use of *all* the parts of the respiratory apparatus is the normal respiratory procedure in

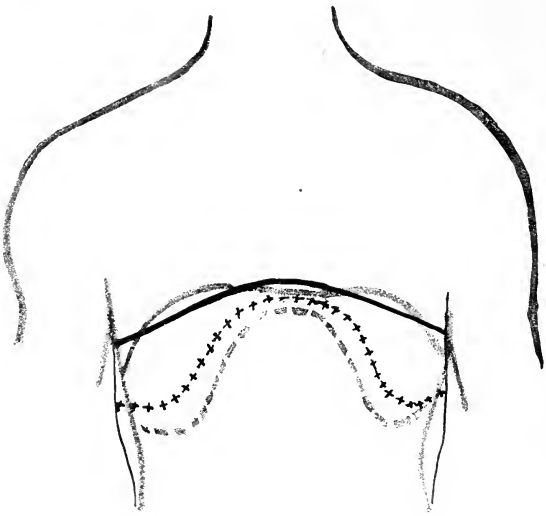


FIG. VII.

Fig. VII represents the lateral recession of the chest-walls and the elevation or passive arching of the domes of the diaphragm during forced expiration. The penciled outlines represent the chest and diaphragm during respiratory relaxation; the inked lines, the same parts during forced expiration, the domes of the diaphragm being pressed upward by the abdominal organs, which are displaced by the contraction of the abdominal muscles. It will be noted that the antero-lateral border indicated by the starred line descends, and the chest-walls recede, during this action in the parts.

mankind; multitudes of people, however, are apparently unaware of this physiological fact. The principal agent in bringing about the continuous changes of shape and capacity of the chest-cavities is the diaphragm, and this brings us to the consideration of its peculiarities of physiological action.

Respiratory Action and Change of Shape in the Diaphragm.

The writer has never happened to see what he considers a correct description of these natural phenomena. Popular descriptions declare that the diaphragm makes a descent during inspiration, and accompanying illustrations represent the antero-posterior arch of the organ as having performed an actual large descent during the inspiratory act. In most cases a descent of two or more inches is represented. This is simply physically impossible, because that part of the organ is so intimately attached to the pericardium and other tissues composing the mediastinal septum, that great motion in that part is not possible. There is some elasticity in the septum as a whole, allowing of some vertical stretching; but this is quite inconsiderable, and even less so in the complete living subject than in the cadaver or vivisected animal, where the abdomen is opened and its viscera removed, and the diaphragm is exposed to view, so that artificial action

provoked in it may be seen. It is not strictly proper to speak of the diaphragm as making a descent, because, though parts of it descend during inspiration, other parts of it may ascend. Some writers speak of its action as being a flattening of the organ, and that is more correct, but it will be more scientific to speak of the action as the *contraction* of the diaphragm.

However strictly true it may be that the *average level* of the diaphragm is lowest during its contraction, it is less so than most descriptions would lead the reader to believe. The greatest points of motion in the diaphragm during its action, are the middle of the domes in the right and left leaflets. At these points, during inspiration, there is a very considerable descent, the amount of which is entirely regulated by the strength of the nervous influence directed into the organ from the nerve-centres, and the degree of muscular contractility that may follow.

In very tranquil breathing, the centres of the leaflets may only descend a small fraction of an inch, while, during forced action, the descent may be two inches or more.

During forced expiration, the whole concavity of the diaphragm may be lifted above the normal level that is usual to it during its moments of relaxation. This elevating process is brought about by the

pressure of the abdominal muscles forcing up the liver, stomach, etc., against the concave surface of the diaphragm.

During ordinary inspiration, when the thoracic walls act in harmonious unison with the diaphragm, and the lower ribs are lifted, and the ensiform cartilage is advanced a little forward and raised upward, the anterior and lateral borders of the diaphragm are slightly elevated, descending again during expiration to the ordinary level, or being carried even lower during forced expiration.

During mild inspiratory efforts, the diaphragm still maintains a moderate curvature in all its parts, but during forced inspiration this curvature is so much flattened out, that a lateral section through the centre of the chest would show the organ inclining in almost straight, though gentle pitches, from the sides of the chest to the mediastinal septum. The crural surface also becomes straightened.

The significance of the large number of muscular fibres in the crura is difficult to explain, unless they act antagonistically to the rest of the organ, preventing too sudden and great strain on the posterior attachments and the spine.

Respiratory Rhythm of the Diaphragm.

The rapidity with which the diaphragm contracts, depends upon numerous conditions. Other things

being equal, the more forcible and thorough the contraction, the less frequently it will need to act. The age of the individual has an effect. In the adult it usually contracts from seventeen to twenty times a minute, while in the infant it may perform forty or more contractions in the same time. The amount of general muscular exertion put forth, the emotions experienced, the stage of digestion, etc.,—all have some influence in controling its rapidity as well as depth of action. Ordinarily, its contractions and relaxations follow each other in regular order, with a slight pause between. The contraction commences quickly and gradually ceases, and the relaxation also commences quickly and gradually decreases its rate of progress. The contraction takes a little longer than the relaxation, and the greater pause is after relaxation. The regularity of the rhythm is altered in all those incidental functions which the diaphragm is often called upon to exert.

Control of the Diaphragm's Action.

The muscular fibres of the diaphragm are of the voluntary variety, and man can exercise a voluntary control of the actions of the organ to a certain degree, but this control has its limits.

Ordinarily, the diaphragm acts without conscious volition, the nerve-centres, from which originates

the nervous impulse that causes the muscular fibre to contract, being influenced either by the amount of carbonic acid gas in the blood, or else by a deficiency of free oxygen.

From whichever cause it may be, just as soon as the excess or deficiency occurs, the nerve centre is stimulated into its functional action, and there results a contraction of the diaphragm. This impulse, after a few seconds of respiratory rest, becomes irresistible and entirely beyond the control of the will. As we have seen, this respiratory condition or need occurs some seventeen times per minute.

By an extraordinary effort of the will, we may delay the action of the diaphragm for some seconds, but then the respiratory impulse becomes uncontrolable, though long-continued training, as practiced, for instance, among the pearl-divers, may enable one to restrain the respiratory action for a minute or more.

We also can only accelerate the diaphragm's rate of action to a certain extent, for here again, after a few respirations, the disturbances in the relative proportions of the oxygen and carbonic acid gas in the blood brings about a cessation of action in the nerve-centres, and the contractions of the diaphragm cease.

With too rapid respiration the blood gets too

much charged with oxygen, and the carbonic acid gas does not escape with its usual rapidity; and an excess of either or both of these gases in the blood acts as an anæsthetic upon the nerve-centres.

Every observer will have noticed how an individual becomes red or even blue in the face after unusual efforts in singing, shouting, etc. The phrase, "shouting until one is black and blue in the face," is well known to all. This change of color is due to a change in the color of the blood, as well as from the effect of the peculiar condition of the blood itself acting upon the nerve-centres that control the supply of the facial blood-vessels.

Incidental Functions of the Diaphragm.

Next to the function of respiration, the diaphragm's most important use is in furnishing and regulating the necessary supply of air, forced through the vocal and speech-organs, in forming *speech* and *song*.

During vocalization, the regular rhythm of the organ is interfered with, and its action is synchronous with the vocal and speech-effects. Its contractions are more decided as a larger supply of air is taken into the lungs, though at less frequent and regular intervals; and its relaxations are more gradual and less smooth than in the ordinary

respiratory rhythm. The quickness of the contraction depends upon the time that can be afforded during the pauses of vocalization, and the relaxation is quick in proportion to the loudness and power of the tone produced.

During speech, the contraction, though quite rapid, is smoothly regular in its action, while the relaxation may be intermittent or jerky, if the exigencies of the tones and effects desired so require. The speaker, as a rule, when talking uninterruptedly, takes every occasion to contract the diaphragm, and this action, in conjunction with that of the other parts of the respiratory apparatus, gives a new, if small, addition to the supply of air held in reserve in the lungs.

The hesitation and uncertainty experienced by the stammerer and stutterer in sending forth well-coördinated nervous impulses from the brain-centres, is apt to be also experienced in the action of the diaphragm, the organ working in a certain unity with the whole speech-mechanism, and taking part in any defective action of the whole apparatus.

In *speaking*, as a rule, the diaphragm does not get so thoroughly relaxed as in *singing*, where the sustaining of a tone often not only requires all the air that can be forced from the lungs by the relaxation of the thoracic walls and flooring, but also requires the utmost coöperative efforts on the part

of the abdominal muscles in pressing the diaphragm above the level that is usual to it in relaxation.

In singing, also, more air is taken into the lungs at each inspiration than in speaking, and hence the contraction of the diaphragm during singing has to be done very quickly and completely. Preparatory to extraordinary loud and long-prolonged tones, the organ is contracted to its utmost extent, and is then most approximately flattened out into a plane. In singing, the nervous control over the diaphragm during expiration has to be developed to the highest degree.

The nerve-centres in the brain are trained to send out just the amount of nervous influence necessary to hold the organ in the desired degree of tension — the supply being smoothly flowing, or gradually increasing or decreasing, or in abruptly intermittent waves, as may be needed. During sudden relaxation of the organ, as in deeply exhausted states, there is a quick and complete cessation of the nervous influence that holds the organ in a contracted state.

The increase or cessation of the controling emission of nerve-force has to be graduated in proportion to the amount of air that is needed to produce tones of varying force, pitch, length and abruptness. In long, smooth, evenly-sustained

legato tones the diaphragm relaxes at a uniformly continuous rate of speed; while in abrupt staccato tones the relaxation occurs in an intermittent series of jerks, proportioned in length and abruptness to the length of the notes produced. The suddenness of their termination is also helped by the action of the larynx and by closure of the lips and contraction of the soft-palate.

The diaphragm and abdominal muscles act together in producing the expiratory blast that is used to produce the extraordinary loud sounds of song and speech. In doing this, the diaphragm relaxes, but is held back in a certain state of tension, while the superficial abdominal muscles contract, and their tension, in connection with the elastic recoil of the rest of the respiratory apparatus, is just sufficient to force the air out of the lungs through the glottic aperture, in the volume necessary for the vocal sounds desired.

A fresh inspiration and consequent diaphragmatic contraction may have to be taken between each explosive tone, such as is emitted in *shouting*, or one inspiratory effort may suffice, the inhaled air being cut up into a number of tones during the following expiration, by closures of the glottis, soft-palate or mouth.

During *sighing* there is a deep, long-drawn contraction of the diaphragm, followed by a somewhat

repressed relaxation and an expiration of the inhaled air mostly through the nose.

In *yawning* the lower jaw is deeply depressed, the shoulders somewhat raised, and during relaxation there is apt to be some inarticulate vocalization.

In *hiccough* there occurs a very sudden contraction of the diaphragm, while, at the same time, the glottis closes, and the indrawn air, striking against the approximated vocal bands, produces the well-known sound that gives the process its name. It is caused by some reflex nervous influence being conveyed to the nerve-centres that actuate the diaphragm and larynx.

In *sobbing* there is also a convulsive action of the diaphragm, though a slower one, and an earlier but complete closure of the glottis.

In *laughing* the diaphragm experiences a series of fluttering motions and interrupted expiratory relaxations, the vocal cords being, at the same time, more or less approximated and in a state of phonation.

In *crying* the diaphragm's actions are not very different from laughing, but the facial expression and vocal effects are very different.

In *chuckling* the jerky motions are all during relaxation of the organ.

In *whistling*, *blowing wind-instruments*, etc.,

the aid of the expiratory muscles is called into play very prominently to steady and keep up the expiratory blast that is produced during the relaxation of the diaphragm.

Coughing is an act used to clear some obstruction from the air-tract, such as accumulated mucus, or it is caused by some direct or reflex irritation that simulates the presence of such an obstruction. The inspiratory drawing of air is deep in proportion to the located depth of the obstacle, or in proportion to the force with which it is desired to drive air along the air-passages. Following the inspiratory contraction of the diaphragm, not only is there a complete immediate relaxation of the organ, but the expiratory muscles are forcibly brought into play, and the glottis is tightly closed so as to secure a strong pressure in the lungs before the glottis opens and the outward explosive rush of air occurs. If the irritating object be above the larynx, the closed lips or contracted soft-palate helps the process of ejection, by directing a strong blast of air against the mucus or other lodged matter.

In *sneezing* there is a quick inspiration and diaphragmatic contraction, followed by a forced expiration that sends the outgoing air rushing mostly through the nose, the soft-palate being relaxed and the faucial pillars contracted.

Certain extrinsic, incidental functions of the dia-

phragm occur,—for example, in *vomiting*, where a rigid contraction of the organ, in conjunction with contraction of the abdominal muscles, helps the muscular fibres of the stomach to press its contents outward and upward. Almost every sea-sick traveler has experienced the sensation of pain felt in the tired diaphragm after a long paroxysm of vomiting. Everyone has also experienced a pain in the side after prolonged laughter; this is mostly due to excessive strain produced by the diaphragm on the parts affected.

Special contractive acts on the part of the diaphragm can be brought about by the effect of medicines known as emetics. Some of these act through reflex action by irritating the mucous membrane of the stomach, while others act directly on the nerve-centres. There are some medicines that act on the nerve-centres, which have the effect of slowing the rate of action of the diaphragm, while others hasten and strengthen its action.

The diaphragm can exert a pressure on the abdominal contents that very nearly equals the maximum effort of the abdominal muscles. According to Samuel Haughton, it may produce a hydrostatical pressure upon the contents of the abdomen of over twenty pounds per square inch. This force is not only brought to bear during the act of vomiting, but, in connection with the use of the abdomi-

nal muscles, is used in the common function of expelling feces from the intestine.

During confinement, with every contraction of the uterus, the diaphragm, being strongly contracted, exerts its pressure on that organ from the top of the abdominal cavity, and thus helps in the expulsion of the fœtus.

During powerful, general muscular efforts, as in lifting, when all the muscles of the trunk are in a state of tension, the diaphragm is rigidly contracted, acting as a fixed point of support for the contiguous muscles.

Respiratory Change of Shape in the Trunk.

It will be proper here to mention certain changes that occur in the external conformation of the body in unison with the actions of the diaphragm. These are:

1. The marked protrusion, followed by the subsidence, of the front and sides of the abdomen. This is partly caused by the abdominal walls being carried forward by the inspiratory movement of the lower border of the ribs, but it is also caused by the displacement of the liver, stomach, etc., these organs being pushed out of place by the under surface of the diaphragm as it contracts During the relaxation of the diaphragm the return of the abdominal walls occurs. This return is due

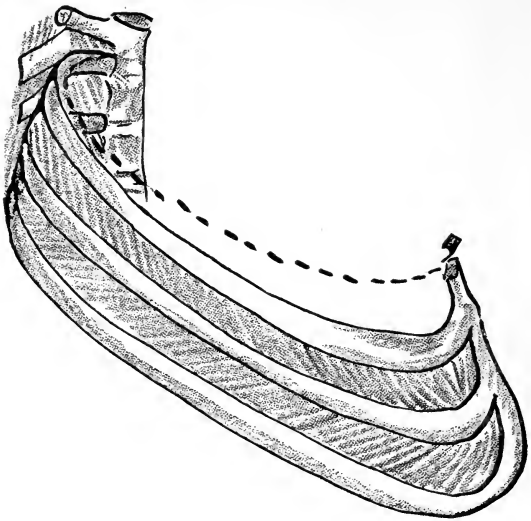


FIG. VIII.

Fig. VIII represents some of the lower prominent ribs attached to the spine and breastbone. It will be observed that they not only form a bow between the spinal column and the breastbone, but that their bowed convexities droop downward. This is their position during respiratory relaxation. During contraction of the diaphragm and intercostal muscles, these ribs revolve somewhat upward on their joints, and the upper rib shown would then occupy the place of the dotted line in the figure. This motion at the same time carries the convexities of the bows outward, thus laterally distending the sides of the chest. The intercostal muscles are represented as running between the borders of the ribs.

to the elastic resiliency of the various parts, which carries them back to their previous position. During long-continued, forced expiratory efforts, the front of the abdominal wall contracts and sinks in beyond its usual position. This action pushes up, to a certain extent, the contents of the abdomen into the concavity of the diaphragm, and helps to expel air from the lungs. This abdominal motion is more or less marked in proportion to the depth and force of the respiratory efforts. In very quiet breathing, when a slight action of the diaphragm is the only muscular motion carrying on respiration, the abdominal movement may be very slight, and may be the only respiratory movement visible. The movement is more marked in males than in females.

2. A lateral expansion of the sides of the chest, caused by the partial revolution upward of the ribs on their spinal and sternal joint-connections. The movement is most marked in the lower part of the chest, and is in proportion to the extent of the respiratory effort.

In health it always occurs in conjunction with the abdominal movement, and may be in connection with the clavicular movement, which we will next describe.

3. During every considerable inspiration, the front of the chest moves forward. In men the

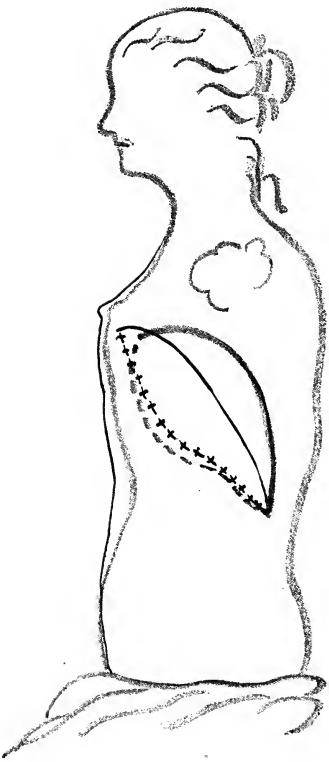


FIG. IX.

FIG. IX.

Fig. IX represents the natural and best manner of breathing. It is a combined act of all the respiratory mechanism. The penciled outline represents the antero-posterior outline of the female trunk during respiratory relaxation. The heavy penciled outline of the diaphragm represents the average height of the curved domes of the organ; and the dotted penciled line, the lateral border of the organ during the same respiratory stage. The inked outline represents the change of shape in the unconstricted female trunk during an ordinary physiological inspiration. The average change of shape and position of the diaphragm during contraction is shown by the inked continuous line. Its border and the elevation in it that occurs during diaphragmatic contraction, is shown by the starred line. This is the correct method of breathing when the best vocal and speech-effects are desired.

movement is most pronounced at the lower part of the chest, while in women the movement is most marked in the upper part beneath the clavicles, from whence comes the name clavicular breathing. The clavicular type is most prominently seen in labored breathing, where all the auxiliary muscles of the shoulders, head and neck help to raise the upper ribs.

4. This movement is only a slight one, and quite inconspicuous and unimportant. It is a slight bulging of the dorsal or back surface of the chest in very deep inspiratory efforts.

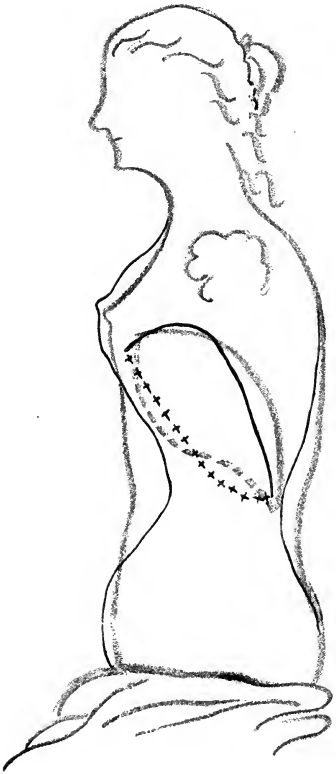


FIG. X.

FIG. X.

Fig. X represents an antero-posterior outline of the trunk of a modern *re-formed* Venus de Milo, superimposed over the outline of that famous pattern of female shape as she was created. The modern outline is copied from the average shape of the corsets now manufactured for, and worn by, the women of New York, A. D. 1885. This cut shows the change of shape that occurs, in the upper part of the chest, in trained clavicular inspiration. The natural position of the diaphragm is represented in penciled lines, and its inefficient action in the re-shaped trunk is shown in the inked lines. This represents the false method of breathing, too common among female voice-users, and sometimes practiced by males.

Differences in Male and Female Breathing.

In the healthy state, a woman breathes more than a man through the action of the upper parts of the chest, while in a man the diaphragm has to do proportionally more work. The reasons for this increased motion in the clavicular region of the female chest are probably these:

During gestation, the action of the diaphragm is much impeded by the pressure upward, produced by the presence of the gravid uterus, which, in connection with the other abdominal viscera, increases the pressure against the under surface of the diaphragm. This circumstance necessarily throws more work on the upper part of the female chest, and this increased functional action has been perpetuated through heredity.

Furthermore, the large mammary development in the female necessitates a larger blood and nerve-supply to the upper part of the chest; and blood-pressure and nerve-force being directed to this part of the body, the neighboring organs also receive an increased blood and nerve-supply, and have thus gained their superior relative size and powers of motion.

Certain Natural Phenomena which Occur Synchronously with the Action of the Diaphragm.

In health, all of the parts of the respiratory and vocal apparatus work in a definite and harmonious unison. In a sufficiently deep inspiration, the intercostal and other muscles are called into action along with the diaphragm, although they are a little tardy in joining in; the diaphragm commencing the functional act synchronously with every inspiration, the arytenoid cartilages in the larynx make a partial revolution, being actuated by the posterior crico-arytenoid muscles; and, in so doing, draw apart or abduct the posterior ends of the vocal bands. The extent of the abduction is great in proportion to the depth and quickness of the inspiration.

During respiratory relaxation of the diaphragm, laryngeal relaxation also occurs, the respired air being driven out between the flaccid vocal bands. This harmonious action will go on involuntarily,

but it is subject to the will, and its regularity is intermitted during vocalization or phonation, thereby breaking up irregularly the outgoing air-column during speech, song, coughing, etc.

During each inspiratory effort, the nostrils are more or less expanded by the action of the dilating muscles attached to the wings of the nose. This movement is clearly seen during forced respiration, either in the healthy subject or after disease makes extraordinary respiratory efforts necessary.

When the complicated movements of the larynx, throat and mouth are brought into play during song and speech, the diaphragm's movements are nicely regulated as to extent and rhythm of motion, so as to furnish the right amount of air necessary for producing the effects desired.

Relation of the Circulation of the Blood to the Action of the Diaphragm.

The heart is the principal agent engaged in propelling the blood through the circulatory system of blood-vessels, which supply the body with its fluid nourishment. This is done by its alternate contraction and relaxation, each contraction squeezing out into the arteries the blood that has run into the organ from the veins, during its relaxation. But the heart is located in the cavity of the chest, and is subjected to the alternate changes of pneu-

matic pressure that take place inside the chest during inspiration and expiration. This change of pressure, though not occurring in unison with the contraction of the heart—the inspiratory change of pressure occurring only once to three or four heart-contractions,—still acts as a help in emptying and refilling the heart. This respiratory action can readily be noted in the blood's circulatory pressure by means of a suitable recording instrument, known as a manometer.

During inspiration, it will be remembered, a partial vacuum is formed in the chest; and this vacuum, of course, also surrounds the heart and great vessels connected with it, withdrawing some pressure from their walls, and thus allowing them to refill with blood more easily.

In expiration, there is a slight excess of pressure in the chest, a pressure greater than that of the atmosphere, and this, exerting its influence, helps to press out the blood from the heart. This fact being so, it is clearly evident that the full action of the diaphragm, as a chief agent of respiration, is essential to a thorough aërification of the blood.

Actions of the Diaphragm Resulting from Extraordinary Causes.

If an individual be struck over the epigastric region in front of the solar plexus of the great

sympathetic nerve, the region known in sporting parlance as "below the belt," the shock is so great, and the whole attention of the nervous system is so taken up by the extraordinary sensation, that the respiratory centres do not send out their accustomary impulse, and hence there is a paralysis of the diaphragm that persists for some moments. The same effect is also seen in some persons, who, experiencing suddenly a great fright or other mental emotion, have the ordinary functions of the body momentarily suspended, including the motions of the diaphragm, and the individual is breathless and speechless.

In many individuals, especially in women, the effect of a sudden fright is to cause a quick spasm of the diaphragm and of the glottis, which action usually causes the emission of a scream. In this case, the vibration of the vocal bands is produced by the inspiratory current. When a person is attacked by an epileptic fit, the well-known scream is the result of the same cause. There is a sudden tonic spasm of the whole muscular system, including, of course, the diaphragm and glottis. The inspired air, which is with difficulty drawn between the approximated vocal bands, produces the scream. This action is quite distinct from the ordinary screaming of nervous women, children, and occasionally of men.

The instinct of self-preservation prompts most voiced animals to cry out on being hurt, and when the individual is unaccustomed to mental reflection and self-control, the cry or scream is apt to begin even before the hurt commences, if the imagination leads the individual to think that the hurt is coming; sometimes there is even no thought present, the scream being merely an outward manifestation of an emotional feeling.

The nervous system of women is more sensitive than in men, and they are more easily startled and frightened than the sterner sex, but their want of control and the outward manifestation of emotion by screaming has nothing to do with any peculiarity of action of the respiratory apparatus. It is proper to note here, though, that some neurologists assert that the respiratory and speech-centres are relatively larger in females than in males. If this were true, such a structural cause would afford a rational explanation of the phenomenon of such action in women.

Comparative Physiology of the Diaphragm.

The respiratory action is essentially the same in all those superior vertebrate animals known as mammals, of which man is the preëminent example. One of the most prominent physiological distinctions of this class of animals is the method of respira-

tion that is known as internal or pulmonary, which is carried on by the aid of both lungs, and the prominent action of the muscle that is peculiar to the class, that is to say the diaphragm.

The respiratory method in birds is intermediate between that of mammals and that of the reptiles of the class below. In birds, most of the respiratory effort is carried on by the action of the thoracic or chest-walls, the diaphragm being absent or rudimentary. It would be proper to designate it as sternal breathing, most of the motion being a protrusion and recession of the largely-developed sternum. It differs from the respiration of mammals in that the *expiration*, in ordinary breathing, is the motion that calls forth most muscular effort, while *inspiration* is due to the elastic rebound of the tissues of the chest and abdomen.

The rudimentary diaphragm, when present, also aids the respiratory effort by pulling the lungs backward and downward. The air is drawn into the lungs, and from thence finds immediate access to nearly all parts of the body, including the thorax, abdomen and bones.

This peculiarity in the construction of birds gives them a very light body in proportion to their size, and accounts for their wonderful ability of giving utterance to such powerful and long-sustained voice-notes.

In the ostrich and other large birds, where the diaphragm is more perfect, its action more nearly resembles that of man; but even in these the air finds entrance through the lungs to the thoracic or pleural cavities, and respiration is not so thoroughly carried out as in the mammalia.

When we examine such inferior animals as the reptiles, we find all trace of diaphragmatic action lost. In snakes, where one lung alone is usually developed, and extensively drawn out along the spine, the thoracic change of shape necessary to draw in and force out air, is brought about by an imperfect motion on the part of the very numerous ribs.

Lizards, also, use their ribs for breathing, which, by their slow and imperfect motion, compress and dilate the pulmonary cavity; but it is a poor process, for these animals do not have active respiration.

In tortoises the scapular arch acts in place of ribs, but these animals have no true voice. They have no epiglottis, and the hissing sound they produce is formed in the mouth.

In the so-called amphibia, as for example the common frog, there are not even ribs to do the work of the diaphragm, the muscles of the mouth acting as a substitute for that organ. They breathe air by swallowing it. The air enters the mouth

through the nostrils, and its return is prevented by an internal valvular fold and by the tongue being placed against the palate-openings; the gullet or œsophagus being closed by contraction, the air is forced into the lungs by the action of the muscles attached to the hyoid-bone. The lungs alone in these animals are not sufficient to aërify the blood, and the skin materially aids the pulmonary organ in this function.

Fishes breathe by taking water, which of course contains air, into the mouth and forcing it backward and outward over the gills or branchiæ, the latter acting as lungs for the creature.

The larger proportion of aquatic animals, including the mollusca, articulata, fishes and batrachia, have the circulating fluid aërified by these branchiæ, some of which are located outside of the body; while in others, as in fishes, the organs are partly protected by gills. Of course, all these lungless animals are voiceless.

There is a curious exception to this method of respiration in the mollusca, which occurs in the common land snail (pulmonifera). This snail has a lung or air-chamber opening to the outer world by a round orifice in the side of the animal. The air in this cavity seems to renew itself by law of diffusion without special mechanism. The air is probably also furnished to the bodies of insects by

this same law through their numerous tracheæ. Of course insects have no voices, all their sounds being produced by special apparatuses provided for that purpose.

Functional Development of the Diaphragm.

In the fœtus the diaphragm is quiescent; the lungs are in a state of solidity, and the blood is aërified by way of the umbilical cord, in the placental tufts that are intimately connected with the maternal uterine surface. Of course, the fœtus has no voice, which can only be produced after pulmonary respiration has commenced. At birth, the shock produced by the exposure of the skin to the cool outer air starts, through reflex action, the respiratory mechanism into activity. The motion of the diaphragm is at first very sluggish, and it is some days before the lungs become fully inflated, and the diaphragm fully at work. The infant at first requires but little air, and respires considerably through its skin. The functional power of the diaphragm increases with its anatomical growth and the exercise given to the organ, reaching its full powers at the maturity of the individual and after the fullest exercise of its physiological capabilities.

THE HYGIENE OF THE DIAPHRAGM.

From what has now been told of the anatomy and physiology of the diaphragm, it should be conceded, as a sequence, that the organ is a very important one, and that its proper action is very necessary to the welfare of the human body. Furthermore, it will here be proper to indicate those conditions which are most favorable to its well-being and healthy action. Certainly it is deplorable to see the amount of ignorance extant in relation to this organ.

It is certain that some of the ancients have had their attention directed to it, because there was a prevalent belief among them that it was the seat of the soul; a belief probably engendered through the sensations experienced in the solar plexus as the result of decided mental emotion. The location of the plexus, which is at the posterior border of the diaphragm, would readily lead one to attribute such sensations to the diaphragm itself.

Ignorance in regard to the diaphragm was, however, not confined to the ancients, or is not to the medical student of this latter day. This lack of knowledge is wide-spread. We once asked a highly-accomplished teacher in one of the established schools of the day, what she knew about the diaphragm. She replied that she thought it had

something to do with the breast-bone. Well, so it has; she was right, so far as her knowledge extended. It is almost needless to add that this lady wore a corset, but we are happy to say that her intelligent appreciation of the subject has since led her to dispense with that deforming appliance as an article of dress.

A knowledge of the anatomy, physiology and hygiene of the diaphragm, as well as of the other organs concerned in respiration, vocalization and speech, is particularly desirable for every speaker and singer. All knowledge broadens the intellect, and this particular knowledge enables the individual to use more intelligently the organs with which he works. It would also tend to prevent him from indulging in practices or methods that would injure the apparatus. Furthermore, he would be in a better receptive condition to absorb the teachings of the instructor.

It may be stated without fear of contradiction, that to be a competent teacher and voice-trainer, the instructor must be a master of all these details of his profession; otherwise he will not be able to properly direct his pupil, or to correct wrong methods of using the vocal and respiratory organs. This imperfect knowledge is too frequent a deficiency among instructors. One constantly meets lady singers who, otherwise highly trained, cannot

deliver a good, sustained tone simply because they cannot call the diaphragm into full action. Inquiry too frequently elicits the fact that they have not been instructed properly in this respect.

Diseased Conditions to which the Diaphragm is Subject.

The diseases of the diaphragm are few in number. The protected position of the organ shields it from frequent accidents, and its physiological activity in even the most tightly-constricted waist tends to keep the organ in a tolerable state of nutrition and health, although its full condition of health can only be expected when it is fully used. Gunshot and punctured wounds, and rupture of the organ from external violence, are about the only surgical diseases of the diaphragm. Sometimes the organ does not become entirely fused at birth, and an opening is left between the thorax and abdominal cavity. This may persist without causing much inconvenience to the individual, but, occasionally, the organs of the abdomen may protrude through the opening, causing what is known as a diaphragmatic or phrenic hernia.

Inflammation of its serous coats is its most frequent disorder. If the upper coat is affected, the condition is known as diaphragmatic pleurisy, and if the under coat, diaphragmatic peritonitis. Neu-

ralgia, rheumatism and abscess of the organ are infrequent complaints.

The diaphragm may be displaced upward in corpulent persons by the fat layers of the abdomen, by an enlarged liver, or by distension of the stomach and intestines with gas, which condition occurs in peritonitis, and in persons who habitually overload their stomachs. Sometimes the organ becomes paralyzed, and then abdominal breathing is absent. This condition does not necessarily become directly dangerous to life, the upper part of the chest doing the necessary respiratory work; but, of course, all activity of life in the individual must cease.

Sometimes there occurs a tonic or continuous spasm of the diaphragm, in which case the lower part of the chest is strongly expanded and immovable; it causes great dyspnœa or want of breath, and even suffocation is threatened. In tetanus, or lockjaw, this condition frequently causes death. Hiccough is a disease, being a rapid, clonic or intermittent spasm of the diaphragm.

There is one condition that is common in the diaphragm, and that may be properly called a disease. It is a state of atrophy or imperfect nutrition, in which there is a diminution in the bulk of the organ. This condition may be caused in various ways; most frequently it is the result of defi-

cient exercise of the organ, and this may be caused by the individual not taking sufficient general exercise; or, what is more frequent, some impediment is placed in the way of the full action of the organ, such as constriction of the waist. This depreciated condition of the diaphragm is one that is adverse to the general well-being of the body. Its functional action being imperfect, respiration and circulation are not perfectly carried on, and the result is that the whole body is not as well nourished as it would be if the diaphragm was thoroughly developed in its structure and function.

With the organ in this state, it is impossible to sing and speak in the best manner. On this point *competent* vocalists, speakers and voice-trainers agree unanimously. It is impossible to bring out the full abilities of the phonating and articulating mechanism unless the *whole* of the air-propelling and controling apparatus is harmoniously used, and of this apparatus the diaphragm is the most important part.

Another important sequence of a lack of functional activity in the diaphragm, is the effect produced on the organs that are in its vicinity, from the deficient motion they receive. The lower parts of the lungs do not receive their full amount of motion. They do not expand as fully as they should, and do not receive their proper share of

blood from the heart, and hence, being poorly nourished, are subject to attacks of disease. When the lower parts of the lungs are not used enough, there has to be a compensatory over-action in the upper parts of those organs to fill even ordinary respiratory need. This over-action invites too great a supply of blood to the upper parts of the lungs, producing a state of hyperæmia, or even more serious inflammatory conditions. The writer has repeatedly had under his care cases of disease in the trachea and bronchial tubes that would not yield to treatment until the waist was liberated from thraldom, and the lower parts of the lungs allowed to do their normal work.

The liver, stomach and other intestinal organs also suffer if they do not receive the full amount of motion that they would get with complete activity of the diaphragm. In such cases of deficient action, the flow of the bile may be seriously impeded.

All results from *over-use* of the diaphragm are so infrequent that it is scarcely necessary to mention them. By over-use the organ may become hypertrophied or enlarged, and in this state is irritable and less capable of easy control than in an ordinary healthy state. Emphysema, or dilation of the pulmonary air-cells would be apt to follow over-use of the organ. Such conditions would only be likely to occur in players on wind-

instruments, glass-blowers, professional athletes, etc., and would hardly pertain to singers and speakers, except in a few cases where the voice is over-forced.

It must not be forgotten that a poor structural and functional development of the diaphragm is also accompanied by a like condition of the nerve-tracts and nerve-centres which actuate the organ.

Conditions Essential to the Nurture and Healthy Action of the Diaphragm.

1. The organ should receive a proper supply of nourishment. It receives this through the blood, which, besides being thoroughly aërified by proper methods of respiration, should contain, in correct proportions, the food-elements necessary for nutrition, and be devoid of excessive proportions of effete products that might be present through imperfect processes of digestion, elaboration and excretion. The maintenance of this condition requires the use of a well-regulated food-supply, and the living of a generally good hygienic life on the part of the individual.

2. Regular exercise of the diaphragm is a *sine qua non* to its well-being. It needs using to a certain extent to subserve the purposes of its general nutrition, and it needs practical cultivation to enable

it to perform with precision and ease those extraordinary actions which are used in the practice of the arts of singing and declamation.

No special gymnastic performances are required for the carrying out of the first purpose. One or more daily, brisk out-of-door walks, and some special exercise of the upper extremities and trunk, as, for example, by the use of the Indian clubs, will call forth its functional actions to a sufficient degree to keep the organ in good order.

For its special uses in singing and speaking, the diaphragm has to have special culture. As a general rule, this exercise will be obtained by its rhythmical and harmonious use with the other organs of respiration, phonation and articulation, without any particular attention being directed to the organ itself. In the healthy individual, the nervous system is so harmoniously and perfectly adjusted, that the simple willing of the sound or effect desired will bring about the harmonious action of *all* the organs engaged in producing the sought-for result. But in some cases, where, through false methods or other causes, the diaphragm is undeveloped or works imperfectly, special gymnastic exercises will have to be instituted for its culture.

3. Every obstacle should be removed that interferes with the proper action of the diaphragm.

The best position of the body that can be taken, so that the organ can make its best efforts, is that of the upright, standing posture. This position must be easy and not strained, stiffly erect, bent forward nor to the sides. The head also should be held erect, and, if the individual reads from a book, it should be held by the hands or on a reading-desk at a height from which it can be easily read without bending the shoulders or the head. In this position the diaphragm and the rest of the respiratory apparatus are free to act in the best manner.

An over-loaded stomach, or one containing indigestible, fermenting food, producing gases which distend the organ, is an effectual obstacle to the action of the diaphragm. Every singer and speaker knows this fact practically, though they may never have thought of the matter scientifically. The diaphragm cannot fully contract when the stomach is distended; besides, the attention of the nervous system is taken up with the active process of digestion, and cannot have so much energy to spare to work properly the vocal and respiratory apparatus. If food must be taken immediately before the diaphragm is to be put to hard work, it should be an easily absorbable and digestible liquid.

Very often the diaphragm cannot do its work

properly unless some nutritive support be given to it, the organ being under very poor control when the individual is tired or exhausted, and has a small amount of nerve-force in reserve.

A person, whose abdomen is loaded with fat, cannot use the diaphragm to its fullest capacity. A proper food regimen and vigorous exercise in such persons, would be necessary to remove this obstacle. But the greatest obstacle to the proper action and development of the diaphragm, is that of pressure against the surface of the trunk from without, and this brings us to the subject of

Corsets and Waist-Constriction.

The corset is the worst enemy of the diaphragm. This is not the place for a full dissertation on the subject of impropriety in dress, but its relation to our subject is so intimate, that some allusion to it must be made.

The habit of corset-wearing is one, that, among many others, shortens life. This appliance kills slowly, and to the unlearned imperceptibly; nevertheless the corset is a murderous instrument. Owing to woman's physiological ability to breathe more than man with the upper ribs, she can stand the effect of the fashion longer than the sterner sex; but, if it were not for the nightly recess the diaphragm receives from the constricting pressure

of a tight waist, it would soon atrophy, and life to the corset-wearer would be a very brief span indeed.

When one really takes the subject into his mental range, and thinks that this vicious habit is passively countenanced by men of science, of letters and of morals, and practiced by their wives and daughters, one's mental emotion is scarcely sufficiently under control to talk or write collectedly on the subject. The practice probably grew out of the ancient habit of bandaging the waist to support the breasts. The only rational excuse that we ever knew for the use of the corset, is this one of support.

It may be said here that, in most cases, support of the breast is not necessary, and, if it be needed, can be more properly afforded by a support hung from the shoulders.

The habit has grown from generation to generation, and seems now to be ingrained into the female being. How many generations it will take to eradicate the idea that a constricted and supported waist is right in a woman, no man can say. The mother commences to put the idea into execution from the earliest infantile days. An umbilical bandage on an infant for the first few days is a prudent procedure, but after the umbilicus is healed, the human waist in the healthy male or female

should know no restraining or constricting pressure during life. Why should a baby's waist be bandaged for the first year or two of its existence? We asked an experienced mother this question. She replied that some thought it made them feel comfortable, and *improved their form*, and that, anyway, it had always been the custom, and that was why she did it. The old idea, it will be observed. The form that is adapted to the various structures which it contains, in the mother's eye is not correct, and hence must be reformed.

The process is commenced in the infant. The little girl is put into a *corded waist*, and the pressure gradually applied. One little girl, who came under our observation, told us that she left the waist unbuttoned because it hurt. That same waist would not meet at the back by three inches unless pressure was brought to bear on it.

At puberty the little girl advances to the dignity of the real corset, with its lacing constricting powers. The pressure is gradually increased and imperceptibly applied, and at maturity the woman is a deformity. The upper part of the thorax is over-developed; the lower ribs are pressed inward; the diaphragm is undeveloped; the spine is more or less curved; the muscles of the waist are undeveloped and weak; the lungs and heart are compressed; the abdominal organs are displaced,

mostly downward; there is recession of the epigastric region, and the woman has a pendulous abdomen.

The strange part of the whole matter is, that no woman ever knows that her waist is constricted. She will tell you energetically that she never laces tightly, that she is peculiarly formed, and *always* that she can put her hand under her corset at the waist. She does not know that all the tissues under that waist are very soft, nine-tenths being water, and that they, or even human bone, will shrink away and disappear under the slightest pressure, if only it be continued.

Every woman who has grown up in a corset, no matter how loosely worn, is deformed.

Any constriction of the waist, no matter how slight, interferes with the action of the respiratory structures, and especially interferes with the action of the diaphragm. If the lower ribs cannot expand and rise laterally to their fullest extent, and do not attain their natural form, and if the abdominal walls cannot have full freedom to expand, the action of the diaphragm is *imperfect*.

Among the wonderful illustrations of the adaptability of the human structure to the conditions that environ it, is the comparative success to which lady singers can attain without the full use of the diaphragm. The writer well remembers the as-

tonishment he experienced one evening at a concert, during his boyhood days, while listening to a certain tight-waisted-no-neck-to-her-dress cantatrice perform some vocal gymnastics. The alternate buoyant distension and cavernous sinking in of the sub-clavicular region, was to him simply marvelous; and it is still a wonder to him to see how the physiological capacity for motion in this part of the chest can be developed. Nevertheless such development is a great mistake, and no singer or speaker can sing or speak so easily or effectively as when he uses the *whole* of the machinery forming the bellows of the vocal apparatus.

Not only is the corseted waist an offense against hygienic law, but so is also every sort of waist-constriction caused by any tight garment or girdle.

There is no practical difficulty in avoiding such impropriety in dress. Clothing for the trunk can all be hung on the shoulders by simply having a waist to every garment. In short, let women wear clothing made exactly on the principle of the comfortable loose wrapper that is now in vogue for a negligé costume. If the corset be given up by one accustomed to its use, some time will be required for the weakened tissues of the waist to become strong and healthy, and able to carry out their natural functions of support with ease to the indi-

vidual. Such a person would soon find great difficulty in breathing, if the corset were replaced.

In the cases coming under the writer's observation, where corsets have been abandoned, there has been, in a few months after uncasing the waist, a very decided increase in girth at the lower part of the chest, and a marked development and better nutrition of the whole thorax.

A whole chapter could be written on the ethics of the subject, but space and place forbid our making extended comment on this subject. The evils it works in the body are not confined to the diaphragm. Any experienced gynecologist can tell of the many female ills he has to combat, as a result of this and other improprieties in methods of dressing. We close this part of the subject with the declaration, that the putting of a corset on a child is a slow *murder* of that child, and if she be of a phthisical or consumptive tendency, it is not so very slow murder either.

Special Exercise for the Diaphragm.

It has already been stated that the well-being of the diaphragm requires that it should be regularly exercised and trained. This exercise and training should be continuous and sufficient to bring it up to a status of full ability to do the work required of it, but it should not be carried beyond that

point. The exercise should be regular and continued, because, if the organ be properly developed, and then its proper exercise be neglected, it will be liable to fall into a relaxed, unhealthy condition that would be a greater evil than if the organ had remained undeveloped.

The physician is constantly meeting these cases of disease that occur in organs that have been over-developed and then neglected. This state can readily be seen in the larynx. Lecturers, who speak continuously during the lecture season and have no trouble with their throats, very frequently find, during their season of rest, that they easily become hoarse, and have other disagreeable symptoms of disordered throats. If the training be carried beyond the necessary point, the diaphragm would be apt to become irritable and eccentric in its motions, and not effectively under control.

For this reason we deprecate any general instructions that would lead the learner to give particular attention or training to any individual part of the vocal and respiratory mechanism. It may lead to an over-development of the part. A workman should know every part of the tool he is using, so as to know when it works well or otherwise, and whether he is using it to the best advantage, or is injuring it; but when he is executing an artistic piece of workmanship, his attention should be

directed to the effect sought for in the work in hand, and not to the construction and working of his tool.

The instructor and student ought to know how the diaphragm should work naturally, and if it is doing its work correctly; but, as a general thing, no special attention should be directed to the organ. Let all *obstacles* to the perfect working of the respiratory apparatus be removed, and then the simple exercise of the cerebral powers of imitation and volition will, in most cases, result in the correct working of the whole apparatus.

But, if the diaphragm is not sufficiently developed, and does not work correctly, how shall it be exercised? Let the student examine the manner of his or her own breathing, some morning after a refreshing night's sleep, while still in bed, and, of course, still clothed in unconstricting habiliments. Lying flat on the back and quietly breathing, if the hand be placed on the upper part of the abdomen, it will be found to be gently rising and falling, and perhaps the lower ribs will expand and contract laterally to a slight degree. This outward motion in the walls of the trunk is caused by the regular contraction and relaxation of the diaphragm. This style of respiration is the type to follow, only, of course, in cases of greater exertion it will be more pronounced. It is the type of res-

piration that will give health and the best control of vocal effects to those who practice it.

To develop the muscular strength of the diaphragm, it is recommended to proceed as follows: It may only be necessary to take vigorous general exercise to such a degree as to require deep and thorough respiratory effort; but, as a special gymnastic performance, the student may stand erect, or even inclined a little backward, with the clothing entirely loose around the waist and chest. Then, with the larynx entirely open, draw air in suddenly to the greatest extent, hold it for three or four seconds, then suddenly let the air escape through the opened larynx and nose without producing vocal sound. Repeat this a few times, but not so fast as to produce any such marked effects in the circulation as will cause giddiness or swimming in the head.

The exercise should at first be executed only once a day; later, it may be done several times each day. It may be varied by allowing the relaxation of the organ to proceed gradually and smoothly, or with crescendo, or decrescendo rates of speed; or it may be broken up into intermitted and sharply-divided periods, regulated as to rhythm, if one please, by such time as may be written in any selected musical score.

For the most part, though, these various actions

of the diaphragm can be more advantageously and conveniently cultivated synchronously with voice-production, in singing and declamatory exercises.

How to Breathe.

The diaphragm is of such importance in the animal economy that justice cannot be done to its well-being, nor can breathing be properly executed, unless it is brought into play as a chief agent in the respiratory act. The general rule may be laid down, that, although in the ordinary exertions of singing and speaking, the chest should not be over-dilated, nevertheless the individual should take every opportunity to inspire often, so as to always keep an abundant supply of air in the lungs.

Let a moderate chest full of air be drawn in, and then expended properly, and without waste, slowly, quickly, by intermitted puffs, and by the actual pressure of the muscles of forced expiration, as the requirement may call for. Send the column of air out through the mouth or nose, or both, if the effect sought for requires it; but *always* draw the air through the nasal passages, if possible. The nose is the normal air-route for all ordinary occasions in breathing, and the mouth should only be brought into use during extraordinary occasions.

During the short pauses that occur in continuous singing and speaking, it is practically impossible

for most persons to draw enough air quickly into the lungs through the nasal passages. The effect of so doing produces a disagreeable whistling inspiratory sound, and the respiratory muscles have to work too hard in overcoming the friction of the indrawn air; but as much of the air should be drawn through the nose as possible, and the mouth held open only enough to allow the passage of a sufficient auxiliary supply to meet the needs of the moment. If the mouth be held too widely open, the air reaches the throat in too cool and dry a state, and overloaded with dust and other impurities that would otherwise be deposited on the sinuous surfaces of the nasal cavities and on the tongue and roof of the mouth.

Breathing through the mouth is a wrong method and leads not only to irritation of the throat, but the nasal passages, missing the normal amount of stimulus from the rush of air through them, are apt to lose tone and the mucous membrane becomes relaxed, and falls into a state of passive catarrh, and is too easily affected by inflammatory attacks.

Thus we have reached the end of our subject, at the anterior openings of the nose—the apex of that complicated respiratory and vocal mechanism, the basement flooring of which is that too little understood structure known as

THE DIAPHRAGM.

APPENDIX.

Since writing the foregoing essay, nearly a year has elapsed. During that time, both in private and in dispensary practice, I have had numerous opportunities of observing in my patients the effects of non-use of the diaphragm, and these have always been decidedly unfavorable. Of course, the greatest damage entailed by such non-use has been apparent in the bad effect on the general nutrition of these individuals,—bad effects that have been the outgrowth of interference with the functions of respiration and circulation, and also of lack of motion in contiguous organs, or of displacement of organs more remote, due to the restraint and forced immobility of the waist.

However, such results would be of less interest to voice-users, in this connection, than would mention of certain bad results that have been more markedly shown in produced disorders of the throat,—disorders characterized by serious *discomfort*, or by plainly evident *impairment of the voice.*

Disorders from this cause are much more common than would be usually supposed. Time after time I have had voice-users come to me for treatment, complaining of sore throat, or of hoarseness,

or of some other impaired voice-quality, in all of whose cases I have come to the same conclusion as to the real predisposing cause, namely: *A constricted waist*, or, in other words, non-use of the diaphragm and its auxiliary breathing mechanism in producing certain effects of voice in speech and song.

The human larynx and pharynx are usually passive organs, in the control of their owner, and often exhibit, to a surprising degree, an obliging capacity for doing work which, in reality, is not functional. These organs may perform a certain amount of this extra-functional work without apparent damage; but, in many cases, even a slight amount of such unnatural demand will create rebellion and disorder in these parts of the general vocal apparatus. Occasionally, a man will have some throat-disorder from this cause, but where the laryngologist has one male patient of this kind under his care for treatment, he has fifty female cases; and, in the vast majority of cases, the cause is the *corset*.

It may be laid down as a rule, to which, however, there are a few exceptions, that if *all* the organs that would naturally take part in producing song and speech were perfectly unimpeded in their action, they would individually take their harmonious part in such production. Occasionally, the

exception is met. One meets male singers and speakers who try to produce effects in pitch, modulation, etc., with the muscular apparatus of their throats, that should be done with the diaphragm and lower rib-muscles. They mouth their words and tones, so to speak; and, if they do so, the chances are that they will get a troublesome sore throat, or a hoarse, husky tone of voice for their pains.

If an unnatural action, or performance, is forced on the throat, or if the throat is required to do work that should have been done by the large respiratory muscles, it must naturally suffer great and unnecessary wear and tear, and even strain; or, may be, ifretrievable damage. And yet much the larger proportion of the lady singers of the day maltreat their vocal apparatus in just that manner. The only way in which such artistes retain their voices, is to perform an amount of work with their throats very greatly less than would be quite possible for them, if they thoroughly utilized the diaphragm and its assistant muscles. Furthermore, these singers finish their artistic careers without ever having arrived at the extent of their vocal possibilities; and, it seems reasonable to suppose, not having retained their voices as long as they might have done, if they had made a harmonious use of

all the parts comprising the vocal apparatus. Such artistes, therefore, have to lose a large amount of pecuniary return by reason of shortened years of vocal ability, or from being obliged to decline work during enforced necessary periods of rest, that would have been productive of valuable moneyed returns.

Sometimes it is impossible to convince artistes that they must rest, if they do not wish to run serious risk of permanently injuring their voices. It is no slight effort for one whose bread and butter, and perhaps managerial favor, depends upon their vocal efforts, to decline a profitable engagement from merely prudential reasons. How many, alas! can date the beginning of an impairment of the voice to the evening when they did not listen to the dictates of prudence in this respect. There certainly must be many voice-trainers who are fully aware of the desirability of instructing their pupils in this physiological requisition to proper voice-production; but there must be many who are ignorant on the subject, or who neglect their duties.

During the past season I had the honor to be consulted by a prominent artiste, whose delightful voice is well known to most lovers of good music. She was troubled with a peculiar sore throat, which, after careful study, I diagnosticated as an inflammation of the extra-laryngeal muscles, due to im-

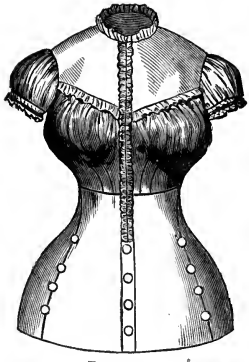
proper or rather inadequate use of the lower part of the chest in singing. Of course, I had to deliver a lecture on the subject of breathing in relation to tone-production. This lady had had (presumably) the very *best* of instructors on both sides of the ocean, and yet she told me that I was the first person who had ever told her that she did not breathe correctly,—her breathing was almost entirely clavicular in its type. What a commentary on the *best* instructors!

I feel that there is some slight hope of universal enlightenment on this subject when, occasionally, I have the fortune to hear a lady singer who is able to emit a long-sustained, evenly-modulated note, and to notice that her ability is usually recognized by approbative applause. I experience delight when I observe that every such lady singer has a waist *ample in size* to the carrying out of this function of the vocal apparatus. I repeat, "*ample*"; that is to say, *sufficient*—neither too large nor too small,—a waist that is *seemly* for its purposes, and, therefore, beautiful. If society could only possess a thorough knowledge of the physiology of the human female waist, it is doubtful if smallness, stiffness or immobility in it would be considered a physical beauty. It is a further encouragement to be informed that at least one of

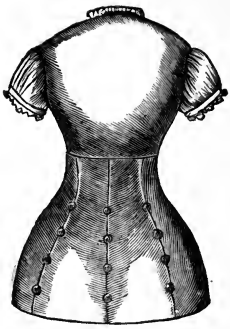
our important conservatories of vocal music requires the abolition of the corset in its pupils.

It may not be inappropriate to place here, as a sort of guide-board to any reader who may wish to set out on the path of reform in this matter of waist-constriction, a few words of encouragement and direction. It is not such a tremendous undertaking, after all. It merely requires the making and wearing of a waist reasonably well-fitted to the body, but having *abundance* of room around the waist and furnished with rows of buttons below the top of the hips, to which the various garments must be hung. Or a separate light waist may be included in each garment. A perfectly hygienic dress may be adopted which will not at all interfere with the general styles of fashion, always excepting such as require "*snugness*" and immobility of the waist.

The best waists substituting the corset that I have seen, are those devised by Mrs. O. P. Flynt, 319 Columbus Ave., Boston, Mass., of which an illustration is here given.



FRONT VIEW.



BACK VIEW.

These waists are worn in my own family, and I recommend them to my patients. There may be others as good or better, but others so well adapted to the peculiar conditions of female later-day existence have not come to my notice. It is but fair to add, that this recommendation, though sanctioned by Mrs. Flynt, is entirely voluntary and gratuitous on my part. Mrs. Flynt has certainly rendered an important service to society by the invention and introduction of these waists, and is, therefore, deserving of substantial recognition by all good-wishers of the race.

J. M. W. K.

168 West 58th St., New York.