and thrown over on the opposite cheek. The parts are restored and sutured in place after the tumor is removed.
Alfred C. Wood.

RESINS. See *Active Principles.*

RESOPYRIN. See *Antipyrin.*

RESORBIN is a readily absorbable ointment base made by emulsifying expressed oil of almond with yellow wax, soap, gelatin, and water, and adding lanolin to give it a proper consistency. It was introduced by Lebermann, who used it as a vehicle for mercury, as more readily absorbed and less greasy than blue ointment. He also employed it in various skin diseases. In course of time it tends to become rancid.
W. A. Bastedo.

RESORCIN: RESORCINOL.—Resorcin, chemically *metadioxybenzene*, $C_6H_4(OH)_2$, is one of a trio of isomeric diatomic phenols, of which pyrocatechin and hydroquinone are the other two members. It is official in the United States Pharmacopœia under the title *Resorcinum*, Resorcin.

Resorcin occurs in colorless, needle-shaped crystals, having a peculiar smell, resembling that of carbolic acid, and a bitter-sweetish taste. Resorcin dissolves readily in water, and still more readily in alcohol and in ether. In its effects resorcin resembles its congener, carbolic acid, but is, in general, less active than that substance, and, in particular, very much indeed less poisonous, constitutionally. Resorcin inhibits bacterial growth, but probably less potently than carbolic acid. Locally, the drug is without effect upon the sound skin, but applied, undiluted, to a moist mucous membrane, it is mildly caustic, while at the same time anæsthetic and healing. By reason of the anæsthesia it produces, resorcin may be applied even to such sensitive parts as the mucous membrane of the larynx (Andeer). Internally, resorcin may be given in very considerable doses, as compared with carbolic acid, and such doses, administered to a fevered subject, will show to a marked degree the peculiar antipyretic effect so characteristic of the phenols. After a dosage of from 2 to 3 gm. (from gr. xxx. to gr. xlv.) there set in, in a few minutes, quickening of heart action and of breathing, reddening of the face, and buzzing in the ears, with giddiness. Within fifteen minutes sweating begins, speedily becoming active, whereupon the antecedent derangements abate, and at the same time the pyrexial temperature rapidly falls—so rapidly as perhaps to reach the normal point within an hour. The sweating does not last long, so that after the lapse of an hour from the time of dosing, the fever patient may have a naturally moist skin only, with temperature and pulse rate reduced to the normal. But while defervescence by resorcin is quick to occur, it is also quick to give way to the natural tendency of the fever to regain its former height. Within from two to four hours, therefore, the temperature often begins its succeeding rise, and within a single additional hour may have attained its original height. Such rapid after-risings of temperature may be attended by a chill. Resorcin is variable in its action; sometimes the fall of temperature is slight, and sometimes the by-effects are excessive and even alarming. Thus, after medicinal doses, there have been observed delirium and illusions, with muttering speech and convulsive trembling of the hands, and, in one case at least, a deep comatose sleep. In overdosage resorcin is competent to induce constitutional poisoning after the general type of poisoning by the phenols—producing giddiness, insensibility, profuse sweating, great reduction of temperature, and general collapse, with olive green coloration of the urine. Such alarming condition has followed a succession of doses increased from half a drachm to two drachms. Therapeutically, resorcin has been used for both local and constitutional medication. Locally, resorcin is possibly available for a simple "antiseptic" effect, but is surpassed in this therapeusis by so many other agents as to be little used for the purpose. But for a combined antizymotic and *healing* effect the local application of resorcin may be quite serviceable. Thus injections of a five-per-cent. aqueous solution have been made into the bladder, in cystitis, and into suppurating cavities, with good effect, and salves of resorcin have abated malignant and syphilitic ulcerations. A spray of a two-per-cent. solution has been used in whooping-cough; and a ten-per-cent. solution has been praised for local application to the throat in diphtheria. Internally, resorcin has been used for its antipyretic action, in which application the medicine presents the feature of a fair degree of safety and efficiency combined; but the action is evanescent and attended by disagreeable excitement and sweating. The dose of resorcin for an antipyretic effect ranges from 2 to 4 gm. (from gr. xxx. to xlv.), best given in divided doses and administered, dry, in a wafer or capsule, or in solution in water, sweetened and aromatized. Constitutional effects are also asserted (Andeer) to be procurable, in diseases attended by an affection of the skin, by inunction of resorcin in admixture with vaseline, in proportion of from five to eighty per cent., such effects being the abatement of symptoms in so-called zymotic diseases. Andeer claims thus to have produced striking amelioration in such diseases as smallpox, scarlet fever, measles, and leprosy, by inunctions, over the whole body, of resorcin vaseline. Resorcin has been used as an intestinal antiseptic, under a variety of conditions, in doses of one or two grains every two hours.
Edward Curtis.

RESPIRATION, PHYSIOLOGY OF.—Respiration is the function by which living cells obtain oxygen and get rid of carbonic-acid gas. It is an essential factor in the existence of both animals and plants, being a necessary accompaniment of the chemical processes underlying life. In the higher animals respiration is a very complicated process, consisting of many stages, but in lower forms it is comparatively simple and may be studied to advantage.

COMPARATIVE.—*Protozoa.*—Simple one-celled organisms like the amœba, live in a fluid medium, water, which surrounds them on all sides. From this surrounding medium the dissolved oxygen is absorbed by the general surface of the body, and distributed to all parts by diffusion or by currents set up by the contracting vacuoles, or by some unknown form of cell activity. The carbon dioxide is got rid of by a reverse process. This simple form of respiration is probably very similar to the process by which the cells of the higher animals obtain their supply of oxygen and return their carbon dioxide to the surrounding lymph, constituting the so-called "internal or tissue respiration."

Cœlenterata.—In this group each animal consists of a central cavity surrounded by two layers of cells (see Fig. 4098). Oxygen is taken in to some extent by the external surface, but also by the central body cavity, which serves the double purpose of food absorption and respiration. This prepares us to find the lungs of higher animals having a common embryological origin with the organs of digestion, and suggests the close relationship of the two processes. The currents set up to and from the central cavity by the movements of the body wall and of the tentacles facilitate the respiratory processes by bringing fresh fluid with a new supply of oxygen within reach of the absorbing cells.

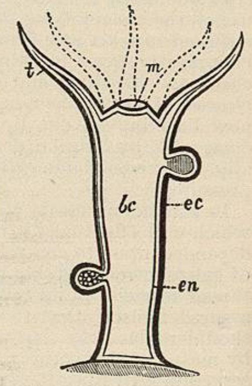

FIG. 4098.—Hydra, diagrammatic, showing Body Cavity *bc*, body wall in two layers *en* and *ec*, tentacles *t*, and mouth *m*. (After Bell.)

Worms.—In this heterogeneous division of the animal kingdom we find a circulating fluid or blood capable of

carrying the oxygen from the surface of the body where it is absorbed, to the cells in the interior which have need of it. In some cases the blood contains a special substance, hæmoglobin, with which the oxygen can enter

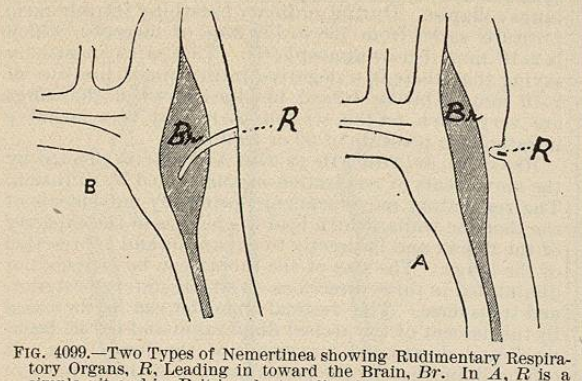

FIG. 4099.—Two Types of Nemertinea showing Rudimentary Respiratory Organs, *R*, Leading in toward the Brain, *Br*. In *A*, *R* is a simple pit and in *B* it is a duct ending blindly among the cells of the brain. (After Bell.)

into loose combination while being carried about. In the worms we find for the first time special organs of respiration. Sometimes these are little more than grooves or pits supplied with cilia to favor the renewal of the oxygen-containing medium. In other cases we find these pits becoming deeper so as to form ciliated ducts (Fig. 4099).

Insects.—In insects we find a system of tubes (tracheæ) adapted for air breathing. These are distributed through the body, and the renewal of the air within them is favored by movements of the legs and wings.

Higher Animals.—As we ascend the scale we find further developments of the organs of respiration, such as to offer the greatest respiratory surface in the smallest possible space. This is seen both in the gills of fishes and the lungs of air-breathing animals. The arrangements for the renewal of the oxygen-containing medium are elaborated and reach their highest development in the bony thorax of the higher vertebrates with their costal and diaphragmatic breathing. The blood-vascular system also becomes better adapted for taking up oxygen and carrying it rapidly all over the body.

The human embryo in its respiratory function, as in other things, passes through many of the stages represented in lower forms. The one-celled ovum, like the amœba, takes in oxygen by its general surface from the fluids which surround it in the uterus. As growth proceeds it develops a blood-vascular system, but for a time continues to take in its oxygen by the general surface of the surrounding membranes. When the placenta is formed, the fœtus has a special organ of respiration, but obtains its supply like a fish from a fluid medium, the mother's blood. At birth the tying of the cord shuts off the placenta, and the consequent deficiency of oxygen stimulates the centre in the medulla to initiate the first respiratory movements. The opening up of the lungs diminishes the pressure in the pulmonary vessels, and thus determines an increased blood supply to these organs. The foramen ovale closes and the adult condition is rapidly established.

THE ORGANS OF RESPIRATION.—These include the *air passages* leading into the lungs from outside and comprising the nose, pharynx, larynx, trachea, and bronchi; the *lungs* which contain the respiratory surfaces (air sacs or alveoli) in which the interchange of gases takes place, the divisions and ramifications of the bronchi leading down to the alveoli, and the supporting connective tissue in which run the blood and lymph vessels and the nerves; the *pleuræ* which cover the lungs and line the thoracic walls with a smooth slippery membrane facilitating movement; the *thoracic walls* which enclose the lungs and which are strong enough to protect them and yet mobile enough to be the medium through which the expansion of the lungs is effected; the *muscles of respiration*, including the diaphragm and the muscles acting upon the ribs; the *nervous mechanism* through which all the respiratory processes are initiated and regulated.

The *nose* serves a useful purpose in warming the inspired air and thus protecting the other air passages from too sudden changes of temperature. The *larynx* is especially concerned in speech and voice production. It also plays an important part in preventing dust particles and noxious gases from entering the lungs by the cough and spasm which these substances excite when they come in contact with its mucous membrane. The *trachea* and *bronchi* consist of tubes of fibrous and elastic tissue supported at regular intervals by incomplete rings of cartilage. The portion behind, where the cartilage is absent, is supplied with plain muscle tissue by which the tubes can be somewhat constricted. The mucous membrane consists of loose lymphoid tissue. It is supplied with mucous glands, which keep the surface moist, and is lined with ciliated columnar epithelium. The cilia carry the mucous secretion and inhaled dust particles up toward the larynx. The *lungs*. As the bronchi enter the lungs they divide and subdivide, forming the bronchial tubes, to the smallest of which the name bronchioles is applied. The structure of the trachea and bronchi is continued into the bronchial tubes with certain modifications. The cartilaginous rings are replaced by irregular plates of cartilage distributed at intervals around the tubes, and even these are not found in the very smallest bronchioles. The unstriped muscle becomes relatively more abundant as the size of the tubes diminishes and it forms a continuous layer of circular fibres. The epithelium changes from columnar to cubical, and in the smallest tubes mucous glands are not found. The lungs may be seen to be divided into innumerable tiny sections known as lobules, of which each has a diameter of 1–3 cm. They are of pyramidal shape, and are divided from one another by a little fibrous tissue. A bronchial tube entering such a lobule divides several times, forming tiny bronchioles. If we follow the bronchiole along we will find the epithelium changing from cubical to pavement, and we will see an occasional air sac or alveolus opening out from the side. These tubes supplied with alveoli are known as respiratory bronchioles. Each respiratory bronchiole ends in a dilated passage called an alveolar duct, into which open a number of infundibula. An infundibulum is a cone-shaped expansion with the apex toward the duct. Extending out from it are numerous hemispherical expansions known as air sacs or alveoli which very greatly increase the total surface (see Fig. 4100).

The wall of an infundibulum consists of a thin basement membrane lined by epithelium, the so-called "respiratory epithelium." The cells composing this epithelium are of two kinds: non-nucleated platelets resting upon the blood capillaries and smaller nucleated cells between. Around the infundibula is spread out a network of capillaries so dense that the meshes are narrower than the vessels themselves. Between the air in the air sacs and the blood in the capillaries nothing intervenes but the two layers of epithelium belonging to the alveoli and the capillaries respectively. In some cases the capillary may be in contact with the epithelium of two contiguous alveoli (see Fig. 4101).

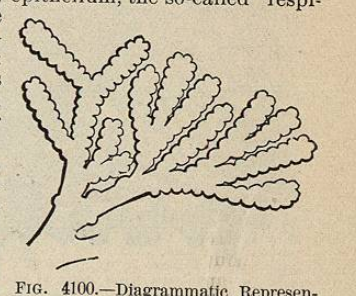
FIG. 4100.—Diagrammatic Representation of the Ending of a Bronchial Tube in Sacculated Infundibula. (After Schaefer.)

The capillaries distributed to the air sacs are from branches of the pulmonary artery. The walls of the bronchial tubes and the connective tissue of the lungs are supplied by the bronchial arteries belonging to the systemic circulation. The connective tissue which intervenes everywhere between the infundibula and under the pleura is rich in elastic tissue. The nerves of the lung come from the anterior and posterior pulmonary plexuses, which are formed by branches from the pneumogastric and sympathetic. The sympathetic fibres come off from the inferior cervical ganglion, annulus of Vieussens and stellate ganglion, and can be traced back to the upper thoracic nerves. See also *Nasal Cavities, Larynx*, etc.

PHYSICAL RELATIONS OF THE LUNGS TO THE CHEST WALL AND THE EXTERNAL ATMOSPHERE.—Before birth the lungs are solid organs; that is to say, the opposite walls of the alveoli and bronchial tubes are in contact, and form merely potential spaces communicating through the respiratory passages with the outside. At birth the thoracic cavity is enlarged by the action of the muscles of respiration. The additional space which results must be filled up as it is formed, for "nature abhors a vacuum." The only avenue through which anything can enter the thorax to fill it is through the respiratory passages, and so air enters, expanding the lungs and keeping them in contact with the receding chest wall. Throughout life the lungs continue to follow the movements of the chest wall. If the chest is enlarged, air enters the lungs, expanding them sufficiently to fill it up. In doing this the air has to overcome the elasticity of the lungs. During rest the air exerts upon the inside of the lungs the same pressure as upon the external surface of the body, 760 mm. of mercury or fifteen pounds to the square inch. When the chest is suddenly expanded, as in inspiration, the air within the lungs is rarefied and the pressure within the lungs, *the intrapulmonary pressure*, is diminished. During expiration the thorax diminishes in size, compressing the air in the lungs, and the intrapulmonary pressure rises. In either case movement of air in or out of the lungs takes place till the intrapulmonary pressure is again equal to atmospheric when equilibrium is established.

The pressure in the pleural cavity and in the mediastinum is known as the *intrathoracic pressure*. It is always less than atmospheric because the elasticity of the lungs tends to pull them away from the chest wall, and protects the latter from part of the intrapulmonary pressure. The more the chest is expanded the more is the elasticity of the lungs brought into play, and the more does intrathoracic pressure fall below atmospheric. The intrathoracic pressure is often spoken of as *negative*, meaning that it is less than atmospheric. The fact that it is so may be seen when an opening is made in the chest, as in this case air is drawn into the pleural sac and the lungs collapse. During ordinary breathing intrathoracic pressure varies from 758 to 752 mm. of mercury, which is 2–10 mm. below atmospheric. This is expressed by saying that there is a negative intrathoracic pressure of 2–10 mm. During forced inspiration, when the lungs are very much on the stretch, there may be a negative intrathoracic pressure of 30 or 40 mm.

RENEWAL OF THE AIR IN THE ALVEOLI is effected by the movements of respiration supplemented by diffusion. The respiratory movements are primarily movements of the thoracic walls, which lead to changes in the capacity of the thorax and indirectly to expansion and contraction of the lungs. The size of the thorax can be increased or diminished in three directions—vertical, antero-posterior, and transverse. The vertical diameter can be increased by the descent of the arched diaphragm and by the backward and downward movement of the lower ribs. It can be diminished by the passive return of the diaphragm to its arched position of rest, assisted by the contraction of the abdominal muscles, which force the viscera up against the diaphragm and increase its arch.

The antero-posterior diameter is increased by the raising of the ribs from the resting position, in which they slant downward, to one in which they extend more directly forward, carrying the sternum with them. In quiet breathing the upper end of the sternum acts as a fulcrum and the lower end is pushed out; but in very deep inspiration the upper end is also raised and extended forward. The antero-posterior diameter is diminished by the thorax returning to a position of rest as a result of gravity and elastic recoil.

The transverse diameter is increased by the outward and upward rotation of the ribs. Any tendency of the contracting diaphragm to draw in the lower ribs is overcome by the fact that the abdominal viscera are compressed by its descent and tend to press the ribs outward.

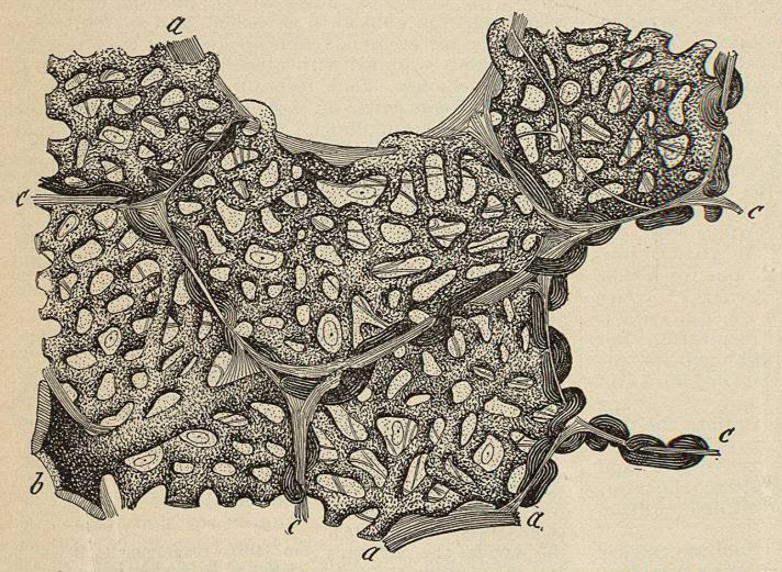

FIG. 4101.—Section of Injected Lung, Including Several Contiguous Alveoli. (F. E. Schultze.) (Highly magnified.) *a, a*, Free edges of alveoli; *c, c*, partitions between neighboring alveoli, seen in section; *b*, small arterial branch giving off capillaries to the alveoli. The looping of the vessels to either side of the partitions is well exhibited. Between the capillaries is seen the homogeneous alveolar wall with nuclei of connective-tissue corpuscles and elastic fibres. (Schaefer.)

MUSCLES OF RESPIRATION.—In ordinary inspiration the vertical diameter is increased by the descent of the *diaphragm*, assisted by the *quadratus lumborum* and *serrati postici inferiores*, which fix the lower ribs. The antero-posterior and transverse diameters are increased by the *scaleni, levatores costarum*, and *serrati postici superiores*, which fix the two upper ribs and assist the elevation and eversion of the others, and by the *external intercostals* which raise the lower ribs. Both the *external and internal intercostals* by their contraction give strength to the intercostal spaces and enable them to withstand the atmospheric pressure. Expiration is largely passive, being brought about by the influence of gravity and the elastic recoil of the thorax, and by the relaxation of the diaphragm which allows it to be forced up again by the pressure of the abdominal viscera. Some claim that the descent of the ribs is assisted by the contraction of the interosseous portion of the *internal intercostals*.

In forced inspiration a great number of additional muscles are called into play, first those having attachments to the ribs or sternum, and later a very great number which indirectly assist the enlargement of the chest or the opening up of the respiratory passages. Forced expiration is assisted by the action of the abdominal muscles, which press on the viscera and so push up the diaphragm, and also by those muscles

of the abdomen and back which pull down the lower ribs.

TYPES OF RESPIRATION.—An infant breathes mostly with its diaphragm. Such breathing is spoken of as the *diaphragmatic* or *abdominal type*. In adults we find a

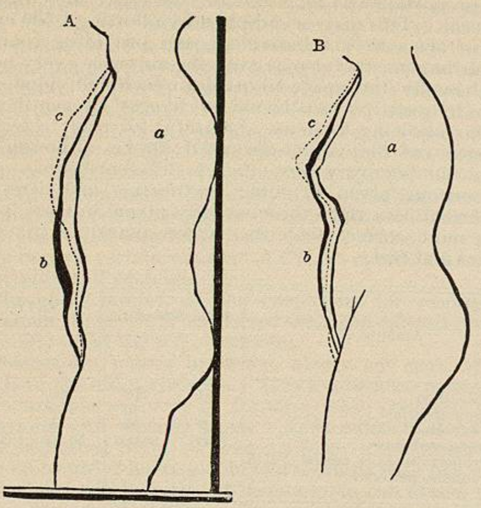

FIG. 4102.—*A*, Inferior Costal and *B*, superior Costal Type of Breathing. *a, a*, Outline of body in forced expiration; *b, b*, heavy continuous line. The outer margin indicates the contour of the body in ordinary inspiration and the inner margin that of ordinary expiration. The relative thickness of this line in the two sexes shows that in the male the greater movement takes place in the abdomen and lower thorax (inferior costal) and in the female in the upper thorax (superior costal). *c, c*, Contour of forced inspiration. Note that forced inspiration is of the superior costal type in both sexes. (After Hutchinson.)

difference in the manner of breathing between the male and female. In the male the movements of the abdomen and lower part of the thorax are more pronounced, forming the so-called *inferior costal type*, while in the female movements of the upper chest predominate, and we speak of the *superior costal type*. This difference in the sexes is not found in all races, and so is ascribed by some to the influence of dress, but others see in it an adaptation of woman for her sexual life, pregnancy, through natural selection (see Fig. 4102).

THE QUANTITY OF AIR BREATHED.—During ordinary quiet breathing about 300 c.c. of air is taken into the lungs with each inspiration and expelled with each expiration. This is called the *tidal air*. By a forced inspiration an additional quantity, known as the *complemental air*, may be taken in. Its volume is about 1,700 c.c. The air that can be expelled by an effort after an ordinary expiration is the *supplemental air*, and measures about 1,500 c.c. The air remaining in the chest after the most powerful expiration is the *residual air*, amounting to about 1,000 c.c. The total quantity that can be taken in after a complete expiration or breathed out after the fullest inspiration is called the *vital capacity*, and includes the complemental, tidal, and supplemental air. It measures therefore in a typical case about 3,500 c.c. *Lung capacity* is the total quantity of air in the lungs after a forced inspiration, and is equal to the vital capacity plus the residual air, or about 4,500 c.c. All these quantities naturally vary very much in different individuals and under different conditions, but the above numbers may be taken as more or less typical.

The quantity of air breathed in any given case can be estimated by means of an instrument known as a spirometer (see Fig. 4103).

THE CHANGES THAT TAKE PLACE IN THE AIR.—In the lungs certain things are taken from the air and others added, as shown in the following table, in which the quantities are given in volumes per cent.:

	Inspired air.	Expired air.
Nitrogen	79	79
Oxygen	20.96	16.03
Carbonic acid	.04	4.4
Aqueous vapor	Variable.	Saturated.
Argon, etc.	Traces.	Traces.

It is to be noted that the volume of oxygen lost, 4.93, is slightly greater than the volume of CO_2 added, 4.36, so that the total volume of the expired air is slightly less than that of the inspired air.

The expired air is warmed to the temperature of the body and is also fouled by organic emanations given off from the lungs and respiratory passages. The principles on which the analysis of expired air is carried out may be conveniently studied in the apparatus designed by Waller, which is one of the simplest and yet sufficiently accurate for most purposes (see Fig. 4104).

In other methods the carbon dioxide is absorbed by soda lime or by baryta water instead of by sodium hydrate, and arrangements may be made for passing the air through a chamber containing sulphuric acid for the arrest and estimation of the aqueous vapor.

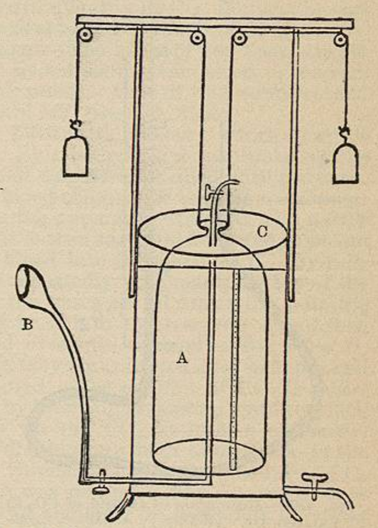

FIG. 4103.—Diagram of Hutchinson's Spirometer. (Landois.) *A*, Graduated cylinder serving as a receiver for the breath; it is supplied with a stopcock at the top for the ready expulsion of air, and is balanced by weights passing over pulleys. *B*, Mouthpiece with tube reaching nearly to the top of the graduated receiver (*A*), when the latter is sunk in the reservoir ready for an experiment; there is a stopcock in this tube near the first angle to prevent regurgitation of air. *C*, Reservoir for the graduated receiver. In using the spirometer the reservoir and graduated receiver are filled with water, or, to prevent the absorption of carbon dioxide, with a saturated aqueous solution of common salt (NaCl). When ready for an experiment, the stopcock at the top of the receiver is closed and that in the tube of the mouthpiece opened, and the breath forced into the receiver. The receiver rises as fast as the breath displaces the water. After the breath is forced into the receiver the stopcock in the tube of the mouthpiece is closed, and the water outside and inside the receiver brought to the same level, so that the air within the receiver shall be at the atmospheric pressure. The amount of breath within the receiver is then read directly from the scale attached to the receiver. For accurate measurement the breath should stand a few minutes to acquire the temperature of the liquid over which it is collected, then the various corrections for aqueous vapor tension, and the variations from the standard temperature and pressure, should be made.

RESPIRATORY QUOTIENT OR RESPIRATORY COEFFICIENT.—As is shown in the table given above, the volume of oxygen absorbed is greater than the volume of carbon dioxide excreted. The relation of one to the other is expressed as $\frac{CO_2}{O_2}$ and is known as the respiratory quotient. If all the oxygen taken into the body reappeared in the expired air as CO_2, the volumes would be equal and the respiratory quotient $\frac{CO_2}{O_2}$ would be 1. Some of the oxygen, however, combines with hydrogen to form water, and is excreted as aqueous vapor by the lungs, or as water by the skin and kidneys, and thus does not leave the body as CO_2 at all, but as H_2O. The respiratory quotient varies with the relative proportions of carbon, hydrogen, and oxygen in the food. Carbohydrates contain in themselves just enough oxygen to satisfy all the hydrogen present, so that only the oxidation of the carbon has to be provided for by the oxygen taken in by the lungs. Thus the presence of a large amount of carbohydrate in the diet tends to make the respiratory quotient approach 1. Fats and proteids, on the other hand, contain a relative excess of hydrogen, and require oxygen for combination with it, so that the CO_2 excreted represents only part of the oxygen absorbed and the respiratory quotient falls below 1.

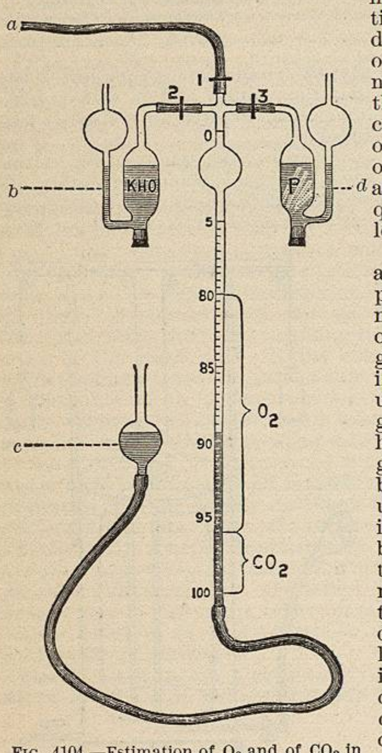

FIG. 4104.—Estimation of O_2 and of CO_2 in Expired Air. (Waller.) A 100 c.c. measuring tube graduated in tenths of 1 c.c. between 75 and 100. A filling bulb. Two gas pipettes. The measuring tube communicates by three tubes guarded by simple taps 1, 2, 3, with the inlet and with the gas pipettes. It is first charged with acidulated water up to the zero mark by raising the filling bulb, tap 1 being open; it is then filled with 100 c.c. of expired air, the filling bulb being lowered until the fluid in the burette has fallen to the 100 mark. Tap 1 is now closed, the measuring tube containing 100 c.c. of expired air with unknown quantities of CO_2 and of O_2. The amount of CO_2 is ascertained as follows: Tap 2 being opened, the air is expelled into a gas pipette containing KHO by raising the filling bulb until the fluid has risen to the zero mark of the measuring tube. Tap 2 is now closed, and the air left in the gas pipette for about a minute, during which the CO_2 present is entirely absorbed. The air is then drawn back into the measuring tube by lowering the filling bulb while tap 2 is open. The volume of air (minus the CO_2, which is being absorbed) is read, the filling bulb being adjusted so that its contents are at the same level as the fluid in the burette. The amount of O_2 is next ascertained in a precisely similar manner by sending the air into a second gas pipette containing sticks of phosphorus in water, and measuring the loss of volume (due to absorption of O_2) in the air when drawn back into the tube. A gas pipette works thus: fluid in its lower half is displaced into its upper half, when air is driven in from the measuring tube, and returns to its original place, when air is drawn back. If desired, the apparatus can be connected with a vessel in which a frog or mouse or excised muscle has been placed and the consequent alterations of the gases O_2 and CO_2 measured in a similar manner. *a*, Inlet or outlet; *b*, gas pipette for absorption of CO_2; *c*, filling bulb; *d*, gas pipette for absorption of O_2.

Temporary variations in the respiratory quotient may be due on the one hand to oxygen being absorbed in excess and stored up as tissue oxygen, or on the other hand to tissue oxygen taken in long before being made use of for oxidizing some of the carbon. The former tends to lower the respiratory quotient and is seen during rest; the latter raises it and is seen in conditions of activity and quickened metabolism.

VENTILATION. — The withdrawal of oxygen from the air and the addition of CO_2 and organic matters that takes place during respiration renders it vitiated or unfit to be breathed again. When a room has been breathed in until the amount of CO_2 has risen to 0.07 volume per cent., the air becomes more or less stuffy, although in very badly ventilated rooms the proportion may reach ten times this figure. The closeness or stuffiness is due principally to the organic emanations, of which some are of an odorous nature. This is shown by the fact that much larger quantities of CO_2 can be added to the air of a room in other ways without causing any inconvenience to the inmates. Air containing even as much as twenty-five per cent. of CO_2 can be breathed safely for a short time if there are no other impurities in it, and if it contain plenty of oxygen. An ordinary individual requires about 2,000 cubic feet of air per hour if the proportion of CO_2 is not to rise above 0.07 volume per cent. This may be supplied by allotting 1,000 cubic feet of space to each individual, and providing ventilating arrangements for renewing the air twice every hour. The smaller the space allotted to each individual the more frequently must the air be changed by ventilation.

The following table may be useful for ready reference on some of the points discussed above, although the exact numbers vary very much in different people. The proportions given in cubic centimetres and litres are somewhat less than those usually given, but are probably more correct than the larger quantities given in inches and feet.

Amount of	ONE BREATH.		TWENTY-FOUR HOURS.	
	Cu. in.	C.c.	Cu. ft.	Litres.
Air breathed	30	300	350	7,000
Oxygen absorbed	1.5	15	17.5	350
CO_2 excreted	1.3	13	15	300
Air rendered close (Proportion of CO_2 raised to 0.07 volume per cent.)	5,000	50,000	50,000	1,000,000

THE BLOOD AND ITS GASES.—While the air on one side of the respiratory epithelium is being constantly changed by the movements of the chest and by diffusion, the blood on the other side is being changed by virtue of the circulation. The blood is brought in a venous condition by the pulmonary artery and its branches, and is carried away in an arterial condition by the pulmonary veins. The gases of the blood are the same qualitatively as those of the atmosphere, but are not present in the same proportions. The proportions naturally vary somewhat, but the following are approximate in volumes per cent. of blood:

Blood.	O.	CO_2.	N.
Arterial	20	40	1-2
Venous	10	46	1-2

In considering the nature of the connection between the blood and its gases it is necessary for us to keep in mind the various constituents of blood and their power of taking in gases. The *plasma* may for our present purpose be considered as made up of water, salts, and proteids. *Water* is capable of holding a certain quantity of gas in solution, the exact amount depending on the nature and tension of the gases surrounding it, and on the temperature. If water be exposed to a mixture of gases it will absorb and hold in solution a quantity of each, which will depend on the quantity of that particular gas in the mixture. Each gas present in a mixture exists at a certain tension, and exerts what is called a *partial pressure*. This partial pressure is not affected by the amount of any other gas that may be present. Thus if a jar were half full of water and the rest of it occupied by air, the water would take up from the air a certain amount of nitrogen and a certain amount of oxygen. If now pure nitrogen were pumped into the jar without allowing any of the air already there to escape, the tension or partial pressure of the nitrogen in it would be increased and the water would take a proportionately larger amount into solution. The tension or partial pressure of the oxygen would remain, however, what it was before, and the water would not absorb any more. If now pure oxygen were pumped in, the partial pressure of oxygen in the jar would be increased and the water would take a proportionately larger amount of this gas into solution.

The nitrogen of the blood is held chiefly in simple solu-

tion in the water of the plasma. The oxygen and carbon dioxide, however, are present in much larger proportions than water could take into solution at the tension or partial pressure of these gases prevailing in either the lungs or the tissues. These gases must therefore be attached to the other constituents of the plasma or to the corpuscles. *The salts of plasma* include among others considerable quantities of sodium carbonate. This salt is capable of combining with carbonic acid gas to form sodium bicarbonate. There is reason to believe that the carbonic acid is principally held in the blood in this chemical combination. Sodium phosphate, another constituent of the plasma, may combine with carbonic acid too, forming sodium bicarbonate and sodium biphosphate. *The proteids* of the plasma, especially the globulins, are also claimed to have some power of combining with carbonic acid gas. *The corpuscles*, both red and white, may similarly carry a certain amount of CO_2 in combination with their salts and proteids.

The chief interest of the corpuscles for respiratory purposes, however, is connected with the colored proteid hæmoglobin of the red corpuscles.

Hæmoglobin makes up about ninety per cent. of the solids of the red corpuscles. It is a substance possessing a remarkable property of forming loose chemical combinations with various gases. As it exists in the blood it is combined with oxygen to form oxyhæmoglobin. One molecule of hæmoglobin can combine with one molecule of oxygen or 1 gm. of hæmoglobin can attach to itself 1.34 c.c. of oxygen. In arterial blood the hæmoglobin is nearly saturated with oxygen, and in venous blood it still has some oxygen associated with it. Oxygen-free hæmoglobin or reduced hæmoglobin is not usually present in the body, but can be demonstrated in parts where the circulation has been stopped for from forty to three hundred seconds (Vierordt).

There are a number of compounds and derivatives of hæmoglobin which can be most readily distinguished by the absorption bands in their spectra. In the article on *Blood* in another volume of this HANDBOOK, they are described in some detail, and their spectra are figured.

Oxyhæmoglobin is the bright red substance which gives the color to arterial blood. In this compound the oxygen is present in a very loose chemical combination, and may be readily taken up by the tissues of the body or by reducing agents.

Methæmoglobin is a brown substance formed by the action of oxidizing agents on oxyhæmoglobin. It is found in the blood in cases of poisoning by chlorate of potash and similar substances. Methæmoglobin is of no use for respiratory purposes, as the oxygen is too firmly united to be abstracted by the tissues, although it is readily taken up by strong reducing agents, such as ammonium sulphide, with the formation of hæmoglobin (reduced).

Carbonic-Oxide Hæmoglobin.—If illuminating gas be inhaled the carbonic oxide which it contains unites with the hæmoglobin of the blood in place of the oxygen by virtue of the fact that CO possesses the stronger affinity of the two for hæmoglobin. This quite destroys the oxygen-carrying properties of the blood and results in death.

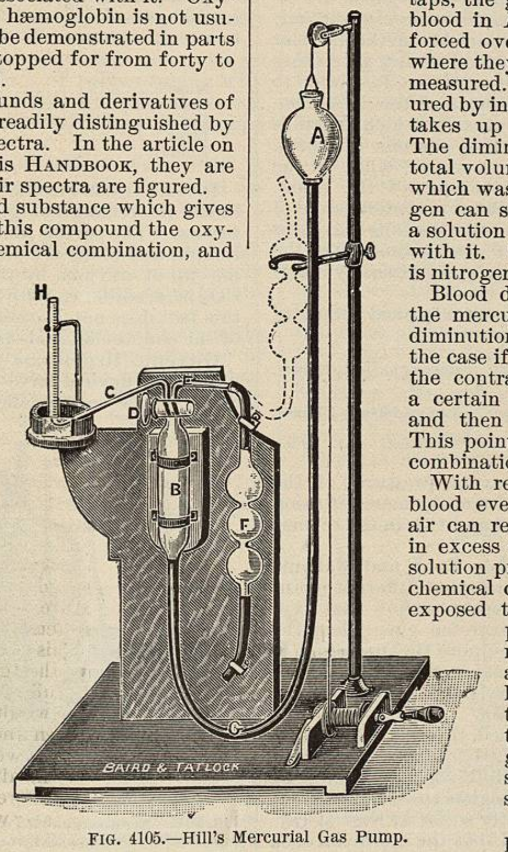

FIG. 4105.—Hill's Mercurial Gas Pump.

Other gases, such as NO, H_2S, etc., may also destroy the oxygen-carrying power of the blood by replacing the oxygen, or by otherwise changing the hæmoglobin molecule.

Hæmatin.—Hæmoglobin may be decomposed under the action of heat and acid or alkali into two parts, a proteid of unknown nature, usually referred to as globin, and a brown coloring matter rich in iron and designated hæmatin.

Hæmochromogen, or reduced alkaline hæmatin, may be formed by the action of reducing agents on hæmatin, or by breaking up hæmoglobin in the absence of oxygen. Hæmochromogen has the same power of uniting with gases as hæmoglobin has, and in fact has been shown to be able to attach to itself the same quantity (of CO) as the corresponding amount of hæmoglobin. Hoppe-Seyler taught that hæmochromogen existed as such in hæmoglobin, and lent it its gas-carrying property. This is disputed, however, by Gamgee (Schaefer's "Text-book").

The proteid part of the hæmoglobin molecule is believed by many to be of the nature of a globulin. It is probable that the small quantity of CO_2 that can be carried by hæmoglobin is attached to this proteid part.

The Mercurial Pump.—The gases of the blood are obtained for analysis by subjecting the blood to the vacuum of a mercurial pump. One of the simplest and best is that of Leonard Hill (see Fig. 4105).

A is a reservoir filled with mercury which may be raised or lowered. By raising it and manipulating the various taps the whole apparatus is filled with mercury. By lowering it the blood chamber *F* is made a vacuum. *F* is separated from the apparatus, weighed, and partly filled with blood. It is then reattached and the gases are drawn off from the blood into the reservoir *B*. By raising and lowering *A* repeatedly with manipulation of the taps, the gases are all drawn off from the blood in *F* into the reservoir *B* and then forced over into the eudiometer tube *H*, where they are collected over mercury and measured. The amount of CO_2 is measured by inserting potassium hydrate which takes up the CO_2 to form a carbonate. The diminution which takes place in the total volume of gas is the amount of CO_2 which was present. The amount of oxygen can similarly be measured by using a solution of pyrogallic acid, which unites with it. The gas remaining unabsorbed is nitrogen.

Blood does not give off its oxygen in the mercurial pump in proportion to the diminution in the pressure as would be the case if it were in simple solution. On the contrary, very little comes off until a certain degree of vacuum is reached, and then large quantities are given off. This points to its being in loose chemical combination.

With regard to the CO_2, the fact that blood even when exposed freely to the air can retain an amount of CO_2 greatly in excess of what it could hold in simple solution proves that this gas too exists in chemical combination. Now if plasma be exposed to the mercury pump and the pressure sufficiently lowered, much of the CO_2 is given off, and must therefore be quite loosely combined. Another portion is not given off without the addition of an acid or hæmoglobin (red corpuscles), which seem able to liberate it from some more stable compound.

The nitrogen is given off in proportion to the diminution in the pressure, and the view generally held is that it is in simple solution in the plasma.

THE INTERCHANGE OF GASES BETWEEN THE BLOOD AND AIR.—Here we find ourselves face to face with the fundamental question of the relation of epithelial cells to the processes taking place through them. Does the