through the arteries, capillaries, and veins; and the blood must, therefore, feebly enter the minute vessels in the gills, where purification takes place.

The parts of the circulating system most difficult to be understood, are the valves of the heart and their action. Both these can be beautifully shown in a cow's heart, the vessels of which have been cut high up, and as little injured as possible. The hard suet being cleared from the base of the heart, to show the bicuspid valve between the left auricle and ventricle, pass the finger into the large opening of the aorta (which is the vessel butchers often hang the heart by) nearest the heart, when will be felt the semilunar valves at the mouth of the left ventricle. These must be broken down by cautiously introducing a scalpel, or penknife, and cutting and then forcibly rupturing them with the finger. Having done this, close all the openings on the sides of the aorta, by tying them, or transfixing them with a needle, and twisting thread round it, or putting a small cork in the largest, fastening with needles, and twisting thread around them, &c. Now pour water gently into the aorta, and notice where it escapes. This will be by the left auricle, which is to be cautiously removed, (but not cut quite to its base,) until the valves are exposed. If water is now poured quickly into the aorta, the bicuspid valve will be seen to be lifted up, and to prevent its escape; or, what is better, the air may be made to take the place of the water, by drawing in the breath and blowing forcibly, in quick succession, through the aorta. The action of the valve during life may thus be shown with tolerable accuracy.

When this has been examined, the heart should be cut through transversely, two or three inches above its apex, to show the greater thickness of the left than the right ventricle. The left ventricle and aorta may then be cut up to show their internal surface—the fleshy columns and tendinous cords, which assist the heart in contracting, the appearance of the bicuspid and semilunar valves, the grooves leading to the branches from the aorta, &c.

The actions of the semilunar valves may now be shown by cautiously cutting away the right ventricle, till the valves at the mouth of the pulmonary artery are exposed. Take a pig's bladder, and cut about two inches off each extremity. Sew the narrower end round the inner surface of the pulmonary artery; pour a jugful of water quickly into the bladder, and the action of the valves, in preventing its return, will be seen.

By mixing Paris plaster (which may be got from any plasterer) bulk for bulk with the water, casts of the pulmonary valves, of the left ventricle, &c., may be made, and cut out when dry. To take a cast of the right ventricle, the pulmonary valves must be broken down, as above. These make very instructive preparations, when the valves, &c., are distinguished by being coloured.

Attention should also be directed to the great difference in muscularity between the auricles and ventricles, and to the sounds of the heart as they can be heard by applying the ear to the left side of the chest of a thin person. The first dull sound is supposed to be produced principally by the contraction of the ventricles; the succeeding sharp sound by the falling back of the blood on the semilunar valves.

In disease, these sounds become louder and much altered—in some cases resembling the blowing of bellows, and in others, the rasping of a file, &c. The contraction of the heart is called its systolé, the time it rests its diastolé.

To show the fibrin of the blood, get some from the butcher, (who extracts it by turning his fingers in the blood while coagulating), and wash it till it is pure white. The coagulability of the serum (which can easily be got from any surgeon) should be shown by heating it in a Florence flask.

As mentioned in the text, the microscope shows the circulation in a frog's foot.

Other figures to illustrate this section may be found in "Animal Physiology" in the Library of Useful Knowledge, pages 69, 70, 71, 73, 74; in Dr. Roget's Bridgewater Treatise; in Dr. Smith's Philosophy of Health; in Bell's Anatomy, &c.

[The foregoing explorations are not recommended for young people.]

SECTION IV.

RESPIRATION.

71. We have seen, in the preceding section, the course which the blood pursues. We have now to consider the changes it undergoes in that course. It will be recollected that the left side of the heart sends the blood into the general system: this is called the *systemic circulation.* The right side of the heart sends it into the lungs, and this has received the name of the *pulmonic circulation.* But if the blood that goes to the lungs were returned in the same state as it is sent, death would be the consequence, for venous blood is a poison to the body; and this is the reason why an animal dies when the air is prevented from getting into its windpipe, by hanging or drowning. Bichat showed this very decisively. He connected, by a tube, the jugular vein of one dog with the carotid artery (which sends the blood to the brain) of another, and allowed the venous blood to flow into it. The immediate effect of this was, that the dog in whose brain the venous blood was made to circulate, became com-

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126. What two circulations are spoken of?
127. Bichat's experiment.

pletely insensible, and would in a short time have died. On allowing the arterial blood, however, again to circulate in its brain, the dog was quickly restored.

72. What are the changes, then, that take place in the lungs, and how are these changes effected? These questions will be best answered by first knowing what the lungs are. The lungs (vulgarly called *lights*) are principally composed, 1st, of air-tubes (bronchi) of which the windpipe (trachea), is the commencement, and which divide and subdivide until they terminate, as has been supposed, in very minute bags or air-vesicles; and 2dly, of the pulmonary artery (Fig. 15, E, and Fig. 16, *p*, *a*), which branches out upon the sides of these air-tubes. Fig. 20 shows the windpipe, with the lungs entire on one side, and with the branches of the air-tubes dissected on the other. These tubes are said to terminate in vesicles, which vary in size from the 50th to the 10 th part of an inch in diameter. The lungs are also seen in Fig. 21, in their natural situation in the chest.

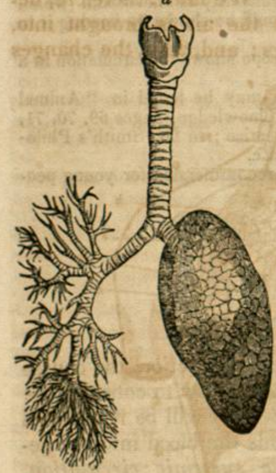

Fig. 20. Windpipe and Lungs.

73. If we tie up tightly in a bladder a quantity of venous or dark blood, we shall find, in a short time, that exposure to the air has changed the colour of the portion near the surface. The air has passed through the bladder, and has converted the venous into red or arterial blood. Exactly the same thing takes place in the lungs; for the air, in the air-vesicles, is separated from the blood in its vessels by a membrane not more than the thousandth

128. Describe the diagram.
129. The experiment with the bladder.
130. What changes its colour?

part of an inch in thickness. But we shall find, immediately, that it is not the blood alone that is altered in its qualities. The air undergoes alterations. The blood in the lungs also becomes fit for supporting life; the air becomes unfit for this purpose. We must, therefore, describe, 1st, the means by which the air is brought into, and then removed from, the lungs; and, 2dly, the changes

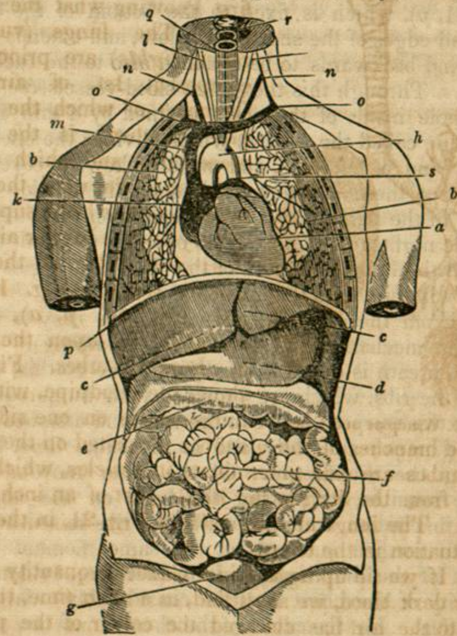

Fig. 21. Front view of the contents of the Chest and Belly.

a, the two ventricles of the heart. *k*, the right auricle. *s*, the left auricle. *h*, the aorta. *l l*, the carotid arteries. *n n*, the jugular veins; and *o o*, the subclavian veins, terminating in *m*, the superior vena cava. *b b*, the lungs. *q*, the windpipe. *r*, the gullet. *p*, the diaphragm. *c c*, the liver. *d*, the stomach. *e*, transverse arch of the colon, part of the large intestines. *f*, the small intestines. *g*, the bladder.

131. What change occurs in the blood and in the air?
132. Explain the diagram.

of composition that thence occur in the air and in the blood.

74. The lungs are contained in the chest or thorax (Fig. 7, *rxr*), a conical cavity formed by the breast-bone before, the back-bone behind, and the ribs above and on the sides. It is separated inferiorly from the abdomen or belly by a fleshy movable partition called the *diaphragm* (Fig. 21, *p*), which is fixed to the bottom of the breast-bone and edges of the short ribs before, and extends downwards and backwards to be attached also to the back-bone behind. Through this the gullet, blood-vessels, &c., pass. The whole inside of the chest is lined by a thin smooth membrane called the *pleura*, which divides the chest into a right and a left side, and which likewise covers the lungs; but these are, nevertheless, on the outside of the pleura, in the same way as the head is on the outside of a double nightcap. There is no opening to admit the air between the lungs and sides of the chest, but it gets easily by the windpipe into the air-tubes of the lungs.

75. From these explanations it will be easy to understand the mechanism of *respiration* (breathing). Drawing in a breath is called *inspiration*. We do this, 1st, by raising the ribs, which are provided with numerous muscles for this purpose between the ribs, and attached to the ribs and neck; and, 2dly, and at the same time, by depressing the diaphragm. Of the latter movement we become sensible, by placing the hand on the abdomen during inspiration, when we notice the ribs raised, and find the belly pushed outwards at the same moment by the descent of the diaphragm. It is, therefore, evident that the cavity of the chest must be considerably enlarged by inspiration. But the cavity of the chest cannot be enlarged without something filling it up; and as no air can get between the lungs and sides of the chest, if the windpipe remain open, the air necessarily rushes by it into the air-tubes and vesicles of the lungs, and blows them up as we might blow up a bladder. The muscles that acted during

133. Describe the bony structure of the chest.
134. What separates this from the abdomen?
135. What lines the chest, and covers the lungs?

inspiration having become relaxed, the expulsion of the air from the lungs is effected principally by the elasticity of the ribs, and by the contraction of the muscles of the belly pushing up the diaphragm. It is called *expiration*.

76. It must be manifest, from considering these arrangements, that the amount of blood and air brought together in the lungs must be very great. The whole extent of the air-tubes in man, taken collectively, has been calculated by Hales at about 20,000 square inches, and by Monro at twenty times the surface of the human body; the branches of the pulmonary artery, which ramify upon this surface, are so twined and interlaced that they have received the name, from anatomists, of *the wonderful network;* while the air received into and expelled from the lungs, and consequently brought into contact with its air-tubes and blood-vessels, cannot be less, in an ordinary man, than between 3000 and 4000 gallons daily.

77. Fresh supplies of air, then, that the blood may be purified, are the essential objects of a respiratory apparatus; and from the necessity of having some modification of such an apparatus, no animal whatever is exempted, although the supply of air required varies much. A frog or a lizard, for example, will live a considerable time in air which a bird has been forced to breathe till it has died, and insects will live for a long period even in the air that has ceased to support both the bird and the lizard. Fishes, again, whose gills, it was formerly mentioned, perform the same office as our lungs, can exist upon the small portion of air they extract from the water in which they swim. But, however small the quantity required, none can want it altogether; and if any of them be placed under the receiver of an air-pump, and the air be exhausted, they immediately become distressed, and die in a short time.

78. There is one remarkable circumstance that may be noted, when the motions of the heart, or intestines, and those of respiration, are contrasted. The motions of the

136. Define inspiration and expiration.
137. What of the extent of the air-tubes in the lungs?
138. What quantity of air?

former are entirely removed from the influence of the will, and usually do not excite in us any consciousness of their existence; while those of respiration are always accompanied by a sensation, if not also by an act of volition. Before air is drawn into the chest, we have always a peculiar sensation, reminding us that a fresh supply of this material is required. At first, this sensation is merely a gentle intimation; but, if neglected, it becomes so intolerably painful as to compel us to relieve it by breathing. When an individual becomes partly insensible, the sensation requires to be considerable before he attends to it; and accordingly we find, that, instead of breathing, as we ordinarily do, fifteen or twenty times in a minute, he will breathe only once in half a minute, a minute, or a minute and a half. When insensibility increases still further, this and all other feelings become extinct, and then he dies. Upon this principle an explanation has been given of sighing. When a person sighs, the mind has been intensely fixed on some object. The consequence is, Dr. Darwin supposes, that he forgets for a short time to breathe, until the sensation in the chest becomes so importunate as to oblige him to make a more than usually full inspiration to relieve it.

79. The mechanism of respiration is considerably modified in other classes. Whales (which breathe air) have parts that are thought to serve as reservoirs, both of venous and arterial blood; and this is conjectured to be the reason why they are able usually to remain under water twenty minutes, and sometimes upwards of an hour, without breathing. The lungs of birds, instead of being free in the chest, are fixed to its sides, and also have openings in them which allow the air to pass into air-cells that pervade almost every part of their bodies. As a proof of this, if the windpipe of an eagle be tied, and the largest bone of its wing (humerus) be broken, it can breathe through the

139. How do animals differ in their need of air?
140. What of voluntary breathing, its frequency, and cause of sighing?
141. What is peculiar in whales?
142. The wonderful peculiarity of birds illustrated.

broken bone instead of its windpipe. It is this arrangement that causes the respiration of birds to be called double, for the air acts on the blood, 1st, in passing through the lungs to the air-cells; 2dly, in passing out of these, and probably also while it remains in the air-cells. Hence, they consume more air than any other class of animals.

80. Reptiles can act but imperfectly on the air, from the cells of their lungs being very large, and, from this cause, of course diminishing the surface upon which the blood-vessels have to be distributed. The frog has no ribs, nor has it any diaphragm, the abdomen and chest forming but one cavity. As a substitute for these, the air is forced into the lungs by a species of deglutition. A frog perishes if its mouth is kept open, because, before this deglutition can be accomplished, the mouth must be closed.

81. The surface occupied by the gills of fishes is often very considerable. Those of the skate are said to have a surface nearly equal to that of the human body. The reason why air cannot usually be directly breathed by gills, is believed to be principally because they become collapsed and dry. The eel, the crab, and some other species, that breathe by gills, can, however, breathe in air for a considerable time.

82. The only other modification of the respiratory apparatus we shall refer to is that of insects. The veined appearance of the wings of the butterfly is produced by what are called tracheæ, that have openings on the surface (stigmata) for admitting the air, and extensive ramifications over the body. There are similar openings on the sides of the bee-worm and in other species. If these are closed, the animal immediately dies. In all the lowest classes of animals, and even as high as the class of reptiles, the skin is also an active respiratory organ.

83. What has been said may render intelligible the mechanism by which the air is introduced into the body. It will now be necessary to describe the changes that take place there. The atmospheric air, when it goes into the

143. Singularity in the frog, and fishes, and insects.
144. Composition of the air before and after respiration.

lungs, is composed of about four parts of a gas called nitrogen, and one part of another gas called oxygen.* But the air which comes out from the lungs is not the same in composition, for a considerable quantity of oxygen is found to have disappeared, and in its stead we find another gas, called carbonic acid, which is produced by the union of a portion of oxygen with the carbon which forms a large ingredient in the composition of the blood and of the body in general. Carbonic acid is a gas which is fatal to animal life, and it is therefore discharged from the lungs. If an animal is made to inhale it, insensibility and death follow in a very few minutes. We have already seen that the venous blood is a poison to the animal body, and it is probably this same carbon, or the carbonic acid, that makes it noxious. It appears that about 45,000 cubic inches of oxygen are consumed by an ordinary man in twenty-four hours, and that 40,000 inches of this gas go to form the carbonic acid produced during the same period, the remainder of the oxygen probably combining with other ingredients of the blood. Under different circumstances, however, the consumption of oxygen varies. It is considerably greater when the temperature is low than when it is high, and during digestion the consumption has been found one-half greater than when the stomach is empty. By violent exercise, when the stomach is empty, it has been found to be augmented to three times its usual quantity, and to four times its usual quantity when food has been taken after this.

84. When we thus see the great quantity of pure atmospheric air which a single individual requires to carry off the noxious parts of the venous blood, and to convert this into arterial blood, we can easily comprehend why such dreadful consequences should follow the breathing of a highly vitiated atmosphere. The most melancholy instance of this kind on record, is the well-known one that occurred in the Black Hole at Calcutta. In this dungeon,

* We omit mention of the small quantity of carbonic acid in the air.

145. What is discharged in expiration, and why?
146. Proportion of oxygen consumed in a day.

18 feet square, and having only two small windows on the same side to admit air, 146 men were immured. In six hours 96 of them had died from suffocation, after the most horrible sufferings; and in the morning, when the doors were opened, only 23 out of the whole number remained alive.

85. From the same cause we can understand how hurtful it must be continually to breathe the air of ill-ventilated rooms, confined sleeping apartments, crowded low-roofed schools, or other places in which numbers are assembled together, and where ventilation is not particularly attended to. A long-continued and constant residence in such places most certainly shortens life by several years, and not unfrequently terminates it rapidly, by giving rise to consumption and other fatal disorders.

86. It must not be supposed, however, from what has been said, that the carbonic acid given off from the lungs is to be viewed as a merely noxious material. If it were retained, death would undoubtedly take place; but if no carbonic acid were formed, we shall find that the heat of our bodies could probably not be maintained. When charcoal is burned in atmospheric air, the changes which occur seem to be almost precisely similar to those that are produced by respiration. Oxygen disappears, and carbonic acid is formed. It seems reasonable, therefore, to conclude, that the heat produced in both cases is connected with these changes. That the production of animal heat bears some resemblance to combustion, is rendered probable by the following considerations:—1st, It has been determined by experiment that the charcoal contained in the carbonic acid formed during a given period by respiration, would give out, when burned, fully more than half the heat produced by the animal in that period. It takes no less than about eleven ounces of carbon to form the carbonic acid of an ordinary man's daily respiration. Dr. Milne Edwards thinks that this, and the superabundant

147. Illustration of the importance of fresh air.
148. Necessity of ventilation.
149. Necessity of carbon to animal heat.
150. Analogy between combustion and respiration.

oxygen which is absorbed by the blood, (which probably combines in great part with hydrogen to form water,) will account for nine-tenths of the heat an animal produces, the remaining tenth probably being the product of the friction of the different parts of the body, the changes occurring in secretion, &c. 2dly, This view is supported by the fact, that the temperature, in the different classes of animals, very accurately corresponds to the quantity of oxygen consumed. The temperature of birds is highest, and they consume most. The young, among the Mammalia, consume the least, and have the temperature lowest. Indeed, it may be remarked, that the young of most of the Mammalia, including children, have much difficulty in supporting any great degree of cold when separated from their parents; and where incautious exposure takes place, the mortality among them is found to be very great. Reptiles, which consume little oxygen, have a temperature only a few degrees above the medium in which they live; and the same may be said of fishes, with the remarkable exception of the Cetacea, (whale, porpoise, &c.,) which have a high temperature, but consume much oxygen, as they breathe the air by lungs.

87. It has been thought, however, that as the carbonic acid is given off in respiration, and the oxygen disappears at the same time, the temperature of the lungs ought to be much higher than that of other parts, and it was to meet this difficulty that Dr. Crawford proposed his celebrated *Theory of Animal Heat*. He maintained that the capacity for heat (as chemists call it) is greater in arterial than in venous blood;* that as this enlargement of capacity

* What is meant by capacity may be rendered intelligible thus:— If we mix one pound of water at the temperature of 60 degrees, with another pound at 91 degrees, the resulting temperature will be exactly the medium, or 75½ degrees. But if we mix a pound of water at 60 degrees with a pound of quicksilver at 91 degrees, the resulting temperature will be only 61 degrees, because the capacity of water is so much greater than that of quicksilver, that the heat which raises the quicksilver 31 degrees will raise the water only 1 degree.

151. How is this theory sustained?
152. What of Crawford's theory?
153. Explain the note.

takes place in the lungs, at the same moment as the heat is generated, a considerable portion of it must be absorbed; and that this latent heat comes to be given out, as the arterial, in its course, is again gradually converted into venous blood.

88. It will be observed, that Dr. Crawford's theory supposes, 1st, that the capacity for heat in arterial is greater than in venous blood, which subsequent observation has not shown to be the case. Dr. Davy states the capacity of both to be very nearly the same. 2d, It supposes that the carbonic acid given off during respiration is *formed in the lungs*, from the direct combination of the oxygen of the atmosphere with the carbon of the blood, which also appears to be incorrect, for it has been shown, by Dr. Edwards and others, that carbonic acid is produced in large quantities, even when an animal is made to breathe a gas containing no oxygen. A frog can be made to breathe nitrogen or hydrogen gas, even for several hours together, without losing its vitality; and in such cases, it is found that nearly as much carbonic acid is formed as when the animal is allowed to breathe atmospheric air. It therefore seems probable that the carbonic acid is *formed in the blood*, and is merely given off or separated at the lungs. There is another theory that has been proposed by Lagrange and Hassenfratz, two German physiologists, and which is supported by the fact ascertained by Professor Magnus, that venous and arterial blood both contain carbonic acid and oxygen, but that the carbonic acid is in larger and the oxygen in less quantity in the venous than in the arterial blood, which seems to avoid the difficulties involved in Dr. Crawford's theory. The oxygen, these physiologists suppose, when it is absorbed by the blood in the lungs, exists there only in a loose state of combination; as it circulates, the union with the carbon, &c., of the blood is supposed to become more intimate, the carbonic acid being thus formed probably in the capillaries; and the heat comes thus also to be gradually disen-

154. Objections to this theory.
155. What are the other opinions stated.

gaged, and diffused through every part of the body. Professor Müller calculates that the quantity of carbonic acid which has been ascertained to exist in each cubic inch of venous blood, is sufficient to account for the whole quantity exhaled from the lungs. Professor Liebig, a high authority, takes nearly the same view of this subject. Many other facts, however, prove that both secretion and the nervous system are connected, directly or indirectly, with the production of animal heat. We can only state generally, also, that the body possesses the power of keeping down its heat to nearly the natural standard, even when exposed to a very high temperature. Sir Charles Blagden remained, without any great inconvenience, in a room, the temperature of which was 52 degrees above that of boiling water, until eggs were roasted hard, and a beefsteak made ready by blowing air on it. Indeed, the heat of his body, though the temperature of the apartment was 264 degrees, rose only three or four degrees above 98 degrees, its natural standard. It has been found that the principal agent in keeping down the temperature, is the immense evaporation that takes place from the lungs and skin. Accordingly, when the skin is varnished, or the air of the apartment is saturated with moisture, so as to prevent evaporation, a temperature one-half so high can hardly be borne.

89. Having now given a short but connected account of the physiology of the circulation and respiration, we cannot but remark how varied and how complicated are the agents employed, and yet how accurately each of these performs the part assigned it. Such investigations as those with which we have been occupied, form the proper foundations of natural religion. No one can rise from the study of these parts of the animal frame, without intensely feeling that *design*, and design of a kind the most exquisite, guides every motion and change of the vital fluid. Never did any piece of machinery invented by man, indicate with greater precision the intentions of its maker.

156. How is the living body protected from high heat?
157. From what surfaces?
158. What reflections are suggested?

90. The voice is produced in what is called the larynx, at the top of the windwipe, (Fig. 20, *a*.) The air, in passing through its opening, (*glottis*, Fig. 11, *e*, and Figs. 22 and 23,) causes parts called vocal ligaments to vibrate, and to give out the different varieties of sound. These sounds can be further modified by the parts in the mouth, &c., so as to produce articulate speech. Singing-birds have a simple larynx at the top, and a complicated one at the bottom, of the windpipe.

91. When foreign bodies, such as cherry or plum stones, get into the larynx or windpipe, they cause excessive irritation, and not unfrequently death. A few years ago, a woman came under the care of Mr. Liston, who stated, that six months previously she had been nearly choked by a piece of bone, while eating some hashed meat; that when she was almost suffocated it had passed downwards into the windpipe, and that she could since then feel it lodging at the top of the chest, on the right side. Her statement was so precise that Mr. Liston resolved to attempt its extraction. He cut down into the windpipe at the bottom of the neck, passed his instrument downwards three or four inches towards the right lung, and felt the bone. But he found his instrument opened in a wrong direction to seize it. This difficulty had, however, been anticipated by the accomplished operator. Another pair of forceps, opening differently, was produced; the bone was seized and extracted, and the woman left the hospital in a few days quite recovered.

92. Other affections of the top of the windpipe produce suffocation, and among these, by far the most common and fatal is *croup*. This disease consists in inflammation and swelling of the inner or mucous lining of the larynx and windpipe. When allowed to gain ground for even a few hours, the surgeon meets with few more rapidly fatal diseases. The cause of this will

Fig. 22.

Fig. 23.

159. What of the structure concerned in the voice?
160. To what accident is the larynx liable?
161. Do foreign bodies ever enter the windpipe?

easily be understood, from looking at Figure 22, which shows the natural size of the opening (rima glottidis) through which all the air had to pass, in a weakly child 11 years old. Figure 23 is the same seen from within. The least diminution of this opening is fatal.

93. When the inner or mucous membrane of a few of the larger branches of the windpipe is slightly inflamed, it is called *a common cold;* when the inflammation is greater, and extends to the lesser air-tubes (bronchi), it is called *bronchitis*, and is often denoted by considerable wheezing in the breathing;* when the air-vesicles, and the substance which connects them, become inflamed, it is called inflammation of the lungs (*pneumonia*). The last is a very fatal disease, if not early checked. The importance of early attention to it will be understood from this, that it consists of three stages, in the first of which the part of the lungs affected is merely engorged with the watery serum of the blood. A smart bleeding will frequently at once remove this. But if allowed to remain, this rapidly passes into the second stage, in which the lung becomes solid like a piece of liver (*hepatization*), and ultimately into the third stage, when the solid portion is infiltrated with matter (*pus*). The two latter stages are comparatively seldom recovered from.

94. When the membrane (pleura) covering the lungs and lining the inside of the chest is inflamed, it is called *pleurisy*, or *pleuritis*, and is denoted by the sharp cutting pain which is felt when we draw a breath. If uncombined with pleuritis, the pain in pneumonia (inflammation

* Millers, masons, sawyers, grinders, and others who are exposed to the inhalation of various kinds of dust, are very subject to this disease, and have their lives much shortened by it. Dry grinders seldom live beyond 30 or 35 years. In M. Lombard's returns for Geneva, the average longevity of stone-cutters is stated at 34 years, of sculptors at 36 years, and of millers at 42 years; while painters live, on an average, to 44, joiners to 49, butchers to 53, writers to 51, surgeons to 54, masons to 55, gardeners to 60, merchants to 62, protestant clergymen to 63, and magistrates to 69 years.

162. What disease occurs here?
163. What of cold, and bronchitis, pneumonia, and hepatizations?
164. What of the mortality from bronchitis?

of the lungs) is not great. It is rather tightness of the chest, and oppression of the breathing, that are felt. These are caused by the difficulty the air finds in getting admission into the condensed air-vesicles. From the same cause, pneumonia is generally attended by rapid and heaving breathing. As the quantity of air that can be brought into contact with the blood is diminished, fuller and more frequent inspirations require to be made. If the hepatization extends to the whole of one lung, then there can be no motion of the chest on that side, as the air enters only to the other lung. These signs are of especial importance in children. Whenever the breathing of a previously healthy child becomes rapid and heaving, alarm should be felt for its safety.

95. The branches of the windpipe have another coat below the inner or mucous one, which, like that of the intestines, is muscular, and can, it is thought, contract and diminish their size. This contraction is supposed to be the cause of the sudden difficulty in breathing, so often felt by asthmatic persons. In asthma, however, other causes combine to produce this difficulty; for, 1st, there is generally more or less habitual inflammation of the larger air-tubes; and, 2dly, from the repeated violent fits of coughing, the air-vesicles become distended or ruptured, so that the cavity of the chest is permanently filled to a considerable extent with these distended vesicles (*bullæ*). The surface of the lungs of old asthmatic persons may be seen studded with these, like little bladders, sometimes as large as walnuts.

96. The only other disease of the lungs we shall notice, is the almost invariably fatal one, consumption (*phthisis pulmonalis*). This disease consists in the formation, in the lungs, of a peculiar substance called tubercle. Tubercles are at first small semi-transparent bodies, like pins'-heads; but as they increase in size and number, they unite, and form masses generally like yellowish cheese, occasionally as large as a walnut or an orange. At a later period, this cheesy matter becomes softened,

165. What of pleuritis, asthma, and consumption?

and is coughed up, leaving cavities in the lungs more or less extensive, under the irritation of which the patient sinks. Consumption, from very accurate calculations, is known to cause about one in every five deaths in Great Britain, so that some knowledge of the causes which produce it is important to almost every one. From extensive statistical inquiries made in Geneva by Dr. Lombard, he has found that the average number of consumptive cases occurring in all the different professions of that town, is 114 in the 1000. In some it rises much above, while in others it falls greatly below, this average number. Thus, among varnish-painters no less than 37 out of the 100 were found to have died of this complaint, while of gardeners only 4 in the 100 fell a sacrifice to it. The causes which principally tend to produce consumption, Dr. Lombard finds, are, 1st, breathing air in which mineral, vegetable, or animal powders are floating: among polishers, sculptors, stone-cutters, plasterers, watch-hand-makers, &c., the proportion of consumptive complaints is 177 in the 1000. 2d, Sedentary occupations seem to have a great effect in producing this disease, the mortality among clerks, printers, tailors, engravers, &c., being 141 in the 1000; while among such active professions as carpenters, blacksmiths, slaters, agriculturists, &c., the average proportion is 89 in the 1000. 3d, Indigent persons seem about twice more liable to consumption than those living in easy circumstances: annuitants in Geneva, who may be reckoned as generally leading an easy, comfortable life, average only 50 consumptive persons in the 1000. 4th, The more or less impure state of the air breathed, its temperature, dryness, &c., seem to influence considerably the production of consumption. In professions in which life is spent in shops or manufactories, the proportion of cases is 138 in the 1000; while in those professions in which life is spent principally in the open air, only 73 in the 1000 become its victims. An atmosphere loaded with animal emanations, such as is breathed by butchers, tanners, candle-makers, &c., seems to act rather

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166. Causes of consumption, physical and chemical in their action.

as a preventive to this complaint, the average among these professions being only 60 in the 1000. Breathing a moist air seems also a preventive circumstance, as weavers, dyers, bleachers, watermen, &c., are found liable to it only in the proportion of 53 in the 1000; while those who breathe a hot dry air, such as toolmakers, enamellers, file-smiths, &c., have 127 in the 1000 affected. These deductions may be considered as, at least, approximations to the truth, and they in general agree with what might have been expected, as we know that even in the lower animals consumption can be produced at pleasure by general debilitating causes, or by irritants applied directly to the lungs. A large proportion of the monkeys brought from their own warm to this cold and changeable climate, die of this scourge of our race; and M. Flourens, a French physiologist, has shown, that by keeping chickens in a dark and damp cellar, and upon a scanty diet, they are rapidly carried off by this affection. Though the lungs are the parts most usually affected by this disease, it is a mistake to suppose that it is a merely local complaint. Very commonly, the cheesy matter is found, at the same time, in the liver, mesentery, and many other parts; and there can be little doubt that the essential cause of the whole is a particular form of constitution, either inherited from parents, or brought on by irregular habits, want of fresh air and exercise, or other diseases and circumstances that enfeeble the body. Where the predisposition to this disease is very great, we see whole families cut off by it; but when the predisposition is less, we often notice only those affected that follow occupations, or have contracted habits, that impair their health.*

* We have said that consumption is a hereditary disease, or arises from a peculiar constitution transmitted from parents to children. This is what is called the scrofulous constitution, which can often be detected by a practised observer, but of which it is not easy to give any definition, except that the formation of tubercular (cheesy) matter in any part always denotes it. When much developed, and when it

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167. Observations upon inferior animals.
168. Consumption constitutional and hereditary.
169. What practical reflections are suggested?

97. In concluding the subject of respiration, we may mention that a French physician, named Laennec, invented a simple instrument, called the stethoscope, which enables us to ascertain very accurately, from the sounds of the air passing through the lungs, what is going on within. Different diseases are denoted by the modifications of sound they produce, often with as much precision as if we saw through the walls of the chest.

The mechanism of respiration may be beautifully seen in the hare. After skinning, &c., open the belly, take out the intestines, liver, &c., and cut through the back-bone high up with a strong knife. The diaphragm, separating the belly from the chest, will then be seen. To show the parts contained in the chest, next take away the fore-legs, and cautiously detach the ribs from the breast-bone, on each side, except at the top and bottom, breaking or snipping through with scissors the detached ribs near the back-bone, and removing them. The breast-bone will thus be left in its place, supported by a rib or two at the top and bottom, and the division of the chest into two halves by the pleura—the heart lying in its bag or pericardium—as well as the appearance and position of the lungs, will be seen. Great care must be taken in opening into the chest, and in cutting the ribs posteriorly, not to injure the lungs. To show the action of the lungs, the windpipe must now be cut down upon in the neck, cut through, and detached, and a small tube tied into it. When this is gently

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affects the glands of the neck, it is vulgarly termed "king's evil." Constitutions are variously tainted with it, however, from a very slight to a very high degree; and it may easily be conceived how generally the taint is diffused, when we have stated that one in every five dies in this country from one of its forms. There are many other diseases, the tendency to which is derived from parents, such as asthma, insanity, gout, &c.; and there can be little doubt that this class of diseases constitutes the great bar to the physical improvement of the human stock. Until correct views on this subject become more general, little hope of improvement can be entertained. At present, persons in every rank make eager inquiries as to the worldly condition, &c., of those who are likely to form their partners for life; but how seldom does it happen that the tendency to even serious hereditary disease forms a bar to their union, or that persons even take the least pains to satisfy themselves whether such exists! The great part of mankind neglect far too much the fact that they are animals, and that they are therefore subject to those general laws which regulate the transmission of peculiarities or diseases to their children. Hence, from this serious error, they fail to take the precautions which are necessary to secure an approach towards physical perfection in their own progeny, and the neglect of which they would be ashamed of, even in regard to their dogs and their horses.

170. What of Laennec's instrument?

blown into, the lungs will be seen to be inflated. A much more elegant mode of showing their action, however, is, carefully to take out both windpipe and lungs, and to attach them as represented in Fig. 24, where *a* is a bottle, six or seven inches high, and about three wide, such as is used by druggists, with the bottom cut off; *b* is the hare's lungs (with the windpipe left moderately long) tied to a notched tin tube (*c*), that passes through a cork accurately fitting the neck of the bottle; *d* is a wooden piston, three-fourths of an inch thick, covered with soft leather, which is stuffed with hair, and oiled to make it fit accurately. When the handle of the piston is drawn quickly down, the air rushes by the tube and windpipe into the lungs, and inflates them, and this can be repeated by pushing the piston gently up, and then again drawing it quickly down. The bottle must be of the same width throughout, and the lungs must not be cut or injured in any part. The lungs should be in the bottle, and the windpipe tied on the tube, before the cork is fitted into the bottle. This is a remarkably striking experiment, and should be seen by every one who wishes to form a just conception of respiration.

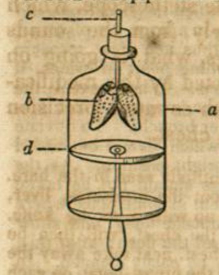

Fig. 24.
Hare's lungs in a bottle.

The power of oxygen in supporting combustion, and of carbonic acid in extinguishing it, should also be shown by introducing a lighted candle, fixed on a wire, into jars of these gases.

That the expired air contains carbonic acid, may easily be shown by breathing through a tube immersed in newly prepared lime water. The carbonic acid throws down the lime in the form of carbonate of lime.

By placing the ear to the upper part of the chest of a young person, the murmur produced by the air rushing through the air-vesicles may be heard; or the stethoscope may be used for hearing this, as well as the sounds of the heart.

The air-cells of birds may be seen in the pigeon, by opening the belly on one side, and then (while pressure of the fingers on the ribs prevents any escape of air from the lung on that side) blowing air into the windpipe, as directed above.

The gills of a cod or haddock (recent or dried) should also be examined.

Preparations of the bronchial tubes are generally made by anatomists with wax. These, however, have the disadvantage of being easily broken. We have used, instead of wax, some of the metals. Equal parts of tin and lead answer well for the larger bronchi. Take a sheep's lungs, clear away fat, &c., but taking care not to injure them, and cut off the windpipe three or four inches above the lungs; dry the interior of the windpipe by introducing pieces of lint on the end of a stick, and afterwards allowing it to remain exposed to the air for a few hours. Then transfix the windpipe at the upper part with two darning-needles crossed, to hang the lungs by; fasten the needles to the ring of a retort-stand; fasten a wide-mouthed tin funnel, supported by another ring of the retort, in the windpipe, and pour in the melted metal; boil the lungs for two hours, cut out the preparation, and varnish with wax dissolved in boiling spirits of wine. A much more delicate preparation can be made in the following manner:— Instead of tin and lead, take the composition called the *fusible metal*,* and pour it into the lungs, and then place these in a large pot of water, to be kept boiling for an hour. The air is thus in a great measure expelled; and as the metal melts at the boiling point of water, it finds its way into the most minute ramifications. When heated, the air in the air-tubes causes the lungs to become buoyant, which prevents the metal getting properly into the lower bronchi. To obviate this, the lungs may be enveloped in a cloth, which should be loaded with heavy weights, to keep them in the upright position. As the metal is extremely brittle when hot, the lungs should not be taken out of the pot till they are cold; then hang them in some place where flies can deposit their eggs, moistening the outside daily, and allow them to remain until the maggots eat away all the flesh; after this, hang them in water until the preparation can be easily cleaned. In making both preparations, about one and a half pounds of metal are required, and the tin filler should be heated to make the metal run the easier. If any of the large branches are broken, any tinsmith will easily solder them. When well managed, preparations we have made in this way have a truly wonderful appearance; the bronchial tubes, though beautifully distinct, and as fine as hairs, presenting almost a solid mass. The existence of air-vesicles has been doubted by some authors, and these preparations seem to us to support this opinion.

Other illustrative figures for this section will be found in Bell's Anatomy, vol. i., page 599; Dr. Smith's Philosophy of Health, vol. i., page 243; "Animal Physiology," in the Library of Useful Knowledge, pages 88, 89, 90, 92, &c., &c.

[Some of the foregoing experiments are unsuited for schools, but models of the respiratory apparatus, made of papier maché by Dr. Azoux, of Paris, can now readily be obtained in this country.]

SECTION V.

SECRETION AND NUTRITION.

98. We have seen, in the preceding sections, that there are arrangements for circulating the blood and for keeping it pure. The great object in these arrangements seems to be, that the substances required in the different parts of

* The *Fusible Metal* may be composed of two parts bismuth, one lead, one tin, and one quicksilver, to be all melted together and well mixed.

the system may be separated from the blood in a proper state. There is a class of bodies, known by the name of glands, whose office appears to be principally to form different secretions. Thus, the liver is a gland, which is said to secrete (separate) bile: the salivary glands, we have seen, secrete saliva; and so on with the others. It would be a mistake, however, to suppose that secretion is performed only by glands, for thin membranes, without any glandular structure, produce numerous secretions; and the deposition of the solid parts of the body takes place without the intervention of any thing like glands. It seems to be the capillary vessels, themselves, in these cases, that are employed; and even in glands, however minutely we examine their structure, there can be detected almost nothing but endless subdivisions of circulating vessels, and ducts for collecting and carrying off the secreted fluid.

99. It will be impossible for us even to refer individually to the numerous substances produced by secretion. We shall, therefore, mention particularly only a few, and make some general observations regarding the whole.

100. The liver (Figs. 12, *l*, and 21, *c*) is the largest gland in the body. We have seen that it secretes the bile, which probably serves important purposes in digestion. The numerous ducts of the liver unite and form one large duct, called the hepatic duct (Fig. 12, *h*), from which the bile passes into the common duct (*i*), or into the gall-bladder (*m*), to be poured, when required, into the upper part of the intestinal canal. The bile is an alkaline fluid, which contains, besides other substances, a peculiar resinous principle. Unlike other secretions, it is formed from the venous blood. The whole veins of the stomach and intestines, instead of going directly to the right side of the heart, first unite to form one great trunk (vena portæ), which divides, like an artery, in the substance of the liver; and

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171. What sources of secretion are pointed out?
172. Define secretion, nutrition, &c.
173. What is peculiar in the structure of the liver?
174. What is the bile and its uses?
175. Describe the circulation of the liver.