John Percy Esqre M.D.
with the Author's respects

THE

ANATOMY AND PHYSIOLOGY OF THE LUNGS.

THE STRUCTURE OF THE LUNGS,

ANATOMICALLY AND PHYSIOLOGICALLY CONSIDERED,

WITH A VIEW TO EXEMPLIFY OR SET FORTH, BY INSTANCE OR EXAMPLE,

THE

WISDOM, POWER, AND GOODNESS OF GOD,

AS REVEALED AND DECLARED IN

HOLY WRIT.

THE WARNEFORD PRIZE ESSAY,

FOR THE YEAR 1844.

BY JOHN MOORE,

STUDENT OF "THE QUEEN'S COLLEGE," AND RESIDENT MEDICAL OFFICER
OF THE QUEEN'S HOSPITAL, BIRMINGHAM.

"Nam ut aliud nihil in omnibus animantibus, *ita in ipso pulmone*, ubique sapiens natura, temerè nihil, neque sine causa quidquam fecit."—GALEN, Lib. vi. cap. 10.

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TO THE

REV. SAMUEL WILSON WARNEFORD, L.L.D.,

RECTOR OF BOURTON ON THE HILL,

THIS PRIZE ESSAY

IS INSCRIBED,

AS A HUMBLE TRIBUTE

OF RESPECT AND GRATITUDE,

BY

HIS FAITHFUL SERVANT,

THE AUTHOR.

ARGUMENT.

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THE ANATOMY

AND

PHYSIOLOGY OF THE LUNGS.

PART I.

The wisdom, power, & goodness of God visible in the economy of human nature.

THE different modifications of matter—organic and inorganic—have been variously treated of, as illustrative of the Omnipotence, Omniscience, and Beneficence of God: apathy, prejudice, and superstition have however respectively[a] prevented the study of the human frame from yielding the full amount of its all-powerful testimonies to these attributes of the Deity; a transient gleam of light occasionally shone forth from the darkness which o'ershadowed alike the religious and scientific world in the middle ages; but it is only within the last three centuries that anatomy and physiology, rapidly advancing in importance and interest, have contributed to the illustration of the Divine powers and purposes. By unravelling the once-supposed inexplicable sympathies between parts apparently unconnected, these sciences

[a] Eunt homines mirari alta montium, ingentes fluctus maris, altissimos lapsus fluminum, oceani ambitum, et gyros siderum, seipsos relinquunt nec mirantur.—ST. AUSTIN.

daily afford fresh examples of wisdom and design in the construction of man, and moreover fully demonstrate that no portion of creation, animate or inanimate, is more replete with evidences of Divine wisdom, power and goodness, than that

> "———heav'n laboured form, erect! divine!
> Heav'n assumed majestic robe of earth
> He deigned to wear, who robed the vast expanse
> With azure bright; and clothed the sun in gold."—YOUNG.

In the construction of man, the complexity of parts, though widely differing yet, harmoniously blending to conduce to one great end—the maintenance of life—cannot but strike the beholder with grateful admiration; but above all does the inscrutable connexion of mind and body—combining to constitute him, not as one of the brute creation, a mere animated machine "which indeed exists for a time and, as a summer's sun, passes away never to be renewed," but a being, blessed with reasoning faculties, appropriating to him pleasures more exalted than other animate nature is capable of appreciating—point him out as indeed the noblest work of the creation. At the same time the insufficiency of all human endeavours, to determine the special residence of the spiritual or intellectual part of the stupendous whole, must impress upon man the conviction that this admirable combination of matter and mind, originated with some prime agent or superhuman power ruling over all.

Purport of the following essay.

The following essay is written for the purpose of showing, by the consideration of the "Structure and physiology of the lungs," the "Wisdom, power, and goodness of God, as revealed and declared in Holy Writ;" and though the conformation and office of each and every portion of the human frame be capable of affording proofs of these, I cannot imagine any better calculated to evince them, than that whose special function it is to cleanse and vitalize the blood, on the good quality of which depend the maintenance and the due performance of all the other functions of the body; fully impressed with the truth of the opinion of the estimable founder of this prize, that aught that can draw our attention to the contemplation of these evidences of the Divine attributes must be productive of good, cheerfully, though diffidently, do I undertake the task; and, should my demonstration of God's power, wisdom, and goodness, be as successful as my veneration of them is sincere, I shall not have laboured in vain.

Importance of the respiratory function.

Respiration is a function essentially necessary to life, and consequently ranks highly in the animal economy; by it the blood, blackened and vitiated during its passage through the systemic capillaries, and joined by newly elaborated matter (chyle), becomes exposed to atmospheric influence, and by this exposure, in a manner to be hereafter considered, is re-arterialized and rendered fit for the nutrition of the body, and the stimulation of its various organs.

Variable structure of respiratory apparatus in different classes of animals.

The organs by which respiration is effected in the different classes of animals, offer an almost endless variety of structure; but everywhere, by their admirable adaptation to the wants, habits, and general conformation of the animal to which each form respectively appertains, afford testimony to the wisdom, power, and goodness of their designer.

Polypifera.

In the lowest classes of animals no special organ appears to have been provided for the accomplishment of the respiratory function; but its absence is here compensated for by the whole surface of the body, soft and delicate, readily permitting the penetration of the fluid which surrounds it, to exercise a vitalizing influence upon its circulating current; this is the case with the polypifera.

Echinodermata. In the Echinodermata, water is admitted into the general cavity of the body, and bathes all its viscera, ensuring a complete exposure of the circulating fluid to the influence of oxygen; the whole peritoneal surface thus acts the part of a respiratory apparatus.

Annelida. In the Annelida, the respiratory organs are sometimes tufted branchiæ, as in the Arenicolæ; sometimes—as in Hirudines—they consist of membranous pouches, having each a separate opening, or spiracle, through which aerated water is admitted.

Insecta. In Insecta, air is inhaled through a series of Stigmata, and conveyed through numberless tubes to the various portions of the body; by this arrangement the specific gravity of the insect is considerably diminished, and its capacity for flight augmented in equal ratio.

Arachnida. The Arachnidans, inhabiting damp situations, appear to present a combination of lungs and branchiæ; the pulmo-branchiæ are hollow viscera, resembling bags, the walls of which are folded in laminæ for the purpose of increasing the capacity of the respiratory surface; air finds entrance into these by distinct orifices which open into each.

Crustacea. Another remarkable form of respiratory structure is that witnessed in many of the Crustaceans; in the Branchiopods, for instance, the legs, covered by fringed lamellæ, are continually exposed to a fresh current of water by the constant motion which the little animals maintain, and answer the purpose of branchiæ.

Gasteropoda. In the Gasteropoda, of which the common snail is an example, a capacious chamber is provided, communicating with the external atmosphere by a large opening on the right side of the body near to the margin of the shell; through this aperture air is constantly inhaled and expelled by the alternate contraction and dilatation of the muscular floor of the cavity, whilst the vessels ramify minutely upon the roof of the chamber.

Fishes.

Fishes breathe by delicate branchiæ[b] or gills, which are arranged upon a series of four bones or branchial arches, covered in by a valve or operculum, whose orifice is placed behind them; this the fish opens and closes at will; respiration is effected by keeping water in contact with the gills through which the carbonated blood passes; when the confined water becomes unfitted for further use, it is discharged by opening the operculum (by means of muscles specially provided for the purpose), and thus respiration continues, fresh supplies of water being taken in by the mouth and discharged through the operculum, in alternate succession.

Amphibia.

The young water newt (Triton Cristatus) has gills appended to the sides of its neck, and, as in its mode of progression, so also in its appearance, does it resemble a fish; on the twelfth day however, the young Tadpole begins to emit air from its mouth, thus evidencing the commencing development of lungs; about the forty-second day it begins to assume the character of the adult Triton; the branchiæ now rapidly degenerate, and in four or five days from this time entirely disappear; the opercula close; the lungs, two

[b] That fishes breathed by their branchiæ was known to Galen: he writes "Sed earum quas Branchias nuncupamus, constructio ipsis vice pulmonis est."—De usu part: lib. vi. cap. 9.

simple membranous sacs, are nearly as long as the body itself, and the young Triton is an air-breathing animal. The lungs of the *perfect* Frog[c] are two membranous bags having open parietal cells, (Tab. iii. fig. 2.) over which minutely ramify the pulmonary vessels.

Aves.

In the class Aves, the bronchi terminate in lungs which are fixed to the ribs by the serous membrane lining the common thoracic and abdominal cavity; these lungs are of a spongy texture, and contain innumerable cells which communicate, by means of orifices seen on the external pulmonary surface of the lungs, with large membranous cells situate around the pericardium, and between the abdominal viscera.

Mammalia.

In the Mammalia, the lungs are of a different type to those already mentioned: the trachea and the pulmonary artery and veins here run together from the root towards the periphery of the organ, in the form of a triple tree, each dividing into gradually decreasing branches; as this structure forms the subject of the following essay, we will at once proceed to a more intimate consideration of it.

Number and general characteristics of human lungs.

§1. In man, the lungs—two in number, right and left—of spongy and vascular texture, and united at their centre by the roots of the vessels whose ramifications form the chief part of their bulk—combine to make a single bi-lobed organ, destined to be the seat of the respiratory process; this is contained in a cavity whose walls, strong, elastic, and of compound structure, have so close a relation, in situation and office, to the pulmonary apparatus, that a brief survey of their component parts would appear needful.

[c] The young Frog undergoes an analogous metamorphosis to that of the Triton.

§2. The thoracic cavity is conical in shape, the apex being placed above, the base below, the lateral exceeding the anterio-posterior diameter; it is bounded anteriorly by the sternum and costal cartilages; laterally, by the ribs of either side, and by the intercostal muscles; and posteriorly by the structures already mentioned, and by the dorsal portion of the vertebral column, the projection of which into the cavity, here separates the lungs. The superior boundary, formed by the first ribs and the thoracic fascia, gives passage to the œsophagus, to the trachea, and to the vessels and nerves which issue from or enter the thorax in this direction; its inferior boundary is the diaphragm which separates it from the abdominal cavity; this muscle is of great importance in the respiratory function, and therefore demands further detail; of vaulted form, its convexity looking towards the thoracic, its concavity towards the abdominal cavity, it arises anteriorly and laterally from the ensiform cartilage, from the lower six ribs and their cartilages, and also from the Ligamentum Arcuatum internum, on either side; it arises posteriorly by two fleshy pillars from the second, third, and fourth lumbar vertebræ upon the right, and from the second and third upon the left side; from these numerous points of origin its fibres converge, to be inserted into a central tendon: rather to the right of the median line is a quadrilateral orifice, through which passes the vena cava inferior; between the two crura, and rather behind the preceding, is an elliptical muscular opening, by which the œsophagus and pneumo-gastric nerves enter the abdomen; still more posteriorly, a tendinous arch is thrown across from one crus to the other, beneath

Thoracic cavity.

which pass the aorta, the vena azygos, the thoracic duct, and the greater and lesser splanchnic nerves.

Shape of lungs. § 3. The shape of the lungs corresponding with that of the thorax, is conical; the apex, truncated and placed superiorly, extends a little above the level of the first rib; the base presents a concavity answering to the vaulted arch of the diaphragm upon which it rests; the anterior borders of the lungs are acute, and, when distended, cover in the heart; the margins surrounding the base are also sharp, whilst the posterior borders are bluntly rounded. The right lung, though the largest, does not extend so far downwards as the left (the convexity of the liver here raising the diaphragm); it is divided into three lobes by two fissures, the one of which extends downwards from the posterior surface near the apex almost to the anterior inferior edge; from this fissure the other descends nearly vertically (with a slight inclination forwards) to the base. The left lung, though smaller, is yet longer than the right; it consists of but two lobes, which are separated by a sulcus, which has the same direction as that of the right side, first described; the inner surface of the lungs is hollowed out to lodge the heart, and to give passage to the great vessels of the thorax.

Colour of lungs § 4. The colour of the lungs, in the healthy subject, varies much at the different epochs of life; in the fœtus they are of a reddish brown colour, which on the occurrence of respiration, is exchanged for a roseate tint; this is retained during the period of youth; in middle-age they assume a mottled appearance, small slate coloured patches being here and there interspersed over their surface; these patches gradually extend, until, in old age the lungs appear of a greyish purple colour; these modifications doubtless depend upon the gradual infiltration into the substance of the lungs of carbonaceous matter such as is frequently found deposited in the bronchial glands. Independently moreover of the diversity witnessed in the different stages of life, the colour of the lungs is much affected by disease.

Bulk of Lungs

§ 5. Their external surface being always in contact with the thoracic parietes (the pleuræ alone intervening), the lungs are necessarily larger or smaller, as the thorax is either expanded or diminished by respiration. All diseases which cause distension of the abdominal cavity, indirectly affect the volume of the lungs, by preventing a due contraction of the diaphragm; effusions between the pleuræ or pericardiac layers, more directly affect their volume, as also do tumours of any kind within the thorax; when any portion of the lung is immediately pressed upon, either atrophy or carnification is induced in it, and, *as a compensative process*, dilatation of the neighbouring parts speedily follows; this dilatation, however, sometimes proceeds to such an extent as to constitute disease (Emphysema). In accordance with the disposition of the thoracic parietes to be constantly apposed to the pulmonary surface, as either diminution or enlargement of the lungs takes place, so does the thorax accommodate itself to their altered condition; in the one case by a gradual flattening of its walls, and in the other, by dilatation of its intercostal spaces.

Weight of Lungs.

§ 6. It is difficult, if not impossible, to arrive at a correct knowledge of the absolute weight of the lungs; Meckel has estimated it at four pounds, whilst Bourgerie says, that they seldom exceed two pounds and-a-half; independently of the natural conformation of different subjects it will, of course, be materially affected by the degree of congestion, and this will vary greatly with the cause of death.

Specific gravity

§ 7. The specific gravity of the lungs, is by far less than that of any other organ of the body: this is owing to the large quantity of air which they contain; they are lighter than water, on the surface of which they float: should infiltration of serum or blood, into their tissue, or tuberculous deposition take place, their specific gravity is much increased, sometimes even, it is found to be greater than that of water.

Density.

§ 8. After respiration has occurred, the lungs in their ordinary state are soft, spongy, and elastic, presenting an irregular lobulated surface, depending upon the different degrees of distension of adjoining lobules; in this condition they still contain much air, only a small portion of which (viz: that remaining in the larger bronchial divisions) can be expelled by pressure, the rest being scarcely removable by the air-pump, "effet" says Bourgerie, "qui semble s'expliquer de lui-même par l'accolement des parois des vaisseux aérifères de médiocre calibre;" continued pressure produces a crackling sound (crepitation) referable to rupture of some of the terminal cells of the air passages. By the injection of air, by means of a blowpipe accurately fitted to the trachea, the lungs may be readily distended, when their surface becomes smooth and glistening, and a delicate cellular structure is easily perceivable beneath the pleura; moderate insufflation may be practiced without producing rupture, but should air be forcibly, or in a large volume suddenly introduced, laceration of the aeriferous structure is caused, and infiltration (sometimes confined to distinct lobules, and sometimes extending to the interlobular tissue[d]) takes place.

§ 9. From experiments instituted with great care by Bourgerie, upon eleven persons, including an old man of 86, and a youth of 19 years, (the mean age being 37 years), he ascertained that the largest amount of air received into the chest *during a forced inspiration*, was 175 cubic inches; the smallest amount inhaled, was 82.04 cubic inches; the mean quantity being 133.87 cubic inches; he found the greatest *forced expiration*, to be 172 inches; the least reached only 92.16 cubic inches; the medium being 139.13 cubic inches: of *ordinary inspirations*, the largest was 34.62 cubic inches; the smallest, 11.39 cubic inches; the mean being 25.42 cubic inches. From the experiments by which he obtained the above results, he also drew the following conclusions:—

That the intensity of the respiratory force, depends upon the volume of the thorax, and the age of the subject;—that the largest thoraces for a determined age, are those which absorb the greatest volume of air;—that, the elasticity of the lungs, and of the thoracic frame-work, is greatest in young subjects;—and, that, from the combination of the two elements, age and

[d] Emphysema may be limited to the lobular structure; it may be confined to the interlobular tissue, or it may affect both simultaneously; the term Vesicular, still applied to the first species, might, with advantage, be exchanged for that of Interlobular, which would be equally unobjectionable, whether the air tubes be supposed to terminate in *vesicles, cells,* or *labyrinthic canals.*

capacity, modified by sex and temperament, results the true "Capacité Physiologique," which further varies with the states of sleeping and waking, motion and repose, calm and passion, and health and disease; so that it is altered, or rather modified, each moment of our existence.

The Pleuræ. Much air still remains in the lungs after the most complete expiration, but we possess no adequate means of ascertaining its quantity.

§ 10. Having premised these general characteristics of the lungs, we come now to consider the special arrangement and organization of their various tissues, the first of which is the pleural membrane which closely invests the lung of either side; as the two pleuræ are nearly symmetrical, the description of one will suffice to demonstrate their respective relations.

In close apposition to the entire lung, dipping deeply into its interlobular fissures, and converging towards its root, the pleura is reflected *anteriorly* over the anterior aspect of the pulmonary vessels and the pericardium, and thence to the outer margin of the internal surface of the sternum, it then proceeds outwards and backwards, and after lining the lateral and posterior walls of the thorax, reaches the lateral portion of the vertebral column, whence it is again reflected over a small portion of the pericardium, and the posterior surface of the pulmonary vessels, when it becomes again continuous with the pleura investing the lung. — *Superiorly*, the pleura lines the thoracic fascia, forming a "cul de sac," which lodges the apex of the lung, and inferiorly it forms a covering to the corresponding half of the convex surface of the diaphragm. The pleura covering the lung is called the pulmonic, that attached to the parietes of its containing cavity, the thoracic pleura.

Like all other serous membranes, each pleura forms a shut sac, commonly called the pleural cavity; but no cavity in reality exists, *excepting as a diseased condition;* ancient medical authors considered that a certain amount of very elastic air was confined within this supposed cavity, which (air) during expiration filled an imaginary space formed between the pleuræ on the contraction of the lungs, and that, in inspiration, this became compressed into a smaller compass; this was the opinion of Galen[e], who states that he has proved it by making incisions into the chests of living animals; the illustrious Haller was led to contribute his powerful sanction to this doctrine, by witnessing the well-known communication between the pulmonary air cells of birds and their thoracic cavity; Haller exposed, with his usual perspicuity, the fallacies of the arguments and experiments brought forward to support this hypothesis, and further, entirely disproved it by opening, under water, the thorax of a living animal, when not a single air bubble escaped; he also maintains that he has frequently seen the lungs in close opposition with the thoracic pleura, from which they never receded, either during inspiration or expiration[f]. Externally the pleura is rough and flocculent, adhering to the parts with which it is in connexion, by means of a loose cellular tissue; its

[e] Administ. Anat. Lib. viii. cap. ult.

[f] Sed etiam ego in vivo animale non infrequenter vidi pulmonem, totum pectus replere, pleuram et costas contingere, et deserere nunquam sive pectus dilataretur, sive vicissim subsideret.—Haller, Elem. Physiol. Lib. viii. p. 130.

internal surface is smooth and polished, and constantly moistened by fluid continually exhaled and continually absorbed; this fluid, in the healthy condition, facilitates the motion of the lungs, but its presence would not appear to be absolutely necessary, for morbid anatomy daily exhibits extensive pleuritic adhesions where no (or comparatively slight) impediment to respiration has been felt during life; and this is seen, says Bichât, "not only in those whom lingering disease has destroyed, but also in those whom violent death has suddenly cut off in a state of apparent health." An inordinate collection of fluid between the pleuræ frequently occasions inconvenience, and sometimes annihilates the vital powers, by compressing the thoracic viscera.

Mediastinum. § 11. Situate in the median line of the thorax, extending from its apex to its base, and having, inferiorly, a slight inclination to the left, is a space termed "The Mediastinum" which, for convenience of description, anatomists have divided into three portions,—an anterior, a middle, and a posterior; all of these are limited, *laterally*, by the reflected layers of the pleuræ.

Anterior. § 12. The Anterior Mediastinum, bounded in front by the sternum, and behind by the pericardium, is triangular in shape; it contains the remains of the thymus gland (in the infant this gland itself), the origins of the sterno-hyoid, and sterno-thyroid muscles, the internal mammary vessels of the left side, and some loose and fatty cellular tissue, in which are contained lymphatic glands and vessels; inferiorly, the anterior mediastinum communicates with the cellular tissue of the abdominal parietes, by means of a triangular space, placed behind the xyphoid cartilage.

§ 13. The middle mediastinum (much expanded,) lodges the heart enclosed in its pericardium, the ascending aorta, the superior vena cava, the pulmonary vessels, and the phrenic nerves. Middle.

§ 14. The posterior mediastinum, of irregular triangular shape, bounded anteriorly by the pericardium and the root of the lungs, and posteriorly by the vertebral column, has within it the œsophagus and the pneumogastric nerves, which enter it from above, the thoracic aorta, the greater and lesser splanchnic nerves, and the thoracic duct. Immediately at the commencement or upper part, by the posterior mediastinum, the division of the Bronchi may be seen. Posterior.

§ 15. It has already been stated that the lungs are divided, the right into three lobes, and the left into two; by extending our investigations, we discover that these lobes are sub-divided into lobules, which are arranged in groupes upon the secondary divisions of the bronchi. The lobules (as represented by Malpighi) are irregular polyhedral pyramids in apposition the one with the other by their plain, unequal surfaces, their contracted apices meeting in a common centre, whilst their bases, more extended, form a common circumference. The lobules are entirely distinct from each other, and are separated by narrow fissures (*interlobular spaces*) which are filled up by an extremely delicate, transparent, and laminated cellulo-serous tissue; the non-communication of adjoining lobules may be readily shown by distending the cellular tissue with air, by means of a blow-pipe, when separate lobules may be dissected out with the scalpel; their independence of the interlobular tissue, as well as of each other, is also demonstrated by pouring mercury into an extreme bronchus, when Proper tissue.

the lobule, or lobules in which it terminates will be exactly filled, whilst none of the metal passes beyond (Tab. iii. figs. 3, 4, and 5); the same result is obtained if a terminal branch of the pulmonary artery, or vein, be injected. Each lobule has within it a bronchial, an arterial, and a venous branchlet with their respective ramifications, and also lymphatic essels and nerves; thus does each constitute a diminutive lung, capable of performing its allotted function, independent of the condition of neighbouring lobules, providing that they offer no mechanical obstacle[g].

Amount of lobular structure in different parts of the lungs variable.

§ 16. As the primary divisions of the pulmonary vessels and bronchi are of large calibre, the proportion which the lobular structure bears to them near the root of the lungs, is comparatively small, but as the vessels decrease in size, the lobular apparatus becomes predominant.

Interlobular tissue.

§ 17. Lining the investing pleural membrane[h], and lodged in the intervals between the lobules appears the delicate cellular tissue before referred to (§ 15); this may be seen by raising the pleuræ, or, by the insufflation of air beneath it, to consist of cells, of

[g] The lungs of a child of eleven months, whose body I examined, presented the following peculiarities, viz:—a few scattered lobules of the right lung were of a light red colour, and creptitant—*the remaining portion offered the perfect fœtal characteristics, as did the whole of the left lung.*—The heart was excessively large, and its right cavities were distended with a thin reddish serum; the body was much emaciated, and all the structures extremely pallid.

[h] Mr. Gulliver has described a fibrous tissue, internal to the pleura, which (resembling the ligamentum nuchæ, or the fibrous coat of the aorta of the ox) invests the whole surface of the lung, forming a strong and elastic, though delicate, capsule to the organ; this tissue he considers an important agent in expiration. I have not been able to discover this in the human subject.

varying size and figure; it everywhere separates the different lobules, which are flattened by its distension; in it the pulmonary lymphatics ramify, as also that portion of the bronchial vessels which supplies the parenchymatous structure; it affords an investment to the bronchi, and to the functional vessels —that which envelops the artery is dense and vascular, whilst that which surrounds the vein is lax, and more sparingly supplied with vessels—; it affords also, to the bronchial glands, a special covering.

§ 18. We now come to the consideration of the *composition* and *structure* of the Aeriferous Apparatus, which consists of the trachea and the bronchi, with their terminations; by means of the two former, the latter (constituting a vast expanse of surface, over which the pulmonary capillaries ramify) communicate with the atmosphere. Aeriferous apparatus.

§ 19. The Trachea (aspera arteria) is a long fibro-cartilaginous pipe, contractile and elastic, rounded in front and at the sides, and flattened posteriorly; its external surface is rough, and it is marked by alternate eminences and depressions anteriorly and laterally; internally it is smooth and polished, and constantly bedewed with moisture: situate in the median line, it commences opposite to the fifth cervical vertebra, and extends downwards (with a slight inclination to the right) as far as the fourth dorsal; its length is from four to five inches, its width being but one— in the female the dimensions are smaller—; at its superior part it is slightly constricted; inferiorly, it becomes somewhat expanded: its length and calibre, of course, vary with the extension or contraction of the neck. The Trachea—its situation and size.

§ 20. Placed partly in the neck, and partly with- Relations of Trachea.

in the thorax, the trachea has extensive and important relations.

Cervical portion.

Its cervical portion, extending from the larynx above to the thoracic fascia below, has lying upon it the thyroid body and the thyroid plexus of vessels; on either side it is in connection with the lateral portion of the thyroid gland, the common carotid and the inferior thyroidean arteries, the pneumo-gastric nerve, and numerous lymphatic ganglia and vessels; posteriorly it rests upon the œsophagus and the recurrent nerves.

Thoracic portion.

The thoracic portion, directly continuous with the cervical, terminates inferiorly in the bronchi; it is placed in the anterior mediastinum, and covered in front by the sternal portions of the sterno-hyoid and sterno-thyroid muscles, the brachio-cephalic artery, the left brachio-cephalic vein, and the aorta; laterally it is bounded, on either side, by the reflected layer of the pleura, and by the pneumo-gastric nerve, having in addition, on the right side, the superior vena cava, and on the left, the left sub-clavian artery; posteriorly it is in connection with the œsophagus, the inclination of which to the left inferiorly, allows the trachea to rest upon a small portion of the vertebral column; its point of bifurcation is separated from that of the pulmonary artery by the posterior bronchial lymphatic ganglia.

The Bronchi.

§21. The bronchi, in which the trachea terminates, are two in number; they pass obliquely downwards and outwards, each to its corresponding lung; the right bronchus divides into three, the left into two branches—one for each lobe— ; the right is of larger calibre than the left, and the two conjoined have a greater capacity than that of the trachea, though either separately is far inferior to it in size. In form and general character the bronchi resemble the trachea.

§22. The trachea and bronchi may be described as cylinders, composed of imperfect cartilaginous rings, connected to each other by fibrous tissue anteriorly and laterally, and completed posteriorly by muscular and ligamentous tissue; containing in their structure muciparous glands, blood-vessels, lymphatics, and nerves. General description of Trachea and Bronchi.

§23. The frame-work of the trachea and bronchi is formed of a series of cartilaginous rings (from sixteen to twenty in the trachea, four in the right bronchus, and from eight to ten in the left) each of which forms about three-fourths of a circle occupying the anterior and lateral portions of the cylinder which they combine to form; (Tab. I. c. c.) their external surface is flattened vertically, and convex from side to side; internally they are still flattened in the vertical diameter, and concave horizontally; their superior and inferior margins are bevelled off to admit of adjoining rings overlapping each other; their extremites are bluntly rounded off to be received between two layers of a ligament, to be hereafter described. (§25.) The rings are not always symmetrical; sometimes two of them are united on one side; frequently a narrow cartilaginous band unites two at some portion of their circumference; and occasionally, a portion of one or more rings is entirely wanting. Cartilages.

The first and last cartilages of the trachea differ from the rest in form; the first, infundibuliform in shape, is intimately connected above to the cricoid Peculiarities of first and last cartilages.

cartilage, sometimes even being confounded with it; the last, triangular in shape, bends outwards to the right and to the left from its prominent superior angle, each lateral portion being placed in the axis of its corresponding bronchus.

Inter-cartilaginous fibres.

§ 24. Fine fibrous bands (Tab. I, d. d.) (having an analogous structure to the perichondrium covering the costal cartilages) pass in different directions from each ring, to those placed next above and below it; in the interstices of these small glands are imbedded, and, here and there, are observed minute foramina, through which vessels pass.

Ligamentous fibres.

§ 25. White, shining, ligamentous fibres (Tab. I. b.) are seen to originate at the inferior border of the cricoid cartilage, to traverse the trachea and bronchi, and to be thence continued into their lobular divisions; these fibres differ in character in the fibro-cartilaginous, and in the purely fibrous parts; in the former they are delicate and scarcely visible, in the latter they are much stronger, being arranged vertically and obliquely in fasciculi of variable size. At the bifurcation of the trachea the vertical fibres diverge to be prolonged into each bronchus, and the same arrangement obtains at the openings into each of the lobular divisions; on either side they embrace, before and behind, the extremities of each cartilaginous ring, forming a *common suspensory ligament;* from this ligament the oblique fibres pass at various angles with the vertical, leaving occasional spaces in which lie the tracheal glands, and through which pass the nutritious vessels.

Longitudinal muscular fibres.

§ 26. Extended throughout the trachea and bronchi, and lying beneath the mucous membrane, are arranged parrallel longitudinal fibres, of a reddish-yellow colour (Tab. I. a a.); these are best marked posteriorly; at the points of divergence of the bronchi they are crowded together, elevating the mucous tunic into folds; they also generally curve round the orifices by which the bronchi and their branches communicate with each other, forming demi-sphincters.

§ 27. Filling the space posteriorly which is void of cartilage, and lying between the fibrous and mucous tissues, are transverse muscular fibres attached to the perichondrium covering the internal surface of the extremites of each ring (Tab. I. b.); by the union of these fibres, in the posterior membranous space, a continuous transverse muscle is formed, having dentated margins; this muscle can be distinctly seen through the mucous tissue in the adult of strong conformation. Transverse dentated muscle.

§ 28. The mucous tunic, continuous with that of the larynx, is a delicate transparent membrane, on the surface of which are, here and there visible, small eminences and depressions, answering to the localities and orifices of the tracheal glands. Mucous membrane.

§ 29. The trachea is nourished by vessels supplied by the thyroidean; numbering from eight to ten on either side, they traverse the external surface of the cylinder, running in an annulated form between its cartilages, anastomosing extensively the one with the other, and perforating the cylinder in every direction. The bronchial arteries generally send upwards (on the posterior surface of the trachea) branches which inosculate with its proper vessels. (§ 48.) Tracheal arteries.

§ 30. The venous net-work of the trachea becomes gradually concentrated into several small trunks which empty themselves into the inferior thyroidean plexus. Tracheal veins.

Muciparous glands.

§ 31. The tracheal glands are little, flattened, ovoid bodies, occupying the different portions of the tracheal structure, some being prominent, others lying more deeply beneath the mucous membrane, but all opening on the internal surface of the cylinder.

Divisions of bronchial canals.

§ 32. The bronchial canals, commencing with the common bronchus of either side, may be divided into three classes, distinguished by their relative situations and size, and not by any clear structural difference (as their general properties *insensibly degenerate* as they approach the periphery of the lungs); they are cylindrical tubes, rough and of variable hardness, presenting irregular elevations and depressions due to the projection of the cartilaginous portions; at first they are somewhat flattened posteriorly, but become gradually more and more circular; they divide into dichotomous branches, in the angles formed by the divergences of which are situate the bronchial lymphatic ganglia. Bourgerie has respectively described the three classes, as

1. Primary, or Lobular.
2. Middle, or those supplying the Lobular groups.
3. Lesser, or Extreme.

Lobular canals.

§ 33. The lobular canals are those which directly originate in the common bronchus of either side; they are three on the right side, and two on the left; those for the superior lobes are short, arising nearly at right angles with their respective bronchi; that for the middle lobe (on the right side) passes downwards and outwards to its point of destination; the inferior divisions pass nearly perpendicularly; all divide into branches of smaller capacity—the middle bronchial canals—.

Middle bronchial canals.

§ 34. The middle bronchial canals are those which form, as it were, the peduncles upon which are arranged the lesser bronchial canals, or those immediately terminating in the lobules; they are numerous, and of very variable size.

§ 35. The lesser bronchial canals may be likened unto pedicels attached to the different branches of the preceding class, and each supporting a separate lobule into which it is prolonged. Lesser bronchial canals.

§ 36. The structure of these canals at first differs little from that of the trachea and bronchi; the annular form of the cartilages becomes, however, gradually lost, and they degenerate into plates of variable size and form, which are irregularly dispersed through the cylinders, and connected together by fibrous tissue; the mouths however by which the branches communicate with their respective trunks, are still tolerably perfectly encircled by cartilage; when the tubes have dwindled to about half a line in diameter, the cartilages are altogether lost sight of. The ligamentous fibres cease with the cartilages, degenerating into a delicate cellular tissue, by which the muscular structure is covered. Longitudinal and transverse muscular fibres still however traverse the air passages, and the latter (instead of being, as formerly, confined to the posterior portion only of the cylinder) now entirely surround its internal surface in an annulated form; after these cease to be demonstrable by the scalpel[1] they may be detected by the aid of the micros- Structure of bronchial canals.

[1] Amissa autem annulari cartilaginum forma, fibræ canales toto complectuntur ambitu, laminis cartilagineis sic insertæ, ut ex parte super has transcurrant, neque omnino desinunt, ubi cartilaginibus illi jam non obsiti sunt, sed oculo armato, quamvis teneriores factæ, facile tamen investigantur, quousque scalpello bronchia aperire licet, maxime in pulmonibus virorum confirmatæ ætatis robustiorumque. —Reisseissen "de structura Pulmonum." p. 9.

cope. The mucous tunic, prolonged from above, lines the canals throughout its course (its tenuity increasing as it descends), and is continued into the terminal air structure.

History of Bronchial terminations. Opinions of the Ancients.

§ 37. The opinions of the older anatomists, with respect to the ultimate terminations of the bronchi, were crude and imperfect. With Malpighi rests the honour of giving to the world those ideas of the pulmonary structure which have led to the more correct knowledge of the present day. In 1661 he wrote, that the pulmonary mass was composed of orbicular and sinuous vesicles, arranged in the form of a honey-comb.[j] Helvetius afterwards taught that these vesicles were nothing more than cellular tissue, variously diffused through the lungs, the cells on every side communicating with each other and also with those of the interlobular tissue: Haller (whose information is generally far in advance of that of his co-temporaries) was led to believe that all the cells of a lobule had a free communication, the one with the other, by observing the structure of the frog's lungs.[k]

j Diligenti enim indagine adinveni totam pulmonum molem, quæ vasis excurrentibus appenditur, esse aggregatum quid ex levissimis, et tenuissimis membranis, quæ extensæ, et sinuatæ penè infinitas *vesiculas orbiculares et sinuosas* efformant, veluti in apum favis alveolos ab extensa cera in parietes conspicimus.—Quoted by Bourgerie, vol. iv. "Des Poumons."

k Id vero utique, cum omnibus meis, calidorum et frigidorum animalium incisionibus consensit, non in aliquam singularem ampullam quemque ramum bronchi terminari, sed cellulosum opus in humano, perinde ut in ranino pulmone esse, *cujus cavernulæ imperfectæ inter se libere communicent*, donec aeris iter lobuli cujusque vagina moretur, prohibeatque, *ne de lobulo in vicinum lobulum transeat.*—Haller, Physiol. vol. iii., lib. 8.

§ 38. In 1808 was written the celebrated[1] essay of Reisseissen—replete with evidences of patient research and philosophical induction:—in it he exposed the fallacy of the generally received doctrine (that a *diffused cellular communication* existed throughout the lungs) by the experiments before referred to. (§ 15) By injection with mercury he discovered, moreover, that the terminal air passages ran in a regular branching manner, the branches gradually becoming more delicate, even to the extreme margin of the pleura, where they presented the appearance of the flower head of the cabbage (Tab. IV. fig. 3.). Having subjected to the microscope a portion of lung (which had been for some days previously placed under water, so that, although some still remained, the greater portion of its contained air had been expelled), he applied heat, so as to rarify the confined air, and thus distend the bronchial branchlets; by moving the air forwards with the scalpel, he observed that these gradually became shorter and more delicate as they approached the margins of the lobules until they appeared beneath the pleura, of a semi-globular form; by placing a lobule now between glass lamellæ and exercising gentle pressure, he found that the compressed column of air always observed a regular branched course—now being driven forwards—now into lateral branches—and finally terminated in rounded vesicles. As a conviction resulting from these and numerous other experiments, he concludes, "*vias pulmonum spiritales canales teretes esse ad finem cæcos, membranaceos, ex tunica videlicet tra-*

Results of modern investigations.
1808, Reisseissen.

[1] Published in 1822, with numerous illustrations, and a Latin translation by Rudolphi.

chæ mucosa conformatos, aëri, ut supra commemoratum est, planè impermeabiles."[m]

1821, Majendie §39. In 1821, Majendie[n] (whose investigations were confined to sections of inflated and dried lung) stated, that each air tube terminated on reaching the lobule it supplied; that each lobule consisted of *mutually communicating cells* of no regular shape and not having membranous parietes, but appearing to be formed of the last divisions of the pulmonary artery and the roots of the pulmonary veins, and of the extensive anastomoses existing between these vessels.

1823, Picard. §40. Picard,[o] who wrote in 1823, and pursued the same mode of investigation as Majendie, considered that each bronchial tube before entering its lobule, divided into two branches, each of which again became divided into two smaller branches, and that a continuous dichotomous division took place even to the periphery of the lobule: that a series of canals was thus formed, variously intersecting each other, each being accompanied by a corresponding branchlet of the pulmonary artery and veins.

1835, Bourgerie §41. In 1835, Bourgerie[p] published the results of his examination of the terminal air passages; he deprecated "*in toto*" the use of mercurial and other injections, and examined *only* dried and inflated sections of lung: he describes a series of sinuous and labyrinthic cylindrical canals, commencing

[m] Op. Cit., p. 8.

[n] Journal de Physiologie Experimentale, tome I. pp. 78, 79.

[o] Dissertation sur la Pneumonie Aigu, Paris, 1823.

[p] Vol. IV. p. 57. Des Poumons.

by irregular expansions, which terminate the lesser bronchial canals within the lobules, and repeatedly giving off others which every where establish inosculations with those around them.

§ 42. In the "Philosophical Transactions of the Royal Society," 1842, part II, Mr. W. Addison published an interesting paper, "On the Air-cells of the Lungs." In it he maintains, that there are no terminal vesicles, but that the bronchial tubes, after dividing into a multitude of minute branches which take their course in the cellular interstices of the lobules, terminate in their interior in *branched air-passages and freely communicating air-cells;* the branched air-passages he describes as being neither tubular nor cylindrical, but un-symmetrical canals, having parietal cells communicating with each other by small perforations *(oval foramina)* in their walls; the size of these cells, in the lung of a healthy subject of middle age, he estimated at, from $\frac{1}{200}$ to $\frac{1}{300}$ of an inch. "The air-cells of one branch" he says, "do not communicate with those of adjoining branches, except by means of their common opening into a larger branch." The experiment claiming most attention, amongst those made by Mr. Addison, is the following:— 1842, Addison.

Exp. Having arranged a portion of recent lung (placed between two pieces of glass) under the microscope, in such a manner as to enable him to regulate the pressure necessary for the observation, he observed, that the air bubbles changed their situation, not by moving equably through any tube or cylindrical passage, but by sudden starts from cell to cell; he frequently saw a large bubble of air become compressed for a moment in passing from one cell to another, and sometimes divide into two smaller bubbles, one of which passed on to another cell, the other retiring to the spot from which momentary pressure had removed it.

Results of microscopical and other investigations made by the Author.

§ 43. Having, for the few past months, almost daily subjected to examination (by the aid of the microscope and otherwise) fresh and dried, and injected and uninjected specimens of the pulmonary apparatus,[q] I shall not apologize for here introducing the results of my observations of its aeriferous structure: in the first place, however, I must state, that conclusions arrived at from inspection of dried sections of lung (on account of the natural intricacy of the cellular rete, and also of the crisping, which takes place during desiccation) are most fallacious, *unless corroborated by other evidence;* had Bourgerie endeavoured to trace the passage of fluid through his supposed "labyrinthic canals" he would at once have perceived his error; for (as Reisseissen had before shown) at certain definite limits—the closed cellular extremities of the air passages—the contained fluid stops, and by continued pressure is made to return by the same defined ramiform course, through which it had been admitted.

If a pulmonary lobule, injected with mercury and compressed between glass laminæ, be subjected to the microscope, it will be seen, that each bronchial

[q] For examining the pulmonary air-passages, the lungs of young animals are most proper, as emphysema—a frequent condition in the adult, and particularly so in the aged—is not likely to be present in them; it is advisable, where any animal is expressly destined for observation of the aeriferous structure, either to bleed it to death, or to open some large vessel immediately after death, as this plan, by preventing vascular congestion, renders the cellular rete more distinct.

tube *(lesser bronchial canal)* after becoming interlobular, divides, somewhat dichotomously, into passages which again divide and sub-divide in regular branching order, even to the periphery of the lobule, the conjoined divisions present to the naked eye much the appearance of a cypress tree; (Tab. III, fig. 5) these divisions will be seen to be—not as Reisseissen described them, cylindrical tubes but—passages composed of a continuous series of cells, the boundaries of which are marked by depressions between nodulated projections of the metal; each passage pursues an independent course, not communicating with those adjoining it except by their common place of origin, and each terminates in a rounded vesicle, which is very frequently elongated and constricted at its point of attachment to the passage. This structure is best observed where two or three isolated passages are injected, for when all the passages of a lobule are distended, they become so closely apposed as to form a confused unsymmetrical mass of cells.

If a thin section of dried and moderately inflated lung be examined under the microscope, oval foramina will be observed variously dispersed over its surface; "these foramina" says Addison, "are evidently not portions of bronchial tubes, for they have no uniform cylindrical wall, which is necessary to constitute a tube:" they are "portions of the *lobular passages*"—or interlobular continuations of the lesser bronchial canals;—their arrangement differs according as the lobules are divided towards their roots or near to their terminations; in the former case they are seen to be placed in nearly apposed groups; in the latter they are more diffused, the intervals between them being every where completed by cells of either pentagonal or hexagonal shape—generally the latter:—by altering the focus at the same time that these foramina are closely observed, numerous parietal cells are rendered visible, all of which open into the lobular passage, upon which they are arranged, and thus communicate with each other by means of a common central cavity, but *have no direct passage from the one to the other;*[r] as this opinion differs from Mr. Addison's, who describes oval foramina in the walls of the cells by which a direct inter-communication is established, it may perhaps be well for me to record, that I have several times repeated the experiment, which induced that gentleman to form the above conclusion, and have only once or twice—and then only by continued and forcible pressure—produced appearances which would tend to corroborate his description; hence I am led to conclude, that the limited openings through which Mr. Addison saw the compressed air-bubbles pass from cell to cell, were ruptures in the cellular septa, produced by the pressure employed; and this conclusion is still further strengthened by the fact, that Mr. Addison states only that he "*frequently*" saw the appearances from which he draws his inductions: now, were the oval foramina a normal part of the cellular structure, the phenomena produced by them ought to be observed during the passage of air through each inter-cellular septum throughout the lobule. The openings from the parietal cells to the passages are

[r] Each passage is therefore formed, as it were, upon the same type as a lobe of the frog's lung. See Tab. III., fig. 2.

sometimes (but not universally) constricted, whence it happens that the air-bubbles pass from the one to the other by a saltatary motion, and are sometimes much compressed and altered in form during their transit; these constrictions may be readily accounted for when we consider the manner in which the cellular formation takes place.

On the internal pleural surface of a specimen of the lung of a human fœtus of the eighth month, into which mercury has been poured by the trachea, (and which I have now before me) the intra-lobular tubes may be seen to terminate in dilated *culs de sac;* on some of them moreover are distinctly visible lateral dilations, sometimes constricted at the part next the lobular tube; these *vesicles* and the "*membranous septa*" described by Mr. Addison as everywhere present in the interior of the air-tubes of a fœtal lung in his possession, are probably one and the same structure, presenting varying characters, on account of the different mode of preparation of the two specimens, and perhaps also in consequence of their being in different stages of development.

From my own investigations of the fœtal pulmonary structure, I conclude that enlargements pre-exist, regularly distributed through the intra-lobular tubes, which being distended by inspiration at birth, (simultaneously with the previously contracted tubes) form vesicular dilatations everywhere surrounding each tubular branch, and that the branched passages, owing to their greatly increased size, so encroach upon each other as to compress what were globular lateral inflations into parietal polyhedral cells; this mode of formation (necessarily hypothetical) I consider much more probable than the purely mechanical theory of

Mr. Addison, inasmuch as if the formation of parietal cells depended, as he supposes, upon the "*delicate membrane composing*" the air passages offering "*an unequal degree of resistance to the pressure of the air,*" we could hardly expect to find the cellular disposition of the branched passages so regular as we see it throughout.

Upon the membranous terminal dilations of the fœtal air-tubes, I have seen (arranged in an arched form) numerous parallel fibres, (Tab. IV.) doubtless the same as are described by Wagner as "*delicate arcuate fibres surrounding the vesicles,*" which he considers to be "of the nature of elastic tissue, holding the vesicles distended, whilst the vessels spread freely over their surface;"[s] from their situation and appearance, as well as for reasons to be mentioned in a future paragraph, (§ 60) I believe them to be muscular.

The size of the pulmonic cells varies at different periods of life, being small in infancy, and gradually increasing with age;[t] different kinds of employment,

[s] Wagner's Physiology, Book II. § 175. Willis distinctly describes these fibres, nearly two centuries since; he says "Cellulæ istæ vesiculares, ut nixus pro expiratione contractivos edant, etiam fibras, uti per microscopium plane conspicere est, musculares obtinent." Pharm. Rat. De Respir. Orig. et usu. A drawing representing these fibres was made for me by my friend Mr. Bradley, from a preparation in my possession, long before I had seen the descriptions of Willis and Wagner.

[t] The general cellular enlargement which is constantly observed in old age, should be looked upon rather as a natural process than as a diseased condition; it is caused by a gradual obliteration of the walls of the cells, and is therefore accompanied by a corresponding diminution in their number. Bourgerie and Lombard (the latter of whom has written a special treatise on the disease so called) limit the application of the term Emphysema to *rupture* of the aeriferous structure; my own observations would tend to support their views; when examining specimens of the disease (in the human lungs, as well as in those of

locality, and disease, also considerably affect their magnitude. Wagner estimates the majority to be from the 8th to the 10th of a line in diameter.

§ 44. Two classes of blood vessels enter into the composition of the lungs, viz. those subservient to their special function, the pulmonary artery and the pulmonary veins;— and those destined for their nutrition, the bronchial arteries and the bronchial veins. **Blood vessels of Lungs.**

§ 45. The pulmonary artery *(vena arterialis)* arises from the left side of the base of the right ventricle of the heart; it passes upwards beneath the arch of the aorta with a slight inclination backwards and to the left for about two inches; then it divides into two branches, a right and a left; the right branch, the largest and longest, passes behind the ascending aorta and the vena cava to the root of the lungs, where it rests upon the right bronchus; the left branch passes in front of the descending aorta and beneath its arch to the anterior and superior border of the left bronchus. The right pulmonary artery divides into three branches, and the left into two—one for each lobe: all these are divided successively into gradually decreasing tubes, one of which accompanies each division and sub-division of the bronchi even to the lobule, which they enter together. **Pulmonary Artery.**

At its origin the pulmonary artery is surrounded by a dense tendinous tissue, to which are attached by semi-circular borders, the concavities of which are directed towards the lungs, three crescentic

the horse,) I have invariably traced upon the surface of the *apparent dilations* irregular membranous bands—the remnants of the inter cellular septa.

valves; (Tab. IV. fig. 5) each of these, composed of two delicate transparent membranes, projects into the arterial cylinder, presenting a free semi-lunar, somewhat thickened margin, in the centre of which is a small roundish cartilaginous tubercle:[u] (Tubercula Arentii). The pulmonary valves lie loose and flaccid, nearly apposed to the arterial parietes; but when the artery has been injected backwards from one of its branches, they form three pouch-like cavities, the convexities of which are directed towards the heart and their free margins meet in the centre of the vessel. Between the membranous layers forming the valves are muscular fibres, both horizontal and vertical; the former (says Haller) "*hold fast the valves to the contiguous side of the heart,*" the latter, inserted into the cartilaginous tubercle already mentioned, "*draw back the said valve, and open its concavity.*"[v]

The lining membrane of the pulmonary artery differs from that of arteries in general, it is more delicate and elastic.[w]

Each division and sub-division of the pulmonary artery represents a cone, the base of which looks towards the periphery of the lungs, whilst its apex is directed towards the right heart.[x]

Independent of the arteries which accompany the

[u] In Vol. I. of John and Charles Bell's Anatomy, the presence of this tubercle in the Aortic Semi-lunars is stated to render them more perfect than those of the pulmonary artery.

[v] Haller's Physiology, vol. i. p. 82.

Cowper, in his "Myotomia Reformata," gives some admirable representations of these fibres. (See Tab. XXXVIII. fig. 5.) Winslow also describes them as "Fibres charnues."

[w] The pulmonary artery is nearly exempt from the ossific deposits to which the arterial system generally is extremely liable.

[x] Bourgerie. "Des Poumons."

numerous bronchial divisions, the pulmonary artery gives off a vast number of very minute vessels, the orifices of which may be seen variously interspersed over its lining membrane. I have traced these vessels through the interlobular tissue, to ramify in which they frequently sent off branches at right angles with their trunks, but I have not been able to follow them into the lobules; from which circumstance, and from the fact of their not having any corresponding bronchial tube, I am led to conclude that these form the medium of communication between the pulmonary and bronchial arteries, and that from these it is that twigs proceed to assist in forming the rete of exhalants which exists upon the pleura. (§ 50.)

§ 46. From the point of bifurcation of the pulmonary artery a small round ligamentous cord proceeds to the commencement of the descending aorta; this dense and impervious is the obliterated "Ductus Arteriosus" of the fœtus. Ductus Arteriosus.

§ 47. The pulmonary veins (Arteriæ Venosæ) originate within the different lobules by numerous branches which gradually converge to form single trunks; these issue from the roots of the lobules, and, decreasing in number and augmenting in size, run parallel with the arterial and bronchial divisions; they finally emerge from each lobe by a single trunk, so that there are three on the right and two on the left side; the two superior veins on the right side, however, generally unite soon after leaving their respective lobes, so that there are usually but four trunks which directly open into the left or posterior auricle of the heart. As on the internal surface of the pulmonary artery, so on that of the larger venous divisions, there may be seen the orifices of diminutive trunks, not Pulmonary veins.

having accompanying bronchial tubes; they are however here less numerous than in the arteries.

In common with the veins of the thorax and abdomen generally, those of the lungs contain no valvular apparatus; I have, however, seen in the pulmonary veins of the calf and sheep, distinct semi-lunar folds of the lining membrane, projecting into the cylinder at the point of communication of each branch with its trunk; they were so placed as to prevent hindrance accruing to the onward progress of the different currents from their conflux being too abrupt, and did not appear capable of preventing regurgitation. (Tab. IV. fig. 1.) In structure the pulmonary veins differ not from others, excepting in their lining membrane, which is continuous with, and analagous to, that of the left cavities of the heart. Every branch of the pulmonary veins is conical in shape, having its contracted part towards the pulmonary periphery, and its dilated extremity towards the left heart.

Muscular fibres surround the elliptical openings of the pulmonary veins, and are prolonged a short distance into their cylinders.[y]

Bronchial Arteries.

§ 48. In the sixteenth century Columbus wrote, "*At ab aorta arteria nullus ramus, neque magnus neque parvulus ad pulmones mittitur.*"[z] And this was then the generally received opinion, although Erasistratus, Galen, and Rhazes had vaguely spoken

y "Nonnullæ venarum pulmonalium originem circumdant."—Haller, Vol. i.

"Venæ cavæ et pulmonales circa suas in sinus insertiones distinctis fibris muscularibus gaudent."—Soemmering. Quoted by Roden, Prize Essay, 1838.

z Lib. XI, cap. 2, De Re Anatomica.

of the existence of such; Ruysch was the first who explicitly and accurately described them.[a]

The bronchial arteries, the true nutrient vessels of the lungs, vary much, according to the statements of different authors, both in their origin and number;[b] I have minutely injected and dissected them in the human subject five times, and have, in neither case, found more than two original trunks; in three of these a right and left trunk were given off separately from the descending aorta just below its arch; (the right trunk in the one case gave off an additional branch to the left bronchus). (Tab. V. fig. 1.) In the fourth dissection a common trunk arose from the anterior aspect of the descending aorta, as it curved behind the left bronchus, which divided immediately into two lesser trunks, the one of which passed upwards upon the posterior surface of the trachea, (ramifying minutely thereon) and anastomosed with its proper vessels; (§ 29.) the other, the larger trunk, after passing a few lines to the right, divided into two branches — the right and left bronchial arteries. (Tab. V. fig. 2.) In the fifth dissection the right bronchial artery arose, in common with a small œsophageal branch, from the superior intercostal; the left came off from the descending aorta, just below its arch. (Tab. V. fig. 3.)

Whatever may be the origin of the bronchial arteries, their distribution is always regular; one always

[a] Hanc arteriam a nemine adhuc observatam esse intrepidè affirmo.—Observat. Anatom. XV, vol. i.

[b] Ruysch describes *one*, dividing into right and left; Bichat, Bourgerie, Cloquet, Lauth, and Portal name *two* as their normal number; Bell and Winslow give *three;* Cruvelhier, Ellis, Haller, Quain, Soemmering, and Wilson describe *four;* whilst Meckel says there are *six*.

runs upon either bronchus, and divides and subdivides into branches, which accompany all the successive bronchial divisions, ramify extensively over their surface, and every where perforate their substance, forming a most intricate capillary network on their lining membrane; small twigs, moreover, traverse the interlobular cellular tissue, which they supply together with the bronchial glands, the tunics of the functional vessels, and the nerves;[c] their ultimate branches assist in forming a delicate rete (§ 50) on the pleura.

External to the lungs, the bronchial arteries anastomose extensively with the neighbouring vessels; they inosculate minutely with the thymic, the œsophageal, the tracheal, the mediastinic, and the pericardiac arteries, and with the recurrent branches from the phrenic and the coronaries of the heart; a direct communication is also established between the right and left bronchials soon after their origin, either by a branch passing immediately from the one to the other, or by the two mutually inosculating with adjoining vessels.

Ruysch made known and depicted the anastomoses, which are so evident between the bronchial and pulmonary arteries within the lungs.[d] In Reisseissen's essay, already quoted, are some excellent representations of these. Dr. Graves discovered that the vessels which ramify upon the *air-cells* cannot be injected from the bronchial arteries, and that

[c] Alii ad tunicas vasorum pulmonalium, alii ad nervos feruntur.—Op. Cit. p. 15.

[d] Repleta enim arteria pulmonali ceraceâ materia, illicò quoque repleti conspiciuntur, ramuli arteriæ bronchialis.—Ruysch, Resp. ad. D. J. H. Gretz.

those distributed to the *lining membrane of the bronchial tubes* cannot be filled from the pulmonary artery; the results of the injections which I have frequently made, fully accord with those of Dr. Graves.

Bronchial veins

§ 49. The bronchial veins were vaguely spoken of by Galen; their presence was afterwards denied by Ruysch; but a short time afterwards their existence was fully established;[e] Winslow gave a correct account of them in 1732.

The bronchial veins are formed by the aggregation of the terminal branchlets of the bronchial arteries; they ramify extensively on the sub-mucous cellular tissue of the bronchi, and commonly end in two or three branches which terminate, the right in the vena azygos or vena cava, the left in the superior intercostal vein. Winslow describes them as being sometimes branches of the Guttural.[f]

A singular termination of the bronchial veins is that noticed by Reisseissen, as follows—

> "*Venulæ enim omnes, quæ maxima pulmonum in parte arteriis respondet bronchialibus, non in similes truncos coëunt, sed in vena pulmonali per totum hujus decursum ora sua aperiunt.*"[g]

I have myself injected the bronchial from the pulmonary veins. "Is this peculiarity" (says Graves) "owing to this blood being dissimilar to other venous blood, in consequence of being aerated in the bronchial tubes? or is it because it may be mixed with

[e] "Bronchiales venas nullas esse, *quod olim Ruyschio credidi* out rarissimas nunc constanter visa utraque porro non credo." Haller, vol. iii. Lib. 8.

[f] De la Poitrine. Sect. 123.

[g] Op. Cit. p. 14.

impunity with the great mass of aerated blood returning from the lung."[h]

Pulmonary capillaries.

§ 50. Between the terminations of the pulmonary artery and the commencement of the pulmonary vein, is a dense net-work of capillary vessels which forms a connecting medium between the two: the communications between the pulmonary artery and pulmonary veins were first noticed by Servetus in 1533, in a work entitled "*De Christianissimi Restitutione.*"[i] In 1628 was accomplished the brilliant discovery of the true course of the blood's circulation, which has rendered the name of our countryman Harvey immortal in the annals of medicine: although his unrivalled genius could not entirely shield him from the envious doubts and criticisms of cotemporaries, we may nevertheless consider the communication between the pulmonary artery and the pulmonary veins, as being, since then, comparatively undisputed. Malpighi gave an elaborate description of the pulmonary capillaries.[j] Reisseissen states that the artery, having followed the course of the bronchus, sends separate branches to the extreme vesicles which, by numerous anastomosing ramifications, traverse their surface and,

[h] Clinical Medicine, p. 200.

[i] Galen thus expressed his ideas of an arterial and venous communication.—" In toto corpore mutua est anastomosis, atque oscillorum apertio arteriis simul et venis transumuntque ex sese pariter sanguinem et spiritum per invisibiles quasdam, atque angustas plane vias.—Lib. vi, cap. 10.

[j] ——rete vero ubique æquale est. Extremitas trunci arteriarum ad apicem pulmonum deducta conspicuis latisque ramis parum in rete implicitis totidem venæ ramis occurrens eidem anastomozatur; lateraliter quoque ab utroque vase emanens rete aream licet miniman cooperit, ita ut sanguis per vas amplum et conspicuum ab arteriâ in venam propellatur, juvantibus etiam reticularibus plexibus.—Malpighi, Op. Posthum. p. 17.

again being formed into small trunks, constitute the commencement of the veins; I have repeatedly seen (by the aid of the microscope) the pulmonary capillaries running over the terminal air passages, in an intricate series of irregular rings enclosing minute membranous islets, such as are seen on the surface of the simple lung of the newt.

The course from artery to vein is so readily traversed, that with a fine injection of gelatine, the veins may be filled from the artery, or "*vice versa*," the artery from the veins; hence it is next to impossible to obtain even an approximate knowledge of the comparative capacity of the two systems.

An extremely delicate network of vessels is formed upon the pleura by diminutive branches of both the pulmonary and bronchial vessels; in the healthy condition this is invisible, but when distended and gorged with blood, (as they are when in an inflamed state) they give to the pleura an uniform red colour, varying in intensity with the degree of inflammation. The existence of these vessels may be shown by a simple experiment practised by Boerhaave, who, on injecting warm water into the pulmonary veins, found that the pleural surface, before dry, was rendered moist;[k] so Reisseissen discovered, on injecting a coloured mass into the vessels, that the pigment being retained, the more fluid portion, free from colour, was poured forth upon the pleural surface.[l]

These vessels, by constantly exuding a thin serous fluid, keep the pleural surfaces moist, and facilitate their motions.

[k] Abr. Krau Boerhaave Perspiratio dicta Hippocrati, § 616.

[l] Op. Cit. p. 13.

Communication between bronchi and pulmonary vessels.

§ 51. Most authors who have treated of the pulmonary structure have recorded a fact easily proved, viz: that the finer portion of matters injected by the pulmonary vessels passes from them into the bronchi. When we consider that a constant interchange of fluids takes place, during life, through the delicate membranes separating the sanguiferous and aeriferous terminations for which to be effected it is necessary that foramina—however minute—should exist, this post-mortem communication between the two systems will cease to excite that surprise which a casual consideration of it would naturally induce; for it may be readily understood how, during life, a salutary contractile power[m] may be exercised which prevents the exudation of the less delicate constituents of the blood, and as this power would necessarily cease with vitality, so may it well be conceived that injected matters would after death, easily pass through the now-dilatable foramina.

Pulmonary circulation.

§ 52. Having considered the arrangement and construction of the pulmonary vessels, we now proceed to examine the mode in which the circulation through them is established and maintained.

The blood contaminated during its systemic circulation with effete matter—*carbon*—and having received in addition a semi-assimilated product viz: *chyle*—is, by the contraction of the right ventricle of the heart, (the flapping back of the tri-cuspid valves preventing its return into the right auricle) directed towards the pulmonary artery, the loose

[m] The *passive* pulmonary hæmorrhages which occasionally take place (as in vicarious menstruation) may probably be attributed to temporary relaxation of the pores through which the watery particles of the blood are usually exhaled.

convexities of the semi-lunar valves placed at the origin of which readily yield to afford it an easy ingress: when once entered into the artery, regurgitation into the ventricle is prevented by the close approximation of the sail-like margins of the valves in the centre of the cylinder; this is caused partly by the blood insinuating itself between the valves and the arterial parietes, and partly by contraction of the muscular fibres of the valves themselves; the artery possesses an inherent elasticity which tends to restore it—when distended—to its former size; it is also endowed with a peculiar contractility, enabling it to contract upon itself;[n] these powers, assisted by the "vis a tergo" of the heart, propel the blood through the numerous arterial divisions, and, with the assistance of an unknown power[o] residing in the capillaries themselves, through the extensive

[n] The salutary and effective contraction of the living artery so far exceeds the imperfect closure resulting from post-mortem elasticity, as clearly to manifest the existence of a *true contractile power;* it does not follow that this should be wanting, because muscular fibre, *strictly so called,* has not yet been discovered in the arterial tunics, for different localities require modifications of structure, and it is by no means unreasonable to suppose, that the ligamentous-looking fibres encircling the arterial cylinders have the power of contracting. Valentin has succeeded in producing contraction of the thoracic aorta, by irritating the neighbouring branches of the sympathetic nerve.—(See Carpenter's Physiology, p. 147.)

[o] The assistance which the capillaries render in the circulatory process is little understood; but that they exercise some influence over it is shown by the experiments of Dr. Wilson Phillip. (see Carpenter's Physiology, p. 418) The contractile power which they seem to possess, is supposed to be provided for the purpose of accommodating the canalicular capacity to the varying quantity of the circulating fluid; no alternate diminution or enlargement of their calibre is observable under the microscope; (See Op. Cit. p. 405 et seq.) this statement I have frequently verified by microscopical observation of the circulation in the web of the frog's foot, in the membranous tail of the newt, and once in the lung of the living triton.

capillary rete: the "vis a tergo" of the heart and arteries still manifests an influence over the circulation after the blood has entered the veins, though its onward movement is now increased by a "vis a fronte" or suction power, dependant upon the dilatation of the left auricle;[p] the purified blood, having at length entered the left auricle, is prevented from exercising a retrograde movement by the contraction of the circular fibres prolonged into the venous cylinders (§ 47) simultaneously with the general muscular structure of the auricle; the former thus act as sphincters and close the venous orifices.

The course of the blood through the lungs has been supposed to be *mechanically* obstructed by the imperfect performance of respiration; Harvey writes "Præterea pulmones in respirando elevantur et concidunt; quo motu necesse est, ut porositates *et vasa aperiantur et claudantur*,"[q] so Haller says, "In expiratione sanguis in pulmones compressos *difficilius recipitur*;[r] but as the lungs, even after the most perfect expiration, still contain a large quantity of air, this hypothesis would appear to be scarcely tenable.

It is highly probable, that the distension of the aeriferous structure by inspiration may further the pulmonary circulation, by diminishing the interlobular spaces through which the vessels pass, as this would naturally propel the blood in the compressible

[p] This is the prevalent theory; but the fact that the venous blood still flows towards the auricles during their contraction—producing the phenomenon termed "pulsus venosus"—(See Müller's Physiology, vol. i. p. 181) would seem to disprove it.

[q] De Motu Cordis. cap. VII.

[r] Op. Cit. Lib. VI. sect. iv. p. 336.

veins (owing to their conical conformation) towards the left heart; whilst the firm character of the cellular sheath of the artery would prevent the compression it was subjected to from offering any material impediment to the influx of blood from the right heart.

Haller states, that during expiration, the blood recedes into the large trunks of the venous system;[s] that the general circulation should be so affected it is difficult to imagine, as the valvular arrangement of the heart would prevent any temporary obstruction of the pulmonary circulation (supposing this to be caused by expiration) from producing a retrograde flow into the systemic veins: Majendie apparently proved by experiment the correctness of Haller's doctrine; he passed a hollow bougie along the cava as far as the auricle, and found the blood issue from it during expiration; he considered that "when the chest contracts, the blood is driven back into the cavæ by the pressure experienced by all the organs of the chest;"[t] it would be expected however, that the elastic pulmonary structure would be much more readily compressed than the mediastinum, which has provided for it a special protection against encroachment; if this space, moreover, were liable to have its capacity altered by respiration, we should expect *diminution* to be produced

[s] Deinde, per experimenta mea, si pectus, aut abdomen, aut collum, aut brachia animalis aperueris, venas grandiores cavam superiorem, inferiorem, jugulares, subclavias, brachiales, mammariamve nudaveris, videbis perinde, dum animal inspirat, sanguinem undique ad cor redire, venasque, quas nominavi, a corde recedere, etiam ad aliquot lineas, depleri, pallescere, explanari, exsangues fieri. *In expiratione vero,* quæ proxima sequitur, *easdem venas sanguine a corde rejecto turgere cæruleas, cylindricasque fieri.*—Op. Cit. Lib. vi. p. 333.

[t] Journal de Physiologie, tom. i. p. 186.—(Quoted by Elliotson.)

by the lateral expansion of the lungs *during inspiration*. Sir David Barry, who plunged his hand into the thorax of a living horse, found the superior cava at every expiration so empty as to feel only like a thin placid membrane.[u]

In the lung of the living triton, the circulation may be readily examined under the microscope; Wagner accurately describes the appearances presented by it: he says, "The pulmonary arteries expand very speedily into a fine-meshed network of intermediate vessels, which in general admit of no more than single files of blood corpuscles, and play about very minute islets of the parenchyma of the lung. The vessels always appear with distinct parietes, and terminate partly in capillary veins of the same character as themselves, partly in larger venous trunks. The blood-corpuscles, mixed with lymph corpuscles, fill both arteries and veins close to their parietes.[v]

Pulmonary Lymphatics.

§ 53. The lymphatic vessels of the lungs are arranged in two sets, the superficial and the deep; the former class had been noticed by Rudbeck, Willis, and Ferrien, before Hunauld demonstrated them proceeding from a part of the pulmonary surface to the thoracic duct. Mascagni first described the deep lymphatics, as well as their anastomoses with the superficial set.

The superficial pulmonary lymphatics may be shown with facility on the surface of fœtal lungs, or upon those of young animals, in which they are comparatively much larger and more numerous than

u "Annales des Sciences Naturelles," Juin, 1827.

v Op. Cit. § 123.

in adults; Mascagni demonstrated them by means of warm water injected by the trachea or pulmonary artery. I have frequently (from the bronchi) distended them with air in the calf's lung, and with air and mercury in that of the human fœtus: forming by their numerous anastomoses irregular polyhedrical rings, and presenting frequent dilatations which mark the sites of their valves, they ramify extensively beneath the pleural membrane, and are continued into the interlobular fissures, by which they communicate with the deep set: they converge towards the root of the lungs, terminating in the bronchial glands.

The deep set originate, according to Mascagni, from the internal surface of the bronchial terminations; ("*ex cavo interno vesiculorum*") they follow the course of the bronchial and vascular divisions, and pass to the small glands situate at their different points of divergence; after communicating by successively increasing branches with the whole of these, they eventually form two or three principal trunks which, like those of the superficial set, terminate in the mass of glands placed in front of and behind the tracheal bifurcation. Haller has seen branches passing to a pulmonary vein.[w]

§ 54. The lymphatic glands may be also divided into two classes—those situated within, and those placed without the lungs; the former are numerous small rounded or oval bodies, occupying the angles of bifurcation of the bronchi and functional vessels, gradually increasing in size as they approach the root of the lung: the latter are larger, and

Lymphatic glands of lungs.

[w] Op. Cit. vol. iii. p. 170.

from ten to twelve in number; they lie in the space left by the divergence of the right and left bronchus, both anteriorly and posteriorly; they are intimately attached by fibrous tissue to the trachea and bronchi, to the aorta, to the pulmonary artery, and to the pericardium; their efferent vessels receive others from the tracheal, the œsophageal, the aortic, and the intercostal lymphatic ganglia, and pass, partly to the *ductus lymphaticus dexter*, but principally to the *ductus thoracicus*.

The pulmonary lymphatic glands in the fœtus are white with a reddish tinge, and are soft and moist; in the young child they are of a reddish brown, which in the adult is changed for a purple colour, and this, in the decline of life, gradually tends to black, owing to the deposit of carbonaceous [x] matter, such as then becomes dispersed over the surface and in the substance of the lung; this deposit sometimes accumulates so extensively as to lead to emphysema, by compressing the bronchial cylinders.

These glands were long since thought to communicate with the bronchi by open mouths;[y] Haller was inclined to this opinion, from the fact of the sputa being frequently charged with the same black matter as is found in the glands, although he admits "quos præterea ductus nunquam viderim."[z] The bronchial glands are subject to earthy and tuberculous depositions, but are little liable to inflammation.[a]

[x] This imparts to the finger a coloration with difficulty removed.

[y] Elles paroissent communiquer par de petites ouvertures avec la cavité des bronches.—Winslow, Anat. p. 603.

[z] Op. Cit. p. 152.

[a] Forbes's translation of "Laennec on Diseases of the Chest." pp. 142, et seq.

§ 55. Wagner writes, "Neither anatomical nor physiological considerations render any satisfactory account of the import and office of the lymphatic vessels," etc. His translator adds, "Our knowledge of the lymphatic system, is chiefly grounded upon artificial injections with mercury, which are at all times extremely deceitful, and liable to lead into error. In the majority of instances we have no kind of security that canals accidentally made in the cellular tissue, by the pressure of the column of mercury, are not described as lymphatic vessels, or, that the cellular sheaths of blood-vessels filled in the same way, are not viewed as lymphatic trunks."[b] I must object to this statement, that where mercury is extravasated into the cellular tissue, it is seen in irregularly diffused masses, and not in a series of well-defined rings, such as the pulmonary lymphatics represent; *when distended with air moreover* and viewed by the aid of the microscope, they appear* as a regularly distributed series of polyhedral rings, composed of cylindrical tubes, presenting frequent sacculated dilations of an uniform character. Use of Pulmonary Lymphatics.

Reisseissen advances some conclusive arguments in favour of the absorbing power[c] of the lymphatics of which the following is the substance, viz: that as the air passages are closed in the fœtus, their extremities would be blocked up by the effete matter of the blood brought there and deposited by the functional vessels, but, for the lymphatics, which, by their large size and number and direct commu-

[b] Wagner, Op. Cit. § 217, and note 424.

* Which may be seen by an accompanying specimen of fœtal lung.

[c] De Structura Pulmonum, p.p. 24, 25.

nication with the bronchi, are enabled to effect its removal;—that after the institution of the respiratory process, the superfluous products in the blood are exhaled with the breath, whence it is that the orifices by which the bronchi and the lymphatics communicate with each other then become so much diminished that the latter can be scarcely, if at all, injected from the former;—that, in equal ratio with the decrease of the comparative capacity of the lymphatic system, black spots and striæ, never seen in the fœtus and seldom during childhood, are seen to occur upon the surface and in the substance of the lungs, and that, if closely inspected, the deposit will be found to have taken place in the course of the lymphatics—especially where these are collected in any quantity,—and that lastly, the lymphatic glands become clogged up, and are little else, in fact, than so many masses of carbon.

Nerves of Lungs, history of

§ 56. The lungs were supposed by Vesalius, Galen, and others of the older medical authors, to be but sparingly supplied with nerves; Haller was of this opinion, and his reasons (embodying those of preceding writers) are thus given:—

"Neque multi neque magni pulmonis nervi sunt, neque viscus ipsum valdè sensile." "In vivis certe animalibus pulmo absque ulla agitatione animalis lancinatur: et in hominis abscessus maximi pulmonis absque febre nasci visi sunt, et absque dolore, neque queruli qui suppurantur."

Immediately afterwards however, he adds,

"*Quin in bronchiis sensus sit, minimè repugno.*"[d]

[d] Op. Cit. vol. iii. p. 170.

Willis, in opposition to the opinions of other authors of his day, stated that the lungs were largely supplied with nerves, the arrangement of which he has depicted in his work already quoted, cap. I. tab. 5.

Winslow describes branches of the eighth pair of nerves, and some also from the sympathetic, as accompanying all the ramifications of the bronchi and bloodvessels, the tunics and membranous parts of the lungs, and ramifying upon the walls of the cells or vesicles.[e]

To Reisseissen we are mainly indebted for a knowledge of the nervous distribution within the lungs.

The nerves which supply the lungs are derived from the anterior and posterior pulmonary plexuses. The anterior pulmonary plexus, formed by two or three branches from each trunk of the pneumogastric nerve or the recurrent laryngeal nerve communicating with branches of the auricular plexus, is situated upon the anterior root of the lung, on either side. The posterior pulmonary plexus, placed on the posterior root of the lung of either side, consists of a considerable number of branches from each pneumogastric nerve, associated with some branches from the great cardiac plexus. From these points of origin nervous filaments proceed and supply the lungs minutely; those from the anterior plexus are said by Swan to pass to the anterior part of each lung, and to the pulmonary arteries and veins; the filaments from the posterior plexus he describes as being distributed to the parenchymatous structure of the lung, the principal being continued along the divisions of the trachea to terminate in the air-cells.[f] Reisseissen had before conjectured that such was the case;[g] he has moreover represented a branch

Origin and distribution.

[e] Winslow, De la Poitrine, sect. 124.

[f] Swan "On the Nerves." p. 16.

[g] Ad extremos autem bronchiorum fines eos persequi non licet, quamvis facilè conjici possit, quum tunica mucipara eo usque producatur et sensilitatem hujus persistere. Op. Cit. p. 20.

from the eighth pair proceeding from the pulmonary to the bronchial artery,[h] another running along the pulmonary vein, and giving off a branch to the capillary rete,[i] and another, which having supplied a bronchial gland, became lost beneath the pleura.[j] I have seen a branch accompanying a bronchial trunk to its termination, sending off filaments to each of its divisions and minutely supplying the interlobular spaces.

The interlacements of the pneumo-gastric and sympathetic, which are so frequent external to them, are in no instance seen to occur within the lungs.[k]

Influence of Nerves over the Respiratory Function.

§ 57. The centre of the respiratory movements is the upper part of the medulla oblongata; to it impressions are principally conveyed by the pneumo-gastric nerve; when this is divided on one side only little effect is produced, but when the nerve is cut through on both the respiratory movements are reduced to about half their usual frequency;[l] irritation of its trunk in the neck causes instant inspiration, but as respiration does not entirely cease upon the division of the vagi it follows, necessarily, that there are other excitors. The nerves distributed to the whole cutaneous surface (more especially may be mentioned the facial) exercise a powerful influence over the respiratory function; the deep inspirations caused by the sudden application of cold, well illustrate this.[m] The motor powers of

h Op. Cit. tab. vi. fig. 2. b. i Op. Cit. tab. vi. fig. 1. a. b. d.

j Op. Cit. tab. v. fig. 2. f. k Quain's Anatomy, (1837) p. 707.

l See experiments of Dr. Reid. Edin. Med. Review, vol. li.

m The power which excitement of the cutaneous surface has of producing inspiration was shown by Beclard, who, on mechanically irritating fœtal kittens still enclosed in the membranes, found inspiratory efforts to take place at each irritation.

the pneumo-gastric nerve are chiefly due to its communication with the spinal accessory nerve.

Dr. Reid has been unable to ascertain whether the pulmonary branches of the pneumo-gastric contain motor fibres; but as Valentin has succeeded in producing distinct contractions of the tracheal rings by irritating this nerve in the rabbit,[n] and as the muscles of the trachea and bronchial divisions are continuous and therefore to be supposed to receive the same nervous influence, analogical reasoning would lead to the conclusion that they do possess motory powers. The sympathetic is probably an assistant excitor to respiration, rendered so not only by its ramifications in the lungs but also by its distribution on the systemic vessels.[o]

As the motor, or efferent nerves, concerned in the function of respiration—those which Sir Charles Bell has classed together in his "Respiratory System"—are situated *external to the lungs* and formed the special subject of the Warneford Essay of last year, (about to be published) in which they were doubtless fully treated of by my much esteemed and talented friend, Mr. Clarkson, it would be superfluous for me to analyze their distribution and office. I may however mention, that by the influence of the spinal nerves, the continuance of respiration is rendered independent of volition, whilst an additional voluntary power over it is conferred by the pneumo-gastrics; thus the necessity for respiration, after an intermission of a few seconds, becomes so urgent as to render nugatory all efforts to prevent it; whilst at the same time we possess the power

n Carpenter's Physiology, 141.

o Op. Cit. 138.

of so modifying the function as to make it subservient to the expressions of our ideas and feelings by the voice.

Pulmonary Development.

§ 58. In the human embryo the lungs appear first about the "sixth week as mere sacs, not more than about a line in length, lying, on either side the heart, in the angle formed inferiorly between the diaphragm and the walls of the thorax, and do not yet receive any particular vessels; they already exhibit traces of division into several rounded vesicles or lobes; they hang by the rudiments of the trachea, a delicate thread, which shows a trifling enlargement superiorly, in the situation of the future larynx;"[p] in the third month they first receive branches of the pulmonary artery; in the fourth month they acquire a reddish colour, and the trachea, before flattened, becomes rounded; in the fifth month they become more vascular, and the trachea is lined with a mucilaginous fluid; in the sixth they are solid and inflated with difficulty, cartilaginous rings now appear in the trachea; in the eighth month the cellular disposition is more perfectly observed, and the cartilages of the trachea are more distinct, the fœtus is now capable of carrying on an independent existence. At the termination of the ninth month the lungs have attained their most perfect fœtal state, and are capable of performing the function of extra-uterine respiration with the necessary degree of vigour.

Changes effected in the lungs by the first inspiration.

§ 59. During the term of intra-uterine existence the large size of the liver, due to its excessive

p "See Wagner's Physiology," § 73, to the excellent description of "Fœtal development" contained in which, I am mainly indebted for the following particulars.

vascularity, presses up the diaphragm, and compresses the thoracic cavity; the "Liquor Amnii" every where surrounding the fœtus has, as yet, formed an insuperable preventative to the introduction of air into the lungs; the existence of a special canal of communication, the ductus arteriosus, between the pulmonary artery and the aorta, directing the greater portion of the blood which enters the former from the right ventricle into the latter vessel, has (together with the contracted calibre of the two primary divisions of the pulmonary artery) prevented more than a very small proportion of the circulating fluid from entering the lungs. On the occurrence of respiration, the dilation of the lungs by the atmosphere presses down the diaphragm, and (owing to the attachment of the pericardium to the diaphragmatic pleura) the heart is at the same time drawn downwards, and the ductus anteriosus, previously placed nearly horizontally, is rendered perpendicular and tense; by this altered condition its sides are approximated,[q] and oppose a mechanical obstacle to the passage of the blood, which is consequently driven, by the contractions of the right ventricle, through the right and left pulmonary trunks into the lungs. By the combined influence of the inspired air and of the blood now circulating through them, an extraordinary change in the physical properties of the lungs is accomplished; the reddish-brown colour which before characterized them, is exchanged for a light roseate hue; though the large supply of air and increased supply of blood augment their bulk and *actual weight*, the presence of the former fluid

[q] This canal becomes obliterated by a kind of concentric thickening of its coats, about the 10th or 12th day after birth.

considerably reduces their *specific gravity*, and instead of as formerly lying deep, dense, and contracted on either side of the heart, they now—expanded and elastic — cover it in, and fill the enlarged thorax.

Respiratory Mechanism.

§ 60. Respiration consists of an alternating series of inspiratory and expiratory movements; for effecting *ordinary inspiration* the contraction of the diaphragm is generally supposed to suffice; by this contraction the convexity of the muscle is depressed and flattened, and the capacity of the base of the thorax consequently augmented; to prevent such an anomalous occurrence as a vacuum,[r] which would be produced were the pleuræ to be drawn asunder by this movement of the diaphragm, atmospheric air rushes down the trachea, and distends the aeriferous structure of the lungs *in exact ratio with the thoracic expansion,* keeping the external pulmonary surface—covered by its pleura—in direct apposition with the pleural lining of the thorax. Bourgerie considers it probable, that a sort of vermicular contraction of their annulated fibres gradually impels onwards the air through the bronchi; this he states however, that he advances with reserve, as a phenomenon which, beyond the perception of the senses, destroys all hope of experimental demonstration.

[r] Dr. Carpenter considers that a vacuum is produced by the enlargement of the pleural cavity; (see his "Human Physiology," p. 433) that none actually occurs is proved by the fact that the pleuræ are always—in inspiration and expiration—directly in contact with each other, as Haller proved by vivisection. (see § 10) Moreover, how could a vacuum occur when a general and intimate adhesion between the pleural surfaces had taken place? Yet this condition is often present, and respiration continues.

Forcible inspiration, such as is caused by momentary excitement or fright, appears to be effected by the scaleni, the intercostal, the subclavian, and the sterno-mastoid muscles. In *diseased conditions* other muscles are brought into action, viz:—the pectorales majores et minores, serrati magni, serrati postici superiores, and latissimi dorsi; these act by increasing the anterio-posterior diameters of the thorax as well as its base.[s]

Mr. Roux says "If we lay open the chest of a living dog, we find the lung reduced at first to one fourth of its former dimensions; but even in this state we observe it *swelling and contracting with an alternate motion.*" As this could not be the result of atmospheric pressure, he considers it to depend upon an *active expansion of the viscus itself.*[t]

Expiration is caused partly by the elasticity of the lungs (distended during inspiration) and *partly by the contraction of the bronchi and their terminal cells;*[u] as these combined powers diminish the bulk

[s] A patient affected with Emphysema will be sometimes seen to keep the neck rigidly extended and the shoulders thrown backwards, by which means the assistant respiratory muscles are more readily brought into action: in extreme cases the hands clutch almost involuntarily the nearest object, the arms being thus kept extended and the shoulders fixed, form a firm centre of action for the pectorales, etc.

[t] Quoted by Laennec, who adds "Another argument in favour of the inherent activity of the lungs, is furnished by the fact of old persons being still able to breathe, and often even without any previous dyspnœa, in whom the cartilages of the ribs are ossified, and the ribs themselves immoveably united with the vertebræ. In such cases it is not probable that the diaphragm is the sole agent in inspiration and expiration.—"Laennec, On Diseases of the Chest." p. 415.

[u] "Thorace ampliato, aër vacuum in pulmone spatium occupat, victisque fibris, fistulam spiritalem quaquaversum extendit, ultra modum, quo quiescit, explicari coactam, unde fibræ elasticæ resilire, circulares sese contrahere nituntur, quo fit, ut desidente thorace, *omnes simul ad*

of the lungs, so does atmospheric pressure, in equal ratio, reduce the capacity of their containing cavity, and thus—in expiration as in inspiration—are the pleural surfaces of the lungs, and the thoracic parietes ever in immediate contact.

When, from disease, the forces already mentioned are incapacitated for effecting expiration, this is *indirectly* produced by the contraction of certain muscles attached to different portions of the thoracic walls; these are the triangularis sterni, the recti, obliqui externi et interni aud transversales abdominis, the pyramidales, sacro-lumbales, quadrati lumborum, and serrati postici inferiores; by their contraction the ribs are depressed and the capacity of the thorax decreased, and thus the lungs are subjected to compression. Dr. Carson attributes expiration entirely to elasticity;[v] from "frequent repetitions" of

expellendum spiritum vires intendantur. Sunt autem: thoracis undique desidentis pressio, tum fibrarum fistulam spiritalem in brevius contrahentium vis elastica, *denique muscularium illam constringentium irritabilitas.*"—Reisseissen, Op. Cit. p. 23.

This opinion had been however previously distinctly expressed by our countryman Willis, of whose works Reisseissen was probably ignorant, as he never refers to them in any part of his essay. Willis writes—

"Ut pro data occasione majorem aëris copiam exsufflent, aut materiam excussiendam ejiciant, *fibris muscularibus donatæ sese arctius contrahunt,* contentaque sua penitùs exterminant. Et enim ordinariæ pectoris Systolæ, quas musculorum relaxationes ex parte efficiunt, aërem forsan totum a Tracheâ et Bronchiis, haud tamen a Vesiculis quaque vice ejiciunt: propter has (quoties opus erit) inaniendas, et totius Pectoris cavitas plurimùm angustatur, et *cellulæ ipsæ vesiculares a propriis fibris constrictis coarctantur.*—Quoted by Derham, see his Physico-Theology, p. 151.

[v] "Two powers are therefore (says he) concerned in regulating the movements and in varying the dimensions of the thorax, the elasticity of the lungs, and the contractile power of the muscular fibres of the diaphragm. Of these powers, the one is permanent and equable, the other variable and exerted at intervals. The contractile power of the

his experiments, he considers it proved that the resiliency of the lungs is balanced, in calves and dogs, by a column of water from a foot to a foot and a half in height, and in rabbits and cats, by one of from six to ten inches.

The arguments in support of the opinion that muscular contractility of the bronchi[w] and their terminal cells assists in expiration, are powerful; that the lungs are not mere *passive instruments* in expiration, as supposed by Dr. Carpenter, appears to be proved

diaphragm, when fully exerted, is evidently much stronger than its antagonist, the resilience of the lungs; but the latter, not being subject to exhaustion, takes advantage of the necessary relaxations of the former, and, rebounding like the stone of Sisyphus, recovers its lost ground, and renews the toil of its more powerful antagonist."—"Philosophical Transactions," 1820, part I.

Dr. Bostock doubts the substantial nature of the premises on which Dr. Carson's opinion is founded.

[w] Haller is referred to by Müller as objecting to the "hypothesis of the lungs themselves aiding in the movements of respiration:" the passage brought forward to prove this is the following—"In pulmone certè *nulla vis est, qua aut sponte dilatetur, aut subsideat,* qui irritabili natura destitutus, musculorum conspicuorum expers, totus mollissima cellulosa tela sit, denique in avibus perpetuo, in homine sæpè, plurima ejusmodi rudiori tela ad pleuram revinciatur.—Haller, Op. Cit. tom. iii. p. 228. As Haller does not here directly mention the bronchi, it is probable that he refers to the non-existence of a general muscular investment to the lungs, for in the same volume, p. 276, under the head

"Contractilis vis asperæ arteriæ et bronchiorum"

he writes, "Neque tamen adeo evidentes etiam carneas fibras exclusero, eas maximè quæ pulmonem undique decurtant, cum bronchi longitudinem sequantur, *atque adeo ab omni ambitu superficiem visceris versus bronchi ingressum contrahant.* Num eas super se adducant invicem, non dixerim: certe in humano pulmone, mortuo atque adeo post expirationem, non ita vicinæ sunt cartilagines, ut inferior sub superiorem se subducat. *Denique valde probabile videtur, idoneosque testes habet, etiam alias, præter has longas, fibras, segmenta cartilaginea intra pulmonem revincire, ut superius solent. Etiam eæ adeo bronchos arctabunt, et aerem expellent.*"

Kremer has witnessed contractions of the tracheal fibres, and Varnier and Wedemeyer have produced contractions of the smaller bronchi by the application of galvanism:—Müller, p. 362.

by the fact, that air injected into the lungs "post mortem" is slowly expelled; this expulsion — the result of elasticity—does not take place so speedily, nor so effectually as when caused by the natural powers; abrupt or forcible pressure upon the distended dead lung moreover produces laceration of the aeriferous tissue, whilst during life a full expiration may be momentarily effected. The phenomena of cough by which hurtful matters are voided from the bronchi, betoken an inherent contractile power;[x] and the fact that coughing may be voluntarily excited, and under certain circumstances arrested, would seem to indicate that bronchial contractility is, in some degree at least, under the influence of volition.

Müller writes, "It is possible, that the fibres of the bronchi may possess a contractile power which is constantly in action, and which may effect the contraction of the tubes on the cessation of the act of inspiration: but *mere elasticity would be sufficient for this purpose.*" He further adds, "In man the dilatation of the bronchi during inspiration, and the shortening of the trachea during inspiration and its length-

[x] A case is recorded by Dr. Graves, (Clin. Med. p. 275,) in which a patient, after suffering frequent attacks of pulmonary hœmorrhage within a short period, for which he had been repeatedly bled, was found by Dr. Stokes "collapsed, almost asphyxiated, and struggling for life." The right side of the chest expanding and contracting energetically, *the left almost fixed and motionless.* Dr. Stokes immediately changed his position, and gave him a glass of wine, when he *made one more effort and violently expectorated a coagulum consisting of fibrin, in some parts nearly colourless, forming a complete solid mould, answering to the left bronchus and its ramifications, down even to some of the minuter tubes.*" Neither *elasticity* of the bronchi, nor compression exercised by the contraction of the thoracic framework, will suffice to account for the expulsion of such a mass. For some excellent arguments in favour of the existence of a *contractile power* in the *bronchi and air-cells,* see Laennec's work, already quoted under the head "Spasmodic Asthma."

ening during expiration, seem to be merely the mechanical results of the dilatation and contraction of the thorax."[y] Now if the elongation and shortening of the trachea could be effected by *elasticity alone,* and if the existence of this property in the bronchi and air-cells could suffice to produce expiration, the muscular fibres which they possess would be useless or superfluous, but "*ut aliud nihil in omnibus animantibus, ita in ipso pulmone, ubique sapiens natura, temerè nihil, neque sine causa quidquam fecit,*"[z] hence we are justified in concluding, that the longitudinal and transverse muscular fibres, everywhere present in the trachea and bronchi and their ramifications, produce such changes, in the size and capacity of the parts to which they belong, as their situation and arrangement respectively render them capable of effecting.

§ 61. The frequency of the respiratory movements varies greatly according to the statements of different observers:—Menzies and Elliotson place it at 14 in the minute, Majendie at 15, Haller at 20, and Sir H. Davy at 26 or 27—the discrepancy which these statements manifest, may be readily accounted for when we consider that the direction of the attention of an individual to the performance of the respiratory function materially affects its frequency and regularity. The number of respirations accomplished in a given time, will be found to vary in different individuals, in health and disease, in sleeping and waking, and in activity and repose; as a general

Frequency respiratory movements.

[y] Muller's Physiol. vol. I. p. 362.

[z] Galen, Lib. vi. cap. x.

rule however, it will be seen that one respiration occupies the same space of time as four pulsations.[a]

Changes which take place in the respired air.

§ 62. The air introduced into the lungs by inspiration is found, after expiration, to have undergone considerable change in its properties and in its chemical constitution; in other words, the mixture of gases, which but a moment before possessed the power of restoring to the blood its lost nutrient qualities, is now unfitted for the performance of that office and, if oft respired, is rendered eminently deleterious.[b]

By the experiments of Lavoisier, Davy, Broughton, Allen, Pepys, Müller, Prout, Christison, Edwards and others, it has been shown,—

"That the air respired is diminished in bulk, and that this diminution, where respiration has been as long continued as could be borne, is equal to $\frac{1}{74}$ of the gas experimented upon;—that the air during respiration, loses oxygen and gains carbonic acid and aqueous vapour, whence its specific gravity is increased;—that air, once respired, contains 8 or $8\frac{1}{2}$ per cent. of carbonic acid, and that when respiration is carried on in oxygen, the quantity of carbonic acid is increased to from 11 to 12 per cent;—that the quantity of carbonic acid generated, varies at different

[a] Dr. Elliotson records the case of a nervous female patient, whose respirations he always found 98, and the pulse 104.—Physiol. p. 215.

[b] Dr. Elliotson "took three dogs, of equal size and strength, and to the trachea of the first, by means of a tube, tied a bladder containing about twenty inches of *oxygen gas*. He died in forty minutes.

"For the second the bladder was filled with *atmospheric air*. He died in six minutes.

"For the third," he employed "*the carbonized air last expired by the second dog*. He died in four minutes.

"The air of the bladder, upon subsequent examination, gave the common signs of carbonic acid gas."—See Elliotson's Physiology. p. 216. Note q.

parts of the day, being greatest between 11 a.m. and 1 p.m., and least between 8½ p.m. and 3½ a.m. and that if the quantity of carbonic acid expired be, from any cause, increased for a period, it afterwards experiences a proportionate diminution;—that nitrogen is constantly exhaled and constantly absorbed;—that respiration may, for a limited period, be carried on in hydrogen and nitrogen separately, or in the two combined, and that these gases are only *negatively injurious*, i.e. *by preventing the ingress of oxygen;*[c]—that oxygen, when respired "*per se,*" acts injuriously, and that other gases are manifestly poisonous; — that the expired air contains *volatile organic matter.*

Mr. Coathupe has estimated the quantity of carbonic acid exhaled by the lungs in 24 hours at 17.856 cubic inches—equal to 5½ ounces of solid carbon.

Dr. W. F. Edwards describes the changes which take place in the air during respiration, as depending upon four points essential to it, viz:

1. The absorption of oxygen *(which disappears).*
2. The exhalation of carbonic acid *(expired)*
3. The absorption of azote.
4. The exhalation of azote.[d]

Changes effected in the blood by respiration.

§ 63. After its pulmonic circulation, the characters of the blood—now called arterial—are found to be much altered; its specific gravity is increased owing to the loss of a large proportion of the water

[c] The loss of carbonic acid *alone* will not account for the arterialized appearance of the blood after its pulmonary circulation, for venous blood, deprived of this by the action of the air-pump, or by exposure to hydrogen gas, does not acquire an arterial colour.—See Müller's Physiology, vol. i. p. 346.

[d] Sur l'influence des agens physiques sur la vie.

entering into its composition, which is *principally derived from the chyle which has just joined it;*[e] it is of higher temperature,[f] contains more fibrin, and coagulates more quickly than venous blood; it has moreover re-acquired the scarlet colour which had been lost during its permeation of the systemic capillaries.[g]

Lavoisier (whose opinion is corroborated by that of Prout) supposed that the blood gave off carbon and hydrogen, which, combining with the oxygen of the atmospheric air contained in the pulmonary cells, formed respectively carbonic acid and water. Tiedman, Gmelin, and Mitscherlich held that venous blood contained a larger quantity of carbonates than

[e] "——— the blood, entering the right side of the heart, has just received the whole of the supply of water which is to be employed in the varied processes of the economy, almost every one of which implies the expenditure of some portion of this fluid; the very first operation to which the blood in commencing is circuit its subjected—exposure in the lungs—*robs it on an average of some sixteen or seventeen ounces of water in the course of the four-and-twenty hours,* and the returning current, the bright-coloured but venous blood with reference to the lesser circulation, must contain this amount of water less than the out-going stream, here the darker but arterial blood. The proportions of watery and solid constituents in the two kinds of blood belonging to the systemic circulation stand in the same relation to one another as they do in the pulmonic: the out-going stream is the more watery, the in-coming stream the more dense *up to the moment of its being joined by the thoracic duct.—The returning current of blood is invariably the more dense.*"—Wagner, Op. Cit. Note 342. Dr. Prout considers that the principle source of the aqueous vapour exhaled from the lungs, *is the chyle and lymph which has just been introduced into the blood from the thoracic duct.*"—(Quoted by Carpenter.)

[f] Davy Researches Physiol. and Anat. vol. i.

[g] Dr. Stevens attributes the red colour of the blood to the influence of the salts contained in its serum. Of this opinion Müller says "However without denying the necessity of the salts to the production of the arterial colour, it must be confessed, that when oxygen acts upon the red particles of the blood surrounded by the saline serum, it gives rise to a brighter colour, without the proportion of the saline matter in the blood being altered.—Müller, vol. i. 346 and 347.

arterial, and that these (carbonates) during respiration were decomposed by acetic acid then generated, and gave off carbonic acid. The experiments of Professor Magnus went to prove that carbonic acid existed in a free state—or was merely dissolved—in the blood; that the quantity of gas contained in the blood, amounted to from one-fifth to one-fourth of its volume; that the oxygen of the venous blood was equal to from one-eighth to one-fourth of the carbonic acid; whilst in arterial blood the oxygen equalled from one-third to one-half of the carbonic acid; he concluded that oxygen was *merely absorbed* in the lungs, that the chemical phenomena depending upon it were perfected in the circulatory route, and that the oxygenized products were thrown off during the pulmonary circulation. "M. Gay Lussac thinks that it is evident that the gases which perform a part in the phenomena of respiration, whether they are absorbed by the blood or emitted from it, merely obey a simple force of dissolution according to the rules established by Dalton."[h]

Liebig has established an ingenious theory of the mode in which the chemical changes, induced in the blood by respiration, are effected; it has the merit of perfectly explaining the various phenomena which result from these changes: he founds his theory upon the fact that "the compounds of iron are capable of depriving other oxidized compounds of oxygen, whilst the compounds of peroxides of iron, under

h See "The Lancet" for May 18, 1844. M. Gay Lussac also showed the absence of positive data in the results of the experiments of Professor Magnus, and stated, "that a fresh examination of the chemical phenomena of respiration had become necessary, and that he and M. Majendie were then engaged in making researches on the subject."

other circumstances, give up oxygen with the utmost facility." As oxygenized iron enters into the number of the constituents of the blood, he concludes that "the globules of arterial blood contain *a compound of iron saturated with oxygen*,[i] which, in the living body, loses its oxygen during its passage through the capillaries. The same thing occurs when it is separated from the body and begins to undergo decomposition—to putrefy. The compound, rich in oxygen, passes therefore by the loss of oxygen *(reduction)* into one far less charged with that element. One of the products of oxidation formed in this process is carbonic acid; and it is obvious, that the globules of the arterial blood, after losing a part of their oxygen will, if they meet with carbonic acid, combine with that substance. *When they reach the lungs they will again take up the oxygen they have lost; for every volume of oxygen absorbed, a corresponding volume of carbonic acid will be separated;* they will return to their former state, that is, they will again acquire the power of giving off oxygen."[j]

Diffusibility of gases important to the respiratory function.

§ 64. As the specific gravity of carbonic acid much exceeds that of atmospheric air, and as the lungs are never entirely emptied by expiration, carbonic acid would then remain within the pulmonary cells, and prevent the access of a fresh supply of air during succeeding inspirations, but that, in acordance with nature's law, by which it is decreed that *one gas should act as a vacuum to another*,[k] the particles of the two become intimately commixed

[i] 10,000 parts of blood contain 8 parts of per-oxide of iron.

Liebig's Animal Chemistry, p.p. 268, 269.

[k] Dalton, "Manchester Memoirs," vol. v.

and equably diffused through the air passages; thus, although some carbonic acid is still detained, it does not prevent the accomplishment of the salutary offices which the inspired air is destined to perform.

§ 65. All animals possess an inherent involuntary power of maintaining a certain degree of heat independent of, and little affected by, external causes;[1] the natural temperature of different classes of animals is very variable, being greatest in birds and mammals, and of these latter it is least in the human species. To none is this property so extensively beneficial as to man—destined by the Almighty to have dominion over all other created beings in all portions of the world—by its assistance he is enabled equally to bear the scorching heat of the Tropics, and the bitter cold of the Arctic regions![m] Are the lungs the *source* of animal heat?

From being considered ventilators of the heart,[n] the lungs came to be thought the source of "*Animal Heat.*" Lavoisier—the inventor of this theory—referred this hidden product to the chemical changes effected by respiration in the lungs; it was advanced that, if his hypothesis were correct, the temperature of the lungs should exceed that of other portions of the body, which was not actually the case. The phenomena of "*Calorific Capacity*" were now brought

[1] Vegetables also possess this power. See De Candollés Physiol. Vegetale, vol. ii. chap. 7. "De la temperature propre des vegétaux, et de quelques phénomènes analogues."

[m] In British India the thermometer rises occasionally to 130°; in Captain Back's voyage to the Arctic Regions, on the other hand, the glass sometimes stood as low 70° or 102° below the freezing point. Carpenter's Human Physiology.

[n] "Ad aërem cordi præparandum pro spiritus lucidi alimonia convenienti." "———Ad caloris ventilationem et refrigerationem." Anat. Thomæ Bartolin. "De Thorace."

forward to substantiate Laviosier's ideas; Dr. Crawford (on the strength of the results of his own experiments) informed the world, that arterial had a greater capacity for caloric than venous blood; and that, in consequence the heat developed during respiration, was conveyed *latent* with the blood through the arterial cylinders, and that it only became *sensible* on entering the venous system; he placed the capacity of arterial blood at 11.5, and that of venous blood at 10.0. Dr. Davy has since shown that *the calorific capacity of the two systems scarcely differs*, being as 10.0 to 10.11.

That the pulmonary function and the temperature of the body are in intimate relation the one with the other, cannot be doubted;[o] when respiration is hurried by disease, the general heat of the body is seen to be raised; in hybernating animals diminished heat and diminished frequency of respiration are in equal ratio, and, as respiration becomes more perfect, the temperature is simultaneously increased[p] —but it must be borne in mind, that *increased circulation* is an usual concomitant of augmented respiration, and that it offers a satisfactory means of accounting for extra-calorific development.

Animal heat doubtlessly depends upon a process of oxidation perpetually going on, as well in the general as in the pulmonary capillary circulation.[q]

o See observations of Mons. Donné, "Archives Générales." See also Edwards "L'influence des Agens Physiques," ch. x.

p Edwards Op. Cit. "De l'influence des mouvemens respiratoires sur la production de Chaleur."

q "The mutual action between the elements of the body, and the oxygen conveyed by the circulation of the blood to every part of the body is the *source of animal heat.*" "In whatever way carbon may combine with oxygen, the act of combination cannot take place

A greater comparative amount of heat must necessarily be generated in the lungs than in other portions of the body, (in consequence of the concentration of so vast a mass of capillaries as they contain in so small a compass) but this will be neutralized by the extensive evaporation (§ 63) therein taking place.

§ 66. "Not only does man need the earth in order to live and be active, but the earth also stands in need of man."[r] Relation of vegetable to animal life.

As in animal, so in vegetable respiration, constantly proceeding, oxygen is unceasingly absorbed, and carbonic acid exhaled; without some compensative process the effect of their mutual assumption of oxygen would be eventually destructive to both, but a fresh supply of that gas is daily obtained by the decomposition of carbonic acid (by a process of digestion carried on under the influence of light) by the leaves and other green parts of plants; by this means carbon is fixed in their tissues and oxygen eliminated—and a greater supply of oxygen is thus given to the atmosphere than there is carbonic acid evolved by vegetable respiration.[s] A reciprocity of interest is thus established between animal and vegetable functions—the perpetuation of

without the disengagement of heat." Animal heat is thus, in fact, dependent upon a gradual and never-ceasing combustion of carbon, which is furnished by the food; should it, however, from any cause be witheld, first the fat, and then the other solids, supply the deficiency of combustible matter—carbon—whence follow emaciation and death. "*The flame is extinguished because the oil is consumed!*" Liebig's Animal Chemistry, p. 17, et seq.

[r] Koreff, "De regionibus Italiæ aere pernicioso contaminatis observationes."

[s] See Lindley's Introduction to Botany, chap. xii. On Digestion, Respiration, and Secretion.

the one, as it were, depending upon the existence of the other—for, as the vegetable appropriates to itself for its nutrition the effete matters of the animal, so does the latter make use of the products of vegetable digestion in the performance of its respiratory function.

Use of Lungs. § 67. The *special use and purpose* of the lungs is to afford a medium of communication between the circulating fluid and the atmosphere, by means of which the former may throw off superfluous carbon and aqueous particles, acquired during its systemic course, and appropriate to itself oxygen, of which it had been therein deprived. As long as the pulmonary function is performed with regularity so long does the blood undergo those changes which are necessary to the maintenance of life; if it be effected too energetically, as in febrile and inflammatory diseases, the system becomes, as it were, hyper-oxidized, for "as food cannot be taken, or if taken, cannot be digested and assimilated; and as the oxygen of the respired air must combine with carbonaceous matter, if life is to continue, it seizes upon and consumes the carbon of the body itself, which therefore, and of necessity, wastes;" if respiration become languid, or deficient in intensity, the circulating fluid remains unstimulating and innutritious, the circulation is consequently impeded, and the lamp of life, gradually deprived of its fuel, "burns more and more feebly, till at length the worn-out frame

Sinks to the grave with unperceived decay."[u]

If, during health, the respiratory process be sud-

[t] Wagner, Op. Cit. note 433.

[u] Lord's Popular Physiology, p. 25.

denly suppressed, although the circulation may for a time, continue, the de-oxidized blood acts injuriously rather than, as before, beneficially, and should the suppression be complete, is even rendered poisonous.

Thus, not only do we see that THE LUNGS ARE ABSOLUTELY NECESSARY TO LIFE, but also, that, for the sustentation of the body in its integrity, the healthy performance of their function is essentially requisite; as Liebig aptly writes, "Respiration is the falling weight, the bent spring which keeps the clock in motion; the inspirations and expirations are the strokes of the pendulum which regulates it;" *if, therefore, the spring be disordered the whole machinery must suffer.*

In addition to their special office, the lungs also form a part of the "vocal mechanism," being, as it were, "bellows capable of transmitting, by means of the connecting wind-pipe or trachea, a current of air, passing through an apparatus, called the larynx —or special organ of the voice—which is placed on the upper part of the wind-pipe."[v][w]

Having now described, as far as my means and opportunities of investigation would admit of, the pulmonary organ and its importance in the animal organism, I take shelter from the charge of pre-

[v] Elliotson's Hum. Physiol. p. 503.

[w] In a paper published by Mr. Frank Romer, in "The Lancet" of December 28th, 1844, he argues, that from "*the inferior or lower part of the trachea spring vibrations, which, on being reflected by the whole length of the tube, produce perfect musical sounds.*" See also part II. § § 5. Note g.

sumption under the acknowledged liberty which belongs to all enquirers into the arcana of science, while I record, with all due deference to longer experience and riper knowledge, the convictions impressed upon my mind by *personal* anatomical examination and physiological study. I now proceed to treat of "The Anatomy and Physiology of the Lungs" as elucidating the supervision of a Supreme Being ruling over all; and as illustrating His "wisdom, power, and goodness, as revealed and declared in Holy Writ."

END OF PART I.

PART THE SECOND.

PART II.

ANATOMY

AND

PHYSIOLOGY OF THE LUNGS,

AS ILLUSTRATIVE OF

THE WISDOM, POWER, AND GOODNESS OF GOD,

AS REVEALED AND DECLARED IN HOLY WRIT.

Introductory Remarks.

Out of the dust of the earth, God formed man in his own image; (Gen. i. 2. and Gen. ii. 7.) but it was not until he had *breathed into his nostrils the breath of life*, that *man became a living soul;* (Gen. ii. 7.) This Divine blessing, bestowed upon the common parent of mankind, is perpetuated unto us his children, but the gift would have been of short duration without the incorporation of some apparatus specially framed for the purpose of continuing and transmitting to us the great primeval gift; but God's wisdom is commensurate with his power and goodness, and the same all-wise Creator, whose breath was Adam's life, gave perpetuity to the blessing, by pre-arranging the organ which was to convey it, and by providing for its energy and efficiency. By the lungs we are enabled, every moment of our lives, to inhale the "breath of life;" and so important is its inhalation that, if prevented, "the blood clogs in its vessels, the heart ceases to beat, feeling is no more, and the busy brain ceases for ever."[a] Wonderful is the Almighty in all His doings! His perfections are manifest in all His works! but in no part of the human structure does His glory shine forth with greater brightness than in the economy of that viscus by which we momentarily appropriate to our use this gracious gift: for whether we examine it separately in its component parts, or in its entire fabric, or analyze the function which it has to perform in the animal system, everywhere do we behold the same amazing testimonies of wise and powerful, benevolent and successful provisions.

Admirable construction of the Thorax.

§ § 1. The first evidence which claims our attention is the admirable contrivance manifested by the shape and construction of the thorax, which encloses, and protects from external injury, the lungs; being conical, the former admits of most extensive variations of capacity, whilst the latter provides for great mobility by the hinge-like articulations of the posterior extremities of the ribs with the vertebral column, by the elasticity of the sternal cartilaginous portions of the ribs, by their arched form, and by the vaulted conformation of the diaphragm or muscular floor of the cavity; this capability of enlargement and diminution[b] is graciously permitted for the purpose of accommodating the size of the

[a] Trans. of Prov. Med. and Surg. Assoc. vol. xii. p. 348.

[b] Circa hos motus divini Conditoris mechanicen, ad regulas Mathematicas planè adaptam, satis admirari non possumus; siquidem nulla aliâ in re manifestiùs, 'Ο Θεὸς γεωμετρειν videtur.—Willis, Op. Cit. § 28.

thorax to the more or less perfect distension of the lungs, and clearly demonstrates the design and protective superintendance of a *gracious and merciful God,* (Neh. ix. 17) whose *mercies are over all his works,* (Ps. cxlv. 9) whose very name *is Love.* (1 John, iv. 8) Though the thorax admit of great variations in its capacity, yet is it also capable under the influence of the will, of "suddenly assuming the qualities and condition of a rigid jointless framework"[c] affording attachment and a firm centre of action to the arms and numerous muscles; of this admirable combination of strength and mobility we may well exclaim with Galen, "Cujus apparatus copiosa facultas admirabilem sapientiam testatur.[d]

§ § 2. No part of the body is more exposed to disease than the lungs: the openness of the air-passages to things destructive to, as well as continuous of, life—to what may be noxious as well as salutary to it—has however many protective and remedial contrivances for the well-being of man; and in no part of the human frame do we find more care evinced to moderate the effects of internal lesion, or to counteract the injuries this organ is liable to sustain; this is first seen in its double arrangement—each half being able to carry on its office without the co-operation of the other;[e] neither is this the only benevolent provision of Omnipotence; each lung is again divided into lobes, and each lobe into lobules, and still it may be said of

Provisions against, and compensations for the effects of, disease.

c Ward's Human Osteology, p. 210.

d De Usu, part. Lib. v. cap. 15.

e Notandum quòd perforato tantùm altero latere *respiratio adhuc maneat sufficiens ad vitam sustentandam.*—Verheyen, Tract II. cap. 6. de Respir.

each of these divisions and sub-divisions that it forms a perfect lung in miniature, containing within itself a proportionate share of all the structures entering into the composition of the whole fabric, and capable of performing its function notwithstanding that those surrounding it may be affected with, or obliterated by, disease.

Benefits derivable from the pleural arrangement.

§ § 3. The pleuræ again afford matter for grateful contemplation; though slight in themselves, yet by their intimate adhesion to the lungs and to the thoracic walls, they keep the former so firmly fixed that their displacement is a thing unknown: at the same time, being lubricated by a never-ceasing exudation, and possessed of an extreme extensibility (which, combined, give greater freedom to the motion of the lungs) they moreover, by their mode of attachment to the sternum and spine, on either side, prevent the lateral expansion of the lungs from inflicting injurious pressure upon the great vessels[f] which lie between them, and to which the mediastina afford a means of transit to their respective destinations: that so many and such important offices should be performed by structures apparently so inadequate is a fact which points to a *vis motrix*, a first great cause, *to the King eternal, invisible, the only wise God.* (1 Tim. i. 17.) But this apparent inadequacy of means to results, carries us far beyond the mere acknowledgement of God's wisdom, power, and goodness, it leads us to see

[f] Hujus intersepti usus alius est primarius, alius secundarius. Primarius, tum ad viscerum suspensionem, ne in latera et posteriorem partem callabantur, tum ad vasa firmanda fulciendaque. Secundarius ne una parte læsa, altera in illius contagionem trahatur. Laurent. Hist. Anat. Hum. Corp. Lib. ix. cap. 5.

the perfect harmony that exists between the conclusions of reason from the facts and phenomena of nature, and the positive declaration of God's revealed word—natural reason discovers in *what appears* the existence of some almighty and all-merciful Being who *does not appear*, but who, from the darkness which surrounds his throne, gives energy and full effect to what seems to man defective in power, and inadequate in efficiency; but does not the word of God speak of this? *the things which are seen were not made of things that do appear,* (Heb. xi. 3.) and again, *the invisible things of God are clearly seen being understood by the things that are made, even his eternal power and Godhead.* (Rom. i. 20.)

§ § 4. Throughout the elaborate structure of the air-passages what exquisite contrivance is manifest! and how admirably has the Divine Fabricator carried out by His power a plan which leaves at an immeasurable distance the grandest triumphs of human genius!

The structure of the air passages by far exceeds the noblest offspring of human genius.

§ § 5. The adaptation of the trachea to its intended uses is most evident and beautiful, since it is the passage through which the life-giving air must be admitted into the lungs, and since the function to which it is subservient is never-ceasing, a constant patency of it is requisite; this is found to be provided for by its cartilaginous rings; as however it is necessary that its calibre should vary with the force of respiration, the cartilages are not perfectly circular[g] but are completed posteriorly by

Adaptation of trachea to its intended uses.

[g] Cartilagines annuli figuram exprimunt, sed circulum integrum non perficiunt unde σιγμοειδεῖς dicuntur: *in quo singularem Naturæ providentiam liceat admirari.* Cartilago namque *ad vocem edendam*

elastic ligamentous fibres, which allow of both dilatation and contraction, the same being effected by transverse muscular fibres which are attached on either side to the internal margins of the extremities of each ring.[h] The construction of the trachea, upon closer inspection, affords new proofs of creative wisdom, or rather of paternal care—of that love and tenderness which a father shows to his children—and are not these *indicia* of Nature in meet accordance with the word of God! Does not the Creator of the world condescend in Scripture to present himself to our love and reverence under the similitude of a *Father who pitieth his own children,* (Ps. ciii. 13.) and does he not invite us to pray to him as *Our Father in Heaven,* (Mat. vi. 9) have we not received the *Spirit of adoption whereby we cry, Abba, Father?* (Rom. viii. 15) To admit of free expansion of the lungs, a longitudinal extension of the windpipe is required, had the cartilages been continued throughout the cylinder this could not have been effected; therefore has God in his beneficence provided an alternate succession of cartilaginous rings and extremely elastic fibres, the latter of which are lengthened as the lungs descend in inspiration and (partly by their inherent

aptissimum est instrumentum, quia mediam inter durum & molle naturam obtinet: molliora præ imbecillitate aërem ipsum remissiùs percutiunt, duriora facilè ipsum evertunt. Itaque ratione vocis totam arteriam cartilagineam esse decebat;—Laurent, Op. Cit. Lib. ix. cap. 14.

h ——— sed quia ad inspirationem, expirationemque nunc contrahi nunc dilatari opertuerat, nunc longiorem, nunc breviorem fieri, totum arteriæ corpus cartilagineum constructum non est, sed interjectæ sunt, inter annulos membranæ, in brutis quidem omnino exangues, *in homine (quod nemo adhuc observavit) musculosæ,* ut videantur cartilaginum spatia opplere musculi perexigui, sese in modum X intersecantes non secus ac intercostales.—Laurent, Loc. Cit.

elasticity, and partly by the contractions of the longitudinal muscular fibres superadded) are again shortened during expiration; shortening of the trachea is still further provided for by the superior and inferior margins of the cartilaginous rings being bevelled off so as to allow of the one overlapping the other.

The posterior ligamentous fibres, already alluded to, are of still further value; intimately attached above to the cricoid cartilage, and throughout to the tracheal and bronchial cartilages, they perform the part of a suspensory ligament to the lungs, rendered necessary by the erect posture peculiar to man—for in man alone has this arrangement been found.[i] Thus do we see that God, who of his infinite goodness has made man "*in form erect pre-eminent,*" has provided special appliances for the purpose of accommodating each of its constituent parts to the well-being and perfection of the whole bodily fabric.[j]

§ § 6. The situation and office of the tracheal glands, and the importance of these minute bodies to render perfect a function absolutely necessary to life, incontestably prove that the goodness of the Creator is discoverable as much in the apparently insignificant as in the more manifestly beneficial works of his creation;[k] for these, most extensively distributed through the trachea, so lie in the inter-

Tracheal glands,—their use.

i Bourgerie Des Poumons.

j And as this Erection of Man's Body is the most complete Posture for him, so if we survey the Provision made for it, we find all done with manifest design, the Utmost Art and skill being employed therein.—Derham's Physico-Theology, p. 284.

k I find, as well in Little as in Great, a kind of Infinite that astonishes me.—Fenelon, p. 53.

stices of its fibres that the contraction of these presses out their contained mucus, the destined end of which is to lubricate the internal surface of the aeriferous cylinder, and thus do they facilitate the entrance of the air necessary for respiration, and moreover protect the tracheal mucous membrane from the irritatating action of the atmosphere—for when not protected by this mucous exudation it becomes acutely sensible to the contact of the respired gases. Natural expiration suffices to carry off any superfluity of this secretion, excepting in disease, when fresh powers are brought into action to accomplish its expulsion; these will be hereafter mentioned when treating of the bronchi.

Tracheal mucous membrane—its apparently inconsistent properties.

§ § 7. The tracheal mucous lining is of such extreme delicacy that even momentary contact with any foreign body, howsoever bland its nature, is productive of the direst symptoms; yet is it perpetually traversed by its natural fluid—air, pure in inspiration, but in expiration charged with effete products; and we are scarcely, if at all, cognizant of its passage; "it is to the junction of these apparently inconsistent qualities, that we owe our safety and our comfort ; our safety to their sensibility, our comfort to their repose."[1]

Relation of Tracheal structure to the motions of the neck.

§ § 8. When we turn from the consideration of its various constituent parts, and contemplate the trachea as a whole, we shall find fresh evidences of divine workmanship, and of the foresight and benevolence of our maker; had it been a solid tube, or firmly fixed in its locality, the extension and shortening of the neck, and the different movements of the head, would have been excessively limited; but by

[1] Paxton's Paley's Natural Theology, vol. ii. p. 185.

its flexible nature, and lax connexion to surrounding parts, all these motions may be accomplished without impediment.

§ § 9. The structure of the œsophagus and of the trachea respectively—so mutually beneficial—appears to be a not inappropriate subject for present consideration. Respiration, as has been before said, is in constant request, and therefore is the trachea an open cylinder; the œsophagus on the other hand—being purposed only for occasional use—is, when quiescent, a mere flattened muscular cord, whose trifling bulk permits the due expansion of the trachea, lying upon it, to take place freely: during deglutition however, it is necessary that the œsophagus should be much distended and enlarged: now, were the tracheal cartilages perfect rings, they would afford insuperable obstacles to such a distension of it as would allow of the free passage of the food, but we have seen that the cylinder, which these cartilages contribute to form, is posteriorly completed by fibrous tissue; the wisdom of this arrangement is most apparent, for, whilst it renders the adaptation of the cylinder to its special purposes more perfect, it, moreover, materially facilitates the onward progress of the alimentary bolus through the œsophagus, *by allowing this latter to encroach temporarily upon its calibre.* How admirably is the construction of each adapted to its destined end, and to those reciprocities of action and re-action which are so necessary to its accomplishment! Silently, though surely, do they admonish the Christian anatomist to exclaim, *Lord, what is man that thou hast such respect unto him, or the son of man that thou so regardest him.* (Ps. cxliv. 3.)

Mutual relation of trachea and œsophagus.

Epiglottis—its use.

§ § 10. Behind the tongue is a flattened triangular fibro-cartilaginous valvular lamella which is usually placed vertically; as the food, during deglutition, passes over the larynx, the valve is then however depressed, and completely occludes the opening of the glottis, thus preventing the entrance of even the smallest particle of food into the air passages, which occurrence would be eminently dangerous, if not fatal: the action of this valve is so perfect that we seldom, if ever, hear of any detriment resulting from its inefficiency: the rareness of such accidents is wonderful, when we consider that the least attempt to draw the breath while we are swallowing, will cause the accident. "This instance (writes the pious Fenelon) is sufficient to show what a marvellous art there is in the frame of the inward parts."[m]

Bronchial structure.

§ § 11. The bronchi present many points of interest in common with the trachea; contraction and dilatation—transverse and longitudinal—enable them to inhale and to expel air; the mucous membrane —continuous with that of the trachea—is still lubricated by the secretion of specially appointed glands; this secretion, when superfluous, is exhaled with the breath, when abnormally secreted, contractility of the bronchi (partly involuntary and partly dependent upon volition) (§ 59) effects its ejection, and this contractility is here rendered more effective by the transverse muscular fibres being prolonged around the whole circumference of the cylinders.

Wondrous conformation of the aeriferous terminations.

§ § 12. And what fresh wonders present themselves to our view as we inspect the aeriferous

m Demonstration of the Existence of God, p. 101.

terminations! these (dilated into a vast expanse of cellular membrane enclosed in a space comparatively small, traversed by innumerable capillaries endowed with muscular fibres, and affording an extensive surface for mediate communication between the vital fluid and the atmosphere) offer such marvels to the view as defy the most strenuous applications of human intellect, even under the guidance of the profoundest knowledge; they are *the secret things that belong unto the Lord our God;* (Deut. xxix. 29) the things which Boyle's pious philosophy led him to call "*privileged things as too sublime for man;*"[n] they are the testimonies of Nature to the certainty of God's own declarations that *he doeth wonders,* (Ps. lxxvii. 14) that he *is wonderful in counsel and excellent in working,* (Is. xxviii. 20) and that *we cannot find out the Almighty to perfection.* (Job xi. 7)

§ § 13. The *general conformation* of the air passages offers an additional incentive to admiration; not only does their conical shape facilitate the entrance of air into the lungs, but their contracted apex moreover by compressing the aerial column at its exit, renders them subservient to the production of sound, and thus indirectly to the expression of our ideas by the voice—this is the most exalted attribute of humanity, and the greatest boon to social intercourse; can this power then be better employed than in sounding the praises of Him who has bestowed upon man the blessing in so much greater perfection than on other living creatures! and can man refuse "*to laud and magnify His holy*

Benevolent adaptation of air-passages to the production of sound.

[n] Boyle's Works, vol. ii. p. 226.

name," saying, in the sublime and grateful language of the church, "*Holy, Holy, Holy, Lord God of Hosts, heaven and earth are full of thy glory! Glory be to Thee, O Lord most High!*"

Divine mechanism evident in the construction of air-passages.

§ § 14. In short so beautifully constituted is the aeriferous structure which we have been considering, and by which the benefits derivable from "the breath of life" are rendered useful to us, so excellent in design are they, so supreme in power, so inscrutable in wisdom, that, to use the words of a pious author, already quoted, "if men do not discover God in these His works, 'tis not because He is far from them! His light shines in darkness. All nature speaks of Him and resounds with His holy name! They would find Him, should they look for Him, *within themselves.* What do we behold in all nature? God! God everywhere, and still God alone! Who is like unto the Lord?[o]

Means provided to ensure regularity of pulmonary circulation.

§ § 15. As it has been ordained by the Almighty Creator, that the blood in its passage from the right to the left heart should permeate the lungs, and as the stoppage of this circulation would be speedily fatal, He has, to ensure its regularity and permanency, provided means and contrivances in the apparatus adapted to convey it, which are everywhere stamped with the seal of Omniscience.

Pulmonary valves—their office and mode of action.

§ § 16. The blood, deteriorated by its systemic circulation, at length arrives at the right ventricle of the heart; on the contraction of this (its retrograde course being prevented by the falling back of the tricuspid valves) it is driven into the pulmonary artery, the loose convex surfaces of the semilunar valves at its origin, readily yielding to

[o] Fenelon, Op. Cit.

the column of blood to afford it admission. What now happens? On the cessation of the ventricular systole the artery contracts upon itself, and thus its capacity is diminished and the compressed blood is driven backwards and forwards, but an insuperable barrier is placed between it and the right heart. *Hitherto shalt thou come and no further,* (Job. xxxviii. 2) is the fiat of the Almighty! the concavities of the semilunar valves are expanded, they are retracted! and this is effected, not by mechanism alone, for this, however perfect, would still admit of some regurgitation; but superadded to the membranes forming the valves are muscular fibres, by contact with the returning column of blood these are stimulated to contraction, and by this contraction the cartilaginous nodules into which they are inserted, are so closely approximated in the centre of the cylinder, that they admit not of the passage of a single drop of blood. On the perfect occlusion of the semilunars, only one passage remains patent for the blood, (and this is in its destined course) along this the continued contraction of the artery propels it, thus augmenting the "vis a tergo" resulting from the heart's impetus. Were the construction of the pulmonary valves the only example of Divine goodness to be met with in human anatomy, with what eagerness would it not be inspected! What astonishment, what exalted ideas of the wisdom and power of their author, and what gratitude towards him would they not excite! if such be not the result of our contemplation it is only because

"A miracle with miracles enclosed, is man!"—Young,

because every portion of the human frame—both in its own structure and in its relation to others—affords proofs of the same gracious provisions for his welfare, because all nature teems with instances of the Creator's superintendence over and care of his creation.[p] It must be the effect of intellectual or moral blindness, if so manifest a blessing as that we are now treating of should be looked upon (as it is by some) merely as beautiful pieces of mechanism, but without directing our thoughts upwards to its Almighty Fabricator and Contriver: a moment's reflection must convince the beholder that the hand of the Deity hath framed them; it is not the want of them that has caused their development, as the materialists would have us to believe, for "*the blood in its right and natural course has no tendency to form them, when obstructed or refluent it has the contrary! These could not grow out of their use, though they had eternity to grow in!*"[q] No laws of affinity and cohesion, of attraction and repulsion, could of themselves produce the phenomena of the pulmonary valves! no principles, mechanical or electrical, could have formed them—no theory of chance, no plastic powers of nature, no combinations of atoms will be able to account for their existence. Instances such as these serve to overcome the most reluctant and refractory spirit, and teach humility; and, under the darkness of such mysteries as these, the teachings of nature will be found to harmonize exactly with the teach-

[p] Sed assiduitate quotidiana et consuetudine oculorum assuescunt animi, neque admirantur neque requirunt rationes earum rerum quas semper vident perinde quasi novitas nos magis quam magnitudo rerum debeat ad exquirendas causas excitare.—Cic. lib. ii. de nat. Deor.

[q] Paxton's Paley's Evidences of Christianity, vol. ii.

ings of revelation, for they give us to understand that we do but see things darkly as through a cloudy glass, (1 Cor. xiii. 12) that *though a man labour to find them out yet shall he not find them—yea farther, though a wise man think to know them, yet shall he not be able to find them.* (Ecclesiastes viii. 17) *Lo! these are parts of his ways, but how little a portion is heard of them.* (Job xxvi. 14) *Teach us what we shall say unto him, for we cannot order our speech by reason of darkness.*

§ § 17. The "vis a tergo" of the heart and arteries suffices in a great measure to effect the capillary circulation; it is assisted however, by an inherent power of the capillaries themselves, which is, as yet, but little understood;[r] but our nescience of this power affords no argument in favour of its independence of divine direction. True it is (as Fenelon advises) that "Man should admire what he understands, and be silent about what he does not comprehend," but the microscopical observation of the pulmonary capillary circulation—globule following globule in an undeviating course through a labyrinthine maze of vessels, whose diminutive calibre is scarcely appreciable—would compel the most desperate votary of "Chance" to acknowledge the insufficiency of his first cause—his idol-god—and with the four-and-twenty in the Book of Revelation, to fall down and say, *Thou art worthy, O Lord, to receive glory, and honour, and power: for thou hast created all things, and for thy pleasure they are and were created.* (Rev. iv. 10, 11)

Powers effecting the capillary circulation.

[r] In Graves's Clinical Medicine, Lect. xxxiii, some powerful arguments are advanced in favour of a partial independence of the "vis-a-tergo" being possessed by the capillaries.

Pulmonary venous circulation.

§ § 18. Admirable and wonderful as are the contrivances already mentioned, as applied to the furtherance of the pulmonary circulation, infinite wisdom has yet provided a fresh force to assist the "vis a tergo" which has been moderated by the friction of the blood against the capillary parietes; this—a suction power produced by a *tendency to vacuum* on the occurrence of the auricular diastole—expedites the influx of the blood to the left auricle which, by the combined powers already mentioned, is at last filled; when the auricular systole takes place, the renovated blood passes into the left ventricle by the subsequent contraction of which it is once more directed upon its nutritive course. It may be enquired, what power prevents the blood from returning into the veins during the auricular systole, seeing that no valves are provided for this purpose, and that the uniform contraction of the auricular fibres would have a tendency to propel a part of it in a retrograde direction, notwithstanding that gravitation favoured its passage into the ventricle? It has been advanced that the constant flow of venous blood towards the heart is sufficient to prevent this; but for this power to be efficient it must be pre-supposed that the way into the auricle lies constantly open, which would be a manifestly detrimental arrangement, since the constant influx of blood would then mechanically prevent the due closure of the mitral valves. Gravitation cannot suffice.[s] It must then be by the contraction of the muscular fibres surrounding

[s] In the inferior "vena cava" gravity would seem rather to favour a reflux.

the orifices, and prolonged into the cylinders of the veins, simultaneously with those forming the substance of the auricle itself. It may be advanced, that a valvular apparatus would have more effectually attained the end in view; but there is this objection against it, viz: that by opposing an *insurmountable* obstacle to any retrograde flow, it would have rendered the left ventricle liable to over distension in the event of temporary obstruction to the general circulation; whilst muscular sphincters—more readily yielding to backward pressure—allow a salutary reflux into the distensible veins to take place, and thus afford time for the arrested circulation to be re-established.[t] Thus we see that God bestows his blessings with such admirable suitableness and sufficiency, that nothing is defective, nothing superfluous, nothing misplaced or disproportionate.

Conical shape of arterial and venous divisions—beneficial.

§ § 19. Tending to render the pulmonary circu-

t Since the first part of this essay was sent to the press, I have been indebted to the kindness of Professor Parker for the loan of Pordage's Translation (1684) of the works of Dr. Thomas Willis, of Oxford; in this is contained much valuable information respecting the "Anatomy and Physiology of the Lungs" which has been either overlooked or unacknowledged by later writers. Willis ascribes the same office to the fibres surrounding the orifices of the pulmonary veins as that which I have referred to them; he writes, "Besides we may observe of the pulmonary Vein, that it does everywhere in its whole length want valves, except where 'tis fastened to the Heart. Which appears by this, that when any liquor is injected into its trunk (just as it is in the Artery) it presently passes through all its branches without lett. *Which ought to be so, to this end, that the blood may always, because of the violence of the passions, freely every way fluctuate and regurgitate in and about the Heart. Besides, that the left Ventricle of the Heart might never be overcharged with the blood impetuously rushing into it*, by the instinct of Nature *the Fibres at the root of the vein being contracted, its course might be inverted and flow back*." Of the Organs of Breathing, and their Use, chap. i. p .8.

lation more facile, and strongly demonstrative of merciful purpose, is the conical conformation of the different divisions of both arteries and veins; in every case is the contracted part towards its starting point—the right heart—and in every case is its dilated portion towards its destined goal—the left heart.

Anomalous structure of pulmonary artery and vein.

§ § 20. The usual accordance observed between structures of the same kind in different parts of the body is departed from in the construction of the pulmonary vessels: that conveying venous blood having an arterial, whilst that carrying arterial blood possesses a venous character. But no where is the wisdom and goodness of the Creator more forcibly exemplified than in these deviations from what appears to be the general course of his operation! the arterial structure of the former vessel enables it to sustain uninjured the powerful impulse of the heart, which, during the capillary circulation, becomes so much diminished, that the delicate venous tunics of the latter are now equally capable of supporting it.

Merciful provision of anastomoses between the pulmonary and the bronchial arteries.

§ § 21. Ossific deposit in the coats of the pulmonary artery is but little known, but still there is a provision manifest in the anastomoses existing, within the lungs, between its branches and those of the bronchial arteries, "when the pulmonary artery and its branches" says Muller, "are narrowed, the anastomoses between them and the bronchial arteries become enlarged."

Inosculations of the bronchial arteries with others external to the lungs—a prospective expedient.

§ § 22. As the arch of the aorta is extremely liable to adventitious deposits, the orifices of the diminutive bronchial arteries are, of course subject to occlusion; but God's care is as much evinced for each apparently-insignificant portion of the human body as the whole would seem to claim at His hands; "sapientia divina nusquam major quam in minimis" this cannot be better shown than by the extensive communications established between the bronchial arteries themselves, and between them and the small arteries adjoining them, external to the lungs.

§ § 23. The discovery of the true course of the blood (of which the pulmonary circulation forms an important part) "has deservedly made Harvey the pride of his country and the admiration of mankind;"[u] if then the mere *detection* of the circulatory route could gain so great honour for a frail mortal, how much more should we not ascribe honour, praise, and glory to that Immortal Being by whom the arterial and venous cylinders *are and were created;* by whom so perfect an apparatus, mechanical and hydraulic, has been constructed to facilitate the passage of the nutritive fluid through them; by whom it has been mercifully contrived, that these cylinders should be maintained in their integrity by the very fluid they convey; by whose tutelary care a medium is established in the lungs, through which such chemical actions may take place between the blood and the atmosphere, as shall render the former, when deteriorated, again nutritious; and who moreover, momentarily superintends the function of each of the thousands of vessels (each possessing a distinct office) traversing the system of every member of the millions of human beings. When we consider that this constant protective care is manifested, not only towards human

If Men so much admire Philosophers because they discover a small Part of the Wisdom that made all Things; They must be stark blind not to admire that Wisdom itself. (Minucius Felix.)

[u] Roden's Warneford Prize Essay, p. 15.

nature, but that it is also extended to the myriads of animate beings which live upon the earth or float in the atmosphere surrounding it, and to the myriads upon myriads of living creatures which people the depths of the boundless ocean, from the vast leviathan to the smallest object appreciable to microscopic gaze, and when we further consider that probably yet other countless myriads exist, whose complicated littleness the inventive genius of man must ever fail in devising means to demonstrate, and that each and every one of these, if deprived but momentarily of Divine superintendence, must infallibly cease to be, our finite comprehension is lost in amazement at the infinity of Jehovah and at the majesty of his attributes; impressed and affected by such an accumulation of the evidences of the creating, upholding, and preserving power of God, the Christian Philosopher feels disposed to say with the pious Bellini (de motu cordis) "Video præsens numen tuum——et in altissima contemplatione defixus, cohibere me minime possum quin exclamem magnus Dominus magnus fabricator hominis—admirabilis rerum conditor—Quam magnus es!"

Interlobular cellular tissue—its beneficent purposes.

§ § 24. Many of the offices which the different parts already mentioned perform in the pulmonary economy, would be but imperfectly ensured but for the admirable arrangement and distribution of the interlobular cellular tissue; forming a compressible space between the different lobules, it allows of their alternate distension and contraction; it affords a passage to the bronchi and to the functional vessels, giving each respectively an investment; adaptation of means to an appointed end is here again evident, for, whilst the covering of the artery, where strength is the main object, is dense, laxity characterizes that of the vein where distensibility is the principal requisite. The interlobular cellular tissue is also beneficial, inasmuch as it allows the bronchial vessels, the lymphatics, and nerves to traverse it on their various errands of stimulation and nutrition.

§ § 25. Of the nerves and their office, for reasons given in the former part of this essay, (§ 57) I shall say but little; I cannot however refrain from noticing the admirable wisdom which they exemplify, by referring to the effects which volition might have produced upon respiration, if this function had been entirely under its controul. Unlimited power over respiration *mercifully* witheld.

How dangerous would have been the grant of unlimited power over this function! Momentary caprice, or anger, or any one of the violent passions might have driven some to suicidal restraints and stoppages of their vital action, entailing upon the sufferers everlasting regret, in a dread eternity.

"Tired nature's sweet restorer, balmy sleep", moreover, (had respiration been dependent upon the exercise of the will) would inevitably have been a fatal calm: on the other hand, if some modifying power over this function had not been permitted, how imperfectly would the beautiful mechanism of the larynx have sufficed for the production of the various modulations of the voice! Such considerations as these still lead to the same conclusion, viz: that the Almighty in His creative power, in His love for His creation, in the benefits He confers, in the evils He prevents, in the dangers He averts, has everlasting claims upon the gratitude of man. He *in whose hand is the soul of every living thing, and the breath of all mankind,* (Job xii. 10) calls upon us by his voice, in this and every other wonderful particular of organization, to renew our thanksgivings, and with holy David to reiterate our Doxology that *his mercy endureth for ever!* (Psalm cxxxvi. passim.)

Fœtal pulmonary development demonstrates the *foresight* and wisdom of God.

§ § 26. What can more strikingly demonstrate the far-forward sight and prospective wisdom of God than the gradual development of the lungs during fœtal existence? They are evidently unrequired (for present use) since the modified respiration which then occurs, is effected in the placenta; an insuperable obstacle to their use is also present in the liquor amnii, which everywhere envelopes the embryo. The temporary respiratory process which is now carried on, must however necessarily cease with the cessation of intra-uterine existence, and therefore have God's Omniscience, Omnipotence, and Benevolence pre-ordained and provided lungs especially fitted to inhale, at birth, the *breath of life.* These fœtal and puerperal wonders call forth renewed expressions of admiration; they most forcibly convince us of the superficial nature of man's profoundest philosophy, and with equal power compel us to acknowledge that *the treasures of Almighty wisdom and knowledge lie deep;* (Col. ii. 3) they serve moreover to bind together the conclusions of natural theology with the declarations of Holy Writ, and establish the analogy which exists between what a religious reasoner may gather from the phenomena of conception, embryotic growth, and parturition, and the positive declarations of Scripture on those subjects.

The testimonies of nature and scripture, of faith and reason concur in their joint reference of these things to the great first cause, *the Father Almighty, maker of heaven and earth, and of all things visible and invisible.* Nature and reason declare that these things must have a cause, for (as Tully says) "*nihil turpius physico quam fieri sine causa quidquam dicere.*"[v] But faith and scripture do more — they proclaim that cause to be Jehovah, the eternal, immutable, self-existent *I am that I am,* (Exod. iii. 14) the terrible God, that liveth for ever and ever: it is he who reminds us in his holy word, that *we know not the way of the Spirit, nor how the bones do grow in the womb of her that is with child;* (Eccles. xi. 5) it is he who has taught our lips to address him as the great author of our being; it is his revealed will that we should hymn the wonders of his watchfulness over us, when as yet we lay in ante-natal darkness, that we should say with David, *thou hast covered me in my mother's womb! I will give thanks unto thee for I am fearfully and wonderfully made: my bones are not hid from thee, though I be made secretly and fashioned beneath the earth; thine eyes did see my substance, yet, being imperfect; and in thy book were all my members written which day by day were fashioned, when as yet there was none of them.* (Psalm cxxxix. 12, 13, 14, 15)

Vital power which conduces to the changes effected in the lungs at birth—incomprehensible to human reason.

§ § 27. How wondrous are the changes produced by the first inspiration! The lungs, which but a moment before were small, dark-coloured, dense, and carneous, are now dilated, of a pale roseate hue, light and spongy; so altered, in fact, as scarcely to be recognized as one and the same

v De finibus, Lib. i. § 6.

organ: these changes could not be effected but for a certain susceptibility to stimulation; this stimulation is dependent upon vitality, but of vitality and by what power the new being directly brings it into action, all man's ideas are vague and hypothetical, and however we may study to arrive at a knowledge of these things, we must at length take refuge in the conclusion, that vitality, like all the other mysteries of creative love, has its source in *Him in whom we live, and move, and have our being:* (Acts xvii. 28)[w] well may the physiologist exclaim in the words of Steno, "Pulchra quæ videntur, pulchriora quæ sciuntur, longè pulcherrima quæ ignorantur."[x]

Adaptation of the various species of pulmonary apparatus to the fluid they are destined to respire.

§ § 28. The adaptation of the parts employed in respiration to the fluid they are destined to respire, and their inability to carry on their office in any other medium than that which is most liberally provided for their use, are facts which ought not to be omitted in the enumeration of the pulmonary evidences of the Divine Benevolence.

The delicate gills of the fish are admirably adapted to aquatic respiration; in air they would be useless. The lungs of the frog are evidently intended for breathing air; the branchiæ of the tadpole are equally surely calculated for respiration in water; it is not their want that produces lungs in the tadpole, for, until their complete development has been accomplished, the animal has been constantly surrounded by water, in which they were totally uncalled for; to suppose that they have been generated by the animal's will would be most

[w] See Physiology of Man, by Todd and Bowman, p.p. 14, 15.

[x] Nic. Stenon. in Proœm. Dem. Anatom. Hafn. 1673.

absurd; for man, with all his superior faculties and much vaunted reason, cannot, even if he will it, *add to his stature one cubit,* (Luke xii. 25) *or make one hair white or black.* (Matt. v. 26)

The human lungs are constituted for aerial respiration; a denser fluid would be detrimental, if not destructive, to their delicate tissues. Of all known gases, that alone which everywhere surrounds him—that which Hippocrates (de Flatibus) calls the "pabulum vitæ"—and which is universally distributed over the surface of the globe, is calculated for man's use; of others, some cannot be respired at all, some are positively poisonous, some only negatively so by preventing the access of oxygen, whilst even this, when undiluted, is an absolute poison.[y]

Beneficial tendency of chemical changes which take place in respiration betokens Almighty and merciful superintendence.

§ § 29. In obedience to certain fixed and unchangeable laws (those *ordinances of Heaven* (Job xxxviii. 33) according to which the Almighty is pleased to guard, and guide, and govern all things created) a constant interchange of elements takes place, during respiration, between the blood and the atmosphere, that interchange being naturally such as to contribute to health and comfort: and do not the salutary chemical combinations and decompositions which are thus constantly carried on in the lungs, without the consciousness of the being for whose benefit they are effected, bear witness, by their natural action and tendency, to that superin-

[y] Pure carbonic acid causes spasmodic closure of the glottis, and death by suffocation; nitric oxide, chlorine, ammonia etc. are directly injurious; nitrogen is negatively so. In cases of poisoning by oxygen, "Death is probably owing to hyper-arterialization of the blood."—See Christison on Poisons.

tending power of ineffable wisdom and goodness perpetually regulating and directing them.

Animal and vegetable functions—conducive to their mutual well-doing.

§ § 30. Lastly to be noticed in connection with animal respiration (as illustrative of Divine wisdom, power, and goodness) is the wonderful manner in which this function and vegetable digestion are made conducive to their mutual well-doing. Were there no vegetable life, the source of that of animals would be soon exhausted! without animal existence the verdant carpet which now covers the earth's surface would decay! the luxuriant foliage which now contributes to its beauty and perfection, would be wanting, and once more would desolation overspread the earth!

Natural evidences of God's wisdom, power, and goodness—in strict accordance with divine revelation.

§ § 31. Such then are the natural evidences of God's wisdom, power, and goodness, derivable from the anatomical survey of the form and texture, situation and protection of the lungs, from their arterial and venous circulation, their tubular and valvular provisions, and the admirable adaptation of all their parts to the supply of breath and purification of the blood. But if these contemplations upon the pulmonary apparatus had been confined to the facts and phenomena which it exhibits, or to those inferences and conclusions which the religious philosopher cannot fail to draw from them, as to the might and mercy, the wisdom and knowledge, the foresight and protective benevolence of the Almighty, the argument would have fallen short of the purpose of the great christian philanthropist, who founded and endowed this essay: had the range of thought and feeling been circumscribed by the boundaries of nature, without taking into account the declarations of God's word, the special design of his munificence would have been frustrated, as it forms the characteristic feature of his endowment that his essayist should not only prove the wisdom, power, and goodness of God by the evidences of anatomy (wherein he would but follow the steps of Paley, Derham, Macculloch, and other natural theologians, whose object it has been to infer those glorious attributes from the wise and benevolent provisions which the human body exhibits) but that he should, moreover, shew that what he has been able to gather, by discourse or reason, from the phenomena of bodily existence, is in meet accordance and beautiful harmony with what the inspired writers have recorded, with what God himself has been pleased to reveal of his glorious nature. By shewing the analogy and parallelism between the teachings of nature and revelation, we come to learn the immutability of God *with whom there is no variableness neither shadow of turning*, (James i. 17) and that the witness,[z] which he has left of himself upon the face of nature, for the instruction of the heathen world, perfectly agrees with, and is confirmed by, those brighter testimonies of his wisdom, power, and goodness, which in the fulness of time he gave to the christian in his written word. By the perception of these analogies the reason of man is enlightened and the faith of the christian established. "By taking extensive surveys of the empire of Jehovah (says the author of the 'Christian Philosophy,'[a] p. 455) we are enabled to perceive the spirit and

[z] "Nevertheless he left not himself without witness, *in that he did good.*" Acts xiv. 17.

[a] The Rev. Mr. Dick.

reference of those sublime passages in the sacred writings, which proclaim the majesty of God and the glory of his kingdom;" another learned and pious writer bears witness to the same truth; he says, "that the works of nature without the aid of the scriptures, would be far less instructive than they now are, and utterly insufficient to guide us in the way of righteousness—the scriptures were designed to be a comment on those works, and to shew us the agency and purposes, the wisdom and goodness of God in their formation."[b] By reasons like these, the founder of the prize seems to have been influenced when he made it a special condition, that an endeavour should be made in the Warneford Essays "to exemplify and set forth, by instances and examples, anatomical, physiological, and pathological, the wisdom, power, and goodness of God, as revealed and declared in holy writ." Bacon, Boyle, Ray, Newentyt, the writers of the Boyle Lectures, and almost all christian philosophers have cited scriptural testimonies for the confirmation of the natural evidences of the divine attributes, and without any intention to derogate from Macculloch's admirable work, nor from the strength of the author's faith, nor the warmth of his piety, it may be observed of his reasoning, that he adhered too rigidly to natural evidences, and drew his boundary line too closely around his argument, when he laid it down as a law for his observance, "that he should never refer to scripture for support, as being the evidence of testimony, since this would be to endanger the ground of his work by that

[b] See Dwight's Theology, vol. iii. p. 471.

faulty logic, which mixes discordant arguments, or by reasoning in circles:"[c] such a course of reasoning and writing would be fatal to that great master argument of analogy which has so often stopped the mouths and silenced the railing accusations of the infidel. Both sorts of evidence, the natural and the scriptural, have been vouchsafed by God's providence for our use, and are profitable for doctrine and instruction; each has its proper place and each its special use, but much there is in common between them, and much for joint and common purposes; and especially that by their united strength and splendour of proof, the power, wisdom, and goodness of God, and all the other attributes of his glorious majesty may leave man without excuse, if he do not acknowledge them, and acknowledging, if he do not adore them, and adoring, if he do not practically apply his adoration for the guidance and governance of his life. Natural evidence alone was able to elicit from a pagan philosopher this beautiful acknowledgment of the divine power and goodness.

"In writing these books, I compose a true and real hymn to that awful being who made us all; and, in my opinion, true religion consists, not so much in costly sacrifices offered upon altars, as in a through conviction impressed upon our own minds, and an endeavour to produce a similar impression upon the minds of others, of his unerring wisdom, his resistless power, and his all-diffusive goodness. For, his having arranged everything in that order and disposition which are best calculated for its preservation and continuation, and his having condescended to

[c] Macculloch's Proofs and Evidences, vol. i. p. 5.

distribute his favours to all his works, is a manifest proof of his goodness which calls loudly for our hymns and praises. His having found the means necessary for the establishment and preservation of this beautiful order and disposition is as incontestable a proof of his wisdom, as his having done whatever he pleased is of his omnipotence."[d]

These religious sentiments were partly suggested to Galen, by the inspection of the human lungs, how much more should they not excite in us—to whom the wonders of their structure are so much more familiar — feelings of gratitude towards him to whom we are indebted for creation and all the blessings we enjoy. But when the scriptural evidences of the same great and holy truths scattered over the book of Job, and the Psalms of David, and in St. Paul's arguments at Athens, (Acts xvii. 22) in Lycaonia, (Acts xiv. 15) are superadded to the dictates of reason and the voice of nature, faith becomes more energetic and affection warmer, philosophy becomes animated with a christian spirit, and all its darkness dissipated by the light of revelation.

That the lungs should be liable to disease does not militate against the merciful attributes of the Almighty.

§ § 32. That the beautiful organ which we have been considering, should, in common with all others of the body, be subject to disease, rather augments than detracts from the merciful character of the Deity; for disease is inflicted upon a part as a warning to the mass of mankind; it teaches the instability of human joys! were all mankind to enjoy uninterrupted good health, how seldom would their minds be directed to the consideration of death! Owing to the sin of our first parents, divine

[d] Galen, "De usu partium," Lib. iii. cap. 14. and Lib. vi. cap. 15. Translated by Dr. Hamilton, Hist. of Med. &c. vol. ii. p. 155.

justice has decreed that our bodies shall be resolved into the elements out of which they have been so mysteriously wrought! *Dust thou art and unto dust shalt thou return,* (Gen. iii. 10) is God's unalterable sentence! but are we hence to conclude that the close of our earthly career shall be eternal annihilation? Then were man's estate—beset as it is with perils and anxieties—miserable indeed, inferior to that of the brute creation. But no! *the dust shall return to the earth as it was, and the spirit shall return unto God who gave it:* (Ecclesiastes xii. 7) we must then rather consider death as the translation of the righteous to a happier sphere. According to the promises of the gospel—and Scripture substantiates what is *concluded by Reason*—our *mortal shall put on immortality,* (1 Cor. xv. 53.) and as the great Architect of the body has shewn wisdom in its construction, and care in its preservation, during our probation on earth, so has His mercy provided for the souls and bodies of the just a beatitude as far excelling the joys of earth as eternity exceeds our temporal existence.[e]

The perfection of the lungs both in their different constituent parts and in their totality manifests the wisdom, power, and goodness of God.

§ § 33. Having now considered the various portions of the pulmonary apparatus, each wonderful in design and perfect in organization, and all combining to establish one stupendous work, whose functions are perpetually carried on without the assistance of the individual they benefit: we may conclude by applying to it the words which a celebrated writer[f] of the present day has applied gene-

[e] "For I reckon that the sufferings of this world are not worthy to be compared to the glory which shall be revealed in us." (Rom. viii. 18.) For our light affliction which is but for a moment, worketh for us a far more exceeding weight of glory. (2 Cor. iv. 17)

[f] Dr. Watson.

rally to the human frame.—"Who can look into the mechanism of this intricate but perfect work, and contemplate the evident marks of exquisite contrivance of which it is full—the endless examples of means adjusted to ends, of compensation for inevitable disadvantages, of direct provisions for animal happiness and enjoyment—without the deepest conviction of the power, and wisdom, and benevolence of its Maker," and without raising his voice in grateful adoration and thanksgiving to Him who is "powerful beyond all power, wise without limits, and, beyond all our thoughts of goodness, The Good?"[g]

[g] Macculloch, Op. Cit.

ERRATA.

Page 6, line 11 and 12, dele *of the lungs*.
— 11, note d, for *interlobular* read *intra-lobular*.
— 13, line 15, for *Haller* read *Harvey*.
— 16, line 8, for *essels* read *vessels*.
— 32, line 10, for *(TAB. IV.)* read *(TAB. II.)*
— 34, line 20, for *general, it* read *general, than which it*.
— 39, note e, for *out* read *aut*.
— 46, line 5, for *placid* read *flaccid*.
— 55, line 18, for *anteriosus* read *arteriosus*.
— 64, note e, for *is circuit its* read *its circuit is*.
— 78, note f, for *callabantur* read *collabantur*.

FINIS.

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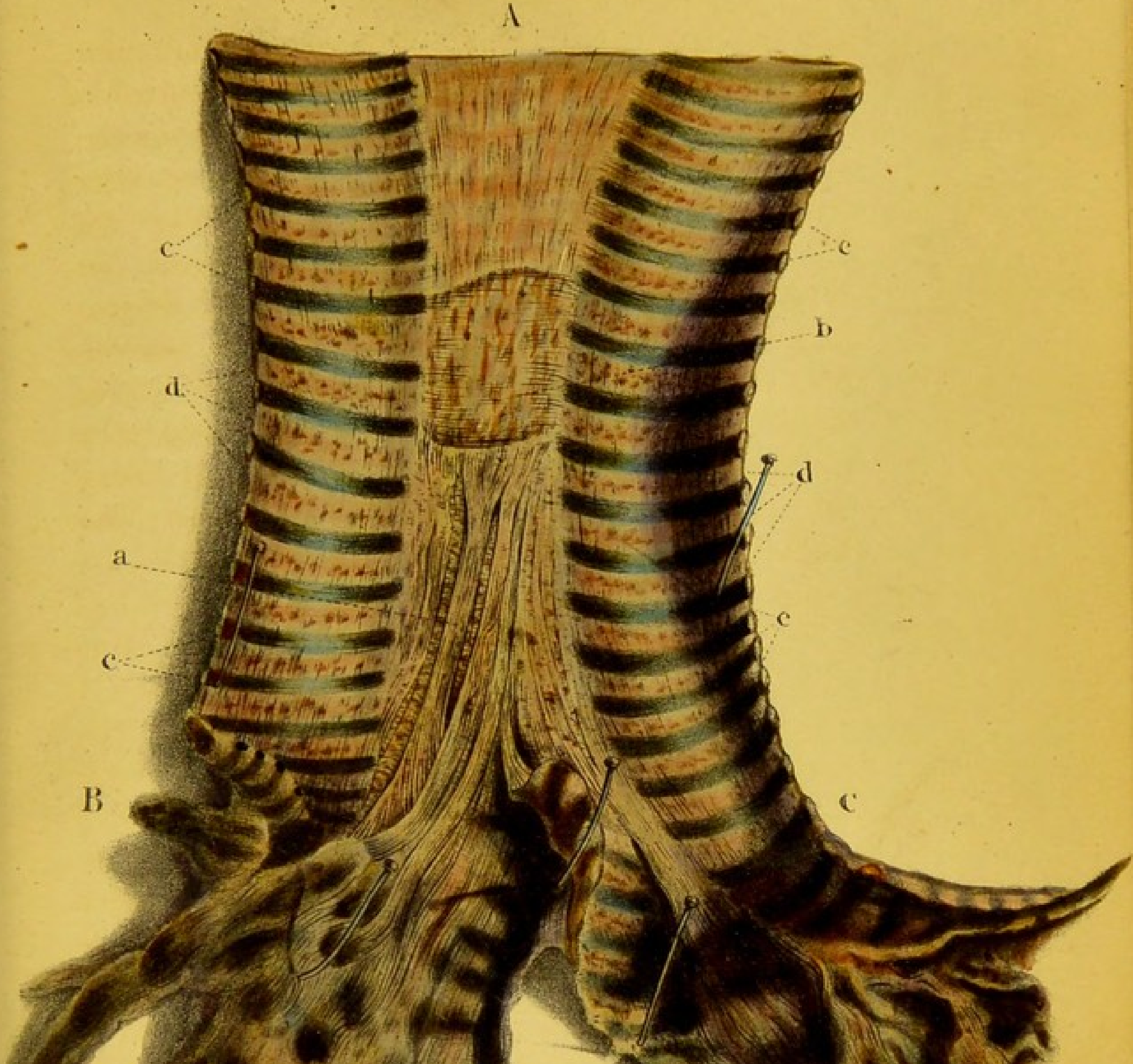
TAB. I.



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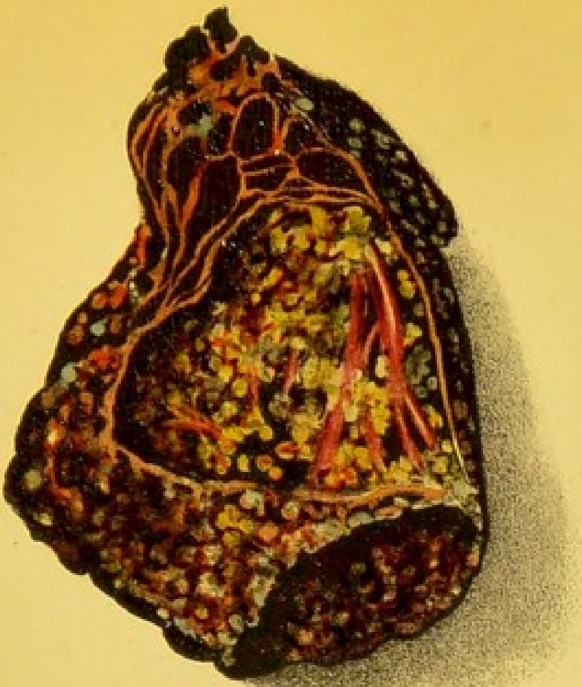
TAB. II.

S. W. Leonard M.M.S. Lond: Lith. *T. W. Bradley Pinx!* *Printed by Reeve Brothers.*

TAB. III.



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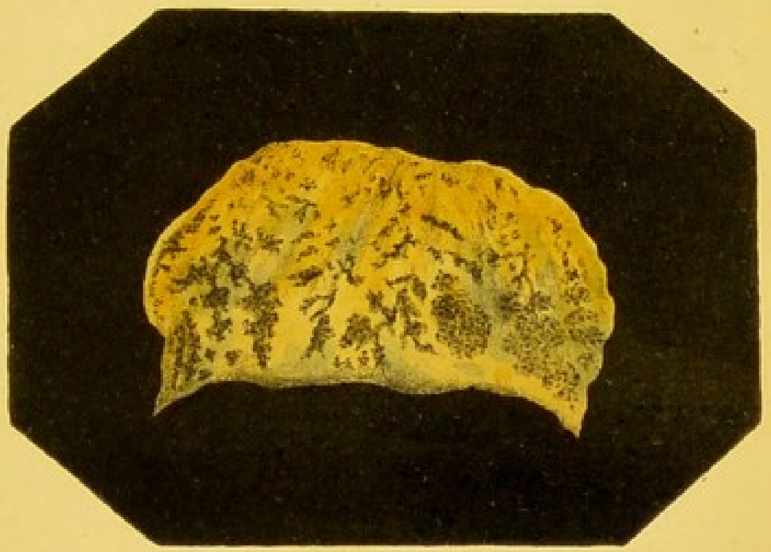

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TAB. IV.

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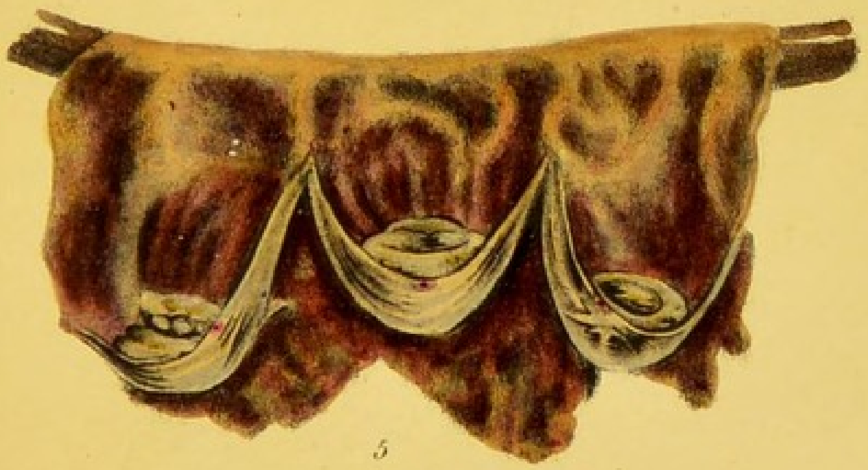

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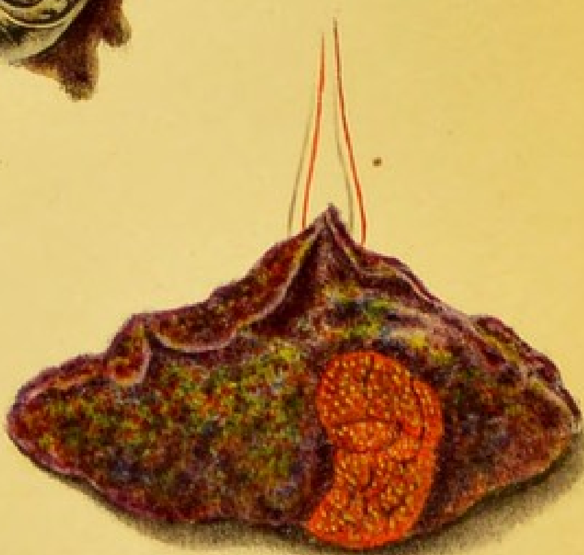

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TAB. V.

Fig: 1.

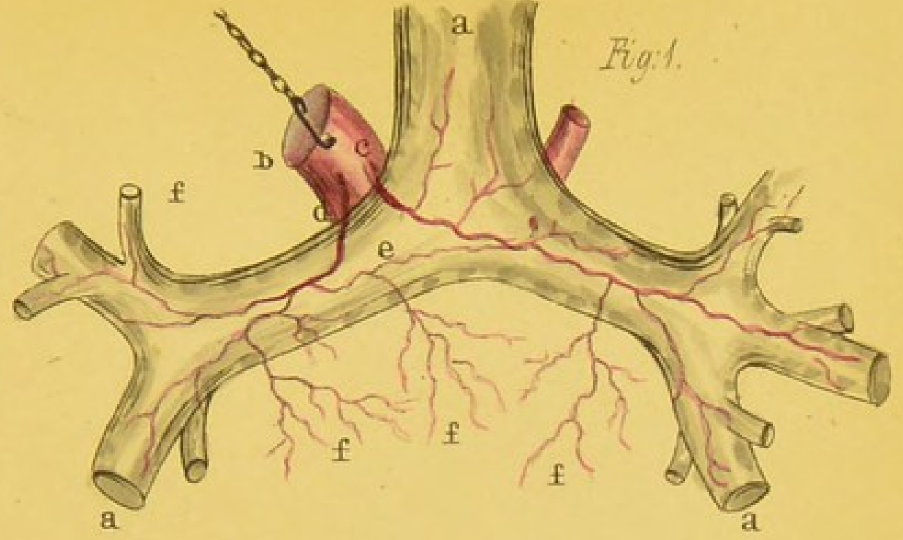


Fig: 2.

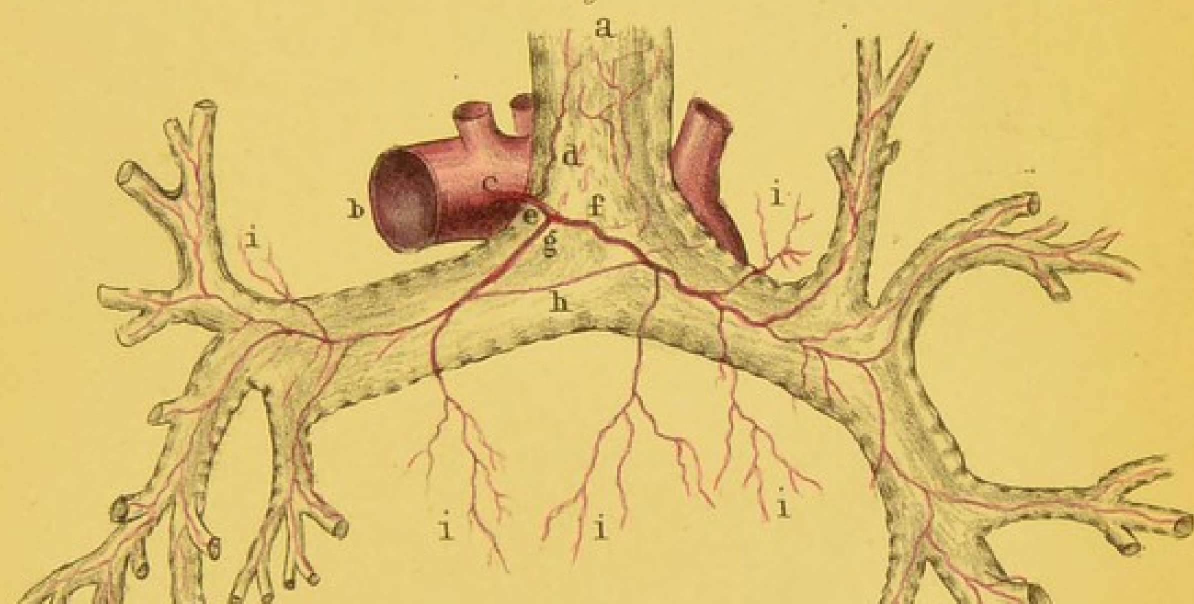
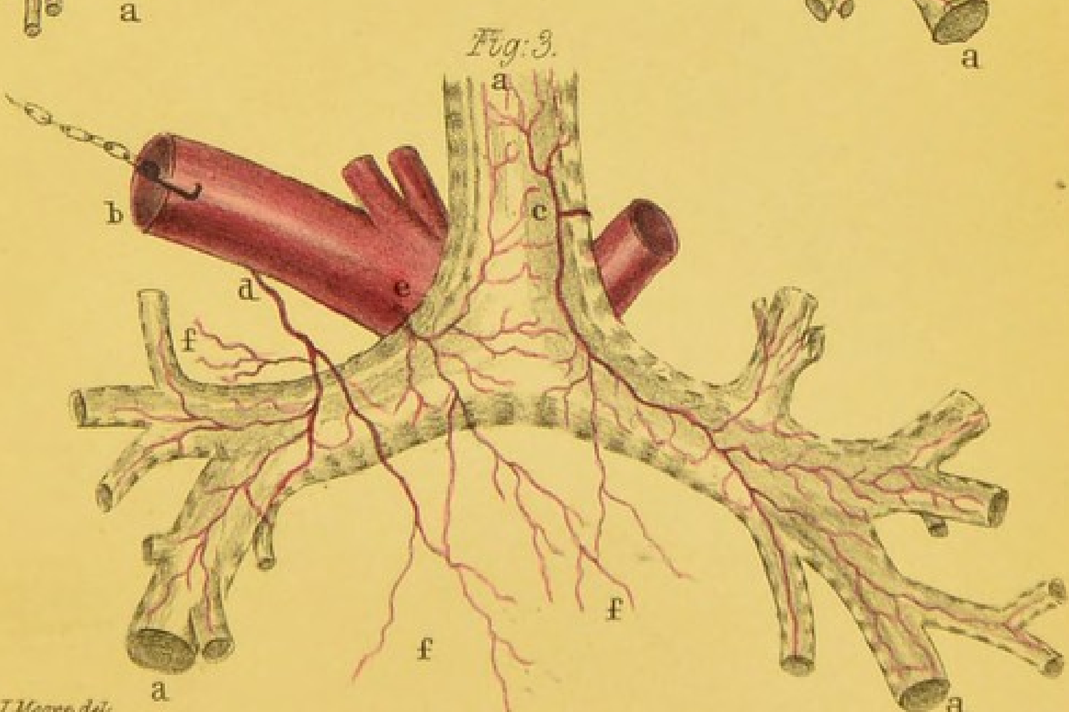


Fig: 3.



J. Moore del.
S. W. Leonard M. M. S. Lond: lith.

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REFERENCES TO THE PLATES.

TAB I.

A. Trachea cut open to show its internal surface.

B. Right bronchus.

C. Left bronchus.

aa. Longitudinal muscular fibres—inferiorly these are seen to curve round the orifices of the bronchial canals, forming demi-sphincters. b. Mucous membrane removed, exposing to view the transverse muscular and the ligamentous fibres. cccc. Cut extremities of the cartilaginous rings. dd. Inter-cartilaginous fibres, in the interstices of which are seen small foramina, which give passage to vessels, and in which are imbedded the tracheal muciparous glands.

TAB. II.

Terminal air-tube of the lung of the human fœtus, (magnified to 800 diameters) dividing into three vesicular dilatations, upon each of which are seen parallel arcuate fibres and vascular rings.

TAB. III.

Fig. 1. Internal surface of lung of human fœtus injected with mercury by the trachea, (seen with a simple magnifier.)

Fig. 2. Frog's lung (natural size) distended with air and dried: the anterior half of left lung removed to shew its open parietal cells; the vessels injected with vermillion.

Fig. 3. Thin margin of calf's lung into which mercury has been injected by the trachea; minute globules of the metal are seen through the pleura, each of which represents the site of a separate cell.

Fig. 4. Marginal portion of human lung into which mercury has been poured by a small bronchial tube; the part to the right is uninjected.

Fig. 5. Thin margin of calf's lung into which mercury has been injected by a small bronchial tube: the arboriform arrangement of the bronchial divisions is here beautifully seen.

TAB. IV.

Fig. 1. Internal surface of pulmonary vein of sheep, showing valvular projections of lining membrane into its cylinder at the different points of convergence.

Fig. 2. Lymphatics of fœtal lung distended with air.

Fig. 3. Surface of fœtal lung, injected with mercury by the trachea, offering the appearance described by Reisseissen as "*instar brassicæ botryitidos stipatorum.*

Fig. 4. Marginal portion of human lung, the pulmonary artery injected with yellow, and the pulmonary vein with red paint; a circumscribed portion of aeriferous structure distended with mercury, poured in by a minute bronchus.

Fig. 5. Origin of pulmonary artery; concavities of its semilunar valves filled with mercury,—in the centre of each valve is seen a small oval tubercle (corpus arentii)—their fibrous structure is distinctly visible.

TAB. V.

Fig. 1. aaa. Posterior surface of trachea and bronchi. b. Aorta. c. Right bronchial artery. d. Left bronchial artery. e. Communicating branch between the two. ffff. Small twigs from bronchial arteries inosculating with corresponding branches of neighbouring vessels.

Fig. 2. aaa. Posterior surface of trachea and bronchi. b. Aorta. c. Small artery arising from aorta, and dividing into d a tracheal branch, and e a common trunk, which shortly divides into f and g, the right and left bronchial arteries. h. Communicating branch between the right and left bronchial arteries. iiii. Small twigs, by means of which the bronchials anastomose with the arteries surrounding them.

Fig. 3. aaa. Posterior surface of trachea and bronchi. b. Aorta. c. Right bronchial artery arising, in common with an œsophagal branch, from the superior intercostal. d. Left bronchial artery arising from aorta. e. Small pericardiac branch, by means of which the right and left bronchial arteries communicate with each other. ffff. Anastomosing branches between the bronchial arteries and those adjoining them.

The whole of the illustrations were taken from original preparations and dissections made by the author. For the drawings in Tabs. I. II. III. and IV. the author is indebted to the kindness and talent of his friend and fellow-student, Mr. T. W. Bradley, of Kidderminster.