

THE BRONCHOPULMONARY SEGMENTS*

No part of the human body shows more important anatomical variations than the lung; important, that is, to the surgeon. Today, not only are these variations recorded in detail but, in addition, the basic anatomical pattern which underlies them is clearly established.

Yet, as recently as 1940, R. C. Brock (now Sir Russell Brock, P.R.C.S.) was 'burning midnight oil', assisted by his secretary, pouring melted Wood's metal down the trachea of cadavers in the post-mortem room at Guy's Hospital, and injecting the individual segmental bronchi of isolated lungs with coloured gelatin. The need for a busy thoracic surgeon to do this time-consuming work is explained by Brock in *The Anatomy of the Bronchial Tree*,¹ in which he states: 'As soon as the lobar branch enters the lung substance and begins to divide, it is in virtually uncharted country.'

Dealing with the elucidation of segmental anatomy he adds: 'Only by a complementary use of bronchial casts or dissections and of specimens in which the segments are injected separately can the full story be learned and depicted.'

If we travelled back a little further in time to the year 1926 to visit the post-mortem room of King's College Hospital, we might find Mr. V. E. Negus (then surgeon to the Ear, Nose and Throat Department, now as Sir Victor Negus, chairman of the Hunterian Trustees) assisting Dr. J. L. Livingstone (then physician at King's College Hospital, now Censor of the Royal College of Physicians), injecting human lungs *in situ* with Wood's metal, to glean essential knowledge of bronchial anatomy for the practice of bronchoscopy. Some of these metal casts are preserved in the Hunterian museum. One of them is illustrated in Figure 1. The comparative crudeness of the casts is an advantage, since the major branches are not masked by minor ones, as in a more complete injection.

The importance of thoracic surgery today is reflected by the fact that there are no less than four thoracic surgeons on the Council of the College of Surgeons at the time of writing. Yet, outside those who practise this specialty, the story of the growth of knowledge of the anatomy of the lungs is not well known. A brief outline of this may therefore be of interest.

The story started nearly three hundred years ago, when Govert Bidloo recorded, in 1685, the preparation of a metal cast of the human bronchial tree. Bidloo claims that he injected fused bismuth, but the melting point of bismuth is far too high for this to be possible. He probably used an amalgam of bismuth and mercury. Such amalgams may be no tougher than wax, and this may explain why Bidloo's casts have not survived.

In the same year that Bidloo recorded the production of his metal cast, Ysbrandi van Diemberbroeck, Professor of Medicine and Anatomy at the University of Utrecht, published a simple woodcut of the human bronchial tree, which shows, without the superimposition of irrelevant detail, all the now-recognized segmental bronchi. Unfortunately Diemberbroeck's description of this figure is misleading.

During the next century the art of injecting with coloured wax, invented by Jan Swammerdam (1637-80), reached the pinnacle of perfection. In 1790, just three years before John Hunter's death, Thomas Pole published the first general textbook of

* Based on an Arnott Demonstration given at the Royal College of Surgeons of England on 30 October 1963.

anatomical techniques. Written with exceptional clarity, this book, entitled *The Anatomical Instructor*, gives a wealth of practical information.² The title-page is shown in Figure 2.

Apart from his mastery of technique, which is revealed in every page of the book, Pole had clear insight concerning the personal qualities essential for success in this type of work. In the introduction to the section describing injection of the lymphatics he says: 'In making quicksilver Injections, the principal ingredients, and the first to be obtained, are time and patience, and not less so, an uniform fortitude against disappointments; for it will not infrequently happen, that with the greatest care, a most promising preparation will be instantaneously destroyed by some trivial accident, when it had been almost completed.' Such advice would not be out of place today, in the preparation of corrosion casts from synthetic resin.

Article XXXI in Pole's book is entitled 'Injecting and corroding the Heart and Vessels of the lungs'.

Pole writes:

For this purpose, those (i.e. lungs) of young subjects should be chosen, on account of the inconvenient size of adult parts.

The first part of the process is to remove as much as possible of the coagula from the cavities of the Heart and adjacent blood vessels, that it may not obstruct the passage of the Injection. The right side of the Heart and pulmonary artery, may be injected by either of the venae cavae, fixing a pipe in one of them, and securing the other by a ligature: its left side and the pulmonary veins may be injected by the aorta descendens, securing by ligature the subclavian and carotid arteries. The Injection by the aorta will be retrograde to the circulation; but we find that, in the dead subject, the valves do not so completely perform their office, as in the living, and that the Injection will in general readily pass into the Heart, though contrary to the natural circulation; but to avoid any risque, they may be broken down by some proper instrument introduced into the aorta. The air cells are next to be injected by the trachea; this is to be done with great care, for if the Injection is forced beyond a certain degree, it will form extravasations in the surface. The two sides of the Heart, and the air cells should be injected with different colours, which, when finished, the parts placed in a natural position, and the pipes removed, the preparation may be put immediately into the acid liquor for corrosion, and finished according to the rules already laid down. . . .

Then follows sound advice on the care of the finished cast, fundamentally important when dealing with these extremely fragile wax casts, but applicable also to the comparatively robust synthetic resin casts, which have replaced wax casts in the modern anatomy museum.

Preparations injected for the purpose of corrosion, should always be carefully handled, lest the injection be incautiously broke, which in their finished state, having no support from the surrounding vessels, will fall to pieces; this would be an unpleasing circumstance, after every-thing else had been successfully conducted. . . .

These preparations require great care and much time to complete them, and when finished, are of all others most liable to be demolished by trivial accidents; it is therefore expedient to defend them as much as possible from possible injuries; . . . for persons who have not made them are not always satisfied with looking, but every now and then trying their strength by the finger, at the expense of destroying its most beautiful parts. . . .

Although a number of wax-injected dried dissections still survive in the Hunterian museum, the wax corrosion casts have long since perished. They have not, however, vanished without trace. For included in the portrait of William Hunter (1718–83) by Pine, which now hangs in the Council Room of the Royal College of Surgeons of

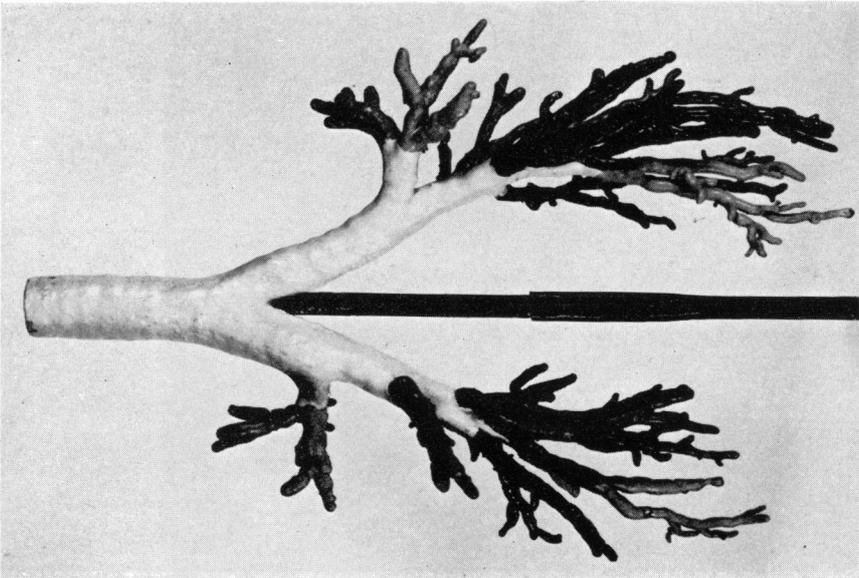


Fig. 1. Wood's metal cast of human bronchial tree. The bronchi have been painted different colours. (Specimen No. M. 2106 from the Hunterian museum.)

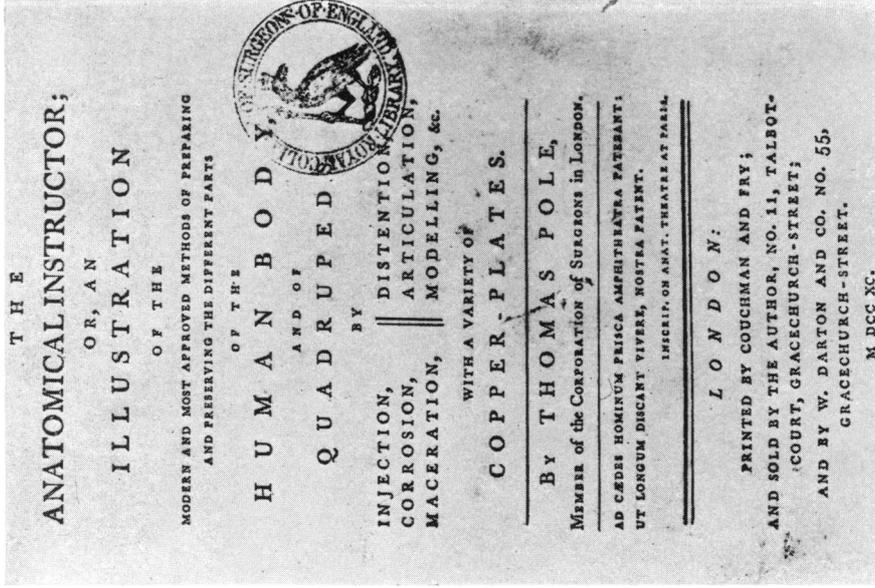


Fig. 2. Title-page of the first edition of Thomas Pole's book on anatomical techniques, published in 1790.

The second edition, published in 1824, has this delightful addition to the title-page:

'A new edition with additional notes, by a GENTLEMAN, who assisted Mr. Bell, in the school of Windmill Street, where, of late, a very splendid addition to lymphatic preparations has been made.'

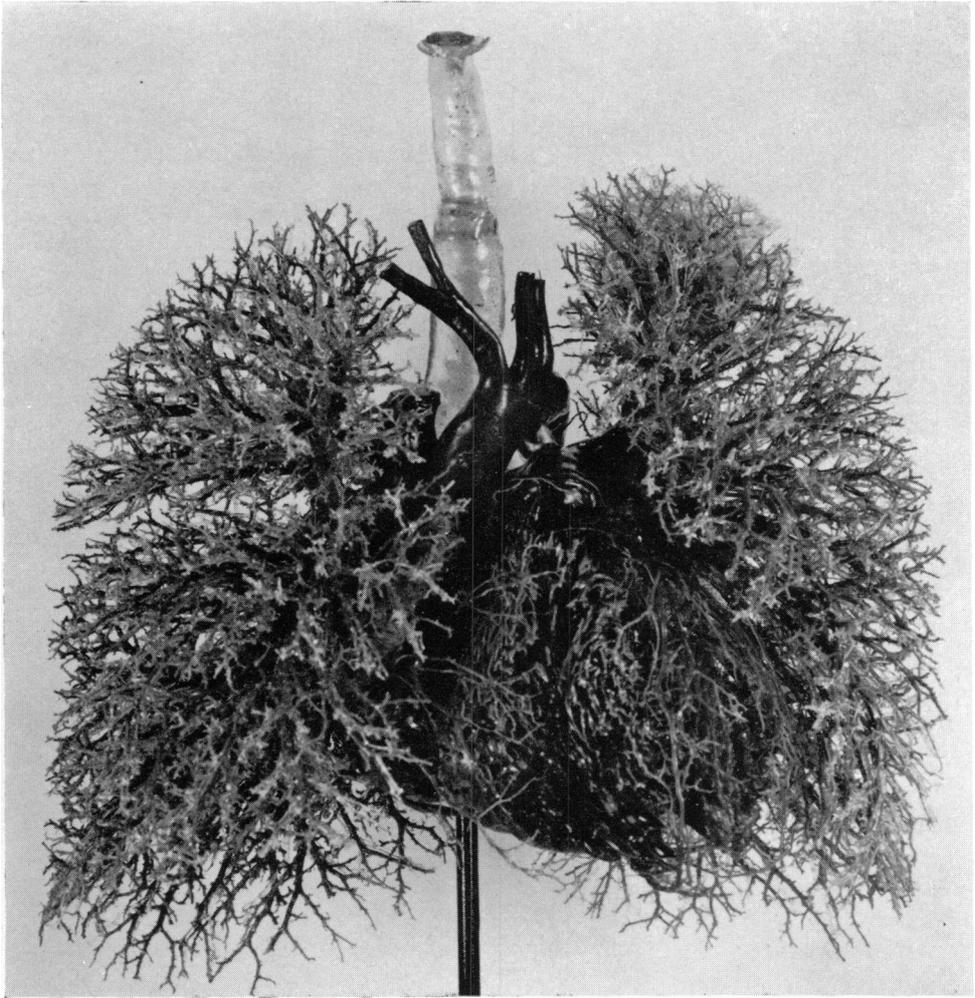


Fig. 3. Marco resin cast of the bronchial tree, cavities of the heart, and blood vessels of the heart and lungs, from an adult cadaver. (Specimen No. S. 254k, from the study series anatomy museum of the R.C.S.)

England, there is an easily recognized wax corrosion cast of human heart and lungs, 'defended', as Pole would have said, by a glass bell jar.

Figure 3 shows a modern synthetic resin corrosion cast prepared from heart and lungs. It can be seen, together with many other corrosion casts, in the study series section of the College museum. Although much stronger than a wax cast, this cast is probably very similar in general appearance to a wax one.

In spite of the perfection attained in injection techniques in the eighteenth century, no progress was made in recognizing the basic structure of the human lung, which was effectively masked by the elaborate branching of the bronchial tree and the diversity of variation in the branches.

The nineteenth century was the era of the comparative anatomists, who demonstrated, among other things, that the same bony elements exist in such widely differing structures as the wing of a bird, the flipper of a whale and the foreleg of a horse. They did not overlook the mammalian lung. The last and by far the most important work on this subject during the nineteenth century was the monograph of the Swiss anatomist Christoph Theodor Aeby (1835–85), published in 1880.³

Aeby, aided by somewhat distorted metal casts, managed to see in the human lung a main stem bronchus extending right to the base of the lung and giving off alternate ventral and dorsal branches. This corresponds closely to the arrangement of the bronchi in typical mammalian lungs. Aeby's prestige was immense, and his early death at the age of fifty, only five years after his monograph was published, may well have made it even more difficult than if he had lived on, for other workers effectively to challenge his views. As it was, his description of the branching of the human bronchial tree was enshrined in textbooks of anatomy for the next fifty years, and blocked the way to progress in this subject.

Yet William Ewart (1848–1929), father of segmental anatomy, published his monograph entitled *The Bronchi and Pulmonary Blood Vessels* in 1889,⁴ only nine years after the publication of Aeby's work.

Ewart was for many years pathologist at the Brompton Hospital. He made the lung his special study. In explaining his motive for choosing this organ, he says: 'Moreover, a suspicion had arisen in my mind that the present deficiencies in our anatomical knowledge . . . might perhaps be held responsible for the halting . . . in the development of Pulmonary Surgery, contrasting with the steady progress made in the surgery of other organs.' Ewart challenged Aeby's views on almost every point. He concluded that Aeby's correlation of the pattern of the human bronchial tree to that of the mammalian was, to put it mildly, 'strained'. He adopted the view, since universally accepted, that the branching of the lung is adapted to the shape of the thoracic cage. The mammalian thorax has a very oblique diaphragm, deep vertebral groove, and the heart is centrally placed. Whereas in man the diaphragm is virtually horizontal, the thorax shallow and broad, and the heart rests on the diaphragm. Hence comparison of the branching of other mammalian lungs with human is not only unprofitable, but actually misleading.

Ewart injected numerous lungs. He filled both bronchi and pulmonary vessels with a low melting-point alloy. He prepared corrosion casts from some of his specimens, while he dissected others. He preferred to inject the isolated lung, rather than to inject it, as most other workers including Aeby have done, in the thorax. He believed that distorted casts, due to the limited control possible when making intra-thoracic injections, had led Aeby astray.

Ewart was the first to recognize that the human lung consists of a relatively small number of separate anatomical units. He says: 'Within each lung large groups of

lobules are kept in practical isolation from each other as regards their air supply. Each of these sub-lobar groups may be considered as forming separate respiratory districts.'

Ewart's monograph contains a full and virtually complete account of bronchial distribution. But the sight of this massive quarto tome, with its 232 pages and twenty formidably complicated figures, is enough to deter all but the stoutest heart from serious study. And so, for nearly fifty years this monument of industry graced the shelves of medical libraries, with some of its pages still uncut, and the fundamental truths it contains buried in a mass of non-essential details.

It was left for Kramer and Glass in 1932, just three years after Ewart's death to rediscover his concept of human lung structure, and coin the phrase 'broncho-pulmonary segment'. And so at last Ewart received, posthumously, the recognition denied to him for more than forty years after the publication of his work.

In 1939 Churchill and Belsey drew attention to the bronchovascular components and the segmental boundaries, and so paved the way to segmental resection.

There still remained the need to get international agreement as to what represents the prevailing pattern, in an organ which shows greater variation than any other in the body.

The rational interpretation of the branching of the bronchial tree is based on three considerations:

(1) *Embryological evidence.* In an enlarged wax reconstruction of the bronchial tree of a five weeks foetus, the buds giving rise to all ten segmental bronchi can be recognized, and little variation is discernible.

(2) *Origin of branches.* A rational interpretation must accept the fact that the exact origin of any individual bronchus may vary considerably, without fundamentally altering the basic structure. Hence the maxim that no bronchus should be classified as supernumerary until ten main bronchi have been counted.

(3) *Distribution of branches.* It must be accepted that the distribution at the surface of the lung of segmental branches is also variable. Individual bronchi compete with each other during growth for the available space. Often one bronchus develops at the expense of its neighbours.

Several workers have published schemes of what they held to be the prevailing pattern of branching of the bronchial tree. Four names deserve special mention in this pioneer work: Forster-Carter in 1942, Brock between 1942 and 1944 and Jackson and Huber in 1943.

There remained the need for international agreement concerning nomenclature. In 1949 the Thoracic Society appointed an International Committee for this purpose. Eight nations were represented. Ten normal segments were recognized and given specific numbers as well as names. This nomenclature was confirmed by the sixth International Congress of Anatomists, meeting in Paris in 1955. The nomenclature was slightly modified at the seventh International Congress of Anatomists, meeting in New York in 1960. At this meeting names were agreed for the principal pulmonary vessels also.

Finally, a special place of honour in this story must be reserved for Edward Allen Boyden. Aided by a team of collaborators, and relying almost entirely on tedious dissection, Boyden made a detailed survey of all known major variations, not only in the branching of the bronchial tree, but also in the arrangement of the pulmonary vessels. Between fifty and a hundred lungs were studied and the findings recorded, both statistically and in numerous diagrams. Writing in 1949, when this work was still in progress, Boyden claims: 'We feel that our work began where Brock left off.'

Boyden's findings are recorded in his masterpiece, *Segmental Anatomy of the Lungs*,⁵ which must be one of the most remarkable anatomical treatises of the century.

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WILLIAM PARGETER

AND THE MEDICAL SOCIETY OF OXFORD 1780-3*

WILLIAM PARGETER is remembered in the history of psychiatry for his *Observations on Maniacal Disorders* (Reading, 1792). In this he made one point, hammered home in six case-histories, which marked the beginning of serious experiments with moral treatment in the management of the insane at a time when they were routinely physicked and restrained, not to say maltreated. He demonstrated that contact could be made with patients however severely disturbed, and that *rapproch*, once established, rendered physical restraint unnecessary and could influence favourably the course of the illness and sometimes indeed initiate recovery. Although his method of catching or 'setting' the patient with his eye may seem primitive, the humanitarian principle underlying it was sound.

Pargeter came of an old Northamptonshire family. He was born in 1760, the son of Robert Pargeter, Rector of Stapleford in Hertfordshire. In January 1777 he entered New College Oxford and graduated B.A. in 1781. Two years later he proceeded to St. Bartholomew's Hospital, London, where he came under the influence of William Austin whom he had got to know and perhaps assisted at Oxford, and David Pitcairn who was particularly interested in insanity† and a Governor of Bethlem Hospital. Among his contemporaries there were Andrew Marshal and John Haslam, both well known for their contributions to psychiatry, but like theirs his name does not appear in the Hospital's books.

In November 1786 he graduated M.D. Marischal College Aberdeen by paying the usual fee of £25 and producing letters of recommendation from Drs. Martin Wall and William Austin. For a time he appears to have practised in London and then in and around Reading. In 1795 he published anonymously *Formulae medicamentorum selectae*, but on the title-page somewhat unfortunately 'By the Author of Maniacal Observations'. This small 12mo of 58 pages, known by a single copy in the Library of the Pharmaceutical Society, added nothing to his reputation and is of interest only as a forerunner of pocket hospital pharmacopoeias. The same year he gave up medicine, entered the Navy as chaplain, served at the Battle of the Nile, and finally

* Paper read at meeting of the Section of the History of Medicine, Royal Society of Medicine, held at Merton College, Oxford, 4 April 1964.

† See Sir Alexander Crichton's *An Inquiry into the Nature and Origin of Mental Derangement*, 1798, dedication and vol. 1, p. 281; and Bethlem Hospital Minute Books, quoted by permission of the Governors of King Edward School, Witley, Surrey.