Evolution of the stethoscope[1]

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The stethoscope has a special place in medicine, being closely bound up with the doctor's image. Although immediate auscultation was known to many before the discovery of the stethoscope, it was only practised by a few, and seldom formed part of the regular examination of patients. References to breath sounds occur in the Ebers Papyrus (c. 1500 BC); the Hindu Vedas (c. 1400–1200 BC); and the Hippocratic writings. Caelius Aurelianus (c. 500 BC), da Vinci, Ambroise Paré, Harvey, Morgagni, Van Swieten, William Hunter, and others also referred to auscultation. Robert Hooke had described heart sounds, and had said 'who knows, . . . it may be possible to discover the motions of internal parts . . . by the sound they make . . .'; but we have no evidence that he ever implemented this suggestion.

The story of how the stethoscope came to be invented is well known. In 1816, René Théophile Hyacinthe Laennec was working at the Necker Hospital in Paris. He was aware of immediate auscultation, as Corvisart, one of his teachers, had occasionally taught it; but Laennec tells us that his friend, Gaspard Laurent Bayle, 'was the first whom I saw employ it'.

The facts behind the birth of the stethoscope are best told in Laennec's own words. 'In 1816 I was consulted by a young woman presenting general symptoms of diseases of the heart. The patient's age and sex did not permit me to resort to the kind of examination I have just described (i.e. direct application of the ear to the chest). I recalled a well known acoustic phenomenon: namely, if you place your ear against one end of a wooden beam the scratch of a pin at the other extremity is most distinctly audible. It occurred to me that this physical property might serve a useful purpose in the case with which I was then dealing. Taking a sheet of paper I rolled it into a very tight roll, one end of which I placed over the praecordial region, whilst I put my ear to the other. I was both surprised and gratified at being able to hear the beating of the heart with much greater clearness and distinctness than I had ever done by direct application of the ear.'

This was the beginning of a great innovation in medicine. Some have written that Laennec got the idea from seeing children playing with a beam of wood; but apart from mentioning the acoustic properties of wood, known since ancient times, Laennec does not refer to such an incident, although it may well have occurred. We know that Laennec first used his primitive stethoscope some time in September 1816, almost certainly before the 13th, and between then and August 1819, when he published the first edition of his book, he carried out extensive investigations. The acoustic phenomena he had in mind was that solid bodies conduct, and to some extent amplify sound; this is why he had tried to roll his sheets of paper as tightly as possible, in order, to exclude the column of air, and why he had later pasted them over with glue. For some time he experimented with solid wooden models, but soon realized the aperture was necessary. He tried various woods, also ivory, gold-beater's skin (inflated with air), and other materials; but concluded that softer woods, such as deal, were best. He learnt to use the lathe, and some of the earliest instruments were made by him and presented to colleagues.

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In February 1818, he reported his findings to the Academy of Science, and in May–July of the same year he lectured before the Academy of Medicine. In August 1819, he published his 'De l'Auscultation Médiate, etc', in two volumes, which sold for 13 francs, and stethoscopes were on sale with the book for an extra 3 francs. Laennec's invention of the stethoscope was important in itself, but far more important was the way he exploited it. His book has been

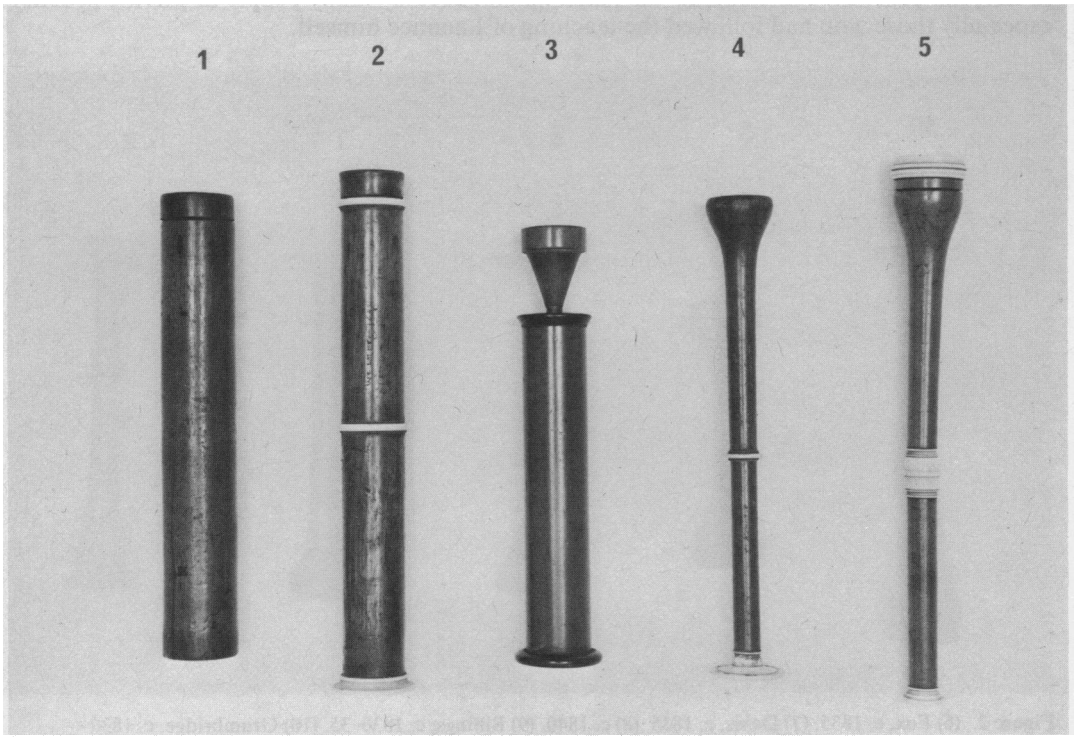

Figure 1. (1) c. 1820. (2) Grumbridge, c. 1823. (3) c. 1820. (4) Stokes, c. 1830. (5) Piorry, c. 1830

hailed by medical historians and generations of physicians as one of the great classics of medical literature. It introduced into clinical medicine the first, major diagnostic 'tool' it had ever had. Auenbrugger's important, but largely neglected little work on percussion (1761) had suggested a 'new method', but not a 'tool'; and although Corvisart had translated his book into French, it was Laennec's invention of the stethoscope which gave a real impetus to percussion, as well as introducing mediate auscultation.

It must have been an exciting time to be an enthusiastic and enquiring physician, in the 1820s, and to read Laennec's descriptions of so many chest diseases – most of which had seldom before been delineated with such clarity, and indeed, some of which had never been described before. He gave masterly descriptions of bronchitis; bronchiectasis; pleurisy; lobar pneumonia; hydrothorax; emphysema; pneumothorax; pulmonary oedema, gangrene, and infarction; mitral stenosis; oesophagitis; peritonitis; and of course, his classic account of tuberculosis, based upon his profound clinical observations, correlated with his equally profound pathological investigations. In addition he described cirrhosis of the liver, which is still known as 'Laennec's cirrhosis'. He introduced a whole new terminology: such terms as stethoscope, auscultation, rales, fremitus, cracked-pot sound, metallic tinkling, aegophony, bronchophony, cavernous breathing, puerile breathing, veiled puff, and bruit. His work on the heart was perhaps less exhaustive and less completely accurate than his work on the chest, but he recognized murmurs and described a 'bruit de râpe' and a 'bruit de soufflet'.

Although the stethoscope came in for some banter, it is obvious from contemporary reviews that praise by far outweighed this. Laennec's book bore all the hallmarks of having been written by such a brilliant observer, that most reviewers recognized its potential importance. Their only reservation was that stethoscopy was rather difficult: a view echoed by many later generations of medical students and doctors – therefore they thought its use would be limited to hospital practice. However, it was taken up and used by many people in private practice, especially those who had followed the teaching of Laennec himself.

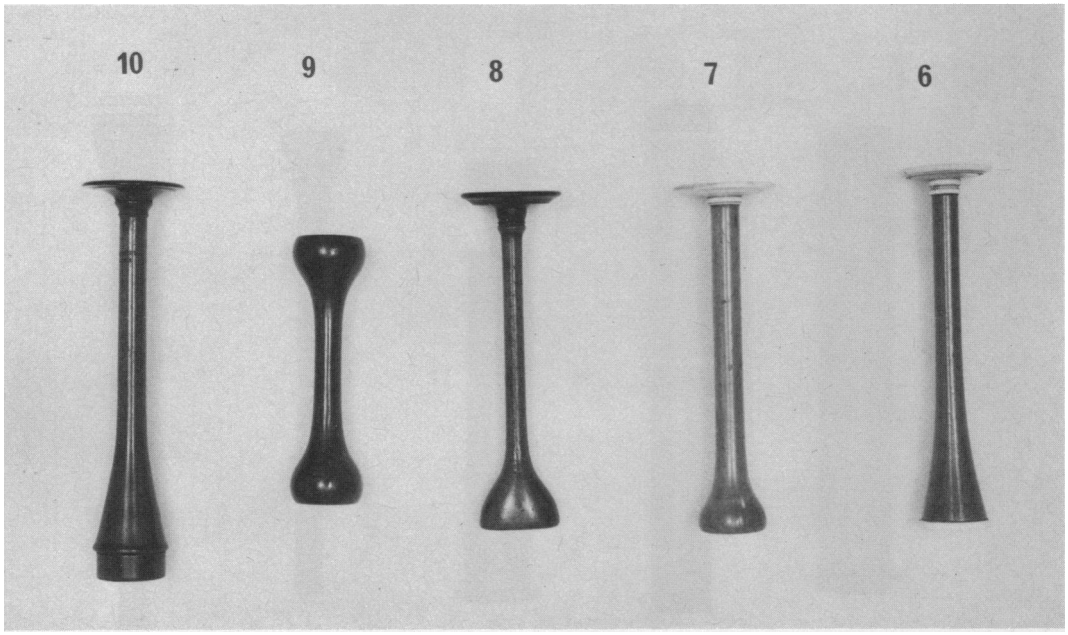

Figure 2. (6) Fox, c. 1835. (7) Davis, c. 1835. (8) c. 1840. (9) Billings, c. 1830–35. (10) Grumbridge, c. 1830

Laennec's book was translated into English by John (later Sir John) Forbes, then Physician to the Penzance Dispensary. He was persuaded to do this by his friend Sir James Clark, who had visited Laennec at the Necker Hospital. Clark was one of the first to adopt the instrument, and employed it in his practice at Rome, which included a large number of consumptives. Between 1821 and 1834 Forbes produced four editions of his translation or version. Although he has received some criticism on account of the liberties he took with Laennec's text, and the way he rendered certain terms, his editions were highly praised in his lifetime, and most reviewers thought (as he did) that he had even improved upon Laennec's original arrangement. Forbes wrote that Laennec's book was based upon his new principles of diagnosis: in other words the stethoscope, and consequently the pathology and diagnosis of the various diseases were blended together 'and the former very generally made subservient to the latter'. Forbes rearranged the whole work, restoring it to what he always thought it ought to have been – two independent treatises: one on pathology, the other on diagnosis.

It is clear that he had strong reservations about the influence the stethoscope was to have, and wrote 'That it will ever come into general use, notwithstanding its value, I am extremely doubtful; because its beneficial application requires much time, and gives a great deal of trouble both to the patient and to the practitioner; . . . Besides, there is in this method a sort of bold claim and pretension to certainty and precision in diagnosis, which cannot, at first sight, but be somewhat startling to a mind deeply versed in the knowledge and uncertainties of our art, . . .' Why did Forbes think it worthwhile translating the book? I think the answer must lie in his realization of the work's great importance as being the most modern text on

diseases of the chest which had appeared up to that date; quite apart from its introduction of the stethoscope.

By the end of 1823, all 500 copies of his first English translation of 1821 had been sold: a thing, as he said, almost unprecedented in a translation from a foreign work. In 1824, hearing from Laennec that his first French edition was out of print, and that he was working on a new one, Forbes wrote to say that he himself was planning a work to include the first English translation of Auenbrugger's 'Inventum Novum', and that he wished to include an up-to-date account of the progress of mediate auscultation: therefore, he asked Laennec to let him have any further information he had about it. This work of Forbes appeared in 1824, and revealed

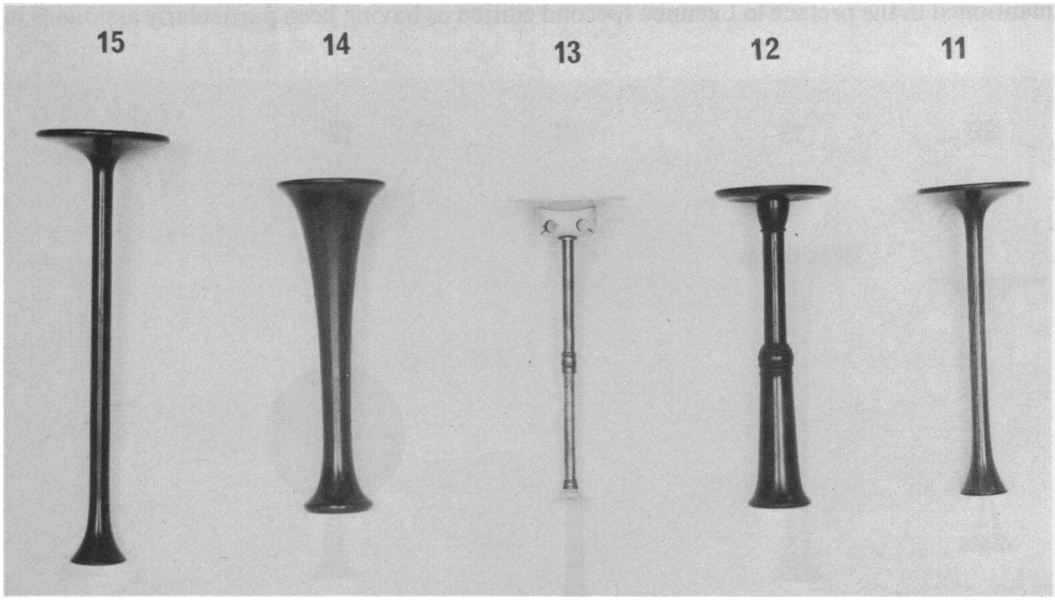

Figure 3. (11) Walshe, c. 1870. (12) Quain, c. 1870. (13) c. 1870. (14) c. 1850. (15) Fergusson, c. 1860

that he had tried to do what Laennec had done – to correlate the stethoscopic findings with the pathological observations.

When he brought out the second edition of his translation in 1827, he acknowledged that he had underestimated the influence the stethoscope was to have – indeed, was already having. The instrument had evolved from Laennec's primitive roll of paper to a wooden instrument consisting of a simple straight tube, about eight inches long, with a conical chestpiece, and a removable obdurator, or funnel-shaped stopper. Names first used were: baton, cylinder, sonometer, medical cornet, or pectoriloque. Laennec's uncle, Guillaume-François, had suggested the name 'thoraciscoscope'; but his nephew disliked this, as it combined Greek and Latin, and finally he chose the name 'stethoscope', from two Greek words meaning 'the chest' and 'to examine'. Laennec's first edition of 1819 illustrated a longer model, about twelve or thirteen inches, in two parts which screwed together; again, with the removable stopper. This was usually retained for heart sounds, removed for breath and adventitious sounds, but replaced for voice sounds.

By November 1819, stethoscopes were on sale in London at Mr Weiss's in the Strand, and by 1820 they were being imported from Paris by Treutell and Würtz, booksellers in Soho Square, and were sold with Laennec's book for an extra 2 francs. When supplies ran out they were made by a woodturner named Allnutt, of Piccadilly, and sold for four shillings. One of the earliest British makers was Grumbridge, of Poland Street, and his instruments sometimes bear his name.

The stethoscope was soon applied to obstetrics and orthopaedics. François-Isaac Mayor had in 1818 described fetal heart sounds, and their usefulness in determining whether the fetus was alive or dead, and also for the verification of twin pregnancies – but had used the unaided ear. In 1822, Lejumeau de Kergaradec published his memoir on the stethoscope applied to this branch of medicine. The instrument was introduced into orthopaedics by J Lisfranc in 1823.

By the time Laennec's second edition appeared in 1826 (the year of his death), a simpler model, without the screw joint, had been introduced; this would have been easier and cheaper to make. By now more and more people were using the stethoscope: Laennec had compiled a list of some 300 students and visitors who had attended his ward-rounds and lectures. Most of these were young men, such as C J B Williams and Thomas Hodgkin, and they were mentioned in the preface to Laennec's second edition as having been particularly assiduous in

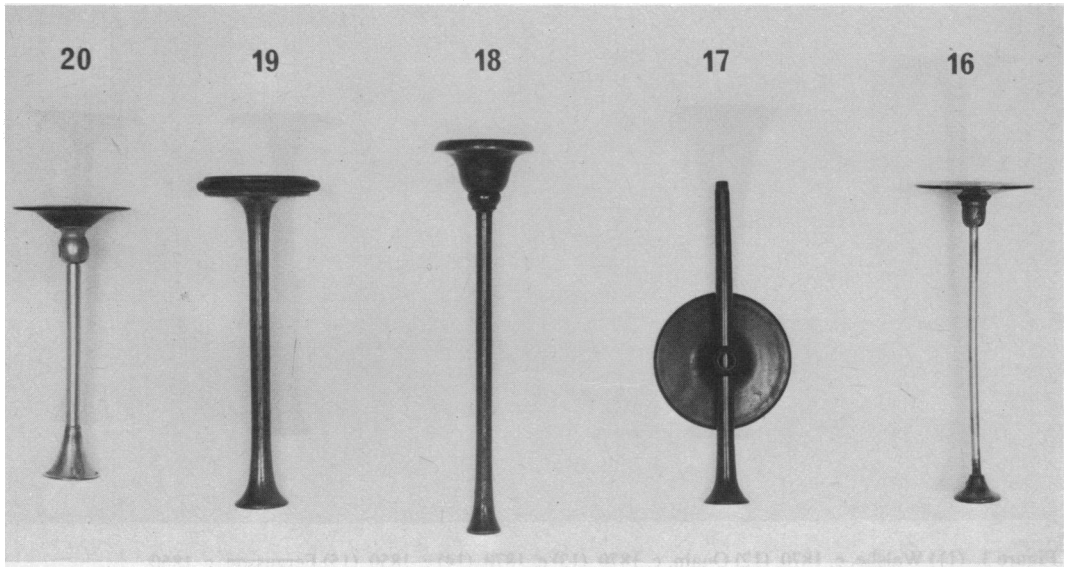

Figure 4. (16) c. 1870–80. (17) Lloyd-Roberts, c. 1879–80. (18) c. 1870. (19) Burrows, c. 1880. (20) c. 1942

following his teaching. In Britain, Sir James MacGrigor encouraged the use of the instrument in the Army, while Sir William Burnet did the same for the Navy. William Stokes, while still a 21-year-old student, had published his little introduction to the stethoscope in 1825, and in it he had emphasized the morbid conditions producing each phenomenon.

The first advance in the stethoscope came in 1828, when Pierre Adolphe Piorry tried to do for mediate percussion what Laennec had done for mediate auscultation. Piorry was also interested in the stethoscope, and is usually credited with reducing its stem to the size of a finger. His book illustrated a beautiful instrument, which divided into two parts, and also included a plessor or pleximeter and an ivory-headed chest-piece.

The next innovation was the flexible, monaural stethoscope, and in 1828–29 Dr N P Comyns, of Edinburgh, described such a model as a substitute for what he called the 'timber cylinder'. It consisted of articulated wooden tubes, and he suggested that it could easily be made binaural; but apparently he never made it so. Sir Andrew Clark, and others, also suggested various flexible instruments. They usually consisted of flexible tubes of coiled brass or iron wire, covered with woven silk or some worsted material. Laennec himself could never practise what we might call 'auto-mediate auscultation'. Although probably aware of his condition, like so many consumptives he continued to hope for recovery until a late stage in his illness. He thought, or perhaps was told by his cousin, Meriadec, that his lungs did not yield signs of pectoriloquism – Laennec's own sure sign of the presence of tuberculosis.

McKusick has described the period between the publication of Laennec's first edition in 1819 and the death of Sir William Osler in 1919 as 'the Golden Age of stethoscopy'; and it saw the development of the instrument in many forms, some monaural – some binaural. Often we can identify and date them with accuracy, from published descriptions or makers' catalogues. Stethoscopes were often associated with the names of people who had suggested some modification in form or material: Piorry, Stokes, Fox, Davis, Quain, Walshe, Fergusson, Lloyd-Roberts, and so on; but often models appear to differ but little from those described earlier, and reflect personal preference, rather than any obvious advantages. Some people even attached importance to such things as the direction of the grain in the wood.

The next step was the attempt at a binaural instrument. Charles James Blasius Williams, one of Laennec's most brilliant pupils and later, with John Forbes, a Consulting Physician to the Brompton Hospital, tried such an instrument in 1829. It had a trumpet-shaped chest-piece of mahogany, the end of which screwed into a connection to which were added two bent lead pipes. A satisfactory rubber was not available until 1849, when Goodyear added sulphur to it and made it more durable. The lead piping of Williams's rather primitive instrument could be adjusted to fit the ears, but had no proper ear-pieces of any kind, and was difficult to apply. Dr Arthur Leared showed what he claimed was an improved form of Williams's stethoscope at the Great Exhibition in 1851, and this had two tubes of gutta-percha attached to the chest-pieces at one end, and to the ear-pieces (which were just flat discs) at the other. Unfortunately, this instrument needed three hands to use it! In the same year N B Marsh, of Cincinatti, patented a form of binaural stethoscope which employed rubber tubes and rather inconvenient earpieces: this was an improvement, although it still required the use of both hands.

The man credited with the binaural form of stethoscope in its more or less modern form is Dr George Philip Camman. He developed this in 1851 and published an account of it in 1855. His instrument had woven tubing, a wooden chest-piece, ivory ear-pieces, plus a broad rubber band to hold the latter in place. It seems that the spring did not come into use until the 1890s. This was an improvement, in the sense that it was self-adjusting, and could be carried in the pocket. However, the old monaural instruments continued to be used in many forms long after Camman described this, and we know that some people, such as Walter Hayle Walshe of the Brompton, disliked binaural instruments, as he thought they altered the pitch and quality of the sound. E H Syer, writing in 1902, said that the binaural form was not used in England until the 1880s. The monaural form was used as late as 1910, almost exclusively outside the United States, where the binaural form is said to have owed much of its popularity to Sir William Osler. Austin Flint was one of the first to use and advocate it in the US, but in Europe most people still preferred one of the many variations of Laennec's original instrument which were available. World War I may have done something to make Camman-type stethoscopes more popular, although as late as World War II, some German Army medical officers were still using metal monaural instruments, and similar, Russian-made models were captured during the Korean War. Until quite recently metal or wooden models were used in antenatal clinics.

After Piorry suggested his more slender type of stethoscope in the late 1820s, these gradually became shorter, and in Victorian times were often designed to fit into a top-hat by means of a special clip in the crown. Sir Benjamin Ward Richardson had made for him a stethoscope with a folding ear-piece of silvered glass, to serve as a reflecting mirror; the chest-piece had a detachable part shaped to serve as an ear speculum. He found this tended to break in his pocket. Perhaps the most bizarre model ever suggested was that of Dr Aydon Smith, who in 1884 produced an instrument which could be used as a monaural, a binaural, or a differential stethoscope. The tubing could serve as a tourniquet, a catheter, or a stomach tube, and the chest-pieces as an ear speculum, a percussion hammer, or a funnel for administering fluids through the tubing. Even enemas and douches could be given with this!

By now models were still usually made of wood, often deal, although rose-wood, guaiacum and mahogany were also used; but ebonite, papier-maché, and even glass were sometimes employed. In 1873 Hawksley introduced an all-metal model, and in 1876 Hilliard suggested that the stethoscope could be attached to the examiner's head – thus leaving his hands free for auscultatory percussion. Somerville Scott Alison, of the Brompton, described his 'hydrophone',

a rubber bag the size of a large watch, filled with water and placed between the chest-piece and chest-wall. This was said to augment the sounds. Alison also introduced his 'differential stethoscope', which allowed one to listen with each ear to the sounds through separate ear-pieces. Differential stethoscopes had quite a vogue, later forms being the 'Bock' and the 'Aertel'. It was claimed they enabled one to compare quantitatively the first sound at the apex with the second sound at the base, and thus provide information as to the efficiency of the myocardium. As late as 1927, Dr N Boston employed a form using two 'Bowles' chest-pieces. Sir Robert Young, to whose masterly account of the history of the stethoscope I am greatly indebted, thought that up to 1930 the most complex forms of stethoscope were those described by F D Parker in 1918, calling one the 'refractoscope' and the other the 'partial stethoscope'. Parker used these to analyse the third heart sound, and introduced a then fresh auscultatory sign – the 'outflow sound'.

In 1889 James Murray described the rubber ring which could be fitted to the bell-end, and claimed that it fitted better to the chest-wall, quite apart from being warmer for the patient. The old monaural forms continued to go through many modifications. Sometimes the straight stem was graduated in centimetres to measure Krönig's area, and sometimes the ear-piece was grooved and rubber-shod to allow it to be used as a percussion hammer, plessor, or knee-jerk hammer; and this type was known as the 'Burrows pattern'. Stethoscopes were even made with special bell-ends, to facilitate intercostal auscultation of emaciated consumptives. Sir Robert Young thought that it was in regard to these chest-pieces that the greatest variety occurred. The first of these had been conical in shape – then they became bell-formed – and later C J B Williams had suggested the trumpet-shaped ending. He found mahogany less brittle than larch or cedar, but finally adopted ebonite, on account of its strength and ease with which it could be cleaned. Later vulcanite models had a vogue in the 1870s. Stethoscopes designed to fit into a waistcoat pocket were available, and some of these were very ingenious, often making use of a ball-and-socket joint, enabling them to be neatly folded. Some instruments assumed great lengths – even as long as thirty-six inches – and were often recommended for use in prisons or work-houses, as they were said to bear some relation to the jumping power of the flea.

The simple diaphragm chest-piece was not illustrated before the development of the 'phonendoscope', and the first such illustration of a vulcanized diaphragm fitted to a bell-end is in a catalogue of 1900; although James Edward Pollock, of the Brompton Hospital, had mentioned an American attempt to introduce a 'chest-piece membrane' as early as 1850. Sahli referred to the early use of a rubber membrane in 1906; but Samuel Jones Gee, of St Bartholomew's Hospital, who produced six editions of a standard work on auscultation between 1870 and 1907, said that the 'microphone', as he called the membrane, had so far proved of little value in auscultation. In 1894, R C M Bowles, an engineer of Brookline, Mass., patented the modern form of diaphragmatic chest-piece. This was the first, or one of the first models to have a metal or celluloid diaphragm. It was sometimes described as a 'phonendoscope', or 'resonating stethoscope'. At first these diaphragms were shaped like flat-irons, then later they became rounded.

The same year Bazzi and Bianchi introduced the instrument they called a 'phonendoscope', which they claimed gave a louder quality to the sounds. It consisted of a double-diaphragm, either half of which could be used, and contained a connecting-rod, said to convey certain sounds and to enable one to localize organs with remarkable precision. According to the information sheet, this instrument could be used not only for cardiopulmonary sounds, but was also said to be highly effective in transmitting sounds from the ear, the eye, the bladder, the stomach, and the vagina. In spite of these advantages its use never became widespread.

One form of diaphragmatic or disc-stethoscope which had quite a long vogue was the 'Minchin'. A revolving chest-piece was also invented, which could be used either as a membrane or phonendoscope; and then, on turning it, as a simple bell-end. Dual-headed chest-pieces, one end of which was smaller and when turned could be used for children, were also made. Teske's 'stethonoscope' was another ingenious instrument designed to give louder conduction.

Some modifications were designed for teaching, and as early as 1850 Landouzy suggested a multiple stethoscope. It had a number of articulated wooden tubes, forty-eight inches long, and enabled several examiners to listen at once; or, alternatively, one or more could use two tubes and so have a binaural stethoscope. He called this a 'stethograph', but it was never a practicable thing, even with rubber tubes, and was eventually discarded. Some time before 1907 Dr Aitchison Robertson connected a number of binaural tubes to one collector, enabling ten or twelve people to listen at one time. This was said to be useful in cases of aortic aneurysm, where frequent examination was inadvisable. In 1926 Dr Jenner Hoskin described the various models designed for multiple use, including the 'multiple electrical stethoscope'. Probably the first of these was devised by Einthoven of Leyden in 1907. In 1923 Robert Cabot used a 600 foot cable to transmit through an ordinary ear-piece the heart sounds of a patient in a ward to an audience in a lecture room.

In 1926 Sato and Nukiyama described their 'magnoscope', an electrical stethoscope with a three-stage triode amplifier. The modern form of 'Bowles-Sprague' instrument, with a chest-piece combining a bell and diaphragm, was described by Howard Sprague in 1926, and this was destined to have a long vogue. In 1937 William J Kerr and his colleagues described their 'symballophone', a modified stethoscope for the lateralization and comparison of sounds. Rappaport and Sprague of Boston published their paper on the physical laws which govern auscultation in 1941, and in 1971 Ertel and his colleagues published two papers on 'stethoscope acoustics'. Studies have also been made on the influence of length of tubing and the part played by its bore.

Just as the stethoscope is always new to each generation of medical students, it still has some surprises up its sleeve, and in 1961 Dr David Littman published his paper 'An approach to the ideal stethoscope'; since then his simple model, making use of 'Tygon' tubing – the Y section being completely moulded with a single length leading to a dual-headed chest-piece, is now probably the most widely used of modern types.

The Wellcome Institute for the History of Medicine probably has the largest collection of old stethoscopes. Other collections are to be found in the Armed Forces Institute of Pathology (the old US Army Medical Museum) and Continental museums of medical history. In Britain, the Royal College of Surgeons of England and St Bartholomew's Hospital both have collections; while some of our other venerable medical institutions possess old stethoscopes often associated with some eminent figure. There are also, of course, examples in private hands; although in my experience such things are rather rare in commerce. In their day they were everyday medical artifacts, and were often thrown away or lost when their owners died. At the Cardiothoracic Institute we have a small, representative collection. Sir Robert Young left us some rare, early models, one of which – an example of the 'baton de Maréchal' type – may well predate the model illustrated in the first edition of Laennec's book.

The stethoscope has its nonmedical uses, one of the best known being by cracksmen opening safes, who employ it to listen to the tumblers falling into place. It is also used by garage mechanics to 'diagnose' missing cylinders; by plumbers to verify leaks; and by bomb-disposal experts.

The instrument is now such an integral part of medicine that one wonders how the profession ever got along without it. Sir Robert Young wrote that in emergencies a wine glass or vacuum flask made quite acceptable alternatives, and of course there is always the unaided ear. Glasses or tumblers are sometimes portrayed in plays and films, being used to listen in on conversations in adjoining rooms. Over the years many people have said many things about the stethoscope. Sir James Mackenzie is reputed to have said that it had done more harm than good. Dr Dickinson Richards said in 1962 'In order for the stethoscope to function, two things have to happen. There has to be, by God, a sick man at one end of it and a doctor at the other. The doctor has to be within thirty inches of his patient'. It is said that when Dr Francis W Peabody was still conducting ward-rounds, although in the final stages of a malignant disease, one of his interns suggested he might 'skip' one patient, in order to conserve his strength. Dr Peabody said: 'Of course I shall examine the patient and listen to his chest; although I have auscultated thousands of lungs I have never heard two which sound alike'.

In conclusion, we can say that Laennec's stethoscope, an instrument in itself of the utmost simplicity (although its use has always demanded skill, patience, and close study), has had, and still continues to have, a profound effect on medicine. Sir James Kingston Fowler, of the Brompton Hospital, once wrote: 'Those who advise that all stethoscopes should be "scrapped" may be influenced by the fact that they do not know how to use their own' – 'A stethoscope is easier to carry than a cardiograph or X-ray installation . . . Neither are common in the "bush-stations" of West Africa'.

Early in 1977 the 'Pentax ST-1A' came upon the scene. Claimed to be the most advanced form of electronic stethoscope available, it weighs 90 grams and is said to amplify signals many hundreds of times. A far cry from Mr Allnutt's instrument, which in 1820 could be had for four shillings, it costs nearly £50. One wonders what Laennec would have thought of it.

It was highly fitting that when the first periodical devoted to diseases of the chest appeared in 1862, it was titled 'The Stethoscope'. Alas, it was before its time and only ran for four numbers. But the stethoscope, that truly remarkable instrument, is still with us.

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