11. Plymouth Hospital Muster, Public Record Office, Adm 102/620.
12. Instances of poisoning with mercury vapour were collected and recorded by Bernadino Ramazzini in his *De morbis artificum*, Modena, 1700.
13. Two recent cases were reported by D. M. Evans, *Brit. med. J.*, 1962, **i**, 1458.

M. P. EARLES

BENJAMIN BRODIE: PHYSIOLOGIST

IN his autobiography,[1] written in 1855, but not published till 1865, three years after his death, Brodie wrote:

> In the same year in which I entered my new habitation,* Lawrence† having resigned the Professorship of comparative Anatomy and Physiology at the College of Surgeons, the Council of the College appointed me to succeed him, and I delivered my first course of lectures there in the year following. I do not know whether I acted wisely in undertaking that office. With an increasing practice, my lectures on surgery and my duties at the hospital, I had an abundance of occupation; . . . it was only by giving up many hours which ought to have been devoted to sleep that I was able to fulfil my engagements, and even with this sacrifice I had not the satisfaction of knowing that my lectures were such as I could have wished them to be.

Elsewhere he stated that:

> at 9 and 10 o'clock in the evening after my day's work was concluded, I had to arrange my lectures for the following day, and this frequently occupied me till 3 or 4 o'clock in the morning. [He added] On the days on which I had no evening lecture, I was much engaged in dinner society, which however, I never allowed to interfere with my more serious occupation, being of temperate habits, and always returning home at an early hour.

Brodie further related how he held the Professorship until 1823, and delivered four courses of lectures: the two first relating to the structure and physiology of the organs of respiration and circulation, the third to the organs of digestion and the last to the anatomy and functions of the nervous system. He modestly added, 'I may take this opportunity of observing that I have found few things to contribute more to my own improvement than the composition of my lectures . . . it has enabled me to detect my own deficiencies, to avoid hasty conclusions, and has taught me to be less conceited of my opinions than I should otherwise have been.'

But before we consider the lectures given at the College of Surgeons in detail, we should mention briefly Brodie's earlier lectures on physiology. In 1802, at the age of eighteen, he read what was probably his first paper before the Academical Society, a student club with wide philosophical interests. It was entitled 'An Essay on the Principles of Science and the Mode of Conducting Scientific Enquiries',‡ and displayed a good understanding of physiological principles even at that early age. He wrote: 'To the study of Natural Philosophy . . . may be added Physiology, extending its meaning to the investigation of the laws of organised existence whatever shape it may assume, including medicine, which is founded on, or rather is but a branch of, Physiology.' These beliefs he was to develop in future years, and they appear in varying guises in subsequent essays and lectures.

In 1810–11 Brodie read a series of lectures to the Royal Society which earned him the Fellowship of that body, and its Copley Medal, awarded to him when he was only twenty-eight years old. They appeared in the *Philosophical Transactions*,[2, 3] and were

* Savile Row, 1819.
† Sir William Lawrence (1783–1867), pupil of Abernethy.
‡ The original MS. in Brodie's hand is preserved at St. George's Hospital.

later reproduced by Brodie in a little book, entitled *Physiological Researches*, 1851.[4] The Royal Society Lectures cover Brodie's experiments on the influence of vegetable and animal poisons, and they include the well-known series of experiments on curare. As they have been published, they need no further discussion, other than to add that it was in performing the experiments for these lectures that Brodie learnt his experimental techniques. His conclusions from all the experiments may be put briefly thus: that the brain is not necessary to the action of the heart, and that the circulation may be maintained by the heart for a long period of time, provided that respiration is continued artificially and the animal may survive. It may well be claimed that artificial respiration for these purposes was Brodie's chief contribution to physiological science.

He ingeniously devised means for carrying out his experiments, placing rabbits or guinea pigs under a bell jar, having produced cessation of respiration by decapitation or poisoning, and maintaining the artificial respiration by insufflation of air from a gum-bottle, either through a catheter inserted through the nose, or through a tracheotomy (see illus. opp. p. 281).

The Royal College of Surgeons possesses, in all, 679 pages of notes, and these cover the lectures given in 1820, 1821, 1822 and part of 1823, though the only complete series is that of 1820, in which fourteen lectures were given; some of these were read again in subsequent years, the others being additions and revisions. Those of 1820 are chiefly on respiration and the circulation. In 1821 we find added to the list lectures on artificial respiration, death from cold, animal heat, poisonous gases and vegetable poisons; and a concluding address in which Brodie draws the attention of his students to the great college museum and to

> that distinguished anatomist and physiologist who founded this collection and who was endowed with such a combination of intellectual faculties as is rarely met with; but which when it does occur, may be considered as fitting the individual who has been so gifted, in a most remarkable manner, for philosophical researches. The mind of Mr. Hunter could descend to the most patient and diligent investigation of particular facts: and it could, at the same time, take cognisance of the most remote analogies.

A further collection of MS. notes on physiology exists in the Library of St. George's Hospital. These papers preceded those of the Royal College of Surgeons, and were in fact the experimental notes from which Brodie wrote up his lectures. Thus the two sets are essentially complementary to one another and in some cases duplicated.

We should now examine some of these lecture manuscripts in a little detail, for they give us a rather clearer picture of his ideas in the physiological context of his time.

Brodie on Respiration and the Circulation

The 1820 series comprised ten lectures on these subjects, and they linked up with further lectures in the 1821 series, in which artificial respiration and the effects of noxious gases were discussed.

It is difficult perhaps for us to recognize the state of respiratory physiology in Brodie's time. The discovery of oxygen, the demolition of the phlogiston theory, and the discovery by Lavoisier of the nature of gaseous exchange in the lungs, which led to his demonstration of the analogy of respiration and combustion—these were the fundamental discoveries of the end of the eighteenth century. Brodie experimented with oxygen, with air, with nitrogen/oxygen mixtures, and with the oxygen/carbon dioxide exchange.

He was not always on very sure ground. For instance, he wrote: 'Some have considered that respiration is analogous to combustion, but the analogy is not very close, as combustion will not take place at so low a temperature.'

But at the same time he recognized the need of the body for oxygen, and stated: 'it is manifest that the blood in the lungs acquires something which it had not before, and which fits it for the maintenance of life'.

He made careful measurement of the exchange of oxygen for carbon dioxide, using his bell jar with gum-bottle attachment, and estimating the amount of carbon dioxide produced by animals of varying sizes. By attaching the trachea of the animal to the nozzle of his gum-bottle, the animal being under the bell jar, he was able to observe the effect of artificial respiration in the decapitated or curarized animal. Similar experiments were conducted in which the body temperature was measured.

The circulation was studied under conditions laid down seventy years earlier by Albrecht von Haller, whose laws of irritability of muscle included the observation that scarlet (i.e. oxygenated) blood maintains this irritability. Brodie tried to discover whence the stimuli are derived on which the action of the heart depends. Haller had thought that it was the distending effect of the blood on the heart which caused the irritable heart muscle again to contract. Brodie doubted this assumption, remarking that an exsanguinated animal dies immediately, but its heart may still be beating. Similarly, he said: 'a man who loses a lot of blood has a raised heart rate, as if by more rapid motion to make up for the diminished quantity of the circulating fluid', which is indeed the case. He then inquired, following Le Gallois, whether the nervous system may not be the source of the stimulus, basing his argument on analogy with other muscles, with the uterus and bladder, and on the effect of emotions on the heart rate. But, as he observed, a heart removed from a newly killed animal will continue to contract though separated both from the brain cord and from the ganglia of the great sympathetic nerve. So he made the shrewd suggestion that the cardiac plexus of nerves retains the power to stimulate the heart to contract.

This is surely a brilliant piece of anticipation. Intrinsic cardiac nerve ganglia were discovered by the Hungarian Robert Remak, over twenty years later, in 1844. Gaskell of Cambridge showed in 1881 that a nervous origin in the sinus venosus affects the rate and rhythm of the heart, and also starts the propagation of the peristaltic-like motion which passes from muscle fibre to muscle fibre. In 1893 Wilhelm His the younger described the atrio-ventricular bundle which goes by his name, while the sino-auricular node, which provides the driving impulse, was not discovered till 1907, when it was described by Sir Arthur Keith.

Bichat, about 1800, had promulgated his theory of *propriétés vitales*, of each tissue possessing its own type of irritability and contractility, which included the notion that the capillaries produced a pumping effect secondary to that of the heart. Brodie disposed of this idea, maintaining the heart to be the sole propulsive factor.

One other experiment should be mentioned here. On 19 October 1820, Brodie poisoned a dog with rectal tobacco infusion. When the heart ceased acting, the chest was opened and a galvanic current applied to the heart, with one pole over the vessels of the neck. Strong contractions of the diaphragm and intercostal muscles took place, and some very slight contractions of the fibres of the heart, but not enough to propel the blood, or restore the circulation. He had, unfortunately, chosen the wrong drug. Heart-muscle irritability is very sensitive to nicotine. Had he used curare, the heart might have responded to a combination of galvanic stimulation and artificial respiration.

The lectures on respiration led naturally to Brodie's experiments with gaseous, vegetable and mineral poisons, and to his work on artificial respiration, while the latter, in turn, inspired a note on drowning and death by strangulation or hanging.

The section on noxious gases is particularly interesting. Here are discussed the indispensability of air, oxygen being alone capable of maintaining life, though other gases, such as nitrogen—azote, as it was then called—may be admitted to the lungs. Hydrogen is not deleterious, merely irrespirable—as Brodie remarked, it made Sir Humphry Davy dizzy. A question is put. Is carbonic acid gas simply irrespirable or is it deleterious? A guinea-pig under a bell jar in carbon dioxide is rendered insensible for three minutes, but recovers in air. When mixed with air, carbonic acid gas may be breathed.

Gases which are essentially deleterious were investigated, for example, the vapour of burning sulphur and hydrocyanic acid gas, which nearly killed Davy.

But the most interesting of all these experiments is the one with ether, which has been quoted elsewhere.[5] A guinea-pig under a bell jar was made to inhale ether vapour blown over by heating ℥iss of sulphuretted ether over a flame (a risky business, physiology!). The animal first appeared intoxicated, then became insensible, and in eight minutes the respiration had ceased. The heart continued beating, and on removal from the jar, after the application of artificial respiration through a tracheotomy, he recovered in a few moments. Thus did Brodie demonstrate the anaesthetic effect of ether, and the fact that it is reversible. The date on the lecture note is 5 February 1821—that is, twenty-five years before ether was introduced as an anaesthetic agent. What a pity Brodie did not follow up this line! Unfortunately, he gave out that 'ether is a narcotic poison, and narcotic poisons affect the brain'. It is odd that historians of anaesthesia have not previously noticed this experiment, for Brodie published it in his 1851 *Physiological Researches*, p. 144, but it is hidden away in some additional notes and appears to have escaped comment. The notes in this little book were taken direct from the experiment notes now at St. George's Hospital, and the details of the ether experiment may be found among this set, as well as in those of the Royal College of Surgeons.

Among the vegetable poisons which Brodie also investigated were curare—he called it woorara—and the Javan poison known as Upas Antiar. He differentiated very accurately between the respiratory paralysing effect of curare, and the cardiac depressant effect of upas, which is in fact produced by an aconite-like substance. Brodie pointed out that the presence of scarlet blood in the left side of the heart showed that after upas poisoning the heartbeat ceased before respiration.

One more lecture may be noticed: lecture 14 of the 1820 series, entitled 'The Origin and Distribution of the Nerves of the 8th Pair or par Vagum or Pneumogastric Nerves'. This refers, of course, to the nerve which we know as the vagus, the tenth cranial nerve. In a lecture of twelve pages, Brodie quoted his own experiments and those of others, posed questions—some of which are still only partially answered—and continued the work on this nerve, which had been the subject of experiment by Galen, by Vesalius, by Willis, by Soemmering, Meckel and Bichat.

Galen had described this nerve, combined with the glossopharyngeal and the spinal accessory, as the sixth cranial nerve. In Brodie's time, the Galenic description still held, but the nerve had now become the eighth, the par vagum. Brodie did not recognize the eighth, ninth and tenth cranial pairs as separate entities, and his eighth nerve comprised the par vagum, or grand respiratory nerve, with the glossopharyngeal and spinal accessory or 'superior respiratory nerve' (cf. Charles Bell, 1830).[6]

Brodie's experiments on the vagus nerve consisted in division of the main vagal branches at various places in their course. Galen and Vesalius had shown the effects upon the larynx of cutting its recurrent largyngeal branches, division of which produces paralysis of the vocal cords, with loss of voice and suffocation in some animals. Brodie performed this experiment and kept his animals alive by tracheotomy. He also showed that adult animals do not die after division of the recurrent nerves; since the vocal cords were relaxed, the so-called 'cadaveric position', the mature animal survived by adapting to an altered respiratory pattern.

But Brodie's main interest was in the effect of division of the vagi—below the level of the recurrents—upon respiration, circulation and gastric secretion. He mentioned species differences in this connection. Division of one vagus produced no ill consequences, but if both were cut, the animal usually died, horses in an hour or less, a dog in perhaps two weeks. Thomas Willis had supposed the effect to be on the heart, but Brodie showed that the action of the heart does not depend on the integrity of these nerves, provided that artificial respiration was maintained.

He did not, however, notice the best-known effect of vagal division on the heart, namely an increase in rate arising from the removal of vagal inhibition; this was not discovered till 1845, when it was described by E. H. Weber of Leipzig.

Brodie considered that the effect on digestion, which is slowed up by division of the vagi, was secondary to circulatory changes in turn secondary to respiratory changes, and he attempted to restore digestion by stimulating the cut ends of the nerves with a galvanic current, an interesting precursor of a modern operative technique for testing the effect of vagotomy.

In conclusion the end of his lecture may be quoted:

> When the nerves of the 8th pair are divided it is manifest that the sensibility of the lungs must be wholly or in great measure destroyed. Now let anyone experiment on his own respiration, and he will find that a peculiar sensation to the lungs precedes each inspiration. If I may be allowed to use the phrase, the lungs experience the want of fresh air, and this excites the action of the muscles of respiration. In order that respiration should be well performed it is evident that there must be a correspondence between the pulmonary circulation and the action of the muscles of respiration: between the quantity of blood which passes through the lungs and the quantity of air taken into the air cells. Therefore there must be a correspondence between the pulmonary circulation and the action of the muscles of respiration, and the common channel of communication must be the 8th nerves on one side and the phrenic and other nerves belonging to the muscles on the other. The 8th pair influences the brain and the brain influences the muscles and it is remarkable that, according to M. Le Gallois it is from the part of the brain in which the 8th pair has its origin that the nervous influence is transmitted to the diaphragm and other muscles of inspiration.

Brodie established no school of physiology. One has the impression that he repeated his experiments again and again, reproducing his results, but was unable, in the contemporary stage of knowledge, to make much attempt at interpretation. His main work was reserved to surgery. His experiments and lectures, important and accurate as they were in his day, were swept aside as the main stream of investigation was brought to its full nineteenth-century flood by such men as Magendie, Bernard, Kühne, Müller and Ludwig. But we cannot doubt the benefits which Brodie the surgeon gained from his early training as physiologist.

K. BRYN THOMAS

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REFERENCES

1. BRODIE, B., *Autobiography*, arranged by Charles Hawkins, London, Longmans, 1865.
2. —— Experiments and observations on the different modes on which death is produced by certain vegetable poisons, *Phil. Trans.*, 1811, **101**, 194.
3. —— Further experiments and observations on the action of poisons on the animal system, *Phil. Trans.*, 1812, **102**, 205.
4. —— *Physiological Researches*, collected and reprinted from the *Philosophical Transactions*, London, Longmans, 1851.
5. THOMAS, K. B., Ether used to produce insensibility in 1821, *Brit. J. Anaesth.*, 1962, **34**, 588.
6. BELL, Ch., *The Nervous System of the Human Body*, London, Longmans, 1830, Pl. IV and p. clxx.

WHO WERE THE EDITORS OF 'THE ANNALS OF MEDICINE AND SURGERY'?

THE short-lived journal, *The Annals of Medicine and Surgery: or Records of the Occurring Improvements and Discoveries in Medicine and Surgery and the Immediately Connected Arts and Sciences*[1] appeared quarterly—31 March, 30 June, 30 September, and 31 December —in two volumes, 1816–17.[2] It contained sections for (1) original papers—the only notable one was by Prout; (2) reviews—the greater part of each issue; (3) 'Intelligence'. The latter section always included an interesting tabulated 'Comparative View of the State of the Atmosphere, prevalent Diseases, and Mortality of the Metropolis', indicative of the current interest in meteorological theories of disease. The Royal College of Physicians' copy of Volume I has inscribed on a fly-leaf: 'To Dr Baillie From the Editors', and from internal evidence it would seem that there were *two* editors.[3] It would be interesting to know the identity of these gentlemen.

There is a suggestion by one of William Prout's obituarists that Prout and John Elliotson were responsible for the journal's appearance.[4]

> It has been said that this journal was conducted by Dr. Elliotson and Dr. Prout; but the correctness of this statement we have no means of ascertaining. The first volume of the *Annals of Medicine and Surgery* is inscribed in a Latin dedication to Matthew Baillie, M.D., London; the second volume, in the same language, to James Hamilton, M.D., Edinburgh, at that time Physician to the Royal Infirmary.

However, none of Prout's writings makes any allusion to such a responsibility, and I understand that Dr. Harley Williams[5] cannot recall any such indication from Elliotson's work. Does any historian have proof for this claim? It is possible that the editorship might be discovered from internal evidence, and I therefore offer a few remarks which, though conflicting, may shed some light on the problem for other historians of medicine.

1. Prout and Elliotson were very good friends. They had been contemporaries at Edinburgh, and afterwards had walked the wards together at the Borough hospitals of St. Thomas's and Guy's. There are many references to the effect that Elliotson had