divinity that shapes his ends and ours. His claim that he can paint only what he sees must be set aside. Through the pictures we can obtain a sort of line spectrum of the artist. There is a good deal of interest in carrying that idea with one through the Academy exhibition. Of course the artist is not everything; the sitter as the medium of expression counts for something. It is clear from the exhibition that men are mostly clothes, sometimes little else, and women, with here and there an exception, are jewel stands. Clerics have a strong vein of pessimism, with the exception of the Bishop of Worcester; 'dons' are complacently resigned; politics, commerce, and industry are built up round an artificial smile; and marquesses are sly—very sly. But in spite of these intrusions into the natural spectrum we have to ask ourselves what are the lines belonging to the artist. For Orpen there is a strong line of realism and humanity towards the infra-red; he even goes so far as pinning down the unavoidable humanity of Miss Penelope Lawrence, M.D. (143), though he excuses women more easily than men. So does Sir John Lavery. Outside humanity there are not many lines in Orpen's spectrum. We can find more in Jack's picture of H.M. The Queen (133), and still more in his "The Blue Drawing-Room, Buckingham Palace" (103). There is something, too, in La Thangue's "Tying Watercress" (255) and Mrs. Dod Procter's "Morning" (735). W. W. Russell's spectrum is so nearly continuous that he seems to be waiting for a reincarnation either of himself or his sitters to suggest a relation of life's enigmas.

If a crowd round a picture at the private view is any clue to its greatness, "Paolo and Francesca" (179), by F. Cadogan Cowper, seemed to be the favourite, and certainly it is an impressive scheme of colour; but still more on the side of the mystery of divinity is "The Enchanted Road" (350), by F. O. Salisbury, or "Svilata, Avati and Augali Sen, Daughters of Mr. and Mrs. Rimsod Sen" (652), by the same artist, and Clausen's "The Nut-brown Maid" (566). The mystery is not confined to portraits; it is quite impressive in "Theatre Marcellus" (75), by Sydney Lee, though the picture belongs to the red end of the artistic spectrum. But spectrum analysis of character is a perplexing study. Those who visit the Academy may take with them their own instruments. "Quai des Grands Augustins, Paris" (86), by Charles Cundall, is good for demonstration.

## Obituary.

### PROF. E. H. STARLING, C.M.G., F.R.S.

A FEW days ago news was telegraphed from Jamaica that Prof. Ernest Starling died on board the *Ariguaing* shortly before reaching Kingston. Of late years he had had indifferent health and had suffered from disabilities under which one of less heroic spirit could not have continued to work strenuously. His enthusiasm for the discovery of new truths was unimpaired, and his mind was so sympathetic and alert that it was difficult to believe he was not a sound man. Nevertheless, evidences of diminishing capacity for work without undue fatigue were obvious to his friends and a source of anxiety to them.

At the close of the winter session, during which he had been daily occupied with arduous experiments, he was very tired. The weather was cold and dull, and he longed for sunshine and warmth. He therefore decided to take a voyage to the West Indies, in full hope that this would restore his energies and enable him to continue with enjoyment the experimental work with which he was occupied. However, that was not to be, but he had the satisfaction of going down with his flag flying, as he would surely have desired.

Ernest Henry Starling was born in 1866. His father, H. H. Starling, was Clerk of the Crown at Bombay. The family of seven children had perforce to be educated in England. They therefore saw but little of their father and were brought up by their mother, an extraordinary woman, and it is to her influence by heredity and nurture that Starling owed his determination, mental alertness, and much of his charm. As the eldest boy, in the absence of a father he early acquired a sense of responsibility and capacity for managing his affairs, and was, in some respects, unusually mature for his years. He was educated at King's College School. He left at 16½ years of age, having matriculated at the University of London with honours, and proceeded to the study of medicine. He chose Guy's Hospital because his uncle was a Guy's man.

At this time Starling's ambition was to be a physician and live in Harley Street, and it was not until a few years later that he began to doubt the all-sufficiency of this ideal and to contemplate the possibility that he might be able to devote himself to an academic career and perhaps become a discoverer himself. As soon as he touched the study of natural science it was clear that Starling had found his *métier*. The causal relation of facts enthralled him. He was intensely curious, and had a naturally scientific mind. He was gifted with fine intellectual machinery, a good memory, industry, and possessed great powers for work, and it was soon clear to his teachers that they had a very exceptional pupil. The teachers of natural science at Guy's in those days were men of distinction, but they only called for a few hours weekly to deliver their lectures. The one who made a great impression upon Starling was Dr. Debus, of the Royal Military Academy, Woolwich, who gave part of the lectures on chemistry. He was a fine teacher, and the enthusiasm with which he expounded the elements of chemistry was infectious.

At the examination in preliminary scientific subjects at the University, Starling obtained the first place in chemistry and botany and second place in physics. He obtained so many medals and prizes as he proceeded through his medical course that an account of these academic victories at university and hospital would be wearisome. About two-thirds of the academic honours available were secured by him, including a free studentship at Guy's Hospital. These various college and university scholarships sufficed to maintain him, and if he had liquidated the many gold medals awarded to him he would have been able to enjoy comparative affluence.

Physics and chemistry attracted him and the generalisation of biology, but it was when Starling came to study physiology that he met his fate. It cannot be said that his affection for physiology was due to his teaching at the Hospital. It was largely his own discovery, but Foster's text-book made a great impression upon him. After two years' study of physiology, during which he read many original papers, including all the back numbers of the *Journal of Physiology*, he had determined, I think, to become a physiologist, if such a career was economically possible. He had felt the deprivation due to his inadequate knowledge of German, so, after disposing of his second technical examination in 1886, he went, largely with the idea of improving his German, for a few months to Heidelberg, and worked in Kuhne's laboratory. He returned at the end of the year with his hair *en brosse*, much teutonised, and more than ever determined to become a physiologist, However, he had to put these aspirations aside for a while and devote himself to the study of practical medicine. This he did with his usual enthusiasm. Starling found great satisfaction and enjoyment in clinical work. The human side appealed to his sympathetic nature and the immediate value of the application of knowledge to his practical mind. If it had been possible to devote himself whole-heartedly to the study of medicine, as is now possible by the institution of full-time professorships, Starling would have been as happy investigating disease as in a physiological laboratory. Indeed, not many years ago he seriously considered accepting such a position.

Having completed his medical studies and occupied the position of house physician and house surgeon at the hospital and graduated M.D., Starling was confronted with the problem, how he was to live if he were to follow his desire and devote his life to physiology. With his brilliant career at the hospital, the profession of a physician was open to him and success undoubted. He was keenly interested in medicine and pathology, and the temptation to follow the line of less resistance and greater promise of reward was considerable. However, in 1889 he determined to try the rougher path, and became demonstrator in physiology. The rewards of this office were minute, and Starling told me that he owed the possibility of giving his allegiance to science to a British Medical Association Scholarship for medical research. The Scholarship was worth £150 a year, and this addition to his slender salary kept him going. Next year, owing to the death of Wooldridge, a vacancy as joint lecturer on physiology occurred and Starling was appointed. On the termination of the British Medical Association Scholarship he was appointed to the research scholarship of the Grocers' Company of the value of £250 per annum. It was not then so easy to embark on a scientific career without financial resources as it is now, and it is terrible to think how one of Starling's glorious attainments was nearly deterred.

He was confronted, not only with the problem of how he was to continue to subsist on one-third of a salary which was never intended to command the whole services of a physiologist, but also how he was to secure a physiological laboratory to work and teach in. The Grocers' scholarship temporarily solved the first problem, and he determined that adequate accommodation and equipment for teaching and research in physiology should ere long, by some means, be obtained. Meanwhile, being but one of three joint lecturers, he was able to arrange to go and work abroad occasionally. In 1893 he went to Breslau to work with Heidenhain, and later for a few months to the Pasteur Institute, as he was greatly impressed by Metchnikoff's discoveries about phagocytosis. In order that this work might be more available to English students, he and his wife translated Metchnikoff's lectures on comparative inflammation.

Until his hopes for a physiological laboratory should materialise, Starling did his best to secure some improvement of the arrangements for practical teaching and demonstration with the funds available ; meanwhile he repaired to Schafer's laboratory at University College to carry on his researches. Bayliss was also working in the laboratory, and here began a scientific partnership which lasted on and off for thirty years. The two complemented one another in many respects. Whilst both possessed scientific imagination of the highest order, Starling was more ardent and forceful, eager to translate ideas into action, but rather bored with details of technical method. He had never been interested in doing things with his hands, except climbing, although later he became a most beautiful and dexterous operator. Bayliss was the philosophical student, calm, with better critical judgment. He read widely and had a wonderful knowledge of scientific literature, was an excellent mechanic, and found enjoyment in the development of the technical methods of research. How fruitful this partnership was will be seen from the account below of Starling's scientific work.

The equipment at Guy's Hospital steadily improved, and Starling and Bayliss did their work on the innervation of the heart there. By 1895 Starling had planned a really good physiological institute for Guy's Hospital, and secured the assent of the authorities to its erection. These laboratories were completed in 1897 and were, at that time, the best laboratories for physiology in London. The amount of time and effort involved in this accomplishment was considerable. Unwilling authorities had to be persuaded to provide territory and funds and colleagues to make sacrifices of their own legitimate aims, and although it was becoming recognised that Starling was going to be a great man and was an ornament to the staff, this was no easy matter.

Not long after the opening of the new physiological laboratories at Guy's Hospital, the Jodrell chair of physiology at University College fell vacant owing to Schafer's acceptance of the professorship at Edinburgh. In 1899 Starling was appointed. It was a wrench to leave his fine new laboratories, to the construction of which he had devoted so much time, but the emoluments of the Jodrell chair were greater, and the conditions at University College he deemed more favourable to the realisation of his ideals. Moreover, he was determined that it should not be many years before he would have a new Institute of Physiology at University College, for the planning of which the Guy's laboratories would have served as useful exercise.

This determination came to fruition in 1909, when the present fine Institute of Physiology was opened. Starling's plan was not merely for a new physiological school, in which he was naturally more particularly interested, but he wanted all the medical sciences at University College to have the advantages of more commodious and nobler buildings. His original scheme was for an Institute of the Medical Sciences, including anatomy and pharmacology as well as physiology, with a central library, pathology being well housed in the new Clinical School. At first only the physiological section was built, but a few years ago the erection of the whole institute, as originally contemplated, was rendered possible by a generous gift from the Rockefeller Foundation, the directors of which were desirous of devoting funds in the interest of medical science in London. That they chose this particular means of fulfilling their aims was largely, if not entirely, due to Starling, and the noble Institute of Medical Sciences with which University College is now endowed is a fine material monument to the memory of one who not only helped to build up a great school of physiology in London and obtained an appropriate habitation for it, but also was as unsparing in his efforts to secure similar advantages for the other medical sciences.

In 1923 Starling retired from the Jodrell chair and was appointed to a Foulerton research professorship of the Royal Society. He still continued to work at University College, but was relieved of all administrative duties and all teaching except that of a small band of research pupils. His laboratories continued to be a centre of great activity, and a limited number of distinguished young physiologists from Great Britain and abroad still enjoyed the advantage of working in close communion with one of the greatest masters of experimental physiology. It was a happy family.

### STARLING'S PHYSIOLOGICAL RESEARCHES.

"Only by following out the injunction of our great predecessor [Harvey], to search out and study the secrets of Nature by way of experiment, can we hope to attain to a comprehension of 'the wisdom of the body and the understanding of the heart,' and thereby to the mastery of disease and pain, which will enable us to relieve the burden of mankind." (Starling, Harveian Oration, Royal College of Physicians, 1923.)

Starling's interest in physiology was general, but the subjects for investigation which particularly attracted him were those physiological processes which seemed capable of interpretation in terms of chemistry and physics. Whilst realising that adaptation was the essence of organism and had no counterpart in inanimate nature, he had not much sympathy with the neo-vitalists. In his view, if the contraction of muscle was not understood, it was because we did not know enough about physics and chemistry or about muscle.

He was always, from his student days, fascinated with the problem of the heart and the adjustment of its action to varying conditions of the body, and his first paper, written with Bayliss in 1891, was on the electromotive phenomenon of the mammalian heart. Waller had recently studied the electrical variation of the excised heart and also of the heart *in situ* by leading off from the neighbourhood of the apex and base respectively. It was evident to Starling that by photographing the movements of the capillary electrometer, connected with electrodes placed in different positions on the naked heart in the anæsthetised living animal, much might be learnt of the nature of the cardiac contraction; in fact, that a new method of observation was at the disposal of the investigator. At that time, any sort of muscular continuity between the auricles and ventricles was denied, and the view that conductivity was due to some nervous network supplying the fibres was in favour. In this research he enjoyed the co-operation of Bayliss. They set out to ascertain the course and time relations of the wave of contraction in the ventricle, the nature of the transmission from auricle to ventricle and throughout the ventricle, and to examine critically Frédéricq's reasons for regarding the nature of the ventricular contraction to be tetanic.

They succeeded in showing (1) that the ventricular contraction is a single wave starting from the base; (2) that there is a natural block at the auriculo-ventricular groove; (3) that the rate of transmission of the contraction wave is about 5 metres per second. This sounds commonplace at this time, when the electrocardiograph is in general use for clinical diagnosis, but their observations not only formed an important step in the development of our knowledge of cardiac contraction and in the interpretation of disease of the heart, but also, by showing what valuable information could be obtained by the electrical method, stimulated its employment and accelerated the development of the electrocardiograph.

They next explored the separate action of the vagi and accelerator nerves on the auricles, on the ventricles, and on the conducting power of the auriculo-ventricular junction in the mammal. The effects of these nerves on the hearts of frogs and tortoise had been previously studied by Gaskell and Heidenhain, and that of the vagi upon the auricle of mammals. Bayliss and Starling completed the story, showing that there was no essential difference between the hearts of mammals and cold-blooded animals, and that the vagus depresses conduction in auricle, auriculo-ventricular junction and ventricle, and that the accelerator nerves had the opposite effects on all three structures.

Two other important papers dealing with the mechanism of the circulation were published by Bayliss and Starling at this time. One was an exhaustive study of the simultaneous changes in the arterial and venous pressures of various regions of the body under a great variety of experimental conditions. The results showed the universal applicability of the principle of the circulation worked out by Ludwig. They said, in their paper, that the effects produced were such as might have been predicted by any one with a knowledge of the elementary principles of the circulation. However, nobody had predicted them.

The last contribution of this first series of papers on the circulation was an analysis of simultaneous pressures in the aorta and ventricles of the heart *in situ*, by an ingenious method which was a vast improvement on any hitherto devised. They used a continuous photographic record of the changes in volume of a small air-space at the end of a capillary glass tube connected with the aorta and ventricle respectively. This method was free from inertia and aperiodic, and they succeeded in obtaining a true record of the rapid variations occurring in the ventricle and aorta and the precise relation of these to one another. Their measurements have been the tandard of reference ever since.

### TRANSUDATION FROM THE VESSELS AND LYMPH-FLOW.

In 1892, Starling, for a while, relinquished the study of the blood circulation and turned his attention to the mechanism of lymph flow. The conditions determining the equilibrium between the liquids in the blood-vessels and tissue spaces required exploration. Was lymph a transudation or an excretion ? Heidenhain had recently published a stimulating paper on lymph formation, in which he concluded that normally filtration played no part in the formation of lymph, so in 1892 Starling went to work in the Breslau laboratory.

Heidenhain had distinguished two kinds of lymphagogues, and under his inspiration Starling set to work to make a more detailed analysis of the effects of one of them, peptone. In summarising his results he adopted the interpretation of Heidenhain that the experimental facts concerning lymph formation could not be explained by filtration and that it was necessary to suppose a selective activity on the vessel wall. However, on returning to England he continued to work energetically at the problem of lymph formation and repeated all of Heidenhain's experiments. He was able to confirm his facts but came to doubt the correctness of his interpretation. He searched for evidence of lymph-secretory nerves, but found that the nervous system could only influence lymph flow by altering vascular conditions. After years of experimenting he came to the conclusion that it was unnecessary to suppose a secretory activity of the endothelium, and that there was no experimental fact inconsistent with the view that lymph formation was a function of two factors, permeability of the vessel wall and intracapillary pressure. Nevertheless, there were a number of observations equally unintelligible on either hypothesis, and further work with Leathes and Tubby on the absorption of various solutions from the pleural cavities only emphasised that there was yet another factor concerned in determining whether fluid passed in or out of the capillaries.

In 1896 Starling discovered that the missing factor required to afford a complete interpretation of the phenomena was the osmotic pressure of the colloids, to which the walls of the capillaries are relatively impermeable. It had hitherto been supposed that the osmotic pressures of proteins, being so insignificant compared to those of salts, must be of no account in physiological processes. The reverse is indeed the case, because it is only to the proteins that the membrane is impermeable. He therefore set to work to measure the osmotic pressures of the proteins in serum and found them to be, though small, of the order of magnitude of the capillary pressure. The problem was solved. The hydrostatic pressure and the osmotic pressure supplied the balance of forces necessary to explain the experimental observations. These, together with altered permeability of the endothelium, are capable of supplying a reasonable interpretation of ædema and pleural effusion, and formed the subject of his Arris and Gale lectures to the Royal College of Surgeons in 1926.

Starling's work on lymph formation occupied five years, and is of the best he did. After long-continued and difficult experimentation, combined with observation of the highest order of accuracy, this hitherto obscure but fundamentally important region of physiology was finally illuminated by his dexterous experimentation and triumphant imagination.

### THE MOVEMENTS AND INNERVATION OF THE INTESTINES.

When Bayliss and Starling undertook this study, the nerve supply to the small and large gut had been carefully determined by Langley and Anderson, but of the working of the neuromuscular mechanism there were many discrepancies as to fact and opinion. After eighteen months' careful experimenting, with appropriate recording methods devised for the purpose, they were able to reduce the previous chaos to order and to summarise the main facts concerning intestinal movements in a few simple statements. (1) That peristaltic contractions are true co-ordinate reflexes carried out by the local nervous mechanism and independent of the connexion with the central nervous system. (2) Local stimulation of the gut produces excitation above, inhibition below. (3) Besides the local mechanism, every part of the gut is subject to the control of the central nervous system through the splanchnics and vagi, the former being inhibitory and the latter containing both augmenting and inhibitory fibres. This was as far as understanding of the matter progressed until Cannon introduced the method of observation by means of X-rays in an animal fed upon a bismuth meal.

### PANCREATIC SECRETION.

The discoveries of Pawlow had determined the order of events in gastric secretion and their co-ordination through the agency of the nervous system, but although he had found that no secretion from the pancreas occurred until the acid chyme reached the duodenum, just how pancreatic secretion was called forth in an appropriate manner had baffled this great experimenter and his pupils. Popielski had determined that the introduction of acid into the upper part of the small intestine caused secretion from the pancreas, notwithstanding previous section of the vagi and sympathetic or even complete extirpation of the solar plexus. He concluded, therefore, that secretion must be brought about reflexly, by means of some local nervous apparatus.

Bayliss and Starling started their investigations with the idea of deciding where this peripheral nervous mechanism was. They verified all the facts stated by the Russian physiologists but were unsuccessful in proving the existence of any nervous mechanism controlling pancreatic secretion. Nor could they discover how secretion was brought about until they made the crucial experiment which led to the discovery of secretin.

I happened to be present at their discovery. In an anæsthetised dog, a loop of jejunum was tied at both ends and the nerves supplying it dissected out and divided so that it was connected with the rest of the body only by its blood-vessels. On the introduction of some weak hydrochloric acid into the duodenum, secretion from the pancreas occurred and continued for some minutes. After this had subsided, a few cubic centimetres of acid were introduced into the enervated loop of jejunum. To our surprise, a similarly marked secretion was produced. I remember Starling saying, " Then it must be a chemical reflex."

Rapidly cutting off a further piece of jejunum, he rubbed its mucous membrane with sand in weak hydrochloric acid, filtered and injected it into the jugular vein of the animal. After a few moments, the pancreas responded by a much greater secretion than had occurred before. It was a great afternoon.

Bayliss and Starling followed up their discovery in many important directions which space forbids me to mention. A method of obtaining natural pancreatic juice was now available, and they made full use of their opportunities to study trypsinogen and its conversion into trypsin by enterokinase. Their observations were afterwards summarised and their significance illustrated in their Croonian lecture to the Royal Society in 1904.

Starling was also moved by them to much constructive thought and further research on the chemical integration of the bodily functions generally. He proposed the name 'hormones' or chemical messengers for all such active principles formed in one part of the body and distributed by the circulation to excite the normal functioning or stimulation of growth of other parts. This fascinating story, embellished with a wealth of illustration, formed the subject of his Croonian lectures to the Royal College of Physicians in 1905, entitled "The Chemical Correlation of the Functions of the Body."

### RESEARCHES UPON THE ISOLATED HEART.

The behaviour of the heart had interested Starling from the time he was a house physician. His earliest work was upon the heart, and though he diverged into other fields of investigation, the questions which intrigued him at that time always retained their fascination. In 1909 he returned again to their investigation. He had been attempting to dissociate the effects of asphyxia on the circulation into those due to diminished oxygen and increased carbonic acid tension respectively. He used the 'spinal animal,' that is, one in which the brain above the pons has been destroyed. He obtained some interesting information, but the observations were difficult to interpret until he should be able to separate the effects of alteration in the gaseous composition of the blood upon the heart itself.

To arrive at this, it was necessary to be able to record the influence of variations of carbon dioxide and oxygen upon the mammalian heart isolated from the nervous system and not subjected to any simultaneous modification in its nutritive state, in the inflow of blood, or in the amount of work it was called upon to do. To satisfy these requirements the heart must be isolated from the rest of the body and at the same time fed with a constant supply of perfectly oxygenated blood; it must be working under mechanical conditions completely under the control of the experimenter. This was accomplished by a device, now famous, known as Starling's heart-lung preparation, in which the lesser circulation is intact, but the only paths from the left ventricle to the right auricle are (1) through the coronary arteries, (2) through an artificial connexion in which the resistance can be regulated. By appropriate means the pressure and flow in different parts of the circulation can be recorded and also the volume of the blood circulation per unit time and the work done by the heart. If required, the gaseous metabolism of the heart contracting under various conditions can be studied. The limited amount of blood in circulation permits analysis of its contents from time to time. Further, the method is admirably adapted to the observation of the direct effect of drugs, etc., upon the mammalian heart, working under every conceivable condition. Nor does this exhaust the possibilities of Starling's heart-lung preparation as an engine of research into cardiological problems. The flow through the coronary circulation can, if necessary, be diverted and measured so that change in the blood-supply to the cardiac muscle can be determined.

After the perfection of this technique, a series of discoveries were made by Starling and his pupils, which, in conjunction with those of Lewis, have made the laboratories of University College as famous a focus of research upon the circulation as was the laboratory of Carl Ludwig sixty years ago.

The years immediately succeeding the development of this method of studying cardiology were the most productive, from the point of view of scientific output, in Starling's career. He was surrounded by enthusiastic and devoted pupils drawn from all over the world. He had plenty of problems for them to attack, with every prospect of a reasonable reward for their efforts. Starling was unsparing in helping them towards their solution, often performing the more difficult parts of the experiments himself and afterwards writing their papers for them.

It is only possible to indicate the principal researches undertaken and the more fundamental facts established by this happy band of discoverers until it was scattered by the outbreak of war in 1914. Detailed accounts will be found in the publications from his laboratory between the years 1910 and 1915. They are in no case merely qualitative observations but quantitative determinations. They occupy hundreds of pages of the *Journal of Physiology* and other periodicals during this period. They show the marvellous power of the heart, apart from the nervous system, to adapt its work in accordance with the needs of the body as a whole, and also the exquisite mechanisms to enable it to do this within wide limits, without embarrassment or permanent injury.

In the first case the effects of variations in the tensions of oxygen and carbon dioxide in the blood upon the diastolic volume and output of the heart, on its capacity for work, and on the flow through the coronary arteries, were determined. The heart was found to have an astounding power of utilising the oxygen in the blood. When an isolated heart was fed with blood from an asphyxiated animal, the heart removed all but traces of oxygen. The conditions controlling the rate of the heart-beat were studied, and the only influences found to modify the rate of the isolated heart were temperature, the volume of the inflow, and adrenalin. The maximum output of the heart was measured and found to be three litres a minute for a dog's heart weighing 50 gm. Important observations were also made upon the energetics of the heart by determining the oxygen used per unit of work done. The respiratory quotients of the normal and diabetic heart were determined, and from these two sets of observations the efficiency of the heart as a machine working under various loads was determined. The ventricular output was discovered to be independent of the arterial pressure, but, on the other hand, it was found to be dependent upon inflow. From this it appeared that as the heart dilated and its fibres were stretched, it worked with greater efficiency. This was afterwards shown to be the case by his distinguished pupil Lovat Evans.

The experiments upon the flow of blood through the coronary arteries showed that this flow was primarily dependent upon the arterial pressure, but that dilatation of the coronary system occurred when the carbon dioxide tension in the blood increased, when adrenalin was added, and most markedly when some metabolites, the product of the heart's own activity, were added to the blood circulating. In the latter circumstances the increased flow through the coronary arteries was out of all proportion to the pressure in the aorta, a further indication of automatic adjustment to a condition of stress.

Starling having supplied us with a new method of inquiry, many competent physiologists could have ascertained much of the information outlined above, but there was one discovery which is peculiarly the product of his genius, namely, that cardiac muscle, like voluntary, contracts more forcibly as it is stretched even up to the point when the texture is fractured. Therefore to work at greatest efficiency a heart must first dilate, which it inevitably does, as the pressure in front of it increases. This is what Starling calls the "Law of the Heart." As he said in the fine Harveian oration he delivered before the Royal College of Physicians in 1923, when he expounded in simple and beautiful language the results of his researches into the movements of the heart, "The heart has thus the power of automatically increasing the energy evolved at each contraction in proportion to the mechanical demands made upon it, behaving in this way almost like a sentient, intelligent creature."

### Starling's Services during the War.

After War broke out Starling became very unsettled. He wanted to go and fight. Persuaded, if not convinced, that this was not the most suitable manner in which to satisfy his strong tribal instincts, he joined the R.A.M.C. as a Captain and was for some time a medical officer at the Herbert Hospital. Later, as the scientific resources of the country were mobilised, he was made Director of Research at Milbank and was busy experimenting with defensive methods against poison gases. In this he rendered invaluable service to his country, and no one could be better to control a research laboratory. However, at the end of 1916 he was exalted to the rank of Lieut.-Colonel and sent as Chemical Adviser to Salonika, where he had nothing to do. Maybe his impatience of official methods had embarrassed the authorities. In 1917 he resigned his commission, deeming that he could be of greater service as a civilian.

At that time food-shortage seemed most likely to decide the issue, and Starling became chairman of the Royal Society Food Committee and was largely responsible for the value of the advice given by it to the Government. Afterwards he was scientific adviser to the Ministry of Food, and British scientific delegate on the Inter-Allied Food Commission.

In all these capacities Starling rendered yeoman service. He soon had a mastery of the necessary facts, and he was by nature and training able to marshal them comprehensively and arrive at definite conclusions. He was never 'havering,' and he impressed all those statesmen and officials with whom he had to deal. It is doubtful whether any other of our physiologists could have served us so well.

### Later Researches on the Circulation.

For a while, after the War, Starling's work was seriously curtailed owing to ill health, which finally necessitated a serious surgical operation. However, in 1920 he was back again at work, with Anrep, on the central and reflex regulation of the circulation by an ingenious cross-circulation method built up on his heart-lung preparation. In this method the circulation through the brain of an animal is entirely under the control of the experimenter, while the animal's own heart supplies the rest of its body.

A notable discovery was that, whereas rise of aortic pressure leads to dilatation of the blood-vessels so long as the depressor nerves are intact, change in the blood-pressure in the supply to the brain produces the reverse change in the pressure of the rest of the body. These fundamental laws of vasomotor regulation were suspected but never before established.

### The Secretion of Urine by the Isolated Kidney.

The heart-lung preparation affords a means by which any isolated organ may be fed with arterial blood of known composition at any desired pressure, rate of flow, and temperature. It is thus possible to study the functions of an organ apart from nervous influences and from the chemical influences which may arise in consequence of modifications in the blood caused by other organs of the body. After numerous attempts, Starling and Verney succeeded in maintaining the isolated kidney in such a condition that it would secrete abundant urine.

By this method, which demands extraordinary experimental skill, Starling has opened a new chapter on the physiology of renal secretion. Already, many new facts, and others which were previously only matters of surmise, have been discovered and established. His observations with Verney and in collaboration with Eichholtz have shown that the glomeruli filter from the blood plasma its non-protein constituents, and that by using hydrocyanic acid to suspend tubular activity, a pure glomerular filtrate is obtained from the ureter. Also that, whilst urea and sulphate are secreted by the tubule cells, water, chloride, bicarbonate and glucose are re-absorbed by the tubule cells from the glomerular filtrate. Pituitrin increases the amount of chloride and decreases the amount of water eliminated.

The influence of the pituitary gland upon the secretion of the kidney was particularly studied by Starling's pupils, Eichholtz and Bruhl. Their experiments suggest that the inability of the isolated kidney to secrete inorganic phosphate is due to the absence of the pituitary hormone. If this be so, it is another discovery of a chemical correlation of the body for which Starling is largely responsible.

These researches on the isolated kidney were in full swing in April when Starling left for the holiday which was long overdue. They were affording most important results, and doubtless, had he been spared to continue them, he would, with his unrivalled experimental skill, ultimately have succeeded in clarifying our knowledge of urinary secretion as he had laid bare the principles involved in the self-adjustments of the heart to physiological requirements.

### Starling as a Teacher.

Starling was a fine teacher. He had not a natural gift of oratory, but by practice he early became a good, coherent and agreeable speaker. He had a happy way of finding telling phrases to emphasise the main points of his discourse, and sometimes, when feeling deeply, he was eloquent. His enthusiasm was infectious, and his pupils enjoyed his lectures. His influence as a teacher was, however, not confined to those who had the privilege of sitting at his feet. His "Principles of Human Physiology" is the best text-book on the subject in the English language, and is widely used by students on both sides of the Atlantic. It has also been translated into Spanish. As a teacher to research students he was ideal. He loved the companionship of young men. To every one, provided only that he were a serious inquirer after truth, he was ready to extend help, encouragement and friendship.

An account of Starling's scientific career would be incomplete without allusion to the part played in it by his wife. In 1891 he married Florence Wooldridge, the daughter of Sir Edward Sieveking. They were inseparable companions. With unselfish devotion she helped him more than will ever be known. They discussed all his projects together, and for many years she performed for him all the functions of an efficient secretary. Further, in addition to the responsibilities of bringing up their four children, she bore on her shoulders the burden of the humdrum duties of his life, thus releasing the more energy for his work.

Starling was the recipient of many academic honours. Honorary degrees were conferred upon him by the Universities of Dublin, Sheffield, Cambridge, Breslau and Heidelberg. He received the Baly Medal in 1907 and the Royal Medal of the Royal Society in 1913. What place amongst the great discoverers in medical science should be allotted to Starling must be left to the judgment of posterity, but it will be generally conceded by his contemporaries that he was one of the foremost physiologists of our time, and that no one since Harvey has so greatly advanced our knowledge of the action of the heart.

Although no man gave more devoted service to science, Starling's interests were many-sided. He loved music, he loved beauty, he loved a fight; in fact, he loved life. The great charm of his companionship was, in part, due to his extraordinary mental alertness and boyish enthusiasm; like Peter Pan, he refused to grow old. His death means a sad loss to all of us and will be felt not least by the generations of pupils who have been his companions during his lifelong search for new knowledge by experiment. C. J. MARTIN.

## News and Views.

IN a supplement to NATURE for July 3, 1926, Dr. G. E. Hale described his recently completed spectrohelioscope—a visual instrument for observing solar phenomena in monochromatic light—and indicated its large scope in exploring the higher parts of the sun's atmosphere. On p. 708 of our issue this week, Dr. Hale gives us some of his results obtained during the last few months from observations of the hydrogen gases involved in the upper part of the vortex of a sunspot and its attendant region of disturbance. The particular problem to which he has applied his instrument is to determine whether the characteristic appearance of whirl-formation of the hydrogen flocculi surrounding sunspots is hydrodynamical or electromagnetic in origin. These hydrogen whirls, depicted on photographs taken in monochromatic light of $H\alpha$ by the spectroheliograph, had previously been closely studied by Dr. Hale, who found the evidence inconclusive for an explanation of their exact nature, for they appeared to be unrelated to what is presumably a periodic reversal every $11\frac{1}{2}$ years of the direction of whirl of a deeper-seated vortex which gives rise to the magnetic field of a sunspot. He is now able to show in the present article that his recent observations afford a more critical test, which proves to be against the electromagnetic explanation. He states, however, that there still exist several difficulties in the way of explaining the structure of the flocculi along purely hydrodynamical lines.

ONE great advantage of the spectrohelioscope is that it permits the observer to watch continuously the movements of the solar gases, and by means of a 'line-shifter'—a neatly devised accessory—the radial velocity of separate portions of a flocculus can readily be estimated. Although photographs of hydrogen flocculi strongly suggest movements of inflow or outflow, the reality of such motions has, as a general rule, been difficult to establish even from a long series of daily spectroheliograms or from others taken at shorter intervals. With his spectrohelioscope, Dr. Hale has now seen a number of these flocculi being drawn into spots with accelerated velocities, in one instance increasing from 22 to 50 km./sec. at corresponding distances of 56,000 km. and 20,000 km. from the centre of the spot. These and other observations of moving masses of gas in the near vicinity of spots have an important bearing on the motions of related prominences which have been recorded from time to time. The possibilities of this instrument and the remarkable observations which have already been made with it are of the greatest interest.

THE commemoration of Huxley's birthday by an annual lecture delivered at the College with which most of his teaching life was associated, is a new institution, which the Imperial College of Science owes to its Rector, Sir Thomas Holland, who himself was an old pupil of Huxley's. The first lecture in the series was delivered by Prof. E. B. Poulton in 1925 and was of a charming and intimate biographical character. The second lecture, by Dr. P. Chalmers Mitchell, should have been delivered last year, but had to be postponed owing to the general strike. It was delivered on May 4 of this year. Dr. Mitchell took as his title, "Logic and Law in Biology," and, as was to be expected, he delivered an admirably lucid and incisive address. Dr. Mitchell's thesis was that it is a weakness of the human mind to invent imaginary entities to account for the flux of things, and that of these entities the idea of 'law' is the most universal. He pointed out that Huxley had said that every law is a construct of the human intellect, and no more exists outside us than does colour. Dr. Mitchell then went to scourge the concepts of 'vitalism,' 'orthogenesis,' and 'emergent evolution.' If we get rid of all these conceptions, what remains? According to Dr. Mitchell, an increase of 'plain materialistic explanation.' But many will ask: Is not 'materialistic explanation' itself an imaginary concept? There was, in fact, an aura of nineteenth-century materialism and scarcely veiled 'episcopophagy' about Dr. Mitchell's address which was admirably in keeping with one phase of Huxley's character. But the same Huxley who on one occasion said that it was as absurd to talk of the