day they produce, on an average, upwards of 300 tons per week, in some cases 800 or 900 (and in one of the Pittsburg furnaces the enormous output of 1,800 tons has been reached). Mr. Charles Cochrane, an advocate of the hottest hot blast, stated, that, at the works at Ormsby, they began in 1855 with a furnace of 7,000 cubic feet capacity, and with a temperature of air between that of molten lead and molten zinc, using 39.64 cwts. of coke to the ton of pig. In 1857 they used 33.87 cwts.; in 1867 it was only 29.66; in 1877 it had become reduced to 22.64; and in 1882, 21.18 cwts. was the average for all furnaces, small and large, while the larger furnace of 34,000 cubic feet capacity worked the whole year through on 19.38 cwts. per ton of pig. Hence from 1855 to 1883 the saving was 20.34 cwts. of coke per ton of iron; and, in Mr. Cochrane's opinion, fully half this saving was due to the use of the Cowper fire-brick stoves.

Mr. Cochrane has recounted some of the theoretical calculations that have been made. In 1879 he ventured to predict that a ton of iron could be made with 17.90 cwts. In 1881 he had made iron with 18.40 cwts. Another iron-master stated that a furnace has run for eight weeks on less than 18 cwts.

Mr. Hawdon claims that heating the blast from 990° F. to 1400° F. resulted in a saving of 1.5 cwts. of coke to the ton of iron, and that a further heating to 1550° F. was followed by a total saving of 2.5 cwts., bringing the coke down to 21.3 cwts.

In the discussions which took place at the meetings referred to, the prominent iron-manufacturers generally took the ground that the hotter the blast the better the result, up to the temperature of melting iron. Mr. I. Lowthian Bell, however, dissents from this view, and thinks, that, in real ultimate economy, 1000° F. will prove to be about the limit of heat for the blast which it is worth while to strive for.

R. H. RICHARDS.

MODERN PHYSIOLOGICAL LABORATORIES: WHAT THEY ARE AND WHY THEY ARE.[1] — I.

A LITTLE more than seven years ago I announced from this platform that the old biological laboratory was ready for use, — that set of rooms in the third story of this building, which, inconvenient in many respects as they were, will, I trust, always be remembered by some of us with affection, and mayhap with a little pride.

This night on which we have met to celebrate the completion of the new laboratory is, however, an occasion for looking forward rather than backward. But before proceeding to speak in detail of the new building, I feel sure I do but what every one of the members of the biological department present would think me remiss to omit, in pausing a moment to express our gratitude to those to whom we owe it, — first to our founder, Johns Hopkins, for his munificence; and next to his trustees. Probably very few present realize how much time and thought the trustees spent on the building before a stone of its foundation was laid, and during its erection. No one but myself knows how often I have been put in good heart by the cheering words, "Well, Dr. Martin, let us get it right when we are about it." In this connection I cannot refrain from saying, that, though we owe all so much, we owe a special debt of gratitude to Mr. Hall Pleasants, the chairman of the building committee. Throughout the whole summer there was hardly a morning on which he did not visit the building, and that not merely for a glance, but far more often to spend an hour or two hours about it, and make sure that all was going right.

The material result of this liberality, forethought, supervision, and care, is that stately building on the top of the hill. Handsome though not ostentatious, comfortable but not luxurious, pleasant to work in without unnecessary finery, it stands there, for its purpose unrivalled in the United States, and not surpassed in the world.

Substantial, solid, well thought out, suited to its ends, and with no frippery about it, it is now for us to see that our work agrees in character with the building.

There are many here to-night, who, not being biologists, may desire to know what such laboratories are for, and why there is any need of them. I shall perhaps best begin my attempt to answer these questions by stating briefly what our own laboratory is.

It is a building constructed primarily to afford facilities for instruction and research in physiology; and, secondarily, similar opportunities in allied sciences, as comparative anatomy and botany, some training in which is essential (and the more the better) to every one who would attain any real knowledge of physiology. As so many distinct branches of biological science are pursued in it, we call it in general the biological laboratory; but it is a biological laboratory deliberately planned that physiology in it shall be queen, and the rest her handmaids. If, therefore, you visit the building prepared to see a great zoölogical museum or an extensive herbarium, you will be disappointed. I do not underrate, and no one connected with this university can, — bearing in mind the brilliant anatomical researches of Dr. Brooks and others, made among us, — the claims of morphology; and in time I trust we may see a sister building specially designed for study of the structure, forms, and development of plants and animals. But one or the other had to be first chosen, unless we were to do two things imperfectly instead of one well, and there were strong reasons for selecting physiology. In the first place, I think even the morphologists will admit that hitherto, and especially in the United States, they have had rather more than their fair share; innumerable museums and many laboratories have been built for their use; while physiology, if she got any thing, was usually allotted some out-of-the-way room in an entirely unsuitable building, if

[1] An address delivered on the occasion of the formal opening of the new biological laboratory of the Johns Hopkins university, Jan. 2, 1884. By H. NEWELL MARTIN, M.D., Dr. Sc., M.A., professor of biology in the university.

no one else wanted it, and was very glad to get even that. A second and still stronger reason is, that as medicine is slowly passing out of the regions of empiricism and rule-of-thumb treatment, or mal-treatment, it has become evident that sound physiology is its foundation; and this university will at no distant day have a medical school connected with it.

As you walk presently through the rooms of the new building, and see the abundance of instruments of precision for teaching and research — the batteries, galvanometers, induction-coils, and spectroscopes; the balances, reagents, and other appliances of a chemical laboratory; the microscope for every student; the library of biological books and journals; the photographic appliances; the workshop for the construction and repair of instruments — when you see these things, it may interest you to recall that sixty years ago there was not a single public physiological laboratory in the world; nor was there then, even in any medical school, a special professor of physiology. So late as 1856 Johannes Müller taught in Berlin, human anatomy, comparative anatomy, pathological anatomy, physiology, and embryology.

DuBois-Reymond, now himself professor in Berlin, has graphically described the difficulties of the earnest student of physiology, when he attended Müller's lectures in 1840.[1]

"We were shown (he says) a few freshly prepared microscopic specimens (the art of putting up permanent preparations being still unknown), and the circulation of the blood in the frog's web." So much for the histological side.

"We were also shown the experiment of filtering frog's blood to get a colorless clot, an experiment on the roots of the spinal nerves, some reflex movements in a frog, and that opium-poisoning was not conducted along the nerves. There were some better experiments on the physiology of voice, — a subject on which Müller had recently been working; and there was finally a demonstration of the effect upon respiration of dividing the pneumogastric nerves."

In all, you see six experiments, or sets of experiments, in the whole course, in addition to the exhibition of some microscope slides; and all these mere demonstrations. It was hardly thought of, that a student should use a microscope, or make an experiment, himself. If he desired to do so, the difficulties in his way were such as but few overcame.

"He must experiment in his lodgings, where on account of his frogs he usually got into trouble with the landlady, and where many researches were impossible — there were no trained assistants to guide him — no public physiological library — no collection of apparatus. We had to roll our own coils, solder our own galvanic elements, make even our own rubber tubing, for at that time it was not an article of commerce. We sawed, planed and drilled — we filed, turned, and polished. If through the kindness of a teacher a piece of apparatus was lent to us, how we made the most of it — how we studied its idiosyncrasies — above all, how we kept it clean!"

Of course certain men, the men who were born to become physiologists, and not mere attendants on lectures on physiology, surmounted these difficulties. One has only to recall the names of DuBois-Reymond himself, and of such of his contemporaries as Brücke, Helmholtz, Ludwig, Vierordt, Donders, and Claude Bernard, to realize that fact; and undoubtedly there was a good side to it all. Triflers, at any rate, were eliminated; and the class of individuals was unknown who sometimes turn up at modern laboratories (and, judging from a good deal of current physiological literature, sometimes get admitted to them) with a burning desire to undertake forthwith a complicated research, though they would hardly know an ordinary physiological instrument if shown to them, much less how to handle it. They never can wait: they must begin the next morning, believing, I presume, that modern laboratories are stocked with automatic apparatus, — some sort of physiological sausage-machines, in which you put an animal at one end, turn the handle, and get a valuable discovery out at the other.

With one exception, Berlin was not in 1840 worse off than other German universities, so far as facilities for physiological study were concerned, and certainly better off than any university in England or the United States. The exception was in Breslau, where the celebrated Purkinje, single-handed, had founded a physiological institute. It has usually been supposed that in this he followed the example given by Liebig, who founded at Giessen the first public chemical laboratory; but this, *pace* my colleague Professor Remsen, can hardly have been the case. It is to Purkinje that the honor belongs of founding the first public laboratory. Liebig undoubtedly conceived the plan when working in Paris in Gey Lussac's private laboratory, but it was not until 1826 that he began to put it into execution; and at that date Purkinje had already, largely at his own cost, started a physiological laboratory at Breslau, open to students, — on a very small scale, it is true, but still the germ of all those great laboratories of physics, chemistry, and biology, which are now found in every civilized country, and to which, more than to any thing else, modern science owes its rapid progress. Of these there must be at least forty now organized for physiological work; and almost every year sees an increase in their number. How has this come about in the fifty odd years which have passed since the origination of Purkinje's ill-equipped and little known workrooms?

First and foremost, because of the improvement in philosophy which took place as men began to break loose from the trammels of Greek and mediaeval metaphysics, and to realize that a process is not explained by the arbitrary assumption of some hypothetical cause invented to account for it. So long as the phenomena exhibited by living things were regarded, not as manifestations of the properties of the kind of matter of which they were composed, but as mere exhibitions of the activity of an extrinsic independent entity, — a pneuma, anima, vital spirit, or vital principle which had temporarily taken up its residence in the body of an animal, but had no more essential connection with that body than a tenant with the house in which he lives, — there was no need for physiological laboratories. Dissection of the dead body might, indeed, be interesting as making known

[1] Emil DuBois-Reymond. *Der physiologische unterricht, sonst und jetzt.* Berlin, 1878. The quotations from this pamphlet, while giving, I trust, a true idea of the substance of DuBois-Reymond's statements, have been curtailed, and are not to be regarded as literal full translations of the original. — H. N. M.

the sort of machine through which the vital force worked, — just as some people find it amusing to visit the former abode of a great author, and see his library and writing-table and inkstand; and there might be discussions as to the locality of the body in which this vital force resided; to carry out our simile, as to what was its favorite armchair. Various guessers placed it in the heart, the lungs, the blood, the brain, and so forth. Paracelsus, with more show of reason, located it in close connection with the stomach, on the top of which he supposed there was seated a chief vital spirit, Archaeus, who superintended digestion. It is mainly to Descartes,[1] who lived in the earlier half of the seventeenth century, that physiology owes the impulse which set it free from such will-o'-the-wisps. Putting aside all consciousness as the function of the soul, he maintained that all other vital phenomena were due to properties of the material of which the body is composed; and that death was not due to any defect of the soul, but to some important alteration or degeneration in some part or parts of the body.

The influence of Descartes, and in the same half-century the demonstration of the circulation of the blood by Harvey, gave a great impulse to experimental physiology. Both Harvey and Descartes, however, still believed in a special locally placed vital spirit or vital *force*, which animated the whole bodily frame as the engine in a great factory moves all the machinery in it. What a muscle did, or a gland did, depended on the structure and properties of the muscle or gland; but the work-power was derived from a force outside those organs, — on vital spirits supplied from the brain along the nerves, or carried to every part in the blood. As the pattern of a carpet will depend on the structure and arrangement of the loom, — which loom, however, is worked by a distant steam-engine, — so the results of muscular or glandular activity were believed to be determined by the structure of muscle and gland; but the moving-force came from some other part of the body.

The next essential advance was made by Haller, about the middle of the eighteenth century. He demonstrated that the contracting-power of a muscle did not depend on vital spirits carried to it in nerve or blood, but on properties of the muscle itself. Others had guessed, Haller proved, that the body of one of the higher animals is not a collection of machines worked by a central motor, but a collection of machines each of which in itself is both steam-engine and loom; leaving aside, of course, certain of the purely mechanical supporting and protecting apparatuses of the skeleton. This was the death-blow of the 'vital force' doctrine. Extensions of Haller's method showed that it was possible to destroy the brain and spinal cord of an animal, and separate its muscles, its heart, its nerves, its glands, and yet keep all these isolated organs working as in life for many hours. The life of an animal could be no longer regarded as an entity residing in one region of the body, from which it animated the rest; and the word gradually became simply a convenient phrase for expressing the totality or *resultant* of the lives of the individual organs. Physiologists began to see that they had nothing to do with seeking a vital force, or with essences or absolutes; that their business was to study the phenomena exhibited by living things, and leave the noumena, if there were such, to amuse metaphysicians. Physiology thenceforth became more and more a study of the mechanics, physics, and chemistry of living organisms and parts of organisms.

Progress at first was necessarily very slow; physics and chemistry, as we now know them, did not exist; galvanism was not discovered; osmosis was unknown; the conservation of energy was undreamed of; while modern chemistry did not take its rise until the discovery of oxygen by Priestly, and the extension and application of that discovery by Lavoisier towards the close of the last century. Physiology had to wait then, as now, for its advance upon the development of the sciences, dealing with simpler forms of matter than those found in living things. But little by little, step after step, so many once mysterious vital processes have been explained as merely special illustrations of general, physical, and chemical laws, that now the physiologist scans each advance in these sciences in full confidence that it will enable him to add another to the phenomena of living bodies, which are in ultimate analysis not peculiar or 'vital,' but simply physico-chemical. Apart from the phenomena of mind, whose mysterious connection with forms of matter he can never hope to explain, if a modern physiologist were asked what is the object of his science, he would answer, "not the discovery or the localization of a vital force, but the study of the quantity of oxidizable food taken into the stomach, and the quantity of oxygen absorbed in the lungs; the calculation of the energy or force liberated by the combination of the food and oxygen; and observation of the way in which that force has been expended, and the means by which its distribution may be influenced."

Once it was recognized that at least the great majority of physiological problems were problems admitting of experimental investigation, the necessity for special collections of apparatus suitable for experiment on living plants and animals, and for affording students an opportunity to study the play of forces in living organisms, had not long to wait for recognition. Physiological laboratories were organized at first in such rooms as could be spared in buildings constructed for other purposes; later, in structures built for this special end. The first laboratory specially erected for physiological work was built for Vierordt, in Tübingen, less than twenty years ago. So far as I know, our own is the first such building in the United States.

There is still another reason which has combined with the recognition of the independence of physiology as a science to make the modern laboratory, open to all properly prepared students, a possibility; and physiology owes it to this country. I do not forget how Brown-Sequard in Philadelphia clinched and completed Bernard's great discovery of the vaso-motor

[1] See Huxley: *The connection of the biological sciences with medicine* (*The lancet*, Aug. 13, 1881).

nerves; nor the researches of Weir Mitchell on the functions of nerve-centres, and the action of snake-poisons; nor, in later years, the researches of Wood on the physiology of fever; and on various subjects by Bowditch, Arnold, Flint, Minot, Sewall, Ott, Chittenden, Prudden, Keyt, and others. But speaking with all the diffidence which one, who, at least by birth, is a foreigner, must feel in expressing such an opinion, I say, that considering the accumulated wealth of this country, the energy which throbs through it, and the number of its medical schools, it has not done its fair share in advancing physiological knowledge, *but for one thing*, which makes the world its debtor. I mean the discovery of anaesthetics. When Morton, in 1846, demonstrated in the Massachusetts general hospital that the inhalation of ether could produce complete insensibility to pain, he laid the foundation-stone of our laboratory, and of many others. No doubt the men whose instincts led them to physiological research, and who realized that by the infliction of temporary pain on a few of the lower animals they were discovering truths which would lead to alleviation of suffering, and prolongation of life, not only in countless generations of such animals themselves, but in men and women to the end of time, would have tried to do their work in any case. But the men who can steel their hearts to inflict present pain for a future greater gain are few in number. The discovery of anaesthetics has not only led to ten physiological experimenters for each one who would have worked without them, but by making it possible to introduce into the regular course of physiological teaching, demonstrations and experiments on living animals, without shocking the moral sense of students or of the community at large, has contributed incalculably to the progress of physiology.

On the occasion of the opening of the old laboratory I used these words:[1] —

> "Physiology is concerned with the phenomena going on in living things, and vital phenomena cannot be observed in dead bodies; and from what I have said you will have gathered that I intend to employ vivisections in teaching. I want, however, to say, once for all, that here, for teaching purposes, no painful experiment will be performed. Fortunately the vast majority of physiological experiments can nowadays be performed without the infliction of pain, either by the administration of some of the many anaesthetics known, or by previous removal of parts of the central nervous system; and such experiments only will be used here for teaching. With regard to physiological research, the case is different. Happily here, too, the number of necessarily painful experiments is very small indeed; but in any case where the furtherance of physiological knowledge is at stake — where the progress of that science is concerned, on which all medicine is based, so far as it is not a mere empiricism — I cannot doubt that we have a right to inflict suffering upon the lower animals, always provided that it be reduced to the minimum possible, and that none but competent persons be allowed to undertake such experiments."

Those words were a declaration of principle and a pledge given to this community, in which I was about to commence my work. That the work has been carried on for seven years among you, without a murmur of objection reaching my ears, is sufficient proof that Baltimore assents to the principle; and, gratifying as the building of our new laboratory is to me from many points of view, there is none so grateful as its witness, that, in the opinion of our trustees and of my fellow-citizens, I have carried out my pledge. There has been no hole-and-corner secrecy about the matter: the students in the laboratory have been no clique living isolated in a college-building, but either your own sons, or boarders scattered among dozens of families in this city; and no room in the laboratory has ever been closed to any student: what we have done has been open to all who cared to know. On this occasion, when we formally make a fresh start, I desire to re-assert the principle, and repeat the pledge.

[1] *Pop. sc. monthly*, November, 1876.

(To be concluded.)

BERTHELOT'S EXPLOSIVE MATERIALS.

Explosive materials, a series of lectures delivered by M. P. E. BERTHELOT; *translated by* MARCUS BENJAMIN. *A short historical sketch of gunpowder; translated from the German of* KARL BRAUN *by* Lieut. JOHN P. WISSER, U.S.A. *A bibliography of works on explosives; reprinted from Van Nostrand's magazine*, No. 70. N.Y., *Van Nostrand*, 1883. (Van Nostrand's science series.) 180 p. 24°.

THE lectures of Berthelot, which form the more important part of this collection, are devoted to a popular exposition and amplification of the theories which he has from time to time advanced, concerning the constitution and mode of action of explosive substances. The principal topics treated are, the force of explosives; the origin, duration, and speed of propagation of the explosive reactions; inflammation and detonation as modes of inducing explosions; and explosions by influence.

The force of an explosive may be understood in two ways: it may be considered either as the pressure developed or as the work accomplished. The pressure depends principally upon the nature of the gases formed, their volume, and their temperature. The work, on the other hand, is principally dependent upon the amount of heat given off in consequence of the chemical decomposition. In practice, as, for instance, in guns, the transformation of this heat into useful work is never complete, since heat is absorbed by the gun, gases, and projectile, and a portion of the work produced is lost in moving the gases and air projected. Taking all these facts into consideration, it has yet been difficult to explain the great differences which result from the different methods employed for inducing explosions. Berthelot holds that this diversity depends upon the rapidity with which the explosive reaction propagates itself, and the more or less intense pressures which result from it, and he illustrates it as follows: —