University Laboratories and Research.[1]

By Sir J. J. THOMSON, O.M., F.R.S.

PHYSICAL laboratories at the present day are very different from those existing when I began to study physics now, alas, more than fifty years ago. In those days they could be counted on the fingers of one hand. They were not palatial buildings, but for the most part consisted of a few odd rooms, wrung from a reluctant governing body by the importunity of the professor. The physical laboratory of Owens College, now the University of Manchester, where I began my study of physics, was a few rooms which nobody else wanted in Cobden's house in Quay Street, and I believe that one of the rooms in Lord Kelvin's laboratory at Glasgow was an old coal-cellar. The whole equipment of apparatus could in many cases not have cost more than a few hundred pounds. Now almost every university and technical school has a separate building equipped with expensive apparatus.

The provision of these laboratories, and the funds required for their maintenance, has become a very serious question for those responsible for the finances of our universities. I am afraid that physical laboratories are especially expensive. I am afraid, too, that the sums required for their equipment and maintenance are much more likely to increase than to diminish. They have indeed increased very rapidly of late years. Let me give an example of my own experience. At the beginning of this century there were about thirty persons doing original work at the Cavendish Laboratory. Their researches cost the laboratory between 300*l.* and 400*l.* a year. The cost now would be at least six times that amount. As science progresses the instruments required become more and more elaborate and expensive. The old endowments of the universities and the fees from students are quite inadequate to meet the expenses on the new scale. New studies require new endowments; there is still need, nay, there is increasing need, for the 'pious founder.'

It would be ungrateful, however, not to acknowledge the liberal help which is now given to physical science by the Government of the country, partly by grants to the universities, partly by grants for research administered by the Royal Society, and partly by the formation of the Advisory Council for Scientific and Industrial Research, which, among other things, finances the National Physical Laboratory. The Government, indeed, is now giving to physical science far more than any Government gave before. To the liberality of some of the city companies we owe some fine laboratories, and there are many private benefactors to whom our gratitude is due, but there is still room, nay, need, for many more.

It is not necessary for me to dwell on the educational value of the study of science in our universities and schools. Indeed, there are those who maintain that it is the literary studies that are in danger of neglect. I believe, however, that the vast majority of scientific men recognise the great, nay, the vital importance of literary subjects in education, and would view with horror a system from which they were absent. Both are necessary, but in my opinion science without literature would be worse than the old system of literature without science.

The educational value of the training in science depends to a great extent upon work in the laboratory. What are the educational values of science? Are they not that science arouses and does something to satisfy the wonder and curiosity we feel about the marvellous processes going on in the world around us; that it cultivates and develops the powers of observation; that, and this is a most important point, it teaches us to reason about facts that come under our own notice? It gives the student confidence in the powers of reason. I think every teacher of science knows that when a student calculates from the principles he has been taught what will happen, say, when light passes through a system of lenses, and on proceeding to try the experiment finds that the result agrees with his predictions, it comes to him as a great surprise. It comes almost as a shock that human reason can lead to accurate results. Nothing helps a student to use his reason more than the belief that it can be trusted. But to get these educational values from science the laboratory is essential; it is there that the facts on which he has to exert his reason are to be found, where the contact between the facts and the intellectual effort takes place. Again, by his experiments the properties of light, electricity, and so on are impressed upon his mind with a vividness possible in no other way. It is in the laboratory that we realise that close touch with Nature which is essential to the progress of science.

It is the duty of the universities to enlarge the bounds of knowledge, as well as to instruct the community in the knowledge already won. Such research is of great value to the community. The discoveries made in the universities by people working simply to increase human knowledge, without any idea whatever of any industrial application, are the very discoveries which create new industries and revolutionise the old. Take the case of the electrical industry. How did that come into existence? It was not because somebody set to work to develop a method for the transmission of power. It arose because Faraday wanted to try, in the laboratory at the Royal Institution in London, what would happen if he moved a magnet about near a coil of wire. That industry would never have been created if he had simply worked with the idea of discovering something to transmit power. I want to emphasise this point because there are many who say that the only legitimate object of research to which public funds should be applied is research with definite industrial intention. I am the last to decry *ad hoc* research, but it is not enough.

When bows and arrows were the most formidable weapons, it would have been a very good thing to establish a Bow-and-Arrow Research Association to make sure that one had got the best bow and arrow possible. But some man, working to get knowledge for its own sake, discovered gunpowder, and made the best bow and arrow obsolete. The truth is that Nature is so full of wonderful things that there is probably a much better solution of any problem than any we possess. We shall not find it by working directly on the problem, but if we work away, faithfully recording

[1] From an address delivered at the opening of the new science laboratories at the University College of North Wales, Bangor, on November 2.

what we see in our experiments, we shall probably get a hint and arrive at results which may be of importance. It is difficult to say that any discovery which is made is devoid of commercial value. Our experience in the War showed us that the most recondite phenomena, known only to a few, could be applied for the service of the country.

I have heard the fear expressed that the multiplication of laboratories may lead to something like overproduction—that there may not be enough discoveries to go round. Such a fear seems ludicrous to a physicist who knows that a discovery is not a terminus but an avenue opening up new and wider fields for work. We are surrounded on all sides by physical and chemical phenomena of which our knowledge is not even in its infancy, scarcely in embryo. Consider for example the chemical and physical properties of living matter. A tiny seed is put into the ground and becomes with nothing but the soil, water, air, and light a workshop weaving for leaf, flower, and fruit fabrics of exquisite texture, moulding these with unerring accuracy into shapes of the greatest variety and complexity, dyeing them all the colours of rainbow, often spreading the colours in patterns full of minute and elaborate detail, laying up stores of substances, most of which are beyond the power of the chemist to produce, and finally producing other seeds able to produce the same effects. Compared with results like this our workshops, our looms, our dye-works seem clumsy and inefficient. What is the mechanism by which these wonderful results are produced? We have no idea.

To find out the mechanism of this tiny seed we shall have to develop methods of investigating the changes that go on, almost molecule by molecule. Of late years methods have been devised which are continually diminishing the distance between us and the solution of these problems, and in the not too indefinite future we may hope to get to know something of the way in which those marvels are accomplished. This requires the co-operation of many sciences, and it seems to me that the new buildings at Bangor are admirably fitted to take part in this great work.

Richard of Wallingford and his Rectangulus.

By Dr. R. T. GUNTHER.

THE celebration of the sixth centenary of the elevation of Richard of Wallingford to the Abbacy of St. Albans in 1326 is an occasion of far more than local interest, for it is also the celebration of the sixth centenary of the beginning of trigonometry in England.

Richard's father was a blacksmith in the village of Wallingford, who died when the son was only ten years of age, but Richard was fortunate enough to be adopted by the Prior of Wallingford, who sent him to Oxford at the age of seventeen. Six years later he was admitted to the monastery of St. Albans, perhaps, as Sir Edgar Wigram has suggested, because he instinctively recognised that in those days a monastery was the only refuge where a man of science could find license and leisure to prosecute his studies undisturbed. But after three years training, Abbot Hugh sent him back to Oxford as one of the students whom every Benedictine house was bound by statute to maintain at the University, in order to ensure that its learning should be kept up to standard. Apparently to the deep concern of the chronicler, Richard then proceeded to spend valuable time on mathematics and astronomy, which he was expected to devote to theology. But in 1326 he had his reward by being elected Abbot of St. Albans, and, as after events proved, turned his scientific training to good purpose by reducing the debt and by rebuilding the Cloister of his Abbey.

We have two miniature portraits of Richard of Wallingford in the illuminated chronicle of Matthew Paris. In the first he is engaged at his bench making or measuring a circular instrument with a pair of compasses. His simple tools are lying by his side and his Abbot's mitre is on the floor. In the second portrait he is pointing to the famous clock which he made for the Abbey. A point of singular interest is the fact that in both portraits he is represented with a spotty face, indicating the ravages of the incurable disease of leprosy which he had contracted at Avignon. Indeed, of this we have confirmatory evidence in a prayer composed by him in later life after his promotion as Abbot. The words are worth quoting, if only as an example of the devotions of an English man of science of the fourteenth century.

> Though I be a man of lowly state, and smitten by Thy providence with an evil plague, so that I am not worthy to walk among men, but should by law be cast without the camp; yet Thou, O Lord my God, by what secret judgement I know not, dost yet hold me in honour, such honour as I have known none of my parents or kindred to attain to, in all health of body; and as I oft-times remember with wonder at Thy great bounty, dost so incline the hearts of the great towards me, that ever when present, they d not abhor my speech and the deformity of my face and hands, but rejoice to converse with me. . . .

We may, therefore, claim that the miniatures are truthful representations of "The Father of Trigonometry" in England.

Wallingford's trigonometrical methods are indicated in two works, *De sinubus demonstratis* and *De sinubus et arcubus in circulo inveniendis*, and their practical application is further described in his treatise on the Art of working with a Rectangulus.

Two scientific treatises on the 'Albion' and the Rectangulus are dated about the time of his election as Abbot. Fortunately, illustrated copies of the manuscript are still extant and they include many working drawings which reveal the construction of the instruments so clearly that a reconstruction is possible.

The 'Albion' has often been stated to have been the Abbey clock for which he is famous; but the evidence of the original manuscript points to its having been an elaborate Aequatorium or Volvelle composed of a number of circular dials for showing the position of the planets: the name 'Albion,' or all-by-one, having reference to the various operations which could be performed by the one instrument. There is no mention of cogwheels, pulleys, and weights, or of any driving